UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
PORTLAND OFFICE
1201 NE Lloyd Boulevard, Suite 1100
PORTLAND, OREGON 97232-1274

Distributed by E-mail

September 9, 2013

RE: Sovereign review of the 2013 Draft Supplemental Biological Opinion (BiOp) for the Federal Columbia River Power System. F/NWR/2013-9562

Dear Sovereigns:

As you know, NOAA Fisheries is consulting with the Federal Columbia River Power System (FCRPS) Action Agencies to develop a Biological Opinion to supplement its 2008/2010 Biological Opinions on the operation and maintenance of the FCRPS. This action is pursuant to the August 2, 2011 order by the U.S. District Court in Oregon in the matter of *NWF v. NMFS*. We now are soliciting your review and comments on the 2013 Draft Supplemental BiOp. The draft opinion and overview materials are available at:

www.nwr.noaa.gov/hydropower/fcrps_opinion/federal_columbia_river_power_system.html.

As directed by the Court's remand order, NOAA Fisheries will issue a final supplemental BiOp for the FCRPS by January 1, 2014. To ensure that NOAA's final BiOp is informed by the best available scientific and commercial information, NOAA Fisheries and the Action Agencies seek any information, comments, and suggestions you would recommend we consider for this opinion. In order to have sufficient time to consider your written comments on the 2013 Draft Supplemental BiOp, NOAA Fisheries must receive them no later than October 7, 2013. You can submit written comments to 2013DraftFCRPS@noaa.gov. Alternately, you can send comments to:

Danalyn Loitz
NOAA Fisheries
1201 NE Lloyd Blvd, Suite 1100
Portland, OR 97232

We thank you for your review and ensuring we have considered all relevant information in this draft Supplemental Biological Opinion.

Sincerely,

Bruce Suzumoto
Assistant Regional Administrator
Northwest Region Hydropower Division
NOAA's National Marine Fisheries Service

cc: Bonneville Power Administration
U.S. Army Corps of Engineers
U.S. Bureau of Reclamation
State of Washington
State of Oregon
State of Idaho
State of Montana
Confederated Tribes of the Colville Reservation
Spokane Tribe
Confederated Tribes of the Umatilla Reservation
Confederated Tribes of the Warm Spring Reservation
Shoshone-Bannock Tribes
Nez Perce Tribes
Confederated Salish-Kootenai Tribes
Confederated Tribes of the Yakama Nation
Kootenai Tribe of Idaho
Columbia Inter-Tribal Fish Commission
Upper Columbia United Tribes
Confederated Tribes of the Grand Ronde Community of Oregon
Cowlitz Indian Tribe

Endangered Species Act Section 7(a)(2) Biological Opinion

Supplemental Consultation on Remand for Operation of the Federal Columbia River Power System

Action Agencies: U.S. Army Corps of Engineers (Corps)
Bonneville Power Administration (BPA)
U.S. Bureau of Reclamation (Reclamation)

Consultation Conducted by: NOAA's National Marine Fisheries Service (NOAA Fisheries)
Northwest Region

NOAA Fisheries Log Number: NWR-2013-9562

Date Issued:

Issued by:

Will Stelle
Regional Administrator

Sovereign Review Draft

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Contents

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List of Tables

List of Figures

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Abbreviations and Acronyms

Action Agencies	U.S. Bureau of Reclamation, U.S. Army Corps of Engineers, and the Bonneville Power Administration
AMIP	Adaptive Management Implementation Plan
BiOp	Biological Opinion
BPA	Bonneville Power Administration
BRT	Biological Review Team (NOAA Fisheries)
BY	brood years
CBWTP	Columbia Basin Water Transactions Program
CE	Comprehensive Evaluation
CEERP	Columbia Estuary Ecosystem Restoration Program
CHaMP	Columbia Habitat Monitoring Program
CHW	Remand Collaboration Habitat Workgroup
COMPASS	Comprehensive Fish Passage
Corps	U.S. Army Corps of Engineers
CR	Columbia River
CSS	Comparative Survival Study
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
DDT	dichlorodiphenyltrichloroethane
DPS	Distinct Population Segment
EDT	ecosystem diagnosis and treatment
EIS	environmental impact statement
ENSO	El Nino-Southern Oscillation
ERTG	Estuary Regional Technical Group
ESA	Endangered Species Act
ESU	evolutionary significant unit
FERC	Federal Energy Regulatory Commission
FCRPS	Federal Columbia River Power System
FMEP	Fisheries Management and Evaluation Plan
FPC	Fish Passage Center
GIS	Geographic Information System
GPRA	Government Performance and Results Act
HF	Hatchery Fish
HQI	Habitat Quality Improvements
ICTRT	Interior Columbia Basin Technical Recovery Team
IDFG	Idaho Department of Fish and Game
IMW	Intensively Monitored Watershed

IP	Action Implementation Plan
ISAB	Independent Scientific Advisory Board
ISEMP	Integrated Status and Effectiveness Monitoring Program
ISRP	Independent Scientific Review Panel
kcfs	thousand cubic feet per second
lambda	median population growth rate
LCFRB	Lower Columbia Fish Recovery Board of the NWPCC
LCR	Lower Columbia River
LCRE	Lower Columbia River Estuary
LCREP	Lower Columbia River Estuary Partnership
ln	natural logarithmic scale
MAT	minimum abundance thresholds
MCR	Mid-Columbia River
MPG	major population group
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPCC	Northwest Power and Conservation Council
NWFSC	Northwest Fisheries Science Center
ODFW	Oregon Department of Fish and Wildlife
ONI	Oceanic Nino Index
OSGRP	Odessa Subarea Groundwater Replacement Project
P	multiyear means for recent climate scenario
PCBs	polychlorinated biphenyls
PCE	primary constituent element
PDO	Pacific Decadal Oscillation
PIT	passive integrated transponder
PUD	Public Utility District
QET	quasi-extinction threshold
R/S	returns-per-spawner or recruits-per-spawner
RIOG	Regional Implementation Oversight Group
rkm	river kilometer
RM	river mile
RME	Research, Monitoring, and Evaluation
RPA	Reasonable and Prudent Alternative
RRS	relative reproductive success
SAR	smolt-to-adult return
SBU	Survival Benefit Units
SLEDs	Sea Lion Exclusion Gates

SPS	Salmon Population Summary
SR	Snake River
SRSRB	Snake River Salmon Recovery Board
SWCD	Soil and Water Conservation District
T:B ratio	transported (T) and by-passed (B) fish
TDG	Total Dissolved Gas
TIR	transport-to-inriver
UCR	Upper Columbia River
USBR	U.S. Bureau of Reclamation
USEPA	U.S. Environmental Protection Agency
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
UWR	Upper Willamette River
W/LCTRT	Willamette/Lower Columbia TRT
WDFW	Washington Department of Fish and Wildlife
WTT	water travel time

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Terms and Definitions

Abundance	In the context of salmon recovery, abundance refers to the number of adult 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	The idea that contingency actions could be taken to improve the status of a species by reducing adverse effects of the hydrosystem, predators, hatcheries, habitat, and/or harvest.
Anadromous Fish	Species that are hatched in freshwater, migrate to and mature in salt water, and return to freshwater to spawn.
Beverton-Holt Function	This function predicts the number of progeny that will return to spawn from a given number of parental spawners.
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.
Cleptoparasitism	A form of feeding in which one animal takes prey or other food from another that has caught, collected, or otherwise prepared the food
Compensatory Mortality	Refers to mortality that would have occurred for another reason.
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.
Dissolved Gas Level	As falling water hits the river surface, it drags in air as it plunges. With increasing water pressure, the air dissolves into the water and increases the levels of pre-existing dissolved gases.

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.
Diversion	Refers to taking water out of the river channel for municipal, industrial, or agricultural use. Water is diverted by pumping directly from the river or by filling canals.
Diversity	All the genetic and phenotypic (life history, behavioral, and morphological) variation within a population. Variations could include anadromy vs. lifelong residence in freshwater, fecundity, run timing, spawn timing, juvenile behavior, age at smolting, age at maturity, egg size, developmental rate, ocean distribution patterns, male and female spawning behavior, physiology, molecular genetic characteristics, etc.
Dredging	The act of removing sediment from the river bottom to keep the channel at the proper depth for navigation. The continual moving and shifting of sediment makes dredging an ongoing activity.
Early Warning Indicator	The Early Warning Indicator alerts NOAA Fisheries and the Action Agencies to a decline in a species' natural adult abundance level that warrants further scrutiny. This indicator is a combination of 5-year abundance trends and rolling 4-year averages of abundance, based on the most recent 20 to 30 years of adult return data, depending on the species. The Early Warning Indicator would be tripped if the running 4-year mean of adult abundance dropped below the 20th percentile, *or* if the trend metric dropped below the 10th percentile and the abundance metric was below the 50th percentile.
Effectiveness Monitoring	Monitoring set up to test cause-and-effect hypotheses about recovery actions: Did the management actions achieve their direct effect or goal? For example, did fencing a riparian area to exclude livestock result in recovery of riparian vegetation?
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.

Fall Chinook Salmon	This salmon stock returns from the ocean in late summer and early fall to head upriver to its spawning grounds, distinguishing it from other stocks which migrate in different seasons.
Fish Ladder	A series of stair-step pools that enables salmon to get past the dams. Swimming from pool to pool, salmon work their way up the ladder to the top where they continue upriver.
Flood Control	Streamflows in the Columbia River Basin can be managed to keep water below damaging flood levels in most years. This level of flood control is possible because storage reservoirs on the river can capture and store heavy runoff as it occurs.
Flow Augmentation	Water released from system storage at targeted times and places to increase streamflows to benefit migrating salmon and steelhead
Freshet	The heavy runoff that occurs in the river when streams are at their peak flows with spring snowmelt. Before the dams were built, these freshets moved spring juvenile salmon quickly downriver
Implementation monitoring	Monitoring to determine whether an activity was performed and/or completed as planned.
Indicator	A variable used to forecast the value or change in the value of another variable.
Intrinsic Productivity	The average of adjusted recruits per spawner estimates for only those brood years with the lowest spawner abundance levels.
Iteroparity	The ability to reproduce more than once during a lifetime.
Kelts	Steelhead that have spawned but may survive to spawn again, unlike most other anadromous fish.
Lambda	Also known as Population growth rate, or the rate at which the number of fish in a population increases or decreases.
Large woody debris (LWD)	A general term for wood naturally occurring or artificially placed in streams, including branches, stumps, logs, and logjams. Streams with adequate LWD tend to have greater habitat diversity, a natural meandering shape, and greater resistance to flooding.
Legacy Effects	Impacts from past activities (usually a land use) that continue to affect a stream or watershed in the present day.
Levees	A levee is a raised embankment built to keep out flood waters.

Limiting Factor	Physical, biological, or chemical features (e.g., inadequate spawning habitat, high water temperature, insufficient prey resources) experienced by the fish at the population, intermediate (e.g., stratum or major population grouping), or ESU levels that result in reductions in viable salmonid population (VSP) parameters (abundance, productivity, spatial structure, and diversity). Key limiting factors are those with the greatest impacts on a population's ability to reach its desired status.
Major population group (MPG)	An aggregate of independent populations within an ESU that share similar genetic and spatial characteristics.
Management unit	A geographic area defined for recovery planning purposes on the basis of state, tribal or local jurisdictional boundaries that encompass all or a portion of the range of a listed species, ESU, or DPS.
Morphology	The form and structure of an organism, with special emphasis on external features.
Northern Pikeminnow	A giant member of the minnow family, the Northern Pikeminnow (formerly known as Squawfish) is native to the Columbia River and its tributaries. Studies show a Northern Pikeminnow can eat up to 15 young salmon a day.
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	
Photic Zone	The depth of the water in a lake or ocean that is exposed to sufficient sunlight for photosynthesis to occur.
Piscivorous	Describes fish that prey on other fish for food.
Productivity	A measure of a population's ability to sustain itself or its ability to rebound from low numbers. The terms "population growth rate" and "population productivity" are interchangeable when referring to measures of population production over an entire life cycle. Can be expressed as the number of recruits (adults) per spawner or the number of smolts per spawner.
Proposed Action	A proposed action or set of actions
Prospective Actions	Actions from both the FCRPS Biological Assessment and Upper Snake Biological Assessment, August 2007

Quasi-Extinction Threshold (QET)	This is the point at which a population has become too small to reliably reproduce itself, even though there may be a few fish remaining. Since there is debate about the exact population level at which this condition occurs, several possible levels (50, 30, 10, 1) are considered. Results from short-term quasi-extinction probability modeling are used to help assess near-term (24-year) extinction risk.
Reach	The term refers to a length of stream between two points.
Reasonable and Prudent Alternative	Recommended alternative actions identified during formal consultation that can be implemented in a manner consistent with the purposes of the action, that can be implemented consistent with the scope of the Federal agency's legal authority and jurisdiction, that are economically and technologically feasible, and that the Service believes would avoid the likelihood of jeopardizing the continued existence of the listed species or the destruction or adverse modification of designated critical habitat.
Recovery goals	Goals incorporated into a locally developed recovery plan. These goals may go beyond the requirements of ESA de-listing by including other legislative mandates or social values.
Recovery strategy	A statement that identifies the assumptions and logic—the rationale—for the species' recovery program.
Recruits-per-spawner (*or* returns-per-spawner)	Generally, a population would be deemed to be "trending toward recovery" if average population growth rates (or productivities) are expected to be greater than 1.0.
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.
River Reach	A general term used to refer to lengths along the river from one point to another, as in the reach from the John Day Dam to the McNary Dam.
Runoff	Precipitation, snowmelt, or irrigation water that runs off the land into streams or other surface water.
Salmonid	Fish of the family *Salmonidae*, including salmon, trout, chars, grayling, and whitefish. In general usage, the term usually refers to salmon, trout, and chars.

Significant Decline Trigger	The Significant Decline Trigger detects notable declines in the abundance of listed species. This trigger is also a combination of 5-year abundance trends and rolling 4-year averages of abundance. The levels were set based on the same set of historical values used for the Early Warning Indicator. The Significant Decline Trigger would be tripped if the abundance metric dropped below the 10th percentile, or if the trend metric dropped below the 10th percentile and the abundance metric was below the 20th percentile. The Significant Decline trigger, if tripped, results in the implementation of rapid response actions (if not already implemented pursuant to an Early Warning Indicator) to minimize or mitigate for an unforeseen downturn
Smolt	A juvenile salmon or steelhead migrating to the ocean and undergoing physiological changes to adapt from freshwater to a saltwater environment.
Snowpack	The accumulation of snow in the mountains that occurs during the late fall and winter.
Spatial structure	The geographic distribution of a population or the populations in an ESU.
Spill	Water released from a dam over the spillway instead of being directed through the turbines.
Stakeholders	Agencies, groups, or private citizens with an interest in recovery planning, or who will be affected by recovery planning and actions
Streamflow	Streamflow refers to the rate and volume of water flowing in various sections of the river. Streamflow records are compiled from measurements taken at particular points on the river, such as The Dalles, Oregon.
Technical Recovery Team (TRT)	Teams convened by NOAA Fisheries to develop technical products related to recovery planning. TRTs 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.
Threats	Human activities or natural events (e.g., road building, floodplain development, fish harvest, hatchery influences, volcanoes) that cause or contribute to limiting factors. Threats may exist in the present or be likely to occur in the future.
Tule	
Turbine	An enclosed rotary type of prime mover that drives an electric generator to produce power.

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.
Viable salmonid	An independent population of Pacific salmon or steelhead
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., June 2000.

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Section 1: Introduction

1.1 Consultation Overview

1.2 Overview of the 2008/2010 Reasonable and Prudent Alternative

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1.1 Consultation Overview

This section describes the Endangered Species Act (ESA) analysis and determinations NOAA's National Marine Fisheries Service (*hereafter* NOAA Fisheries) is making in this supplemental biological opinion for the Federal Columbia River Power System (FCRPS). This opinion supplements NOAA Fisheries' FCRPS Biological Opinion issued May 5, 2008 (NMFS 2008a, *hereafter* 2008 BiOp) that recommended a Reasonable and Prudent Alternative (RPA) for the FCRPS, which was then adopted for implementation by the FCRPS Action Agencies (U.S. Corps of Engineers, U.S. Bureau of Reclamation, and the Bonneville Power Administration). In litigation challenging the 2008 BiOp, *NWF v. NMFS*, the Court ordered NOAA Fisheries to issue a new or supplemental biological opinion for the FCRPS by 2014 (U.S. District Court 2005). This supplemental biological opinion complies with that court order.

The purpose of a biological opinion is for NOAA Fisheries to evaluate the likely effects of a proposed action on listed species and critical habitat and to apply the statutory standards set forth in Section 7(a)(2) of the ESA, 16 U.S.C. § 1536(a)(2). Similarly, along with other requirements, an RPA to a proposed action must also meet those standards by avoiding the likelihood of either jeopardizing the continued existence of listed species or resulting in the destruction or adverse modification of critical habitat. Sometimes, after consultation is completed, questions arise about whether the original ESA consultation should be reinitiated as required by the consultation regulations, 50 CFR §402.16. Reinitiation is appropriate in this instance to comply with the court-ordered remand to address concerns raised with the 2008 BiOp. In addition, since the 2008 BiOp was issued, NOAA Fisheries has listed an additional species, the southern distinct population segment (DPS) of eulachon, and designated critical habitat for the eulachon and for the southern DPS of North American green sturgeon. Thus, NOAA Fisheries has engaged in a reinitiated consultation on the FCRPS RPA for this species and these critical habitats.

Development of the Reasonable and Prudent Alternative

The FCRPS RPA is unique and therefore warrants explanation. The RPA's origins are informed by litigation over a series of biological opinions for the FCRPS issued first in 2000 and then in 2004. Although, in a typical consultation, an RPA is proposed by NOAA Fisheries as an alternative to the Action Agencies' proposed action, in this case, the Action Agencies presented an RPA in the 2007 Biological Assessment (USACE et al. 2007b). The proposed RPA was a product of collaboration between states, tribes, NOAA Fisheries and the FCRPS Action Agencies, as called for by a court ordered remand (*NWF v. NMFS*, Case No. 01-640, Order issued October 7, 2005). NOAA Fisheries further modified, supplemented, and refined the RPA program of actions proposed by the Action Agencies and concluded, in the 2008 BiOp, that the RPA recommended by NOAA Fisheries met the regulatory definition for an RPA, and, in particular, would likely avoid jeopardizing the continued existence of, or destroying or adversely modifying critical habitat for thirteen species of salmon and steelhead affected by the FCRPS. Among other things, the resulting 2008 RPA consisted of a new FCRPS operation plan designed to reduce the adverse effects of the FCRPS on listed salmon and steelhead as well as a number of strategies and actions intended to improve the productivity and survival of those listed species and the function of their habitat.

The 2008 RPA is intended to be implemented over a 10-year period, from 2008 through 2018. The RPA calls for review of the Action Agencies' implementation of the FCRPS operations and mitigation program in 2013 and 2016. For assessments in 2013 and 2016, the Action Agencies prepare a Comprehensive Evaluation (CE) and, for all three assessments, an action Implementation Plan (IP; RPA Actions 1 and 3). The stated purpose of NOAA Fisheries' assessment is "determining if the RPA is being implemented as anticipated in this Biological Opinion or, conversely, if reinitiation triggers defined in 50 CFR 402.16 have been exceeded." (RPA Action 3).

In 2009, NOAA Fisheries conducted a thorough review of the 2008 BiOp and the best available science and information, and determined that reinitiation of that consultation and biological opinion was not required. NOAA Fisheries' determination was particularly informed by the 2009 Adaptive Management Implementation Plan (AMIP) that provided for a more detailed and aggressive implementation of the 2008 BiOp's RPA. In 2010, NOAA Fisheries and the Action Agencies reinitiated consultation during a court ordered remand to incorporate the AMIP into the RPA through NOAA's 2010 Supplemental Biological Opinion (NMFS 2010a, *hereafter* 2010 Supplemental BiOp). This review coincided with NOAA Fisheries' review of the Action Agencies' 2009 Implementation Plan called for by RPA Action 1.

The RPA has now been reevaluated again for this 2011 court ordered remand, and this reinitiated consultation analyzes the revised RPA with continued reliance on the determinations of the 2008 BiOp in the context of current information regarding the species, environmental baseline, and past and prospective implementation of RPA actions.

Components of this Supplemental Biological Opinion

Specific Mitigation Projects 2014–2018

This supplemental opinion was prepared to comply with the 2011 Court Remand Order, which required more specific identification of habitat mitigation projects for the 2014 through 2018 period (*NWF v. NMFS*, Order issued August 2, 2011).

Specifically Judge James A. Redden determined, in the Remand Order, that:

> [t]he no jeopardy decision for the entire ten-year term of the BiOp is arbitrary and capricious because NOAA Fisheries has failed to identify specific mitigation plans beyond 2013, that are reasonably certain to occur. Because the 2008/2010 BiOp provides some protection for listed species through 2013, however, I order NOAA Fisheries to fund and implement the BiOp until then. [from *NWF v. NMFS*, Remand Order, p. 17]

The Court directed that "[n]o later than January 1, 2014, NOAA Fisheries shall produce a new or supplemental BiOp that corrects this BiOp's reliance on mitigation measures that are not reasonably certain to occur." [Remand Order, p. 23]. Accordingly, this supplemental opinion addresses the Court's concern for the certainty of habitat mitigation to be implemented in 2014 through 2018.

In this supplemental opinion, NOAA Fisheries evaluates the RPA analyzed in the 2008 and 2010 BiOps, as buttressed by the habitat mitigation projects the Action Agencies have identified for implementation in 2014 through 2018. In doing so, NOAA Fisheries is addressing the following principal questions:

- whether the effects of the habitat RPA actions, including those from the newly developed projects, are reasonably certain to occur;
- whether the projects the Action Agencies have identified for implementation after 2014, when added to projects implemented since 2007, are likely to achieve the RPA's Habitat Quality Improvement objectives set forth in RPA Action 35, Table 5, and the associated survival improvements for listed salmonids in tributary habitat, as well as the estuary survival improvements objectives set forth in RPA Actions 36 and 37; and
- whether the methodology used by the Action Agencies to determine the efficacy of the habitat actions uses the best science available.

Consultation for New Species and Critical Habitats

Since 2008, the eulachon was listed for ESA protection as a threatened species. Furthermore, critical habitat for eulachon and green sturgeon has been designated since 2008. Critical habitat for Lower Columbia River coho salmon is also now proposed for designation. All of these are considered for the first time for ESA § 7(a)(2) purposes in this supplemental opinion as species or habitat that may be affected by implementation of the FCRPS RPA.

Current Validity of 2008 and 2010 BiOp Analysis

NOAA Fisheries has also evaluated the current validity of the ESA analysis contained in the 2008 and 2010 FCRPS BiOps. To do so NOAA Fisheries has considered:

- Whether there is new data concerning the status of the listed species, changes to the environmental baseline, and cumulative effects. NOAA Fisheries also considers the information about effectiveness of the RPA's implementation to date. These determinations are informed by the current development of the RPA's Research, Monitoring, and Evaluation program.
- Whether the Action Agencies have implemented the RPA as intended, or whether any significant discrepancies deviate from the effects expected to result from the RPA actions.

NOAA Fisheries concludes that the §7(a)(2) analysis of the 2008 BiOp remains valid, as supplemented in 2010, and further by the additional project definition and analysis contained in this supplemental opinion. Therefore, this biological opinion supplements without replacing the 2008 and 2010 FCRPS BiOps.

For each affected listed species and designated critical habitat, NOAA Fisheries reaches new determinations pursuant to ESA § 7(a)(2) and its implementing regulations based on the analysis in the prior BiOps, and further supported by the analysis provided in this supplemental opinion. In this regard, the determinations herein are similar to that made by NOAA Fisheries in its 2010 Supplemental BiOp where it reaffirmed the validity of its ESA determinations made in the 2008 BiOp.

Incidental Take Statement Revisions

Finally, NOAA Fisheries considers the Incidental Take Statement for the FCRPS operation and mitigation and makes adjustments consistent with the RPA's implementation to date and with currently available information regarding the extent of take and opportunities for minimization. The amount or extent of take described in the Incidental Take Statement is consistent with the analysis in this supplemental opinion.

2013 Assessment

This supplemental opinion also includes the determinations that NOAA Fisheries is required to make in connection with the 2013 assessment concerning adequacy of the Action Agencies' progress toward implementing the RPA. Although a supplemental biological opinion is not required for the purposes of the 2013 assessment, as the court noted, the date for the supplemental biological opinion coincides with the 2013 assessment (Remand Order, p. 19).

1.2 Overview of the 2008/2010 Reasonable and Prudent Alternative

The RPA for the FCRPS is a comprehensive program to protect listed species of salmon and steelhead in the Columbia basin by adopting operations and configuration changes for the FCRPS dams that reduce adverse effects to the species migrating through the FCRPS while, at the same time, implementing habitat restoration actions in spawning and rearing habitat in upstream Columbia River tributaries and in migration and rearing habitat in the River's estuary downstream. Additional RPA actions reduce predation and minimize the adverse effects of FCRPS-funded mitigation hatchery programs, committing some of those programs to conserve the listed species. This RPA program is complemented by a commensurate monitoring and research program to refine and improve the science on which it is based to better guide its implementation and confirm its effects.

In 1999, the Action Agencies proposed a program for the FCRPS that coupled improvements at the dams with mitigation actions in salmon habitat. NOAA Fisheries found, in its 2000 FCRPS BiOp, that the proposal was likely to jeopardize the interior Columbia basin salmonid species, largely because the habitat mitigation actions were not sufficiently defined. NOAA Fisheries developed an RPA in that BiOp (NMFS 2000) that improved upon the Action Agencies' proposal with more specific actions and objectives. After several rounds of litigation and court decisions concerning the adequacy of the RPA, the Action Agencies and NOAA Fisheries, in 2005 through 2007, collaborated with Columbia basin states and tribes to develop the current RPA, adopted in the 2008 BiOp. After careful review in 2009, NOAA and the Action Agencies further defined the 2008 RPA in the AMIP, which NOAA Fisheries integrated into the 2008 RPA in the 2010 Supplemental BiOp. The Action Agencies and NOAA Fisheries now provide in this supplemental opinion further description and analysis of habitat restoration actions to be implemented in the tributaries and estuary.

Hydropower Actions

The first focus of the RPA is for improving the survival of salmon and steelhead migrating in the mainstem Columbia and Snake rivers. Fish survival is affected by the operation and configuration of the FCRPS mainstem dams and reservoirs through which the fish must migrate and is further affected by the management of water released from the FCRPS upriver storage reservoirs. The RPA specifies a program of actions for the operation and structural modification of the mainstem dams to achieve fish survival performance standards coupled with storage and release of water to maintain adequate river migration flows (RPA Actions 4–33 and 50–55). Juvenile salmon and steelhead survival is also limited in the mainstem by fish and bird predators that inhabit the dams and reservoirs. Marine mammals also prey on adult salmonids in the lower Columbia River and estuary. The RPA calls for programs to reduce predation on listed salmonids through relocation, hazing, and bounties, guided by an ongoing research program (RPA Actions 43–49 and 66–70).

Habitat Actions

The RPA's next focus is on enhancing the function of upriver habitat where salmon spawn and rear, as well as down river estuary habitat where salmon transition to the ocean environment. By restoring these habitats, the numbers and fitness of wild salmon and steelhead populations are expected to increase. The RPA specifies biological performance standards that determine the extent to which habitat function, and therefore fish survival, must be improved. The actions undertaken for this purpose are developed by local experts and guided by current salmon research and monitoring. Projects aim to increase stream flows, reduce water temperature, remove barriers to fish access, and increase pools, spawning gravels and side channel habitats (RPA Actions 34–38 and 56–61).

Hatchery Actions

The FCRPS also funds over 100 hatchery programs in the Columbia River basin. Hatcheries can be used to support wild fish until they can be sustained in the wild, but hatchery fish can also compete with wild fish for food and habitat, transmit hatchery diseases, and, through interbreeding, interfere with the wild fish's genetic adaptation to its environment. The RPA calls for scrutiny of the FCRPS-funded hatchery programs to identify those that can contribute to the conservation of wild fish and to reform those that pose a threat to wild fish (RPA Actions 39–42 and 63–65).

Planning, Reporting, and Monitoring Actions

Finally, the RPA requires comprehensive program planning, reporting, and progress monitoring, to ensure this program is effective for ensuring the FCRPS continues to avoid jeopardizing listed salmonid species and adversely modifying their critical habitat (RPA Actions 1–3 and 71–73).

Section 2: New Information Updating the 2008/2010 BiOps

2.1 Rangewide Status of Salmon and Steelhead and Designated Critical Habitat

2.2 Environmental Baseline

2.3 Cumulative Effects

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2.1 Rangewide Status of Salmon and Steelhead and Designated Critical Habitat

In the 2008 BiOp, NOAA Fisheries considered the rangewide status of listed salmon and steelhead species and designated critical habitat affected by the RPA. Those listed species and critical habitat designations are displayed in Chapter 4 of the 2008 Supplemental Comprehensive Analysis (NMFS 2008c, *hereafter* 2008 SCA), including the Federal Register citations. They are summarized in Table 2.1 below.

Table 2.1. ESA-listed species and designated critical habitat considered in the 2008 FCRPS Biological Opinion.

ESA-Listed Species by ESU	ESA Listing Status	ESA Critical Habitat Designated?[1]
Interior Columbia Basin Species		
Snake River (SR) fall Chinook salmon	Threatened	Yes
SR spring/summer Chinook salmon	Threatened	Yes
SR steelhead	Threatened	Yes
Upper Columbia River (UCR) spring Chinook salmon	Endangered	Yes
UCR steelhead	Threatened [2]	Yes
Middle Columbia River steelhead	Threatened	Yes
SR sockeye salmon	Endangered	Yes
Lower Columbia Basin Species		
Columbia River chum salmon	Threatened	Yes
Lower Columbia River (LCR) Chinook salmon	Threatened	Yes
LCR coho salmon	Threatened	Under development at the time of the 2008 BiOp.[3]
LCR steelhead	Threatened	Yes
Upper Willamette River (UWR) Chinook salmon	Threatened	Yes
UWR steelhead	Threatened	Yes

[1] Critical habitat is defined as: (1) specific areas within the geographical area occupied by the species at the time of listing, if they contain physical or biological features essential to conservation, and those features may require special management considerations or protection; and (2) specific areas outside the geographical area occupied by the species if the agency determines that the area itself is essential for conservation.

[2] UCR steelhead listing status was changed from Endangered to Threatened on June 18, 2009 by court order.

[3] NOAA Fisheries has published a proposed rule for the designation of critical habitat for LCR coho salmon (NMFS 2013a).

In the following sections (Section 2.1.1 through 2.1.3) of this supplemental opinion, NOAA Fisheries updates the rangewide status of the species considered in the 2008/2010 BiOps and their designated critical habitat based on new information available. In addition, we discuss the rangewide status of critical habitat proposed for Lower Columbia River (LCR) coho salmon (Section 2.1.3).

2.1.1 Rangewide Status of Interior Columbia Basin Salmon and Steelhead

This section presents NOAA Fisheries' evaluation of the available scientific and commercial data and the analyses that supplement the species status information considered for the 2008 BiOp and 2010 Supplemental BiOp for Columbia basin salmon and steelhead (Table 2.1). NOAA Fisheries' regional staff and its Northwest Fisheries Science Center (NWFSC[1]) gathered additional information relevant to the 2008 BiOp for this remand. We also considered additional information reported by the Action Agencies in the 2013 Comprehensive Evaluation (BPA et al. 2013a, *hereafter* 2013 Draft CE).

Although information from regional status reviews on Snake River sockeye (SR sockeye) salmon is provided throughout this section, the current rangewide status of this species is discussed in detail in Section 2.1.1.6. NOAA Fisheries treats SR sockeye differently in this analysis; the viability status of this evolutionary significant unit (ESU) cannot be quantified as for other interior Columbia species because its persistence depends on implementation of the captive broodstock and reintroduction program, as discussed below.

This section reviews new information to determine if the updated status of interior Columbia basin salmonids[2] differs from our understanding in the 2008 BiOp and reveals effects of the action that may affect the listed species in a manner or to an extent not previously considered. We do this in the following manner:

- First, we review new information regarding recovery goals and the status of listed species relative to those goals in Sections 2.1.1.1, 2.1.1.2, and 2.1.1.3. We find that neither recovery goals nor the qualitative risk categories indicative of recovery have changed since the 2008 BiOp and that NWFSC analyses indicate that the overall trends for all listed interior Columbia basin species (except SR sockeye, for which this question is not relevant, as noted above) have been stable over the last 10 years.
- We review the Base Period population-level jeopardy indicator metrics that informed the 2008 BiOp's jeopardy analysis in Section 2.1.1.4. These Base Period metrics are derived from empirical observations of population status and do not rely on estimates of improved survival resulting from the RPA actions or estimates of underlying changes in environmental baseline processes, which are the subject of other sections of this supplemental opinion. The Base Period indicator metric estimates, which are now informed by several new years of empirical observations, form the starting point

[1] The NWFSC is one of six regional science centers for NOAA Fisheries. Their work supports the conservation and management of living marine resources and their habitats in the northeast Pacific Ocean and beyond. The NWFSC research assists resources managers in making sound decisions that build sustainable fisheries, recover endangered and threatened species, sustain healthy ecosystems, and reduce risks to human health.

[2] 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).

for the quantitative analyses conducted for six interior Columbia basin species in the 2008 BiOp. It is therefore important to determine if this starting point has changed in a manner that would affect other parts of the 2008 BiOp's jeopardy analysis.

- ◊ In Section 2.1.1.4.1 we present a review of the metrics indicative of the survival prong of the jeopardy standard (24-year extinction risk) and the recovery prong of the standard (three productivity metrics indicative of a population's ability to grow). Figures illustrate the time periods relevant to these metrics and the steps in generating the calculations.
- ◊ In Section 2.1.1.4.2, we describe updated population-level data that is available for updated analyses.
- ◊ In Section 2.1.1.4.3, we update the indicator metrics with the new years of observations, producing estimates for an "extended Base Period." These new estimates also incorporate corrections to the original data analyzed in the 2008 BiOp, as provided by the agencies that collect the monitoring information. The corrected and extended Base Period estimates indicate that relative to the estimates in the 2008 BiOp:
    - Nearly all new estimates are within the range of uncertainty described in the 2008 BiOp. The main exception is mean abundance, which is higher than expected for many populations.
    - Point estimates of mean abundance and the abundance trend productivity metric have increased for most populations.
    - Point estimates of 24-year extinction risk have either decreased (i.e., there is less chance of extinction) or remained the same for most populations.
    - Point estimates of productivity based on the lambda metric are lower for most Chinook populations but higher or equally mixed for steelhead, depending upon hatchery assumptions.
    - Point estimates based on the return-per-spawner (R/S) metric are lower for nearly all populations.
- ◊ In Section 2.1.1.4.4 we evaluate the significance of the extended Base Period results relative to 2008 BiOp expectations, including a statistical analysis of the density-dependent effects of unusually high abundances in some years resulting in low R/S, as described in the 2008/2010 BiOps.

- ▪ In Section 2.1.1.5, we review aggregate population information from dam counts that does not directly correspond to population-level indicator metrics, but which gives an indication of likely returns in more recent years. We also review projections for future returns based on ocean indicators.

- In Section 2.1.1.6, we review status information specifically relevant to SR sockeye salmon.
- In Section 2.1.1.7, we review all of the available information regarding the status of interior Columbia basin salmon and steelhead and conclude that new information in Section 2.1.1 regarding the status of interior Columbia basin species is very similar to that described in the 2010 Supplemental BiOp. Additional years of data and new analyses provide support for NOAA Fisheries' continued reliance on the 2008 BiOp's description of the rangewide status of these species and the Base Period metrics applied in the 2008 BiOp's quantitative aggregate analysis.

2.1.1.1 Interior Columbia Recovery Plans

NOAA Fisheries (NMFS 2007a, 2009a) completed the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan[3] in 2007 and the Middle Columbia River Steelhead Recovery Plan[4] in 2009. Neither plan has been revised since that time. The plans include population structure for Upper Columbia River (UCR) spring Chinook, UCR steelhead, and Middle Columbia River (MCR) steelhead, as well as recovery criteria that are consistent with Interior Columbia Basin Technical Recovery Team (ICTRT) viability criteria. They also include a set of actions designed to move listed species towards recovery, including FCRPS actions.

NOAA Fisheries currently is developing a recovery plan for the four listed Snake River species: SR steelhead, SR spring/summer Chinook, SR fall Chinook, and SR sockeye. The target for releasing a proposed plan is early 2014. It is our intent to optimize recovery plan implementation through stakeholder involvement in developing draft products, particularly through NOAA Fisheries' Snake River Coordination Group. The target for final plan completion is 2015. In the interim, several draft products are available.[5] As of August 2013, these draft products include management unit plans for northeast Oregon, southwest Washington, and Idaho; a draft SR sockeye salmon recovery plan; chapters of the SR fall Chinook recovery plan; and draft hydro and harvest modules that will accompany the final Snake River recovery plans.

The recovery products described above are informed by viability criteria and considerations developed by the ICTRT, which were the primary recovery factors considered in the 2008 BiOp. More detailed viability criteria and an updated status assessment are being developed for SR fall Chinook. These should be available in early 2014 and may alter the SR fall Chinook gap analyses included in the 2008 SCA's Appendix B.

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[3]http://www.nwr.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/upper_columbia/upper_columbia_spring_chinook_steelhead_recovery_plan.html

[4]http://www.nwr.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/middle_columbia/middle_columbia_river_steelhead_recovery_plan.html

[5]http://www.nwr.noaa.gov/protected_species/salmon_steelhead/recovery_planning_and_implementation/snake_river/current_snake_river_recovery_plan_documents.html

2.1.1.2. Five-Year Status Review (2011)

NOAA Fisheries completed 5-year status reviews for interior Columbia basin species in 2011 (76 FR 50448) and concluded that the listing status of all species was unchanged from the previous status review (Good et al. 2005), which was relied upon in the 2008 BiOp. Ford (2011) provided detailed supporting information regarding the demographic status of populations for the 5-year status review. The following table (Table 2.1-1) summarizes key findings regarding the risk of each population with respect to ICTRT (2007a) viability metrics.

Most populations had increased abundance, decreased intrinsic productivity, and little or no change in spatial structure or diversity compared to population risk metrics at the time of the previous 5-year review (2005). Overall risk ratings were “high” for all populations of UCR Chinook, UCR steelhead, and SR spring/summer Chinook. There was a mixture of risk categories for SR steelhead, while most populations of MCR steelhead and SR fall Chinook were rated either “Maintained” or “Viable.” For SR sockeye salmon, it was not possible to quantify the viability ratings. Ford (2011) determined that the SR sockeye captive broodstock-based program has made substantial progress, but natural production levels of anadromous returns remain extremely low for this species. Although the risk status of SR sockeye appears to be on an improving trend, the new information considered did not indicate a change in the biological risk category since the previous status review.

Table 2.1-1. Summary of recovery viability metrics for extant populations of interior Columbia basin species from the most recent 5-year status review (Ford 2011). Exact definitions of each rating are found in ICTRT (2007a), and methods of calculation and time periods over which empirical information was evaluated are in Ford (2011).

ESU	Major Population Group	Number of Populations	Integrated A/P[1] Risk[3]	Integrated SS/D[2] Risk[3]	Overall Viability Rating[4]
Upper Columbia River Spring Chinook	Eastern Cascades	3	3 – High	3 – High	3 – High Risk
Upper Columbia River Steelhead	Eastern Cascades	4	4 – High	4 – High	4 – High Risk
Middle Columbia Steelhead	Cascades Eastern Slope	5	2 – Low 1 – Moderate 2 – High	1 – Low 4 – Moderate	2 – Viable 1 – Maintained 2- High Risk
	John Day River	5	1 – Very Low 4 – Moderate	1 – Low 4 – Moderate	1 – Highly Viable 4 – Maintained
	Umatilla / Walla Walla	3	2 – Moderate 1 – High	3 – Moderate	3 – Maintained
	Yakima	4	3 – Moderate 1 – High	3 – Moderate 1 – High	1 – Viable (Maintained) 2 – Maintained 1 – High Risk
Snake River Spring/Summer Chinook	Lower Snake	1	High	Moderate	High Risk
	Grande Ronde / Imnaha	6	6 – High	5 – Moderate 1 - High	6 – High Risk
	South Fork Salmon	4	1 – Moderate 2 – High 1 – Insuff. Data	3 – Low 1 - Moderate	4 – High Risk
	Middle Fork Salmon	9	9 – High	3 – Low 5 – Moderate 1 - High	9 – High Risk
	Upper Salmon River	8	8 – High	2 – Low 2 – Moderate 4 – High	8 – High Risk
Snake River Fall Chinook	Mainstem and Lower Tribs	1	Moderate	Moderate	Maintained
Snake River Steelhead	Lower Snake	2	1 – Maintained 1 – High	2 – Moderate	1 – Maintained?[5] 1 – High Risk?
	Grande Ronde	4	1 – Very Low 1 – Moderate 1 – High? 1 – Insuff. Data	2 – Low 2 - Moderate	1 – Highly Viable 2 – Maintained 1 – High Risk?
	Imnaha	1	Moderate?	Moderate	Maintained?
	Clearwater	5	1 – Moderate? 4 - High	3 – Low 2 – Moderate	1 – Maintained? 4 – High Risk?
	Salmon	12	7 – Moderate 5 - High	5 – Low 6 – Moderate 1 - High	6 – Maintained? 6 – High?

[1] A/P = abundance *and* productivity
[2] SS/D = spatial structure *and* diversity
[3] ICTRT (2007a) A/P and SS/D risk ratings range from High (greatest risk of extinction) to Very Low (least risk of extinction).
[4] ICTRT (2007a) overall viability ratings, which combine the A/P and SS/D risk ratings, are High Risk (at greatest overall risk of extinction), Maintained, Viable, and Highly Viable (at least overall risk of extinction).
[5] ? = uncertain due to lack of data, only a few years of data, or large gaps in the data series.

2.1.1.3. U.S. Department of Commerce FY 2012 Performance and Accountability Report

NOAA Fisheries reported to Congress on Government Performance and Results Act (GPRA) performance measures for listed species in the Pacific Northwest as of fiscal year 2012 (Ford 2012). This report summarizes the most recent 10-year trend as being stable, increasing, or decreasing, using methods described in the 2010 Supplemental BiOp, Section 2.1.1.1.2.

The trend for each population within an ESU or DPS for which data were available was calculated as the slope of the linear regression of log-transformed natural-origin spawning abundance over the last 10 years of available data. Each population trend was classified as "stable" if the slope of the trend was not significantly ($P < 0.05$) different from zero; "increasing" if the trend was significantly greater than zero; and "decreasing" if the trend was significantly less than zero. The trend for the ESU or DPS was inferred from the population-level trends as follows: if 75% or more of the population-level trends were either significantly increasing or decreasing, then the ESU or DPS trend was reported as that category, otherwise, the ESU or DPS trend was reported as either "mixed" or "stable" (i.e., no statistically significant trend), as deemed appropriate.

The results are very similar to those of the 2009 GPRA report, which were described in the 2010 Supplemental BiOp, Section 2.1.1.1.2. Most populations (47 out of 51) were considered stable, with two populations decreasing and two populations increasing (Table 2.1-2). At the species level, all interior Columbia species were considered stable except SR sockeye salmon, which was considered "mixed."

Table 2.1-2. Summary of 10-year abundance trend determinations from the 2012 GPRA Report (Ford 2012).

Listed Species	Most Recent Year(s) in Trend[1]	Number of Populations For Which Trend[2] Could Be Determined:			Overall Species Rating
		Decreasing	Stable	Increasing	
MCR Steelhead	2008–2010	1	13	1	Stable
UCR Steelhead	2010	0	4	0	Stable
SR Spring/ Summer Chinook	2011	1	23	0	Stable
UCR Spring Chinook	2010	0	3	0	Stable
SR Fall Chinook	2008/2009[4]	0	1	0	Stable
SR Steelhead	2010	0	3	0	Stable
SR Sockeye	2011	0	0	1	Mixed[5]

[1] For some species, the most recent year in the 10-year trend varied among populations.
[2] Population trends were considered stable if the slope of the trend was not significantly ($P<0.05$) different from zero and increasing or decreasing if it was significantly different.
[3] Species were considered increasing or decreasing if 75% or more of the populations were in that category.
[4] Methodologies for estimating spawning abundance for this ESU are currently being re-evaluated. Based on past estimates of wild spawning abundance through 2008, the trend of this ESU is stable. Updated estimates for 2009 through 2011 are generally high, indicating continued stability of this ESU.
[5] The total abundance (hatchery + wild) was at recent highs in 2008–2011, and the 10-year (2002–2011) trend of sockeye counts over Lower Granite Dam is significantly positive (slope = 1.74, $P = 0.004$). However, in the past the status of this ESU has been reported as "mixed," in part because of the degree of artificial propagation necessary to maintain the ESU. It again was designated as "mixed" in the FY 2012 report.

2.1.1.4 Updated BiOp Metrics for Six Interior Columbia Basin Salmon and Steelhead Species

The information and metrics presented in Sections 2.1.1.1 through 2.1.1.3 are primarily intended to track the status of listed species relative to achievement of long-term recovery goals. The focus of Section 2.1.1.4 is quantitative metrics indicative of the 2008 BiOp's application of the jeopardy standard, as described in Section 1 of this supplemental opinion and in the following subsections. The 2008 BiOp considered the quantitative metrics and other relevant data in making a qualitative judgment on whether the RPA is likely to jeopardize listed species or adversely modify critical habitat. Each metric and consideration—like average abundance—shows something relevant to the inquiry. All factors, including abundance data, inform a qualitative assessment of the survival and recovery prongs of the jeopardy standard.

The 2008 BiOp's indicator metrics focused on abundance trends and productivity because operation of the FCRPS primarily influences these factors. In describing the current status of interior Columbia species relative to spatial structure and diversity, we primarily rely on Ford (2011), described in Section 2.1.1.2, which indicates no change in those factors since the last status review.

The 2008 BiOp evaluated the effects of the RPA relevant to the survival and recovery prongs of the jeopardy standard in a manner consistent with recovery planning criteria and analyses,

- first, at the individual population level;
- second, at the major population group (MPG) level; and
- finally, reaching conclusions at the species level.[6]

The metrics described in this section informed the 2008 BiOp's analysis at the population level. These metrics apply to the six interior Columbia basin species for which sufficient quantitative information is available[7]. The data included in this section are the most current available and include recent years not available for the 5-Year Status Review and 2012 GPRA report.

[6] Within an ESU or DPS, independent populations are organized into larger groups that share similarities, known as MPGs. They are defined on the basis of genetic, geographic (hydrographic), and habitat considerations (ICTRT 2005). The ESA Section 7(a)(2) standards are applied at the ESU or DPS level, and not at the MPG or population level.

[7] Snake River spring/summer Chinook, SR fall Chinook, SR steelhead, UCR spring Chinook, UCR steelhead, and UCR steelhead

2.1.1.4.1 Review of the 2008 BiOp Indicator Metrics

The 2008 BiOp relies primarily on four population-level indicator metrics for the quantitative portion of its analysis:

- 24-year extinction risk
- Average returns-per-spawner (R/S) productivity
- Median population growth rate (lambda)
- Abundance trends

The geometric mean of the most recent 10 years of natural spawner abundance was also considered as part of the broader analysis, as described above.

As described in the 2008 BiOp, Chapter 7.1, 24-year extinction risk was considered indicative of the survival prong of the jeopardy standard and the three productivity estimates, along with other relevant information such as abundance data, informed the recovery prong of the jeopardy standard. Each of the productivity metrics provides a complementary but slightly different view of the same underlying population processes. As described in the 2008 BiOp, Chapters 7.1.1.1 and 7.1.1.2, each metric has its strengths and weaknesses, particularly with respect to the most recent returns included in the analysis, the treatment of hatchery-origin fish, and the level of complexity (number of assumptions) and data requirements. The narrative below describes the metrics in more detail.

Productivity estimates in the 2008 BiOp were generally derived from 20- to 24-year periods beginning in approximately 1980 and ending with adult returns through 2003–2006, depending on the population. These return years correspond to completed brood cycles[8] from approximately 1980–2000.[9] The 2008 BiOp referred to these historical empirical observations as the "Base Period" to distinguish them from projections that take into account estimated effects of current and future actions for which empirical data have not yet been gathered or do not yet exist, and that the 2008 BiOp referred to as "prospective" estimates. The ICTRT (2007b) used 1980 as the start of their period of recent observations, primarily because it represented completion of the hydropower system, and the 2008 BiOp adopted the same period. Lambda and abundance trend estimates were based on natural-origin adult returns through 2003–2006 depending on the population. Twenty-four year quasi-extinction risk estimates were developed at the population level using a Base Period that began in brood year 1978 and included all subsequent years of data available at that time.

[8] 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.

[9] The exact years for each population correspond to the time periods applied in the ICTRT (2007b) "gap analysis" report, with the initial year generally ranging from 1979 to 1981. These time periods have been applied consistently to key metrics such as R/S productivity, but for some metrics such as lambda, the statistical program requires a common start date for all populations, which was set at 1980.

For this supplemental opinion, NOAA Fisheries used new empirical information (see Section 2.1.1.4.2) to update and extend the 2008 BiOp's Base Period using the same methods applied in the 2008 BiOp to analyze the Base Period data. The new information, in some cases, corrects historical estimates previously considered in the 2008 BiOp. Additionally, we extended the Base Period from the 2008 analysis by adding several years of additional data to those previously available. We then analyzed the data of the extended Base Period to calculate the Base Period metrics used in the 2008 BiOp.

The various Base Period indicator metrics can be confusing so, in this section, we describe them and other relevant information such as average abundance graphically and show how they inter-relate. We begin with the simplest estimates and build to estimates that are more complex:

- Spawners and average abundance
- Biological Review Team (BRT) Abundance Trend
- Lambda
- Average returns-per-spawner (R/S)
- Extinction Risk

Spawners

The starting point for all calculations is the estimate of the annual number of naturally spawning adults in a population, which is produced by state and Federal agencies, tribes, and some other entities such as public utility districts, in coordination with NOAA Fisheries. Considerable work goes into developing these estimates because many populations are not completely censused, so estimates from sampled spawning areas need to be expanded to represent the entire population. Additionally, different areas may be sampled using different methods (e.g., redd[10] counts versus video weirs), and information regarding factors such as fish-per-redd, age structure, sex ratio, and hatchery fraction needs to be applied to the entire population. In many cases, it takes a year or more after spawning occurs to generate estimates that can be used for our purposes. Figure 2.1-1 shows an example of a 2008 BiOp Base Period time series of spawners.

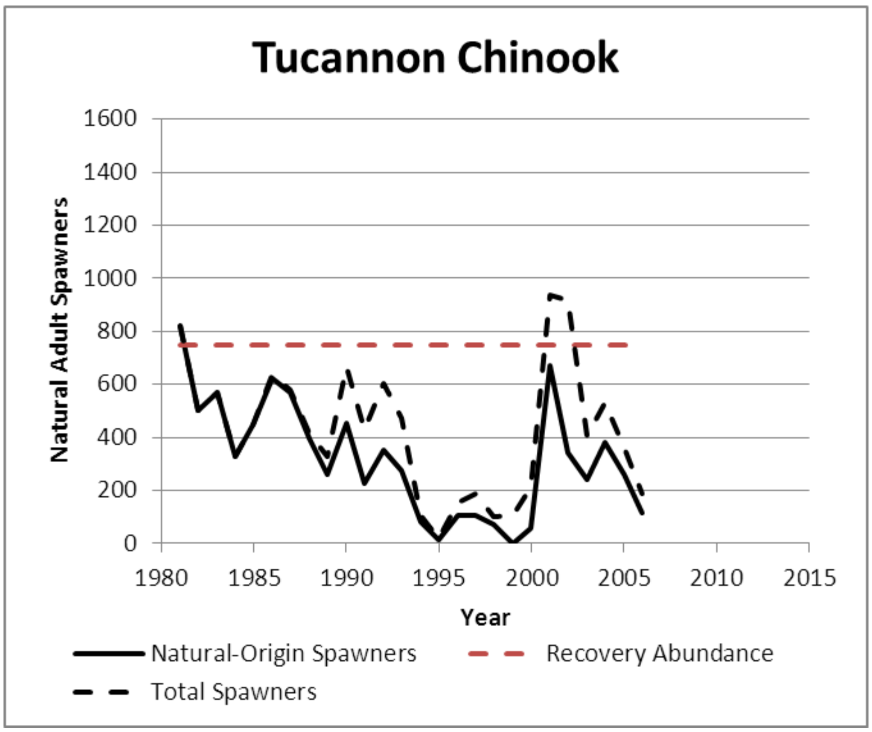

Figure 2.1-1. Annual abundance of adult natural-origin spawners and total (including hatchery-origin) spawners for the Tucannon River population of Snake River spring/summer Chinook. The spawner estimates include potential spawners that were removed for hatchery broodstock. This time series of spawners (1981–2006) corresponds to the Base Period for this population in the 2008 BiOp. The spawner numbers displayed in this figure include corrections from the numbers available in 2008 for some years. The ICTRT (2007a) natural spawner recovery abundance threshold of 750 fish is indicated for reference.

[10] A nest constructed by female salmonids in streambed gravels where eggs are deposited and fertilization occurs.

The 2008 BiOp included calculations of the most recent 10-year geometric mean[11] of natural-origin spawners as one of the descriptors of the status of species. Unlike the other metrics described in this section, the 2008 BiOp did not set an average abundance goal indicative of either the survival or recovery prong of the jeopardy standard, and the Base Period average abundance was not adjusted prospectively to reflect estimated effects of the RPA. However, average abundance is important to track as an element of species status because it indicates current status relative to recovery abundance goals and because we can determine if we are getting closer to the recovery goals over time. (Note that the trend in abundance and prospective adjustment in that trend is captured in the BRT abundance trend indicator metric described below). Figure 2.1-2 shows the geometric mean for the 2008 BiOp Base Period.

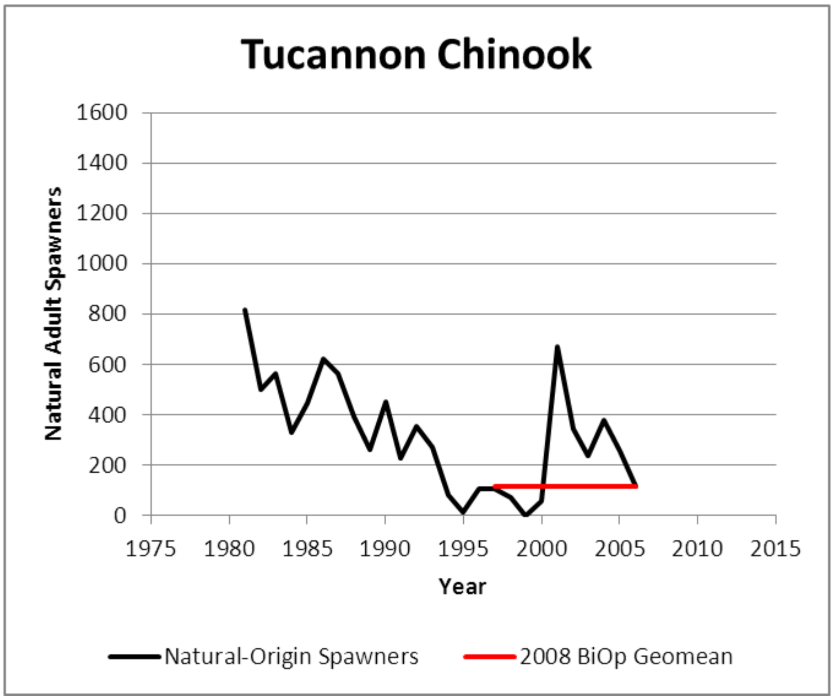

Figure 2.1-2. The most recent 10-year (1997–2006) geometric mean abundance of natural-origin spawners at the time of the 2008 BiOp was 82 spawners for the Tucannon population of SR spring/summer Chinook. The 95% confidence limits for that mean (not shown) range from 35 to 193. The spawner numbers and geometric mean (119) displayed in this figure include corrections from the numbers available in 2008 for some years. The displayed time series represents return years included in the 2008 BiOp Base Period for this population.

[11] The geometric mean is a type of mean or average, which indicates the central tendency or typical value of a set of numbers by using the product of their values (as opposed to the arithmetic mean which uses their sum). The geometric mean is defined as the nth root (where n is the count of numbers) of the product of the numbers. It is most appropriate for determining the mean value of a series of rates (such as survival rates or R/S) or for any series of observations that follows a geometric distribution of many small observations and a long tail with few large observations. We applied it to abundance estimates in the 2008 BiOp because the ICTRT (2007a) used it for this purpose, in part because it discounts the influence of infrequent high numbers and is in this sense more conservative than an arithmetic mean.

Additional years of spawner abundance estimates have become available since 2008. When these are added to the previous years to create an extended Base Period, a new 10-year average abundance can be calculated and compared to that calculated for the 2008 BiOp (Fig. 2.1-3). In this example, the new mean abundance is greater than that calculated in the 2008 BiOp.

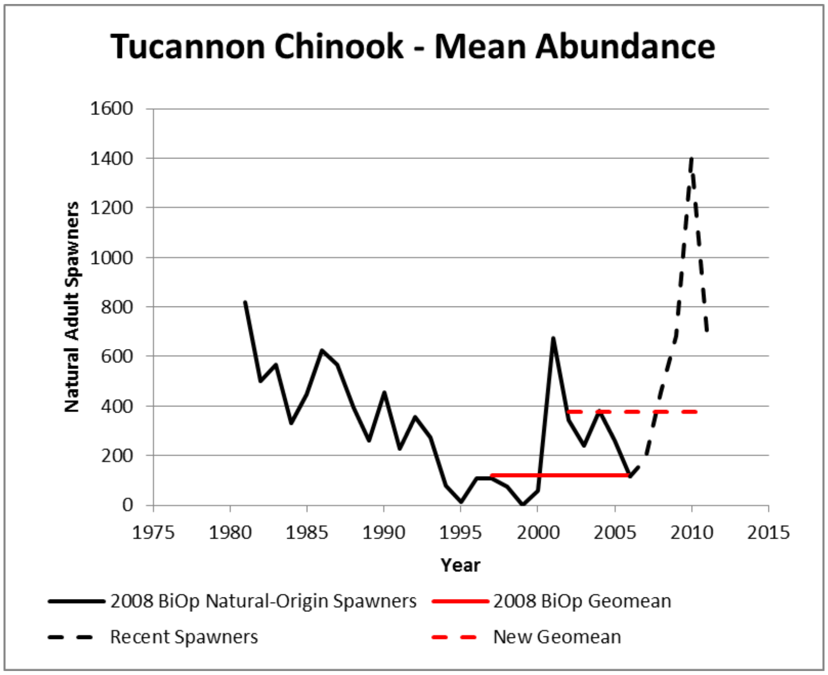

Figure 2.1-3. Addition of five years of new spawner estimates for the Tucannon population of SR spring/summer Chinook. The additional data result in an updated 10-year (2002–2011) geometric mean abundance (375) that can be compared to the mean abundance reported in the 2008 BiOp (86) and the corrected mean for the same years (119; see Figure 2.1-2). The 95% confidence limits (not shown) for the extended Base Period geometric mean range from 246 to 570.

Biological Review Team Abundance Trend

The "BRT trend" productivity indicator metric essentially fits a trend line through the spawner data to determine if the population is growing or declining and by how much. Section 7.1.1.2 of the 2008 BiOp describes this metric in detail. It is also the "trend" metric used in NOAA Fisheries' 5-Year Status Review (Section 2.1.2.2, above) and GPRA Report (Section 2.1.2.3, above), although those reports calculate the trends for different time periods. Biologists have generally observed that populations follow exponential (curved) growth trajectories, rather than linear (straight-line) trajectories, so this metric represents a curved line that best fits the spawner data. However, it is computationally easier to transform the data to a natural logarithmic scale (ln) and then fit a straight line to the transformed data, which is what we do for this metric. When we leave the resulting line in the transformed units, a slope of 1.0 represents a flat line (no trend), a slope greater than 1.0 indicates that the population has been increasing, and a slope less than 1.0 indicates that it has been declining. The 2008 BiOp's prospective action goal for this metric is BRT trend greater than 1.0.

When transforming the original spawner counts to a logarithmic scale, we added 1.0 to all spawner counts because the natural logarithm of zero is undefined and, in some years for some populations, the spawner estimate was zero. Figure 2.1-4 displays the log-transformed natural-origin (spawner +1) data from Figure 2.1-3; the BRT trend line calculated for the 2008 BiOp Base Period; and the BRT trend for the extended Base Period. In this example, the trend has been declining throughout the Base Period and the extended Base Period,[12] but the slope of the extended Base Period line represents less of a decline than that in the 2008 BiOp.

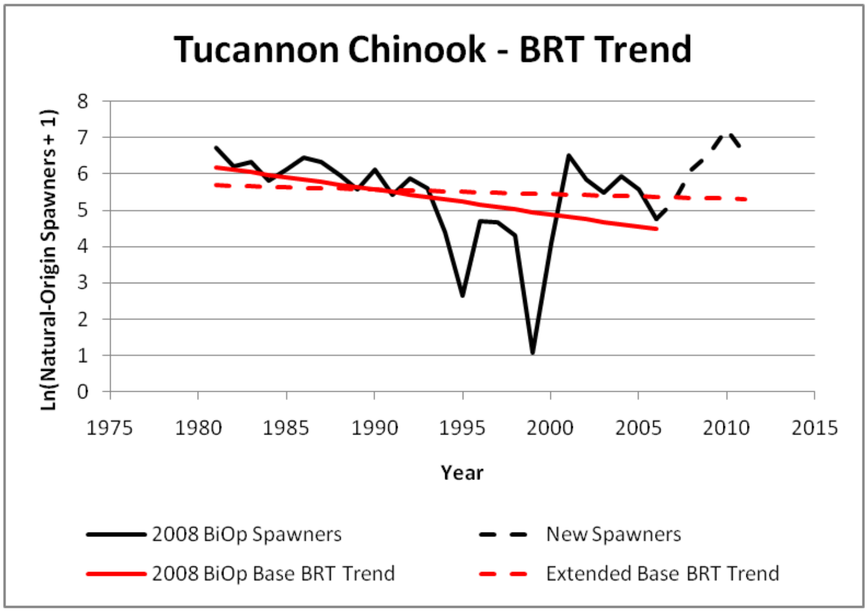

Figure 2.1-4. BRT abundance trend fit to two periods for the Tucannon population of SR spring/summer Chinook. The 2008 BiOp's prospective action goal for this metric is BRT trend greater than 1.0. The trend for the 2008 BiOp Base Period (1981–2006) is 0.92 (i.e., abundance is declining at 8% a year) and the BRT trend for the extended Base Period (1981–2011) is 0.98, a 2% per year decline. Therefore, in this example, although the extended Base Period trend continues to indicate that natural-origin spawner abundance has declined over the time period beginning in 1981, the decline is now less than that estimated in the 2008 BiOp. The extended Base Period slope falls within the 95% confidence intervals (not shown) for the 2008 BiOp BRT trend, indicating that the extended Base Period trend is within the range of statistical uncertainty described in the 2008 BiOp. The 2008 BiOp Base Period spawners displayed in this figure are corrected values, although the 2008 BiOp base BRT trend was calculated from the original values in the 2008 BiOp. A slope of 1.0 (no trend) also falls within the 95% confidence limits and, because the trend is not statistically significant, the 2012 GPRA Report described in Section 2.1.1.3 classifies this population as "stable."

[12] The GPRA Report (Ford 2012a) classifies this population as "stable" rather than as declining. This difference is because (1) the GPRA Report only analyzed the last 10 years of data, rather than the 2008 FCRPS BiOp's 25-year base period or the 30-year extended base period; and (2) the 95% confidence intervals for the trend lines in Figure D (not shown) encompass a slope of 1.0, so the declining trend is not statistically significant.

Median Population Growth Rate (Lambda)

Median population growth rate (lambda) is another measure of productivity and was the primary metric applied in the 2000 FCRPS Biological Opinion (NMFS 2000). The 2008 BiOp, Section 7.1.1.2, explains lambda in more detail. Lambda describes the median annual change in 4-year running sums of population abundance. Running sums are used instead of individual year estimates to filter out sampling error and high volatility in salmon data caused by age-structured cycles (i.e., variable maturation rates, the time between birth and reproduction, and iteroparity[13] [McClure et al. 2003]). Like the BRT trend, populations grow when lambda is greater than 1.0, they decline when it is less than 1.0, and they are stable when it is 1.0. The 2008 BiOp's prospective action goal for this metric is lambda greater than 1.0.

Figure 2.1-5 shows the same log-transformed spawner estimates as in the BRT trend figure (2.1-4), the four-year running sums of those spawner estimates, and lambda calculated for the Tucannon Chinook population's 2008 BiOp Base Period and extended Base Period. Note that the number of running sums is three less than the number of spawner estimates. In this example, hatchery-origin natural spawners are not included in the estimates, similar to the way we fit the BRT trend only to the natural-origin spawners and not to the total spawners. The inherent assumption of this approach in the lambda calculations is that the hatchery-origin spawners are not contributing to the subsequent generation, either because they are unable to reproduce successfully or because their progeny do not survive. We denote this assumption as HF=0 (hatchery-origin spawner reproductive effectiveness is zero). We also calculated lambda under the assumption that hatchery-origin spawners contribute just as much to the next generation as natural-origin spawners (HF=1; not shown). We do not know how effective hatchery-origin spawners are compared with natural-origin spawners for most populations, so these assumptions bookend the possibilities and we include lambda estimates under both assumptions to capture the complete range.

[13] Iteroparity is the ability to reproduce more than once during a lifetime. For example, a proportion of steelhead are able to survive initial spawning and return in subsequent years as repeat spawners.

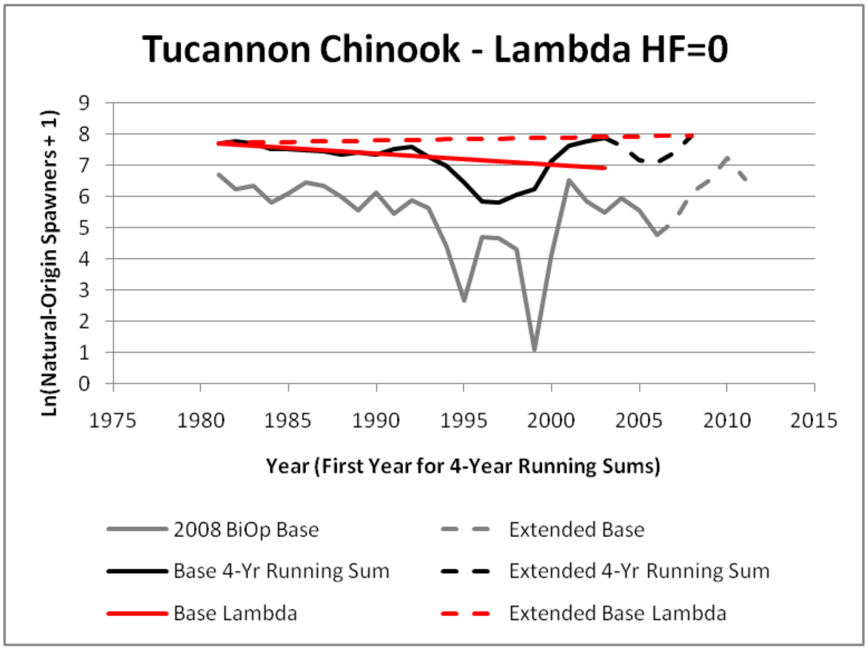

Figure 2.1-5. Tucannon population of SR spring/summer Chinook median population growth rate (lambda), fit to 4-year running sums for two time periods. The 2008 BiOp's prospective action goal for this metric is lambda greater than 1.0. In this example, we assume that hatchery-origin spawners do not contribute to the subsequent generation (HF=0). The median population growth rate for the 2008 BiOp Base Period (1981–2006) is 0.96 (i.e., the population is declining at 4% per year) and the median growth rate for the extended Base Period (1981–2011) is 1.01, a 1% per year increase. Therefore, in this example, inclusion of the additional years and correction of some previous estimates result in an improvement in the lambda point estimate, compared to that estimated in the 2008 BiOp, including a shift to positive population grow. The extended Base Period slope falls within the 95% confidence intervals (not shown) for the 2008 BiOp BRT trend, indicating that the extended Base Period trend is within the range of statistical uncertainty described in the 2008 BiOp. The 2008 BiOp Base Period spawners displayed in this figure are corrected values, although the 2008 BiOp base lambda was calculated from the original values in the 2008 BiOp.

Under the HF=0 assumption, lambda estimates tend to be similar to BRT abundance trend estimates, and a comparison of Figures 2.1-6 and 2.1.-7 shows the similarity in slope estimated by the two metrics. For this particular example, the lambda estimates (0.96 Base and 1.01 extended Base) are a bit higher than the BRT abundance trend estimates (0.92 Base and 0.98 extended Base). The results also differ qualitatively since the BRT abundance trend indicates a declining population in both periods, but the extended base lambda estimate indicates that the population has been growing at 1% per year. Under the HF=1 assumption, estimates of lambda are generally lower (if hatchery-origin spawners are present) and more similar to the R/S productivity estimates described below. For the Tucannon River Chinook population, lambda HF=1 was 0.87 for the 2008 BiOp's Base Period estimate and 0.90 for the extended Base Period estimate.

Returns-per-Spawner

Returns-per-spawner (also referred to as recruits-per-spawner) is a productivity measure that determines whether a population is maintaining itself, declining, or growing. The change is measured as a per-generation rate, rather than as an annual rate like the BRT trend and lambda productivity metrics. If 100 parental spawners produce 100 progeny that survive to maturity (i.e., return to the spawning area over several years, since salmonids can mature at variable ages), then R/S = 1.0 and the population abundance has been maintained over that brood cycle. If, however, only 80 progeny survive to spawn, then R/S = 0.8 and the population is not replacing itself and will be declining unless there is an additional source of spawners; e.g., from straying or hatchery programs. Since each female produces thousands of eggs, there is also the potential for much higher return rates. For example, 200 progeny might survive to spawn, which would result in R/S = 2.0. In this case, the population abundance has doubled in one generation. The 2008 BiOp's goal for this metric was mean R/S greater than 1.0.

We calculated R/S for each generation using the ICTRT (2007a) method, which includes both natural-origin and hatchery-origin spawners in the denominator (S), but only natural-origin returning spawners in the numerator (R), since all of the progeny of the original spawners are by definition of natural origin, regardless of their parents' ancestry. We do not assume the effectiveness of the hatchery-origin spawners, as in the lambda calculations, because we have empirical data that indicate the returns from the combination of all spawners. Figure 2.1-6 shows the total hatchery- and natural-origin spawners for the Tucannon Chinook population as a black line and the returning progeny (combined for all maturation ages and return years) as a blue line. When returns exceed the number of spawners (i.e., when the blue line is above the black line), R/S exceeds 1.0 (i.e., circles are above the 1.0 red line).

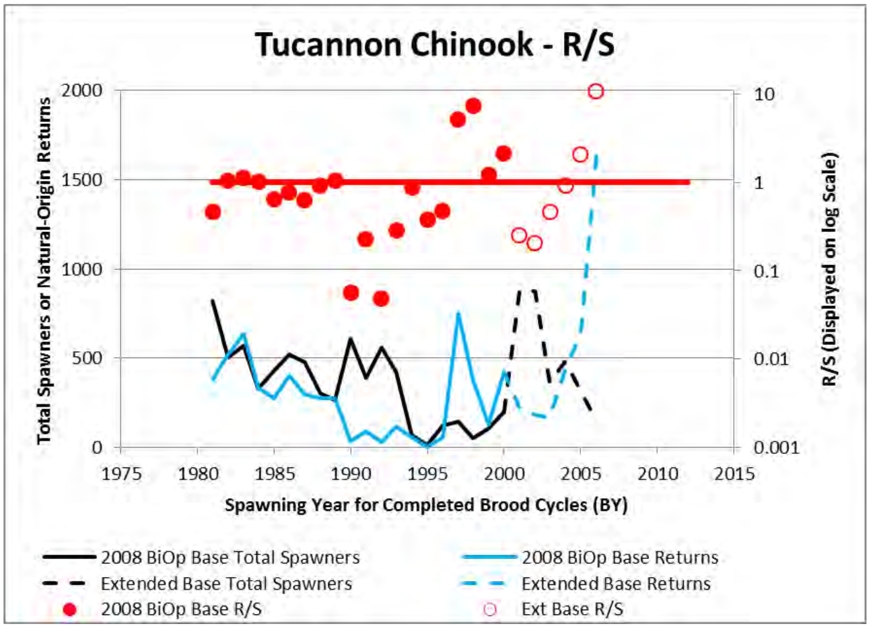

Figure 2.1-6. Returns-per-spawner for the Tucannon Chinook population during the 2008 BiOp Base Period and the extended Base Period. The 2008 BiOp prospective action goal for this metric is a geometric mean R/S that is greater than 1.0 (red line). Total spawners (natural- and hatchery-origin) and natural-origin returns from those spawners are displayed for each brood year (BY). The 2008 BiOp Base Period spawners and returns displayed in this figure are corrected values, although the 2008 BiOp base R/S points represent the original estimates in the 2008 BiOp.

We summarized the R/S estimates using a geometric mean and compared the mean to 1.0. Figure 2.1-7 shows Tucannon River Chinook geometric means that are calculated for the 2008 BiOp's Base Period (1981–2000 brood years) and the extended Base Period (1981–2006 brood years). In this example, there was no difference in the estimates between the two periods, but those estimates (R/S = 0.72) were considerably lower than the estimates obtained from other productivity metrics.

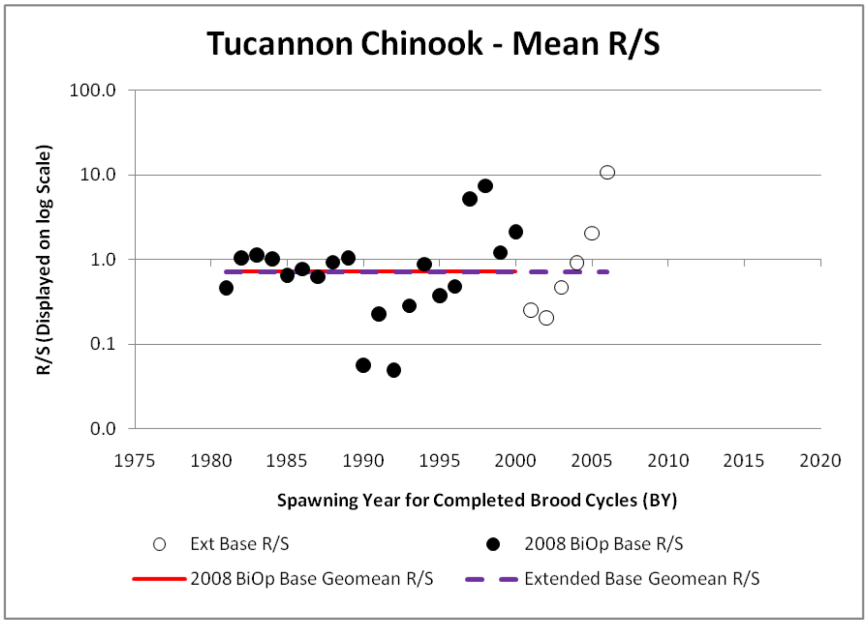

Figure 2.1-7. Returns-per-spawner for the Tucannon Chinook population, including geometric mean R/S for the 2008 BiOp Base Period (1981–2000 brood years) and the extended Base Period (1981–2006 brood years). The 2008 BiOp prospective action goal for this metric is a geometric mean R/S that is greater than 1.0. In this example, the estimate for both periods is 0.72. The 95% confidence limits for the means (not shown) range from 0.48–1.10 for the Base Period and 0.47–1.10 for the extended Base Period. BY = brood year.

Extinction Risk

Extinction risk is the most complex indicator metric included in the 2008 BiOp. As described in the 2008 BiOp, Attachment I, Aggregate Analysis Appendix, quantitative assessment of short-term (24-year) extinction risk is calculated in a manner that is similar to that used by the ICTRT for calculating long-term (100-year) extinction risk. Observed abundance and productivity estimates during the Base Period are used to define a stock-recruitment function that predicts the number of progeny that will return to spawn from a given number of parental spawners. The production functions are the Beverton-Holt (for spring Chinook ESUs) and Ricker (for steelhead DPSs and SR fall Chinook), which are standard in fisheries literature.[14]

Estimates of extinction probability are based on simulations. These start with current abundance and then project a 24-year time series of future spawners. Each projection will have a different outcome due to random error and autocorrelation terms, so the projections are repeated thousands of times to generate a range of outcomes. The proportion of simulation runs that fall

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[14] See discussion of density dependence in Section 2.1.1.4.4 and Appendix C in this document for details, as well as Ricker (1954) and Hilborn and Walters (1992). Briefly, production functions specify the expected number of fish in the next generation as a function of the number of fish in the parental generation. At low parental numbers (low density), the number of progeny exceeds the number of parents; at carrying capacity the number of progeny equals the number of parents; and above carrying capacity the Beverton-Holt model remains at an asymptotic level while the Ricker model predicts a steep decline in the number of progeny compared to the number of parents because of strong density dependence.

below the quasi-extinction threshold (QET[15]) within the 24-year time period represents the probability of short-term extinction. That is, of 1000 simulations, if 300 predict salmon abundance that is below a QET at the end of the 24 years there is a 30% risk of extinction.

Figure 2.1-8 shows an example of this method for the Tucannon River Chinook population. The black line that ends in 2012 represents the observed time series of spawners over the extended Base Period. Many simulations of future population tracks beginning in 2013 are generated from the original data and a certain number of them will fall below the quasi-extinction criteria. In this example, one of the 14 simulations indicated quasi-extinction, resulting in an extinction probability of 7%. (When thousands of simulations are performed, the actual extinction risk estimate for this population is 3%, as displayed in Table 2.1-7).

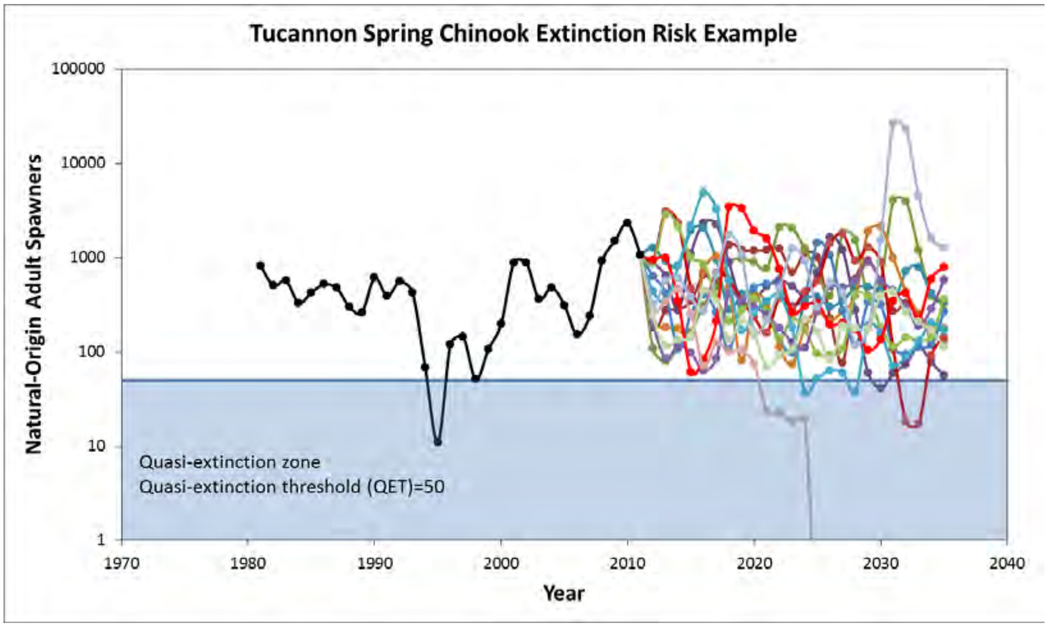

Figure 2.1-8 Example of method used to calculate the quasi-extinction risk of the Tucannon River Chinook population, from Hinrichsen (2013; included as Appendix B in this supplemental opinion). The black line indicates empirical estimates of adult spawners through 2012. Fourteen simulations of abundance from 2013–2037 (24 years) are shown in various colors. One of these simulations drops below a quasi-extinction threshold of 50 fish for four consecutive years, so for this simulation the population is considered "extinct." The risk of 24-year extinction shown in this example is 7% (1/14); the estimate we use for this supplemental opinion is 3%, based on thousands of simulations (Table 2.1-7).

[15] Section 7.1.1.1 of the 2008 BiOp defined extinction as falling below a quasi-extinction threshold (QET) four years in a row (representing a full brood cycle of mature male and female spawners) per recommendations of the ICTRT (2007b). The 2008 BiOp used a QET rather than absolute extinction (one fish) as a criterion because it is very difficult to predict the dynamics of populations at extremely low abundance. Various reviews since the 2000 FCRPS Biological Opinion, which relied upon absolute extinction, suggested that it would be more appropriate to evaluate extinction risk relative to a higher quasi-extinction threshold. Such a threshold does not necessarily represent true biological extinction, but it represents an abundance below which there is great concern from a management perspective and high analytical uncertainty regarding persistence. Choice of an appropriate QET range was the subject of considerable discussion in the 2008 BiOp Section 7.1.1.1.

A number of factors are important in defining extinction risk analyses and the criteria for evaluation. The 2008 BiOp Section 7.1.1.1 presents a detailed discussion of these factors, including choice of the 24-year period to represent short-term extinction risk (i.e., there is greater precision over shorter periods than longer periods; it is more than twice the duration of the biological opinion; and precedent from the 2000 FCRPS BiOp) and primary reliance on a QET of 50 fish (i.e., a level higher than 0 is necessary to account for uncertainty in data and population processes at low abundance, and the choice of the specific level of 50 fish is consistent with ICTRT methods). It also points out why some of the factors are conservative for at least a subset of populations (e.g., some populations have dropped below the 50 fish QET in the past and returned to higher abundance levels; these analyses assume that all hatchery production ceases immediately). The 2008 BiOp did not set an explicit numeric goal for "low short-term risk of extinction," but approximated it as 5% or less.[16]

2.1.1.4.2 New Information in Northwest Fisheries Science Center Salmon Population Summary Database

The NWFSC maintains the Salmon Population Summary (SPS) database,[17] which contains population-level information from state agencies, tribes, and other sources. This database includes four to nine new years of data for most interior Columbia basin populations, as well as data for some populations for which quantitative information was lacking in the 2008 BiOp[18]. In addition to inclusion of new years of data, the data set includes corrections to population estimates from previous years for many populations based on new research that affected factors such as expansion terms for index redd counts and estimation of hatchery fractions. A summary of the new information is included in Tables 2.1-3 and 2.1-4. The 2008 BiOp relied primarily upon calculations that were based on an approximately 20-year period, beginning in approximately 1980.[19] A few populations with shorter time series beginning as late as 1985 were included in these calculations. The 2008 BiOp also included calculations based on a shorter time frame (2008 BiOp, Appendix B) beginning in approximately 1990, but because those results were generally more optimistic than results based on the longer time period, they were given less

[16] NOAA Fisheries has not identified quantitative values of metrics that would indicate a sufficiently low short-term risk of extinction because the estimation of extinction risk is dependent on specific model functions and assumptions (such as quasi-extinction abundance threshold, QET, and treatment of listed hatchery fish) about which there is considerable uncertainty. The ability of a particular set of actions to achieve a goal of no more than any assumed percentage risk of extinction may vary considerably among models and assumptions. For convenience, the SCA includes estimates of survival gaps necessary to reduce 24-year extinction risk to no more than 5%, given the range of assumptions considered in the analysis. Ultimately, the acceptable level of short-term extinction risk is a qualitative policy determination made by NOAA Fisheries consistent with the ESA and its implementing regulations (2008 BiOp, pp. 7.7 and 7.8).

[17] https://www.webapps.nwfsc.noaa.gov/apex/f?p=238:home:0

[18] Not all data submitted to the SPS database have been entered on the publicly accessible web site as of August 18, 2013. The data used for analyses in this draft of the supplemental opinion were obtained from M. Brick, NWFSC, in the spreadsheet "2012 SPS formatted update 70913 inc fch.xls", which is available from NOAA Fisheries, as are spreadsheets and SPAZ output files that used the SPS data to calculate BiOp metrics.

[19] Specific start dates varied by population. The particular time frame was chosen to match the time period used in ICTRT (2007b) survival "gap" calculations.

weight. In the subsequent calculations in Section 2.1.1.4.3 (*Extended Base Period Productivity and Extinction Risk Indicator Metrics Calculated from Updated Population Information*) we follow the convention of including populations with time series that begin no later than 1985 in the longer-term calculations. We have also included Appendix A, which evaluates metrics from 1990 to present and includes populations with time series that begin after 1985.

Empirical information for SR steelhead is restricted to three populations (Table 2.1-4), which was also the case for the 2008 BiOp. The ICTRT (2007a, 2007b) determined the average abundance of “A-run” and “B-run” steelhead[20] based on dam counts, classification of each population as A-run or B-run (or a mixture of the two), and assumptions about the distribution of steelhead among populations. The 2008 BiOp applied the ICTRT’s average A-run or average B-run estimates to each uncensused population, based on its classification, in order to evaluate the prospective effects of population-specific tributary habitat RPA actions on SR steelhead (2008 BiOp, Section 7.1.2.3). The approach used to apply dam count estimates to uncensused populations in the 2008 BiOp is no longer valid, based on recent studies that indicate a more complex structure of SR steelhead populations than is indicated by the previous A- and B-run classifications (Cooney 2013a) and an alternative method will not be reliable until more information is available from ongoing studies (probably two to three more years). Until an alternative approach is developed, the aggregate dam count is the main information available for most populations of SR steelhead (see Section 2.1.1.5.1). We continue to rely on the performance measures in the 2008 BiOp, which were based on the average A- and B-run method, for lack of an alternative method, but do not attempt to calculate extended Base Period average A-run and average B-run estimates.

[20] Inland steelhead of the Columbia River basin, especially the Snake River subbasin, are commonly referred to as either A-run or B-run. These designations are based on a bimodal migration of adult steelhead at Bonneville Dam (first mode is A-run; second mode is B-run), differences in age (A-run generally spend one year in the ocean; B-run two years), and adult size (A-run are smaller; B-run bigger) observed among Snake River steelhead. It is unclear, however, if the life-history and body size differences observed upstream are correlated back to the groups forming the bimodal migration observed at Bonneville Dam. Furthermore, the relationship between patterns observed at the dams and the distribution of adults in spawning areas throughout the Snake River Basin is not well understood.

Table 2.1-3. New Chinook salmon information in the NWFSC SPS database that has become available since the 2008 BiOp.

ESU	MPG	Population	Adult Return Years Included in 2008 BiOp "Base Period"		Last Adult Return Year in "Extended Base Period"	Number of New Return Years Available	Completed Brood Cycles (Brood Years) Included in 2008 BiOp "Base Period"[2]		Last Complete Brood Cycle (Brood Year) Included in "Extended Base Period"	Number of New Brood Years Available
			First	Last			First	Last		
Snake River Spring/ Summer Chinook Salmon	Lower Snake	Tucannon	1981	2006	2011	5	1981	2000	2006	6
		Asotin - Functionally Extirpated								
	Grande Ronde / Imnaha	Catherine Creek	1981	2005	2011	6	1981	2000	2006	6
		Upper Grande Ronde	1981	2005	2011	6	1981	2000	2006	6
		Minam River	1981	2005	2012	7	1981	2000	2007	7
		Wenaha River	1981	2005	2012	7	1981	2000	2007	7
		Lostine/Wallowa Rivers	1981	2005	2011	6	1981	2000	2006	6
		Imnaha River	1981	2005	2011	6	1981	2000	2006	6
		Big Sheep Creek - Functionally Extirpated								
		Lookingglass- Functionally Extirpated								
	South Fork Salmon	South Fork Salmon Mainstem	1979	2003	2012	9	1979	1998	2007	9
		Secesh River	1981	2005	2011	6	1981	2000	2006	6
		East Fork S. Fork Salmon (including Johnson)	1979	2003	2012	9	1979	1998	2007	9
		Little Salmon River (including Rapid R.)								
	Middle Fork Salmon	Big Creek	1980	2004	2012	8	1980	1999	2007	8
		Bear Valley/Elk Creek	1979	2003	2012	9	1979	1998	2007	9
		Marsh Creek	1979	2003	2012	9	1979	1998	2007	9
		Sulphur Creek	1979	2003	2012	9	1979	1998	2007	9
		Camas Creek	1980	2004	2012	8	1980	1999	2007	8
		Loon Creek	1980	2004	2012	8	1980	1999	2007	8
		Chamberlain Creek[1]	N/A	N/A	2012	27	N/A	N/A	2007	22
		Lower Middle Fork Salmon (below Ind. Cr.)								
		Upper Middle Fork Salmon (above Ind. Cr.)								
	Upper Salmon	Lemhi River	1979	2003	2012	9	1979	1998	2007	9
		Valley Creek	1979	2003	2012	9	1979	1998	2007	9
		Yankee Fork	1979	2003	2011	8	1979	1998	2006	8
		Upper Salmon River (above Redfish L.)	1981	2005	2012	7	1981	2000	2007	7
		North Fork Salmon River								
		Lower Salmon River (below Redfish L.)	1981	2005	2012	7	1981	2000	2007	7
		East Fork Salmon River	1981	2005	2012	7	1981	2000	2007	7
		Pahsimeroi River	1986	2005	2012	7	1986	2000	2007	7
		Panther - Extirpated								
Upper Columbia Spring Chinook Salmon	Eastern Cascades	Wenatchee R.	1979	2003	2011	8	1979	1998	2006	8
		Methow R.	1979	2003	2011	8	1979	1998	2006	8
		Entiat R.	1979	2003	2011	8	1979	1998	2006	8
		Okanogan R. (extirpated)								
Snake River Fall Chinook Salmon[3]	Main Stem and Lower Tributaries	Lower Mainstem Fall Chinook 1977-Most Recent BY	1977	2004	2012	8	1977	1999	2007	8
		Lower Mainstem Fall Chinook 1990-Most Recent BY	1990	2004	2012	8	1990	1999	2007	8

[1] Chamberlain Creek was not included in 2008 Biop quantitative estimates. Data is now available for 1985-2012 (1986-2007 BY).

[2] If returns from oldest-aged spawners are rare (approx. 5% or less) for a population, numbers represent near-complete brood years (lacking oldest age returns). Use of near-complete brood years slightly underestimates R/S.

[3] Snake River Fall Chinook estimates are preliminary and expected to change prior to completion of the final Supplemental BiOp.

Table 2.1-4. New steelhead salmon information in the NWFSC SPS database that has become available since the 2008 BiOp.

ESU	MPG	Population	Adult Return Years Included in 2008 BiOp "Base Period"		Last Adult Return Year in "Extended Base Period"	Number of New Return Years Available	Completed Brood Cycles (Brood Years) Included in 2008 BiOp "Base Period"[4]		Last Complete Brood Cycle (Brood Year) Included in "Extended Base Period"	Number of New Brood Years Available
			First	Last			First	Last		
Upper Columbia River Steelhead	Eastern Cascades	Wenatchee	1981	2006	2011	5	1981	2000	2006	6
		Methow	1981	2006	2011	5	1981	2000	2006	6
		Entiat	1981	2006	2011	5	1981	2000	2006	6
		Okanogan	1981	2006	2011	5	1981	2000	2006	6
Snake River Steelhead[1]	Lower Snake	Tucannon								
		Asotin								
	Imnaha River	Imnaha R. (Camp Cr)	1980	2005	2010	5	1980	1999	2005	6
	Grande Ronde	Upper Mainstem	1981	2006	2010	4	1981	2000	2005	5
		Lower Mainstem								
		Joseph Cr.	1981	2005	2010	5	1981	2000	2005	5
		Wallowa R.								
	Clearwater River	Lower Mainstem								
		Lolo Creek								
		Lochsa River								
		Selway River								
		South Fork								
		North Fork - (Extirpated)								
	Salmon River	Upper Middle Fork Tribs								
		Chamberlain Cr.								
		South Fork Salmon								
		Panther Creek								
		Secesh River								
		North Fork								
		Lower Middle Fork Tribs								
		Little Salmon/Rapid								
		Lemhi River								
		Pahsimeroi River								
		East Fork Salmon								
		Upper Mainstem								
Mid Columbia Steelhead	Yakima	Upper Yakima	1985	2004	2012	8	1985	1999	2007	8
		Naches	1985	2004	2012	8	1985	1999	2007	8
		Toppenish	1985	2004	2012	8	1985	1999	2007	8
		Satus	1985	2004	2012	8	1985	1999	2007	8
	Eastern Cascades	Deschutes W.	1980	2005	2011	6	1980	1999	2006	7
		Deschutes East[2]	1990	2005	2011	6	1990	1999	2006	7
		Klickitat								
		Fifteenmile Cr.	1985	2005	2011	6	1985	1999	2006	7
		Rock Cr.								
		White Salmon - Extirpated								
	Umatilla/Walla Walla	Umatilla	1981	2004	2011	7	1981	2000	2006	6
		Walla-Walla[3]	N/A	N/A	2011	19	N/A	N/A	2006	14
		Touchet[5]	N/A	N/A	2012	26	N/A	N/A	2007	21
	John Day	Lower Mainstem)	1979	2005	2011	6	1979	1998	2006	8
		North Fork	1979	2005	2011	6	1979	1998	2006	8
		Upper Mainstem	1979	2005	2011	6	1979	1998	2006	8
		Middle Fork	1979	2005	2011	6	1979	1998	2006	8
		South Fork	1979	2005	2011	6	1979	1998	2006	8

[1] Only the populations with empirical estimates are shown. In the 2008 BiOp, other populations were analyzed using "average A- and B-run" estimates, as understood at the time.

[2] Deschutes East population was only analyzed for "1990 - present" metrics in the 2008 BiOp.

[3] Walla Walla population was not used for 2008 BiOp metrics because the time series was too short (1993-2003, with partial 2004 and 2005 info; 1993-2000 BY). New information is 1993-2011 (1993-2006 BY).

[4] If returns from oldest-aged spawners are rare (approx. 5% or less) for a population, numbers represent near-complete brood years (lacking oldest age returns). Use of near-complete brood years slightly underestimates R/S.

[5] Touchet population was not available for the 2008 BiOp. Because time series does not begin until 1987, it is only used to calculate "1990-present" metrics.

2.1.1.4.3 Extended Base Period Productivity and Extinction Risk Indicator Metrics Calculated From Updated Population Information

Abundance

Mean abundance for the most recent 10-year period was reported in the 2008 BiOp status descriptions for each population. Updated geometric mean abundance point estimates are higher than those presented in the 2008 BiOp are for all Chinook populations and for 17 out of 20 steelhead populations (Tables 2.1-5 and 2.1-6; Figures 2.1-9 and 2.1-10). The three populations with lower mean abundance estimates were the Fifteenmile Creek, Lower Mainstem John Day, and Middle Fork John Day populations of MCR steelhead. Even with the decline, the Fifteenmile Creek estimate is higher than the ICTRT abundance threshold for this population. The mean abundance estimates in the 2008 BiOp were taken from ICTRT (2007b), which did not include confidence intervals but did include ranges. All new mean abundance estimates are within those ranges. Most new abundance estimates are within the 2008 BiOp's 95% confidence limits, indicating that the new results are within the range of statistical uncertainty described in the 2008 BiOp. However, extended Base Period mean abundance for 11 of the 27 Chinook populations and 6 of the 20 steelhead populations were higher than the 2008 BiOp's 95% confidence limits.

Table 2.1-5 Comparison of Chinook Base Period 10-year geometric mean abundance reported in the 2008 BiOp, corrected estimates for the 2008 BiOp's Base Period, and extended Base Period estimates based on new information in the NWFSC SPS database that has become available since the 2008 BiOp. Extended Base Period mean abundance is higher than the 2008 BiOp mean for all Chinook populations. Recent total spawners (including hatchery-origin spawners) and percent of natural-origin spawners are also displayed.

ESU	MPG	Population	ICTRT Threshold Abundance Goal	2008 BiOp				Corrected 2008 BiOp Estimate	New Information					
				Most Recent 10-Year Geomean Abundance (2008 BiOp)	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Return Years (2008 BiOp)		Most Recent 10-Year Geomean Abundance	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Return Years	Most Recent 10-Year Geomean Total Adult Spawners (Including Hatchery-Origin)	Most Recent 10-Year Geomean Percent Natural-Origin Spawners
Snake River Spring/Summer Chinook Salmon	Lower Snake	Tucannon	750	82	35	193	1997-2006	119	375	246	570	2002-2011	600	0.53
		Asotin - Functionally Extirpated												
	Grande Ronde / Imnaha	Catherine Creek	1000	107	67	171	1996-2004	89	137	82	227	2002-2011	304	0.35
		Upper Grande Ronde	1000	38	21	70	1996-2005	47	65	42	100	2002-2011	171	0.19
		Minam River	750	337	250	454	1996-2006	336	489	416	576	2003-2012	525	0.92
		Wenaha River	750	376	250	564	1996-2007	380	436	364	522	2003-2012	465	0.92
		Lostine/Wallowa Rivers	1000	276	187	409	1996-2008	212	370	251	546	2002-2011	847	0.33
		Imnaha River	750	380	215	672	1996-2009	486	460	304	696	2002-2011	1288	0.30
		Big Sheep Creek - Functionally Extirpated												
		Lookingglass- Functionally Extirpated												
	South Fork Salmon	South Fork Salmon Mainstem	1000	601	359	1006	1994-2003	504	813	634	1041	2003-2012	1269	0.65
		Secesh River	750	403	238	680	1996-2005	483	605	408	897	2002-2011	635	0.96
		East Fork S. Fork Salmon (including Johnson)	1000	105	55	202	1994-2003	215	282	199	400	2003-2012	425	0.50
		Little Salmon River (including Rapid R.)												
	Middle Fork Salmon	Big Creek	1000	90	35	236	1995-2004	91	181	115	286	2003-2012	184	1.00
		Bear Valley/Elk Creek	750	182	75	442	1994-2003	189	471	328	677	2003-2012	479	1.00
		Marsh Creek	500	42	10	165	1994-2004	53	221	130	377	2003-2012	225	1.00
		Sulphur Creek	500	21	8	52	1994-2005	19	58	37	91	2003-2012	59	1.00
		Camas Creek	500	28	10	76	1995-2004	29	47	28	77	2003-2012	47	1.00
		Loon Creek	500	51	16	152	1995-2005	46	77	49	119	2003-2012	78	1.00
		Chamberlain Creek	500	N/A	N/A	N/A	N/A	N/A	648	502	836	2003-2012	658	1.00
		Lower Middle Fork Salmon (below Ind. Cr.)												
		Upper Middle Fork Salmon (above Ind. Cr.)												
	Upper Salmon	Lemhi River	2000	79	39	162	1994-2003	79	81	58	112	2003-2012	81	1.00
		Valley Creek	500	34	15	78	1994-2003	34	101	75	135	2003-2012	102	1.00
		Yankee Fork	500	13	5	35	1994-2003	12	16	7	36	2002-2011	32	1.00
		Upper Salmon River (above Redfish L.)	1000	246	157	388	1996-2005	250	360	285	455	2003-2012	433	0.84
		North Fork Salmon River												
		Lower Salmon River (below Redfish L.)	2000	103	65	163	1996-2005	108	125	102	153	2003-2012	127	1.00
		East Fork Salmon River	1000	148	69	320	1996-2005	135	320	210	487	2003-2012	324	1.00
		Pahsimeroi River	1000	127	85	190	1996-2005	129	223	174	286	2003-2012	306	0.73
		Panther - Extirpated												
Upper Columbia Spring Chinook Salmon	Eastern Cascades	Wenatchee R.	2000	222	108	458	1994-2003	215	568	443	727	2002-2011	1531	0.32
		Methow R.	2000	180	76	427	1994-2003	170	398	264	601	2002-2011	1587	0.21
		Entiat R.	500	59	33	107	1994-2003	59	148	114	191	2002-2011	275	0.54
		Okanogan R. (extirpated)												
Snake River Fall Chinook Salmon	Main Stem and Lower Tributaries	Lower Mainstem Fall Chinook 1977-Most Recent BY	3000	1273	699	2320	1995-2004	1189	4655	3489	6209	1999-2008	15091	0.31
		Lower Mainstem Fall Chinook 1990-Most Recent BY	3000	1273	699	2320	1995-2004	1189	4655	3489	6209	1999-2008	15091	0.31

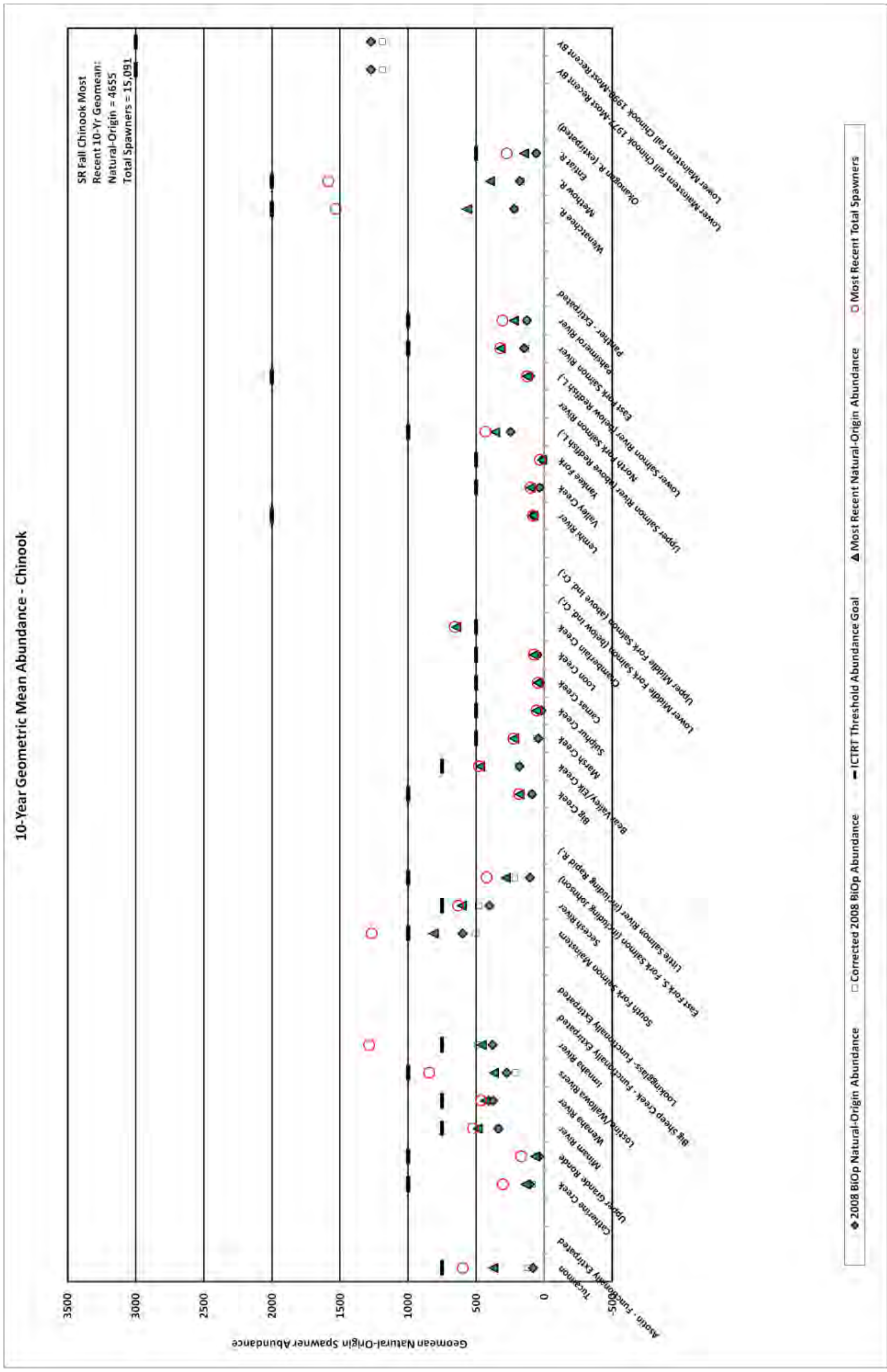

Figure 2.1-9 Comparison of Chinook 2008 BiOp Base Period10-year geometric mean abundance, corrected estimates for the 2008 BiOp's Base Period, and extended Base Period estimates based on new in information in the NWFSC SPS database that has become available since the 2008 BiOp. Means are displayed relative to ICTRT (2007a) recovery-threshold abundance goals.

Table 2.1-6. Comparison of steelhead Base Period 10-year geometric mean abundance reported in the 2008 BiOp, corrected estimates for the 2008 BiOp's Base Period, and extended Base Period estimates based on new information in the NWFSC SPS database that has become available since the 2008 BiOp. Extended Base Period mean abundance is higher than the 2008 BiOp mean for 17 of 20 steelhead populations. Recent total spawners (including hatchery-origin spawners) and percent of natural-origin spawners are also displayed.

				2008 BiOp					New Information					
ESU	MPG	Population	ICTRT Threshold Abundance Goal	Most Recent 10-Year Geomean Abundance (2008 BiOp)	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Return Years (2008 BiOp)	Corrected 2008 BiOp Estimate	Most Recent 10-Year Geomean Abundance	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Return Years	Most Recent 10-Year Geomean Total Adult Spawners (Including Hatchery-Origin)	Most Recent 10-Year Geomean Percent Hatchery-Origin Spawners
Upper Columbia River Steelhead	Eastern Cascades	Wenatchee	1000	900	N/A	N/A	1997-2006	560	978	696	1374	2002-2011	2636	0.37
		Methow	1000	281	N/A	N/A	1997-2006	288	609	490	757	2002-2011	4451	0.14
		Entiat	500	94	N/A	N/A	1997-2006	79	139	101	190	2002-2011	602	0.23
		Okanogan	1000	104	N/A	N/A	1997-2006	78	178	139	229	2002-2011	2307	0.08
Snake River Steelhead[1]	Lower Snake	Tucannon												
		Asotin												
	Imnaha River	Imnaha R. (Camp Cr)[2]	1000	N/A	N/A	N/A	1996-2005	N/A	N/A	N/A	N/A	2001-2010	N/A	1.00
	Grande Ronde	Upper Mainstem	1500	1226	923	1630	1997-2006	1229	1341	1120	1605	2001-2010	1387	0.97
		Lower Mainstem												
		Joseph Cr.	500	2132	1695	2681	1997-2006	2169	2187	1722	2777	2001-2010	2187	1.00
		Wallowa R.												
	Clearwater River	Lower Mainstem												
		Lolo Creek												
		Lochsa River												
		Selway River												
		South Fork												
		North Fork - (Extirpated)												
	Salmon River	Upper Middle Fork Tribs												
		Chamberlain Cr.												
		South Fork Salmon												
		Panther Creek												
		Secesh River												
		North Fork												
		Lower Middle Fork Tribs												
		Little Salmon/Rapid												
		Lemhi River												
		Pahsimeroi River												
		East Fork Salmon												
		Upper Mainstem												
Mid Columbia Steelhead	Yakima	Upper Yakima	1500	85	57	127	1995-2004	85	202	151	271	2003-2012	207	0.98
		Naches	1500	472	312	714	1995-2004	470	1051	795	1390	2003-2012	1078	0.97
		Toppenish	500	322	176	588	1995-2004	306	556	433	713	2003-2012	570	0.97
		Satus	1000	379	278	516	1995-2004	412	1039	739	1461	2003-2012	1066	0.97
	Eastern Cascades	Deschutes W.	1000	456	305	682	1996-2005	463	663	512	858	2002-2011	796	0.84
		Deschutes East	1000	1599	895	2858	1996-2005	1854	2129	1667	2720	2002-2011	2653	0.80
		Klickitat												
		Fifteenmile Cr.	500	703	478	1032	1996-2005	698	615	405	936	2002-2011	620	0.99
		Rock Cr.												
		White Salmon - Extirpated												
	Umatilla/Walla Walla	Umatilla	1500	1472	1204	1799	1995-2004	1466	2364	1927	2901	2002-2011	3135	0.75
		Walla-Walla	1000	650	460	919	1996-2005	722	927	714	1202	2002-2011	957	0.97
		Touchet							396	316	496	2003-2012	523	0.76
	John Day	Lower Mainstem)	2250	1800	1065	3044	1996-2005	1776	1480	909	2409	2002-2011	1872	0.79
		North Fork	1500	1740	1362	2223	1996-2005	1763	1927	1356	2737	2002-2011	2107	0.91
		Upper Mainstem	1000	524	402	683	1996-2005	519	608	413	896	2002-2011	665	0.91
		Middle Fork	1000	756	503	1138	1996-2005	766	693	426	1128	2002-2011	758	0.91
		South Fork	500	259	166	404	1996-2005	263	490	358	670	2002-2011	536	0.91

[1] Only the populations with empirical estimates are shown, as in the 2008 BiOp.
[2] Data represents only the Camp Creek area of the Imnaha, so abundance estimates are not comparable to the ICTRT thresholds. However, the Camp Creek data can be used to assess trends. The Camp Creek abundance estimate increased from 68 to 102 between the two periods.

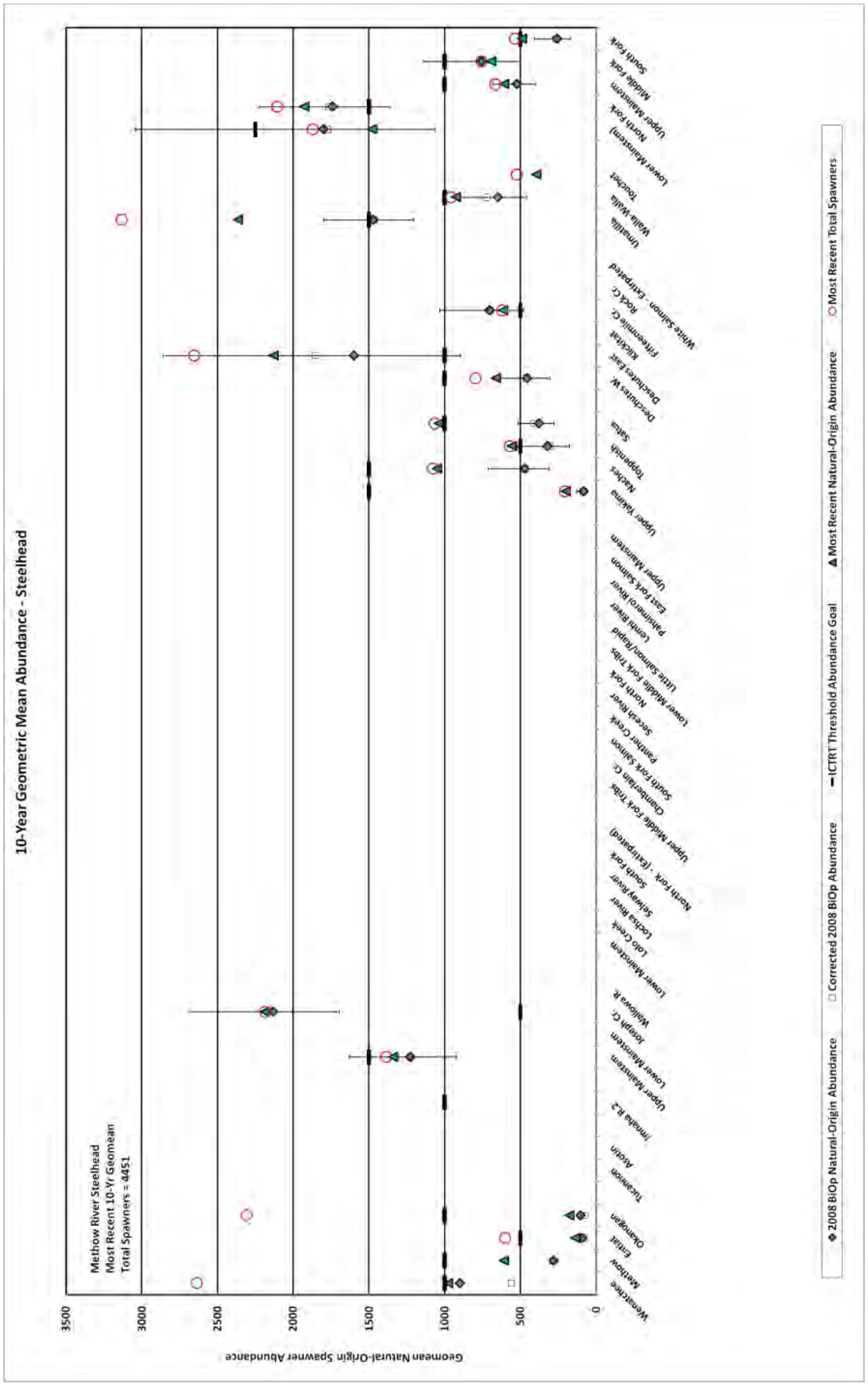

Figure 2.1-10. Comparison of steelhead 2008 BiOp Base Period 10-year geometric mean abundance, corrected estimates for the 2008 BiOp's Base Period, and extended Base Period estimates based on new in information in the NWFSC SPS database that has become available since the 2008 BiOp. Means are displayed relative to ICTRT (2007a) recovery-threshold abundance goals.

24-Year Extinction Risk

Hinrichsen (2013; included as Appendix B) updated Base Period extinction risk estimates using new data in the SPS database and methods identical to those applied in the 2008 BiOp. Appendix B includes estimates of extinction risk based on four QETs, but because the ICTRT and the 2008 BiOp focused primarily on a QET of 50 fish, only the QET 50 results are presented in Tables 2.1-7 and 2.1-8 and Figures 2.1-11 and 2.1-12. As described in Section 2.1.1.4.1 (above), the 2008 BiOp's goal for prospective actions (including projected effects of the RPA and continuation of current management practices) for this metric is approximated at ≤5% extinction risk. Point estimates of extinction risk based on new information remained either unchanged or declined, compared with 2008 BiOp estimates, for nearly all populations (16 of 20 Chinook and 15 of 19 steelhead populations [including directional change for Imnaha Camp Creek]). Extended Base Period extinction risk estimates decreased from >5% to ≤5% for six populations (Tucannon, Minam, Lostine/Wallowa, Imnaha, and Bear Valley SR spring/summer Chinook and Entiat UCR Chinook). As in the 2008 BiOp, 95% confidence intervals are wide for most populations, indicating considerable uncertainty associated with this metric. All new estimates are within the 2008 BiOp's 95% confidence limits, indicating that the new results are within the range of statistical uncertainty described in the 2008 BiOp. New estimates based on alternative QET levels (30, 10, and 1 fish) indicate extinction risks that are the same (if 0% risk) or lower than the QET 50 estimates for all populations.

Table 2.1-7. Comparison of Chinook Base Period 24-year extinction risk at QET 50 reported in the 2008 BiOp, corrected estimates for the 2008 BiOp's Base Period, and extended Base Period estimates based on new information in the NWFSC SPS database that has become available since the 2008 BiOp. The 2008 BiOp's goal for prospective actions for this metric is approximated at <5% extinction risk. Extended Base Period extinction risk estimates are lower than the 2008 BiOp risk estimates for 16 of 20 Chinook populations; however, all new estimates are within the 2008 BiOp's 95% confidence limits. Source of new estimates is Hinrichsen (2013; included as Appendix B in this document).

ESU	MPG	Population	2008 BiOp			Corrected 2008 BiOp Estimate	New Information		
			Base Period Extinction Risk - 24 Years at QET=50	Lower 95% Confidence Limit	Upper 95% Confidence Limit		Extended Base Period Extinction Risk - 24 Years at QET=50	Lower 95% Confidence Limit	Upper 95% Confidence Limit
Snake River Spring/ Summer Chinook Salmon	Lower Snake	Tucannon	0.07	0.00	0.71	0.04	0.03	0.00	0.56
		Asotin - Functionally Extirpated							
	Grande Ronde / Imnaha	Catherine Creek	0.45	0.01	0.98	N/A	0.37	0.05	0.95
		Upper Grande Ronde	0.70	0.07	0.97	0.51	0.48	0.07	0.94
		Minam River	0.06	0.00	0.68	0.04	0.01	0.00	0.47
		Wenaha River	0.26	0.00	0.83	0.18	0.10	0.00	0.64
		Lostine/Wallowa Rivers	0.18	0.00	0.81	0.07	0.04	0.00	0.51
		Imnaha River	0.09	0.00	0.73	0.00	0.00	0.00	0.94
		Big Sheep Creek - Functionally Extirpated							
		Lookingglass- Functionally Extirpated							
	South Fork Salmon	South Fork Salmon Mainstem	0.00	0.00	0.13	0.00	0.00	0.00	0.19
		Secesh River	0.02	0.00	0.42	0.00	0.00	0.00	0.37
		East Fork S. Fork Salmon (including Johnson)	0.04	0.00	0.48	0.07	0.00	0.00	0.37
		Little Salmon River (including Rapid R.)							
	Middle Fork Salmon	Big Creek	0.37	0.00	0.93	0.45	0.29	0.01	0.86
		Bear Valley/Elk Creek	0.09	0.00	0.71	0.09	0.02	0.00	0.45
		Marsh Creek	0.56	0.00	0.95	0.51	0.39	0.01	0.92
		Sulphur Creek	0.55	0.00	0.92	N/A	0.67	0.21	1.00
		Camas Creek					0.92	0.43	1.00
		Loon Creek							
		Chamberlain Creek							
		Lower Middle Fork Salmon (below Ind. Cr.)							
		Upper Middle Fork Salmon (above Ind. Cr.)							
	Upper Salmon	Lemhi River							
		Valley Creek	0.75	0.07	0.99	0.81	0.76	0.17	0.99
		Yankee Fork							
		Upper Salmon River (above Redfish L.)	0.00	0.00	0.71	0.01	0.00	0.00	0.44
		North Fork Salmon River							
		Lower Salmon River (below Redfish L.)	0.37	0.00	0.99	0.31	0.23	0.00	0.78
		East Fork Salmon River					0.23	0.01	0.73
		Pahsimeroi River					0.00	0.00	0.00
		Panther - Extirpated							
Upper Columbia Spring Chinook Salmon	Eastern Cascades	Wenatchee R.	0.02	0.00	0.82	0.06	0.04	0.00	0.64
		Methow R.					0.10	0.00	0.74
		Entiat R.	0.19	0.00	0.82	0.12	0.05	0.00	0.79
		Okanogan R. (extirpated)							
Snake River Fall Chinook Salmon	Main Stem and Lower Tributaries	Lower Mainstem Fall Chinook 1977-Most Recent BY	0.01	0.00	1.00	0.01	0.03	0.00	0.46
		Lower Mainstem Fall Chinook 1990-Most Recent BY							

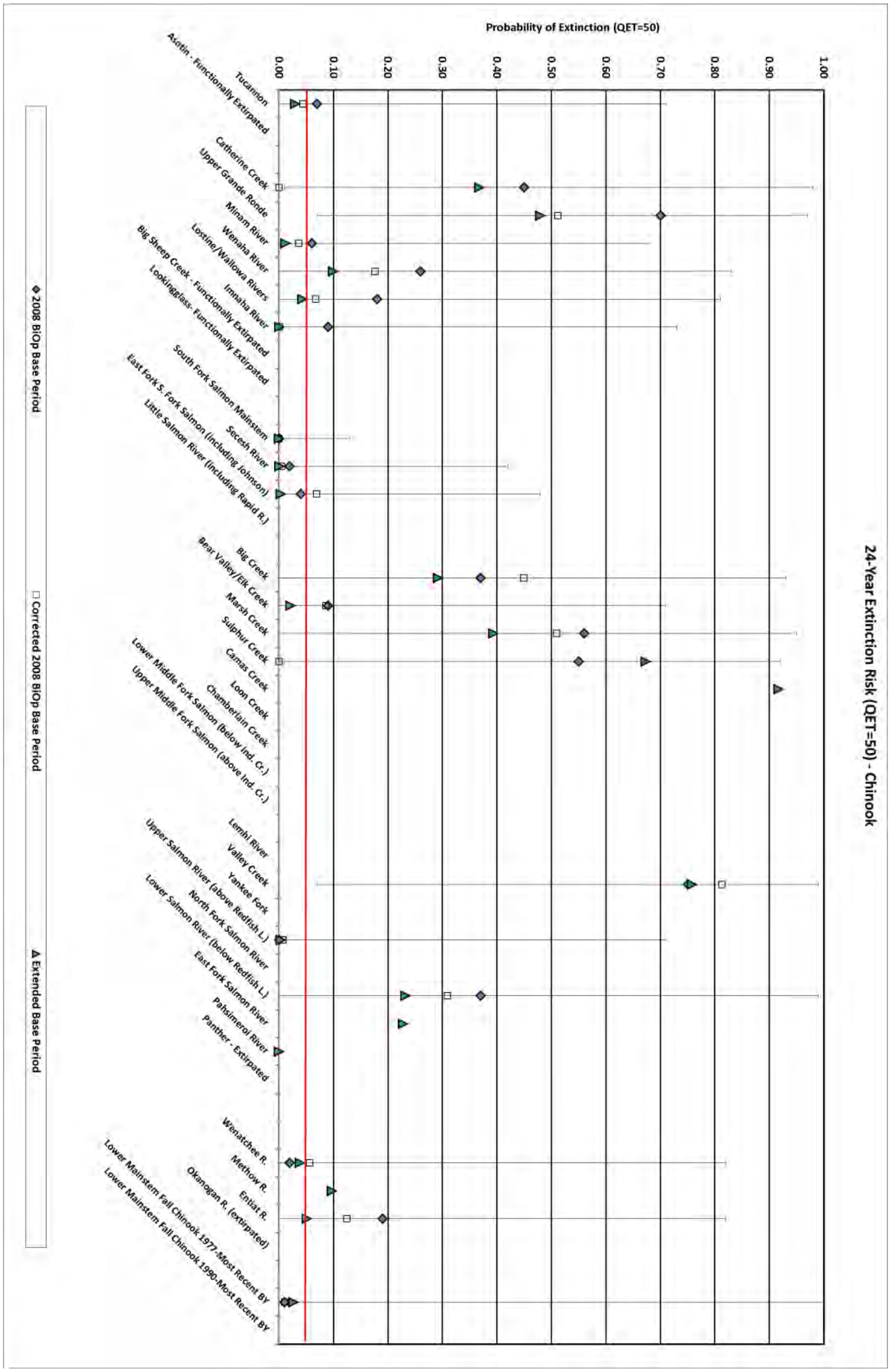

Figure 2.1-11. Comparison of Chinook Base Period 24-year extinction risk at QET 50 reported in the 2008 BiOp, corrected estimates for the 2008 BiOp's Base Period, and extended Base Period estimates based on new information in the NWFSC SPS database that has become available since the 2008 BiOp. The 2008 BiOp's goal for prospective actions for this metric is approximated at <u><</u>5% extinction risk (red line).

Table 2.1-8. Comparison of steelhead Base Period 24-year extinction risk at QET 50 reported in the 2008 BiOp, corrected estimates for the 2008 BiOp's Base Period, and extended Base Period estimates based on new information in the NWFSC SPS database that has become available since the 2008 BiOp. The 2008 BiOp's goal for prospective actions for this metric is approximated at <5% extinction risk. Extended Base Period extinction risk estimates are lower than the 2008 BiOp risk estimates for 16 of 19 steelhead populations; however, all new estimates are within the 2008 BiOp's 95% confidence limits. Source of estimates is Hinrichsen (2013; included as Appendix B).

			2008 BiOp				New Information		
ESU	MPG	Population	Base Period Extinction Risk - 24 Years at QET=50	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Corrected 2008 BiOp Estimate	Extended Base Period Extinction Risk - 24 Years at QET=50	Lower 95% Confidence Limit	Upper 95% Confidence Limit
Upper Columbia River Steelhead	Eastern Cascades	Wenatchee	0.27	0.00	0.92	0.29	0.20	0.00	0.82
		Methow	0.47	0.02	1.00	0.76	0.88	0.31	1.00
		Entiat	0.99	0.10	1.00	0.85	0.89	0.25	1.00
		Okanogan	1.00	0.77	1.00	1.00	1.00	0.78	1.00
Snake River Steelhead[1]	Lower Snake	Tucannon							
		Asotin							
	Imnaha River	Imnaha R. (Camp Cr)[2]							
	Grande Ronde	Upper Mainstem	0.00	0.00	0.01	0.00	0.00	0.00	0.01
		Lower Mainstem							
		Joseph Cr.	0.00	0.00	0.19	0.00	0.00	0.00	0.08
		Wallowa R.							
	Clearwater River	Lower Mainstem							
		Lolo Creek							
		Lochsa River							
		Selway River							
		South Fork							
		North Fork - (Extirpated)							
	Salmon River	Upper Middle Fork Tribs							
		Chamberlain Cr.							
		South Fork Salmon							
		Panther Creek							
		Secesh River							
		North Fork							
		Lower Middle Fork Tribs							
		Little Salmon/Rapid							
		Lemhi River							
		Pahsimeroi River							
		East Fork Salmon							
		Upper Mainstem							
Mid Columbia Steelhead	Yakima	Upper Yakima	0.68	0.08	1.00	0.69	0.78	0.54	0.99
		Naches	0.34	0.00	0.87	0.34	0.46	0.17	0.74
		Toppenish	0.79	0.00	0.97	0.70	0.72	0.49	0.97
		Satus	0.00	0.00	0.30	0.00	0.31	0.00	0.79
	Eastern Cascades	Deschutes W.	0.01	0.00	0.90	0.01	0.00	0	0.37
		Deschutes East[3]							
		Klickitat							
		Fifteenmile Cr.	0.00	0.00	0.44	0.00	0.00	0.00	0.26
		Rock Cr.							
		White Salmon - Extirpated							
	Umatilla/Walla Walla	Umatilla	0.00	0.00	0.37	0.00	0.00	0.00	0.02
		Walla-Walla[4]							
		Touchet[5]							
	John Day	Lower Mainstem)	0.00	0.00	0.38	0.00	0.00	0.00	0.06
		North Fork	0.00	0.00	0.07	0.00	0.00	0.00	0.02
		Upper Mainstem	0.00	0.00	0.67	0.00	0.00	0.00	0.35
		Middle Fork	0.00	0.00	0.44	0.00	0.00	0.00	0.33
		South Fork	0.03	0.00	0.69	0.04	0.01	0.00	0.34

[1] Only the populations with empirical estimates are shown, as in the 2008 BiOp. In the 2008 BiOp, other populations were analyzed using "average A- and B-run" estimates, as understood at the time.

[2] Data represents only the Camp Creek area of the Imnaha, so extinction risk for entire population can't be estimated. "Average-A" estimates were included for 2008 BiOp.
However, the Camp Creek data can be used to assess trends. The Camp Creek extinction risk estimates decreased from 0.54 to 0.33 when original data were corrected and new years were added.

[3] Deschutes East populationwas not included in 2008 BiOp "1980-present" metrics because data set doesn't begin until 1990. As in 2008 BiOp, it is included in shorter-term estimates in an appendix.

[4] Walla Walla population data not available for 2008 BiOp. New data, beginning in 1993, is included in appendix with shorter-term estimates.

[5] Touchet population was not available for the 2008 BiOp. Because time series does not begin until 1987, it is only used to calculate "1990-present" metrics.

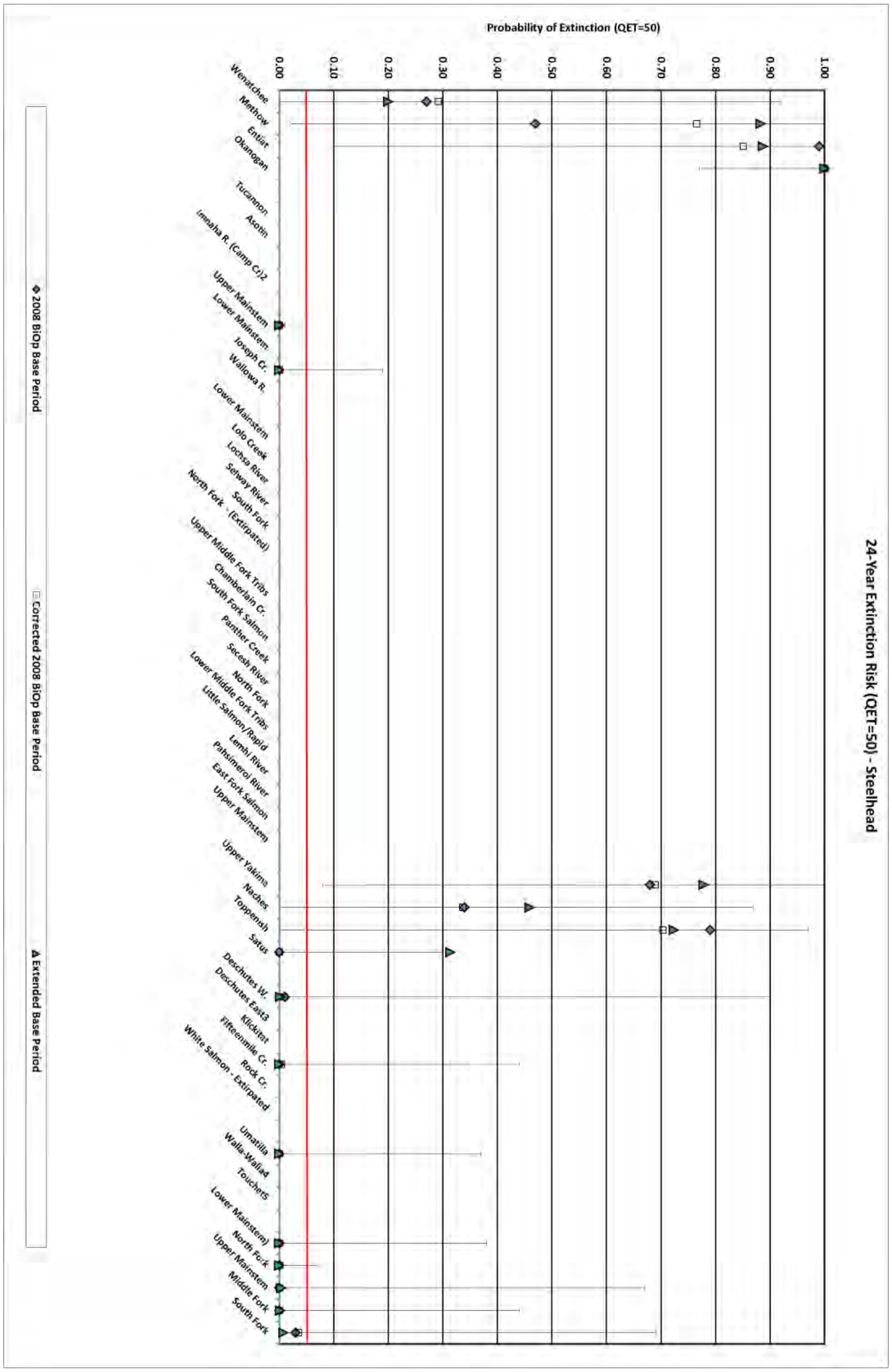

Figure 2.1-12. Comparison of steelhead Base Period 24-year extinction risk at QET 50 reported in the 2008 BiOp, corrected estimates for the 2008 BiOp's Base Period, and extended Base Period estimates based on new information in the NWFSC SPS database that has become available since the 2008 BiOp. The 2008 BiOp's goal for prospective actions for this metric is approximated at <5% extinction risk (red line).

Productivity: Returns-per-Spawner

Average R/S was estimated as described in the 2008 BiOp Chapter 7.1, using new information in the SPS database for the extended Base Period (Tables 2.1-9 and 2.1-10; Figures 2.1-13 and 2.1-14). New point estimates of average R/S were lower than estimates in the 2008 BiOp for most populations (17[18][21] of 27 Chinook and 12 of 19 steelhead populations). As described in Section 2.1.2.4.1 (above), the 2008 BiOp's goal for prospective actions (including projected effects of the RPA and continuation of current management practices) for this metric is R/S greater than1.0. All new estimates were within the 2008 BiOp's 95% confidence intervals, indicating that the results are within the range of statistical uncertainty described in the 2008 BiOp. Although average R/S declined for most populations, a number of the populations with lower estimates continued to exhibit extended Base Period mean R/S that was greater than 1.0 (5[6][21] of 17[18] Chinook and 7 of 12 steelhead populations).

[21] Snake River fall Chinook metrics were calculated using two different methods, as in the 2008 BiOp and ICTRT (2007b) survival gap analyses, and the results differed for the two methods.

Table 2.1-9. Comparison of Chinook Base Period geometric mean returns-per-spawner (R/S) reported in the 2008 BiOp, corrected estimates for the 2008 BiOp's Base Period, and extended Base Period estimates based on new information in the NWFSC SPS database that has become available since the 2008 BiOp. The 2008 BiOp's goal for prospective actions for this metric is R/S greater than 1.0. Extended Base Period mean R/S estimates are lower than the 2008 BiOp estimates for most Chinook populations; however, all new estimates are within the 2008 BiOp's 95% confidence limits.

ESU	MPG	Population	2008 BiOp			Corrected 2008 BiOp Mean Estimate	New Information		
			Mean Base Period R/S	Lower 95% Confidence Limit	Upper 95% Confidence Limit		Mean Extended Base Period R/S	Lower 95% Confidence Limit	Upper 95% Confidence Limit
Snake River Spring/ Summer Chinook Salmon	Lower Snake	Tucannon	0.72	0.48	1.10	0.68	0.72	0.47	1.10
		Asotin - Functionally Extirpated							
	Grande Ronde / Imnaha	Catherine Creek	0.44	0.22	0.84	0.38	0.38	0.22	0.64
		Upper Grande Ronde	0.32	0.18	0.57	0.35	0.36	0.22	0.59
		Minam River	0.80	0.47	1.37	0.80	0.85	0.57	1.27
		Wenaha River	0.66	0.41	1.08	0.65	0.67	0.47	0.96
		Lostine/Wallowa Rivers	0.72	0.41	1.26	0.73	0.69	0.45	1.06
		Imnaha River	0.59	0.40	0.86	0.75	0.56	0.39	0.80
		Big Sheep Creek - Functionally Extirpated							
		Lookingglass- Functionally Extirpated							
	South Fork Salmon	South Fork Salmon Mainstem	0.86	0.59	1.28	0.87	0.76	0.57	1.02
		Secesh River	1.19	0.81	1.76	1.19	1.05	0.74	1.50
		East Fork S. Fork Salmon (including Johnson)	0.97	0.67	1.41	1.04	0.96	0.67	1.38
		Little Salmon River (including Rapid R.)							
	Middle Fork Salmon	Big Creek	1.20	0.66	2.19	1.16	1.12	0.67	1.86
		Bear Valley/Elk Creek	1.35	0.82	2.22	1.34	1.21	0.82	1.78
		Marsh Creek	0.95	0.52	1.75	0.99	0.98	0.60	1.60
		Sulphur Creek	0.97	0.45	2.09	1.02	1.05	0.62	1.79
		Camas Creek	0.79	0.39	1.62	0.79	0.69	0.41	1.17
		Loon Creek	1.11	0.54	2.31	1.22	0.91	0.52	1.60
		Chamberlain Creek					1.06	0.55	2.07
		Lower Middle Fork Salmon (below Ind. Cr.)							
		Upper Middle Fork Salmon (above Ind. Cr.)							
	Upper Salmon	Lemhi River	1.08	0.63	1.84	1.10	0.95	0.62	1.47
		Valley Creek	1.07	0.61	1.87	1.08	1.09	0.72	1.66
		Yankee Fork	0.61	0.28	1.29	0.63	0.50	0.26	0.97
		Upper Salmon River (above Redfish L.)	1.51	0.84	2.72	1.56	1.23	0.76	1.99
		North Fork Salmon River							
		Lower Salmon River (below Redfish L.)	1.20	0.75	1.92	1.20	1.04	0.72	1.49
		East Fork Salmon River	1.06	0.54	2.08	1.22	1.18	0.70	2.00
		Pahsimeroi River	0.51	0.22	1.18	0.56	0.59	0.32	1.08
		Panther - Extirpated							
Upper Columbia Spring Chinook Salmon	Eastern Cascades	Wenatchee R.	0.75	0.46	1.22	0.68	0.59	0.41	0.86
		Methow R.	0.73	0.42	1.27	0.72	0.51	0.32	0.81
		Entiat R.	0.72	0.49	1.05	0.72	0.66	0.50	0.89
		Okanogan R. (extirpated)							
Snake River Fall Chinook Salmon	Main Stem and Lower Tributaries	Lower Mainstem Fall Chinook 1977-Most Recent BY	0.81	0.46	1.21	0.91	0.82	0.64	1.04
		Lower Mainstem Fall Chinook 1990-Most Recent BY	1.24	0.93	1.66	1.47	1.07	0.80	1.43

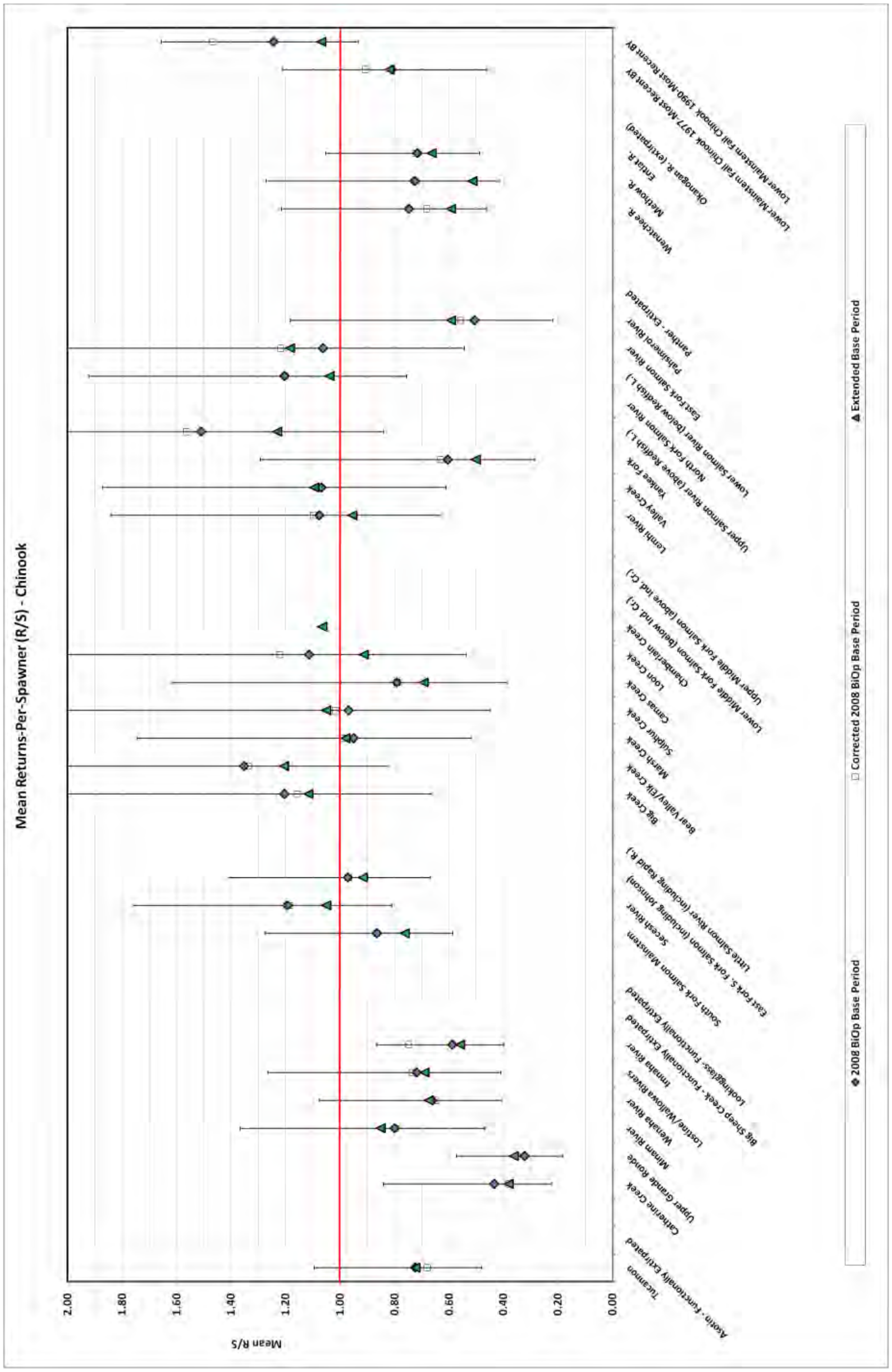

Figure 2.1-13 Comparison of Chinook Base Period geometric mean returns-per-spawner (R/S) reported in the 2008 BiOp, corrected estimates for the 2008 BiOp's Base Period, and extended Base Period estimates based on new information in the NWFSC SPS database that has become available since the 2008 BiOp. The 2008 BiOp's goal for prospective actions for this metric is R/S greater than 1.0 (red line).

Table 2.1-10. Comparison of steelhead Base Period geometric mean returns-per-spawner (R/S) reported in the 2008 BiOp, corrected estimates for the 2008 BiOp's Base Period, and extended Base Period estimates based on new information in the NWFSC SPS database that has become available since the 2008 BiOp. The 2008 BiOp's goal for prospective actions for this metric is R/S greater than 1.0. Extended Base Period mean R/S estimates are lower than the 2008 BiOp estimates for most steelhead populations; however, all new estimates are within the 2008 BiOp's 95% confidence limits.

			2008 BiOp				New Information		
ESU	MPG	Population	Mean Base Period R/S	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Corrected 2008 BiOp Mean Estimate	Mean Extended Base Period R/S	Lower 95% Confidence Limit	Upper 95% Confidence Limit
Upper Columbia River Steelhead	Eastern Cascades	Wenatchee	0.35	0.22	0.55	0.34	0.35	0.24	0.50
		Methow	0.21	0.15	0.30	0.19	0.18	0.14	0.23
		Entiat	0.52	0.37	0.73	0.43	0.37	0.28	0.50
		Okanogan	0.08	0.06	0.11	0.07	0.07	0.06	0.10
Snake River Steelhead[1]	Lower Snake	Tucannon							
		Asotin							
	Imnaha River	Imnaha R. (Camp Cr)	1.45	0.94	2.24	1.45	1.30	0.93	1.83
	Grande Ronde	Upper Mainstem	0.93	0.65	1.33	0.93	0.96	0.71	1.29
		Lower Mainstem							
		Joseph Cr.	1.26	0.84	1.89	1.26	1.15	0.81	1.62
		Wallowa R.							
	Clearwater River	Lower Mainstem							
		Lolo Creek							
		Lochsa River							
		Selway River							
		South Fork							
		North Fork - (Extirpated)							
	Salmon River	Upper Middle Fork Tribs							
		Chamberlain Cr.							
		South Fork Salmon							
		Panther Creek							
		Secesh River							
		North Fork							
		Lower Middle Fork Tribs							
		Little Salmon/Rapid							
		Lemhi River							
		Pahsimeroi River							
		East Fork Salmon							
		Upper Mainstem							
Mid Columbia Steelhead	Yakima	Upper Yakima	1.02	0.69	1.51	1.02	1.17	0.86	1.59
		Naches	1.02	0.69	1.51	1.02	1.13	0.85	1.52
		Toppenish	1.46	0.89	2.39	1.41	1.25	0.88	1.77
		Satus	0.86	0.62	1.20	0.90	1.11	0.84	1.47
	Eastern Cascades	Deschutes W.	0.92	0.67	1.25	0.87	0.82	0.70	0.97
		Deschutes East[2]							
		Klickitat							
		Fifteenmile Cr.	1.17	0.84	1.63	1.18	0.93	0.67	1.30
		Rock Cr.							
		White Salmon - Extirpated							
	Umatilla/Walla Walla	Umatilla	0.94	0.73	1.22	0.98	0.80	0.66	0.97
		Walla-Walla[3]							
		Touchet[4]							
	John Day	Lower Mainstem)	1.24	0.76	2.04	1.44	1.05	0.65	1.68
		North Fork	1.17	0.79	1.75	1.18	1.07	0.77	1.49
		Upper Mainstem	1.07	0.71	1.59	1.08	1.04	0.75	1.46
		Middle Fork	1.17	0.82	1.69	1.19	1.00	0.70	1.42
		South Fork	0.99	0.64	1.54	1.00	1.03	0.72	1.47

[1] Only the populations with empirical estimates are shown, as in the 2008 BiOp. In the 2008 BiOp, other populations were analyzed using "average A- and B-run" estimates, as understood at the time.

[2] Deschutes East populationwas not included in 2008 BiOp "1980-present" metrics because data set doesn't begin until 1990. As in 2008 BiOp, it is included in shorter-term estimates in an appendix.

[3] Walla Walla population data not available for 2008 BiOp. New data, beginning in 1993, is included in appendix with shorter-term estimates.

[4] Touchet population was not available for the 2008 BiOp. Because time series does not begin until 1987, it is only used to calculate "1990-present" metrics.

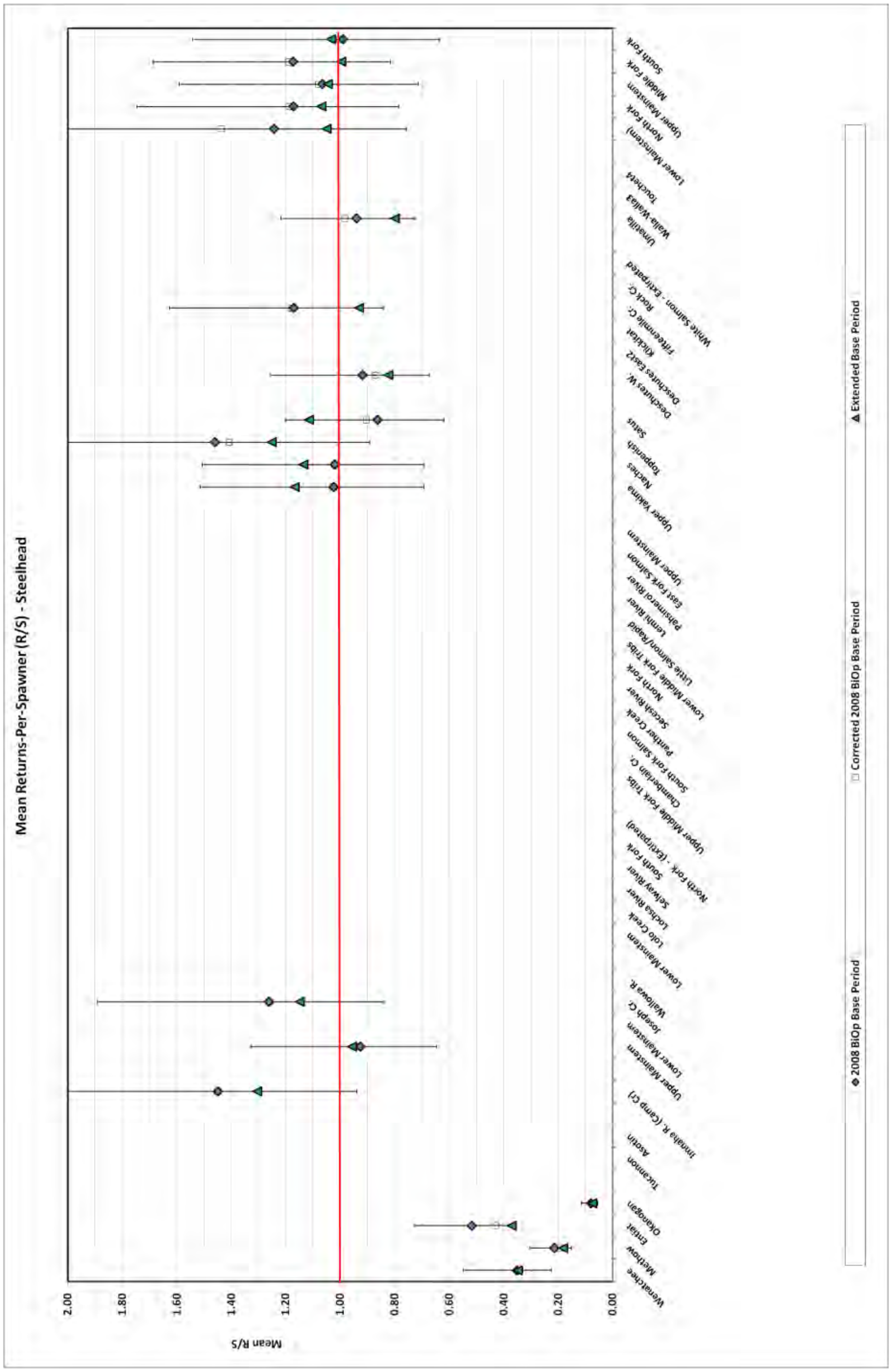

Figure 2.1-14 Comparison of steelhead Base Period geometric mean returns-per-spawner (R/S) reported in the 2008 BiOp, corrected estimates for the 2008 BiOp's Base Period, and extended Base Period estimates based on new information in the NWFSC SPS database that has become available since the 2008 BiOp. The 2008 BiOp's goal for prospective actions for this metric is R/S greater than 1.0 (red line).

Productivity: Median Population Growth Rate (Lambda)

Lambda HF=0

Lambda was estimated as described in the 2008 BiOp Chapter 7.1 using new information in the SPS database for the extended Base Period (Tables 2.1-11 and 2.1-12; Figures 2.1-15 and 2.1-16). As described in Section 2.1.1.4.1 (above), the 2008 BiOp's goal for prospective actions (including projected effects of the RPA and continuation of current management practices) for this metric is lambda greater than 1.0. New point estimates of lambda under the assumption that hatchery-origin spawners are not reproductively effective (HF=0) were generally lower than estimates in the 2008 BiOp for Chinook (18[19][22] of 26 populations), but estimates generally increased for steelhead (11 of 18 populations). All new estimates were within the 2008 BiOp's 95% confidence intervals, indicating that the results are within the range of statistical uncertainty described in the 2008 BiOp. Although lambda HF=0 estimates were lower than in the 2008 BiOp for many populations, most of the populations that declined continued to exhibit Base Period productivity estimates that were greater than 1.0 (14 of 18[19][22] Chinook and 5 of 7 steelhead populations).

[22] Snake River fall Chinook metrics were calculated using two different methods, as in the 2008 BiOp and ICTRT (2007b) survival gap analyses, and the results differed for the two methods.

Table 2.1-11. Chinook median population growth rate (lambda) under the assumption that hatchery-origin spawners are not reproductively effective (HF=0). Base Period estimates that were reported in the 2008 BiOp are compared with extended Base Period estimates based on new information in the NWFSC SPS database that has become available since the 2008 BiOp. The 2008 BiOp's goal for prospective actions for this metric is lambda greater than 1.0. Extended Base Period lambda HF=0 estimates are lower than the 2008 BiOp estimates for most Chinook populations; however, all new estimates are within the 2008 BiOp's 95% confidence limits.

ESU	MPG	Population	2008 BiOp				New Information			
			Base Period Lambda HF=0	Probability Lambda >1.0	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Extended Base Period Lambda HF=0	Probability Lambda >1.0	Lower 95% Confidence Limit	Upper 95% Confidence Limit
Snake River Spring/ Summer Chinook Salmon	Lower Snake	Tucannon	0.96	0.39	0.67	1.38	1.01	0.53	0.77	1.33
		Asotin - Functionally Extirpated								
	Grande Ronde / Imnaha	Catherine Creek	0.93	0.29	0.66	1.30	0.97	0.40	0.74	1.28
		Upper Grande Ronde	0.95	0.26	0.77	1.169	0.97	0.35	0.81	1.16
		Minam River	1.05	0.69	0.82	1.35	1.05	0.73	0.88	1.25
		Wenaha River	1.04	0.66	0.80	1.37	1.03	0.65	0.85	1.24
		Lostine/Wallowa Rivers	1.03	0.60	0.78	1.36	1.04	0.67	0.84	1.28
		Imnaha River	1.00	0.50	0.74	1.36	0.99	0.46	0.79	1.24
		Big Sheep Creek - Functionally Extirpated								
		Lookingglass- Functionally Extirpated								
	South Fork Salmon	South Fork Salmon Mainstem	1.09	0.80	0.83	1.43	1.04	0.75	0.90	1.21
		Secesh River	1.06	0.76	0.86	1.32	1.05	0.75	0.88	1.26
		East Fork S. Fork Salmon (including Johnson)	1.06	0.80	0.88	1.28	1.03	0.64	0.84	1.26
		Little Salmon River (including Rapid R.)								
	Middle Fork Salmon	Big Creek	1.09	0.74	0.78	1.53	1.05	0.69	0.81	1.37
		Bear Valley/Elk Creek	1.11	0.80	0.79	1.55	1.07	0.75	0.85	1.33
		Marsh Creek	1.09	0.75	0.78	1.52	1.06	0.71	0.83	1.35
		Sulphur Creek	1.07	0.67	0.68	1.68	1.05	0.70	0.82	1.35
		Camas Creek[1]	1.04	0.60	0.69	1.57	0.98			
		Loon Creek[1]	1.12	0.79	0.79	1.58	1.01			
		Chamberlain Creek[1]					0.94			
		Lower Middle Fork Salmon (below Ind. Cr.)								
		Upper Middle Fork Salmon (above Ind. Cr.)								
	Upper Salmon	Lemhi River	1.03	0.57	0.66	1.59	1.00	0.49	0.75	1.33
		Valley Creek	1.07	0.69	0.72	1.59	1.03	0.62	0.81	1.32
		Yankee Fork[1]	1.06	0.65	0.67	1.68	0.97			
		Upper Salmon River (above Redfish L.)	1.04	0.61	0.74	1.46	1.03	0.63	0.81	1.32
		North Fork Salmon River								
		Lower Salmon River (below Redfish L.)	1.03	0.60	0.76	1.40	1.01	0.55	0.81	1.27
		East Fork Salmon River	1.05	0.61	0.70	1.57	1.04	0.62	0.77	1.40
		Pahsimeroi River					1.24	0.96	0.96	1.59
		Panther - Extirpated								
Upper Columbia Spring Chinook Salmon	Eastern Cascades	Wenatchee R.	0.96	0.39	0.61	1.51	0.97	0.37	0.77	1.22
		Methow R.	1.02	0.55	0.59	1.78	0.99	0.47	0.74	1.33
		Entiat R.	0.97	0.40	0.72	1.31	0.99	0.44	0.81	1.20
		Okanogan R. (extirpated)								
Snake River Fall Chinook Salmon	Main Stem and Lower Tributaries	Lower Mainstem Fall Chinook 1977-Most Recent BY	1.09	0.87	0.91	1.30	1.10	0.92	0.95	1.27
		Lower Mainstem Fall Chinook 1990-Most Recent BY	1.18	0.94	0.89	1.56	0.94	0.26	0.72	1.23

[1] Valid lambda confidence limit estimates could not be obtained for these populations.

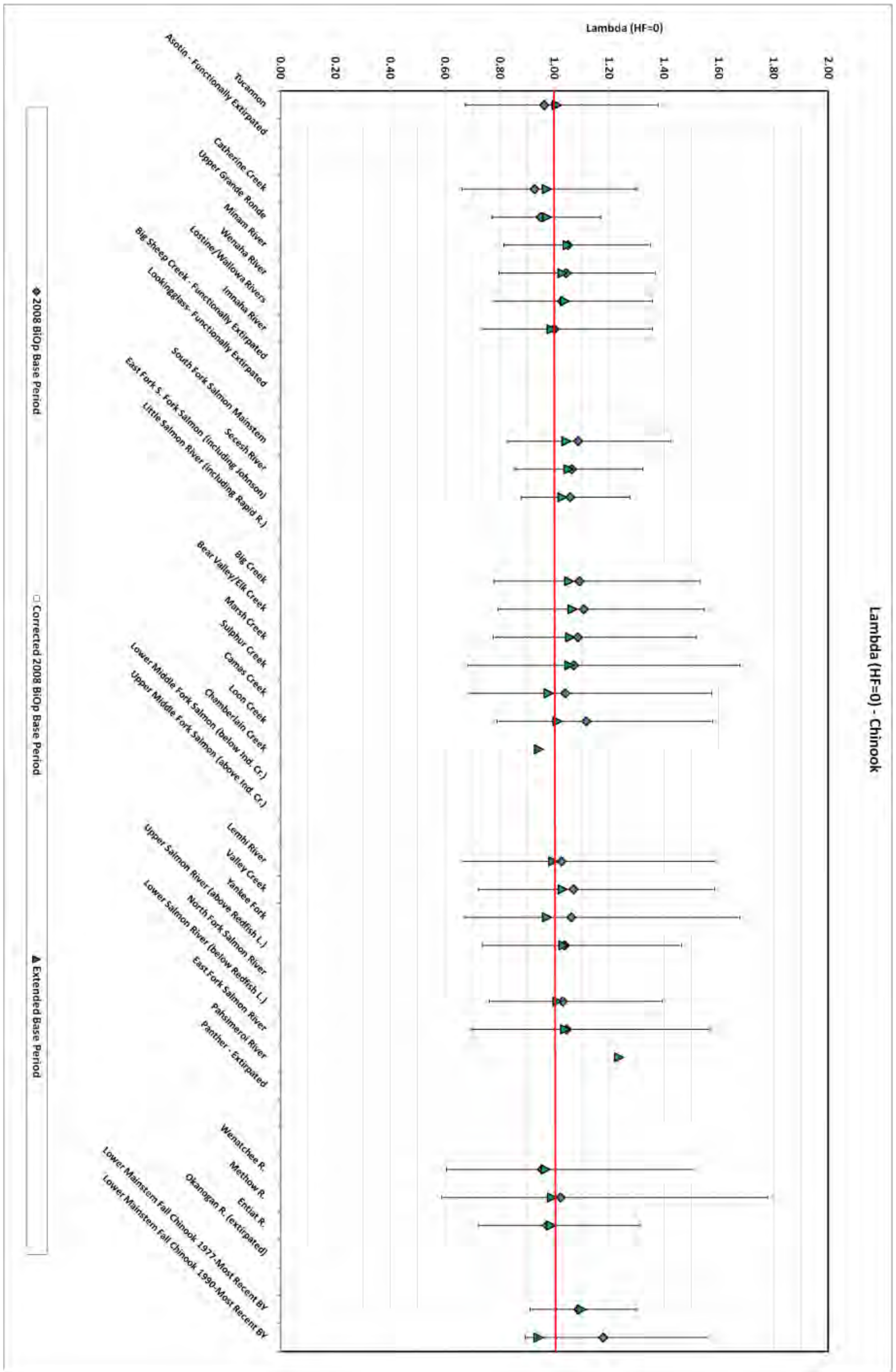

Figure 2.1-15. Chinook median population growth rate (lambda) under the assumption that hatchery-origin spawners are not reproductively effective (HF=0). Base Period estimates that were reported in the 2008 BiOp are compared with extended Base Period estimates based on new information in the NWFSC SPS database that has become available since the 2008 BiOp. The 2008 BiOp's goal for prospective actions for this metric is lambda greater than 1.0 (red line).

Table 2.1-12. Steelhead median population growth rate (lambda) under the assumption that hatchery-origin spawners are not reproductively effective (HF=0). Base Period estimates that were reported in the 2008 BiOp are compared with extended Base Period estimates based on new information in the NWFSC SPS database that has become available since the 2008 BiOp. The 2008 BiOp's goal for prospective actions for this metric is lambda greater than 1.0. Extended Base Period lambda HF=0 estimates are higher than the 2008 BiOp estimates for most steelhead populations; however, all new estimates are within the 2008 BiOp's 95% confidence limits.

			2008 BiOp				New Information			
ESU	MPG	Population	Base Period Lambda HF=0	Probability Lambda >1.0	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Extended Base Period Lambda HF=0	Probability Lambda >1.0	Lower 95% Confidence Limit	Upper 95% Confidence Limit
Upper Columbia River Steelhead	Eastern Cascades	Wenatchee	1.07	0.74	0.83	1.38	1.08	0.81	0.88	1.32
		Methow	1.09	0.78	0.83	1.43	1.09	0.84	0.89	1.34
		Entiat	1.05	0.70	0.82	1.36	1.06	0.77	0.87	1.30
		Okanogan					1.05	0.72	0.85	1.31
Snake River Steelhead[1]	Lower Snake	Tucannon								
		Asotin								
	Imnaha River	Imnaha R. (Camp Cr)	1.06	0.71	0.82	1.37	1.04	0.69	0.85	1.27
	Grande Ronde	Upper Mainstem	0.99	0.42	0.83	1.17	1.00	0.51	0.88	1.15
		Lower Mainstem								
		Joseph Cr.	1.05	0.68	0.82	1.35	1.03	0.66	0.85	1.26
		Wallowa R.								
	Clearwater River	Lower Mainstem								
		Lolo Creek								
		Lochsa River								
		Selway River								
		South Fork								
		North Fork - (Extirpated)								
	Salmon River	Upper Middle Fork Tribs								
		Chamberlain Cr.								
		South Fork Salmon								
		Panther Creek								
		Secesh River								
		North Fork								
		Lower Middle Fork Tribs								
		Little Salmon/Rapid								
		Lemhi River								
		Pahsimeroi River								
		East Fork Salmon								
		Upper Mainstem								
Mid Columbia Steelhead	Yakima	Upper Yakima	1.01	0.55	0.74	1.39	1.03	0.66	0.85	1.25
		Naches	1.02	0.57	0.74	1.41	1.04	0.68	0.85	1.26
		Toppenish	1.09	0.75	0.76	1.57	1.05	0.71	0.85	1.29
		Satus	0.98	0.39	0.76	1.25	1.03	0.67	0.86	1.24
	Eastern Cascades	Deschutes W.	1.02	0.58	0.81	1.29	1.01	0.55	0.85	1.20
		Deschutes East[2]								
		Klickitat								
		Fifteenmile Cr.	1.03	0.65	0.83	1.28	0.99	0.42	0.80	1.21
		Rock Cr.								
		White Salmon - Extirpated								
	Umatilla/Walla Walla	Umatilla	1.04	0.68	0.86	1.25	1.03	0.72	0.90	1.18
		Walla-Walla[3]								
		Touchet[4]								
	John Day	Lower Mainstem)	1.01	0.53	0.71	1.43	1.00	0.49	0.74	1.35
		North Fork	1.00	0.51	0.80	1.26	1.01	0.54	0.84	1.21
		Upper Mainstem	0.99	0.47	0.77	1.28	1.00	0.49	0.82	1.22
		Middle Fork	1.01	0.53	0.80	1.27	0.99	0.47	0.80	1.23
		South Fork	0.99	0.47	0.74	1.33	1.00	0.50	0.80	1.25

[1] Only the populations with empirical estimates are shown, as in the 2008 BiOp. In the 2008 BiOp, other populations were analyzed using "average A- and B-run" estimates, as understood at the time.

[2] Deschutes East populationwas not included in 2008 BiOp "1980-present" metrics because data set doesn't begin until 1990. As in 2008 BiOp, it is included in shorter-term estimates in an appendix.

[3] Walla Walla population data not available for 2008 BiOp. New data, beginning in 1993, is included in appendix with shorter-term estimates.

[4] Touchet population data not available for 2008 BiOp. New data, beginning in 1987, are included in appendix with shorter-term estimates.

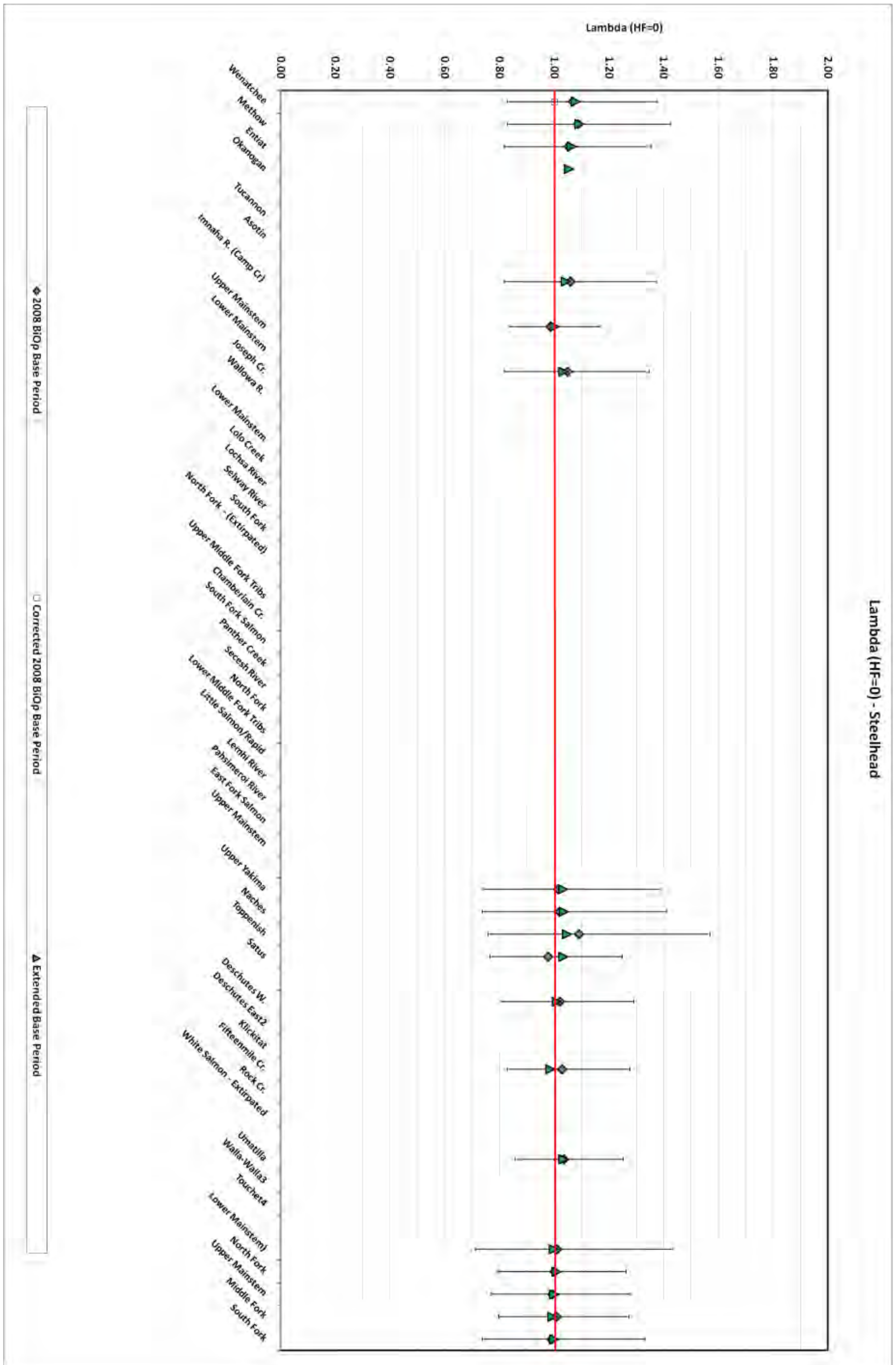

Figure 2.1-16. Steelhead median population growth rate (lambda) under the assumption that hatchery-origin spawners are not reproductively effective (HF=0). Base Period estimates that were reported in the 2008 BiOp are compared with extended Base Period estimates based on new information in the NWFSC SPS database that has become available since the 2008 BiOp. The 2008 BiOp's goal for prospective actions for this metric is lambda greater than 1.0 (red line).

Lambda HF=1

Lambda was estimated as described in the 2008 BiOp Chapter 7.1 using new information in the SPS database for the extended Base Period (Tables 2.1-13 and 2.1-14; Figures 2.1-17 and 2.1-18). As described in Section 2.1.1.4.1 (above), the 2008 BiOp's goal for prospective actions (including projected effects of the RPA and continuation of current management practices) for this metric is lambda greater than 1.0. New point estimates of lambda under the assumption that hatchery-origin spawners are as reproductively effective as natural-origin spawners (HF=1) were generally lower than estimates in the 2008 BiOp for Chinook (20 of 26 populations declined), but estimates increased and decreased in equal proportions for steelhead (9 of 18 populations increased). All new estimates were within the 2008 BiOp's 95% confidence intervals, indicating that the results are within the range of statistical uncertainty described in the 2008 BiOp. Although lambda HF=1 estimates were lower than in the 2008 BiOp for many populations, many of the populations that declined continued to exhibit Base Period productivity estimates that were greater than 1.0 (8 of 20 Chinook populations and 3 of 9 steelhead populations).

Table 2.1-13. Chinook median population growth rate (lambda) under the assumption that hatchery-origin spawners are as reproductively effective as natural-origin spawners (HF=1). Base Period estimates that were reported in the 2008 BiOp are compared with extended Base Period estimates based on new information in the NWFSC SPS database that has become available since the 2008 BiOp. The 2008 BiOp's goal for prospective actions for this metric is lambda greater than 1.0. Extended Base Period lambda HF=1 estimates are lower than the 2008 BiOp estimates for most Chinook populations; however, all new estimates are within the 2008 BiOp's 95% confidence limits.

ESU	MPG	Population	2008 BiOp				New Information			
			Base Period Lambda HF=1	Probability Lambda >1.0	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Extended Base Period Lambda HF=1	Probability Lambda >1.0	Lower 95% Confidence Limit	Upper 95% Confidence Limit
Snake River Spring/ Summer Chinook Salmon	Lower Snake	Tucannon	0.87	0.16	0.63	1.21	0.90	0.18	0.70	1.16
		Asotin - Functionally Extirpated								
	Grande Ronde / Imnaha	Catherine Creek	0.81	0.13	0.53	1.26	0.83	0.10	0.59	1.16
		Upper Grande Ronde	0.82	0.08	0.59	1.13	0.78	0.03	0.60	1.02
		Minam River	0.98	0.44	0.71	1.36	0.99	0.47	0.79	1.25
		Wenaha River	0.93	0.30	0.65	1.33	0.94	0.27	0.74	1.20
		Lostine/Wallowa Rivers	0.94	0.33	0.68	1.32	0.92	0.20	0.72	1.17
		Imnaha River	0.85	0.07	0.67	1.09	0.84	0.06	0.67	1.06
		Big Sheep Creek - Functionally Extirpated								
		Lookingglass- Functionally Extirpated								
	South Fork Salmon	South Fork Salmon Mainstem	0.99	0.47	0.74	1.33	0.95	0.21	0.80	1.11
		Secesh River	1.06	0.74	0.85	1.31	1.04	0.72	0.87	1.25
		East Fork S. Fork Salmon (including Johnson)	1.05	0.76	0.87	1.26	0.98	0.38	0.79	1.20
		Little Salmon River (including Rapid R.)								
	Middle Fork Salmon	Big Creek	1.09	0.74	0.78	1.53	1.05	0.69	0.81	1.37
		Bear Valley/Elk Creek	1.11	0.80	0.79	1.55	1.07	0.75	0.85	1.33
		Marsh Creek	1.09	0.75	0.78	1.52	1.06	0.71	0.83	1.35
		Sulphur Creek	1.07	0.67	0.68	1.68	1.05	0.70	0.82	1.35
		Camas Creek[1]	1.04	0.60	0.69	1.57	0.98			
		Loon Creek[1]	1.12	0.79	0.79	1.58	1.01			
		Chamberlain Creek[1]					0.94			
		Lower Middle Fork Salmon (below Ind. Cr.)								
		Upper Middle Fork Salmon (above Ind. Cr.)								
	Upper Salmon	Lemhi River	1.03	0.57	0.66	1.59	1.00	0.49	0.75	1.33
		Valley Creek	1.07	0.69	0.72	1.59	1.03	0.62	0.81	1.32
		Yankee Fork[1]	1.06	0.65	0.67	1.68	0.89			
		Upper Salmon River (above Redfish L.)	0.98	0.43	0.69	1.38	0.98	0.40	0.76	1.26
		North Fork Salmon River								
		Lower Salmon River (below Redfish L.)	1.03	0.60	0.76	1.40	1.01	0.55	0.81	1.27
		East Fork Salmon River	1.02	0.54	0.66	1.56	1.02	0.55	0.74	1.40
		Pahsimeroi River					0.99	0.46	0.80	1.23
		Panther - Extirpated								
Upper Columbia Spring Chinook Salmon	Eastern Cascades	Wenatchee R.	0.91	0.25	0.61	1.36	0.86	0.07	0.70	1.07
		Methow R.	0.94	0.36	0.58	1.53	0.85	0.10	0.63	1.13
		Entiat R.	0.92	0.21	0.71	1.21	0.91	0.12	0.77	1.09
		Okanogan R. (extirpated)								
Snake River Fall Chinook Salmon	Main Stem and Lower Tributaries	Lower Mainstem Fall Chinook 1977-Most Recent BY	0.95	0.21	0.80	1.12	0.91	0.10	0.78	1.07
		Lower Mainstem Fall Chinook 1990-Most Recent BY	1.01	0.53	0.79	1.27	0.94	0.26	0.72	1.23

[1] Valid lambda confidence limit estimates could not be obtained for these populations.

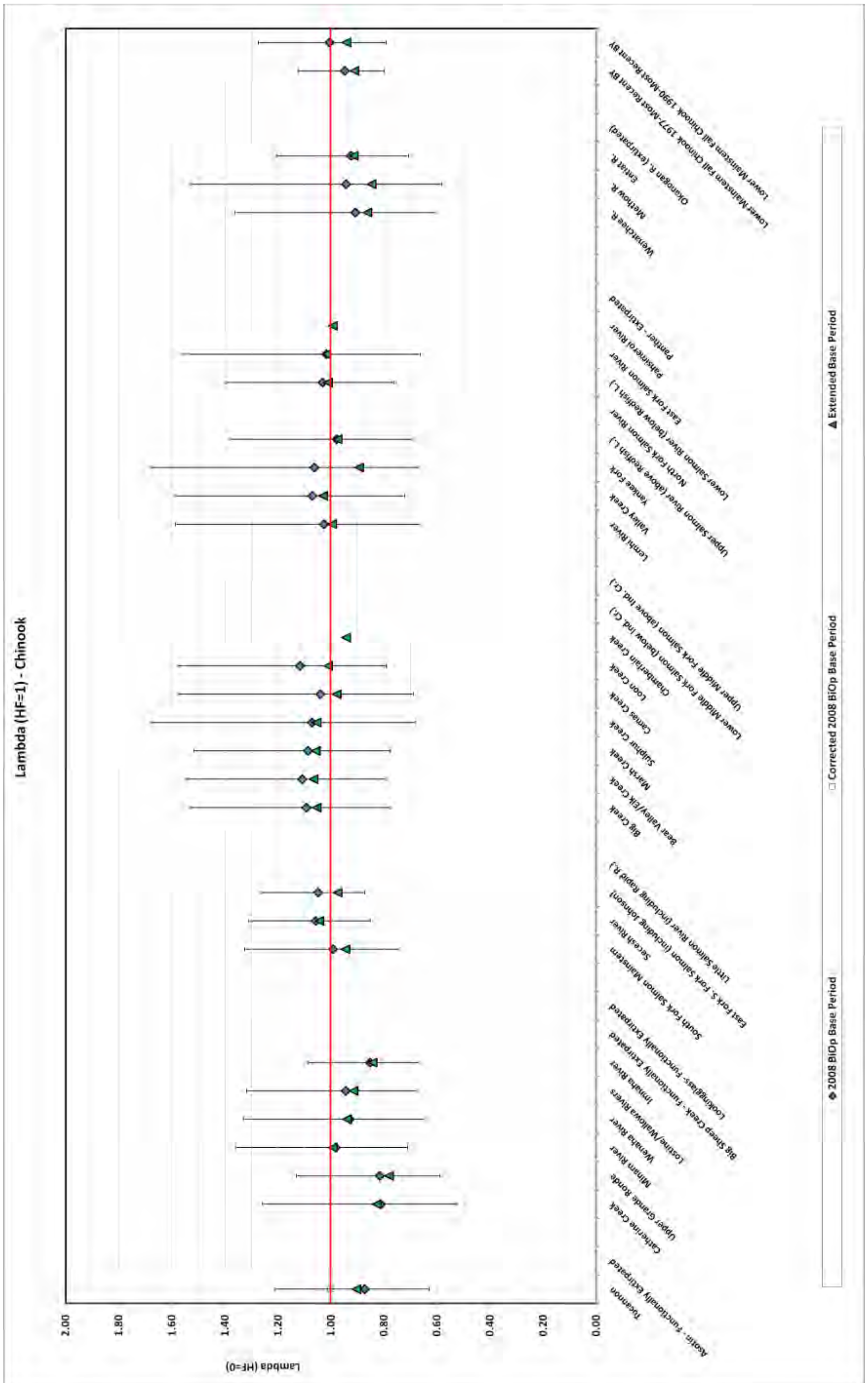

Figure 2.1-17. Chinook median population growth rate (lambda) under the assumption that hatchery-origin spawners are as reproductively effective as natural-origin spawners (HF=1). Base Period estimates that were reported in the 2008 BiOp are compared with extended Base Period estimates based on new information in the NWFSC SPS database that has become available since the 2008 BiOp. The 2008 BiOp's goal for prospective actions for this metric is lambda greater than 1.0 (red line).

Table 2.1-14. Steelhead median population growth rate (lambda) under the assumption that hatchery-origin spawners are as reproductively effective as natural-origin spawners (HF=1). Base Period estimates that were reported in the 2008 BiOp are compared with extended Base Period estimates based on new information in the NWFSC SPS database that has become available since the 2008 BiOp. The 2008 BiOp's goal for prospective actions for this metric is lambda greater than 1.0. Extended Base Period lambda HF=1 estimates are the same or higher than the 2008 BiOp estimates for half of the steelhead populations (9/18) and are lower for the remaining populations (9/18). All new estimates are within the 2008 BiOp's 95% confidence limits.

			2008 BiOp				New Information			
ESU	MPG	Population	Base Period Lambda HF=1	Probability Lambda >1.0	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Extended Base Period Lambda HF=1	Probability Lambda >1.0	Lower 95% Confidence Limit	Upper 95% Confidence Limit
Upper Columbia River Steelhead	Eastern Cascades	Wenatchee	0.80	0.04	0.62	1.03	0.81	0.02	0.66	0.99
		Methow	0.67	0.00	0.56	0.81	0.68	0.00	0.59	0.78
		Entiat	0.81	0.02	0.67	0.97	0.80	0.01	0.68	0.95
		Okanogan					0.56	0.00	0.47	0.68
Snake River Steelhead[1]	Lower Snake	Tucannon								
		Asotin								
	Imnaha River	Imnaha R. (Camp Cr)	1.06	0.71	0.82	1.37	1.04	0.69	0.85	1.27
	Grande Ronde	Upper Mainstem	0.96	0.25	0.81	1.13	0.97	0.32	0.85	1.12
		Lower Mainstem								
		Joseph Cr.	1.05	0.68	0.82	1.35	1.03	0.66	0.85	1.26
		Wallowa R.								
	Clearwater River	Lower Mainstem								
		Lolo Creek								
		Lochsa River								
		Selway River								
		South Fork								
		North Fork - (Extirpated)								
	Salmon River	Upper Middle Fork Tribs								
		Chamberlain Cr.								
		South Fork Salmon								
		Panther Creek								
		Secesh River								
		North Fork								
		Lower Middle Fork Tribs								
		Little Salmon/Rapid								
		Lemhi River								
		Pahsimeroi River								
		East Fork Salmon								
		Upper Mainstem								
Mid Columbia Steelhead	Yakima	Upper Yakima	1.01	0.53	0.74	1.39	1.03	0.64	0.85	1.25
		Naches	1.00	0.51	0.72	1.39	1.02	0.61	0.84	1.25
		Toppenish	1.07	0.71	0.74	1.55	1.03	0.65	0.84	1.27
		Satus	0.96	0.31	0.75	1.23	1.02	0.60	0.84	1.23
	Eastern Cascades	Deschutes W.	0.97	0.35	0.78	1.20	0.96	0.27	0.81	1.13
		Deschutes East[2]								
		Klickitat								
		Fifteenmile Cr.	1.03	0.65	0.83	1.28	0.99	0.42	0.80	1.21
		Rock Cr.								
		White Salmon - Extirpated								
	Umatilla/Walla Walla	Umatilla	0.99	0.41	0.83	1.17	0.98	0.33	0.86	1.11
		Walla-Walla[3]								
		Touchet[4]								
	John Day	Lower Mainstem)	1.00	0.50	0.71	1.41	0.98	0.44	0.73	1.33
		North Fork	1.00	0.48	0.79	1.25	1.00	0.49	0.83	1.20
		Upper Mainstem	0.99	0.44	0.77	1.27	0.99	0.45	0.81	1.21
		Middle Fork	1.00	0.50	0.79	1.26	0.98	0.43	0.80	1.22
		South Fork	0.98	0.44	0.74	1.32	0.99	0.45	0.80	1.23

[1] Only the populations with empirical estimates are shown, as in the 2008 BiOp. In the 2008 BiOp, other populations were analyzed using "average A- and B-run" estimates, as understood at the time.
[2] Deschutes East populationwas not included in 2008 BiOp "1980-present" metrics because data set doesn't begin until 1990. As in 2008 BiOp, it is included in shorter-term estimates in an appendix.
[3] Walla Walla population data not available for 2008 BiOp. New data, beginning in 1993, is included in appendix with shorter-term estimates.
[4] Touchet population data not available for 2008 BiOp. New data, beginning in 1987, are included in appendix with shorter-term estimates.

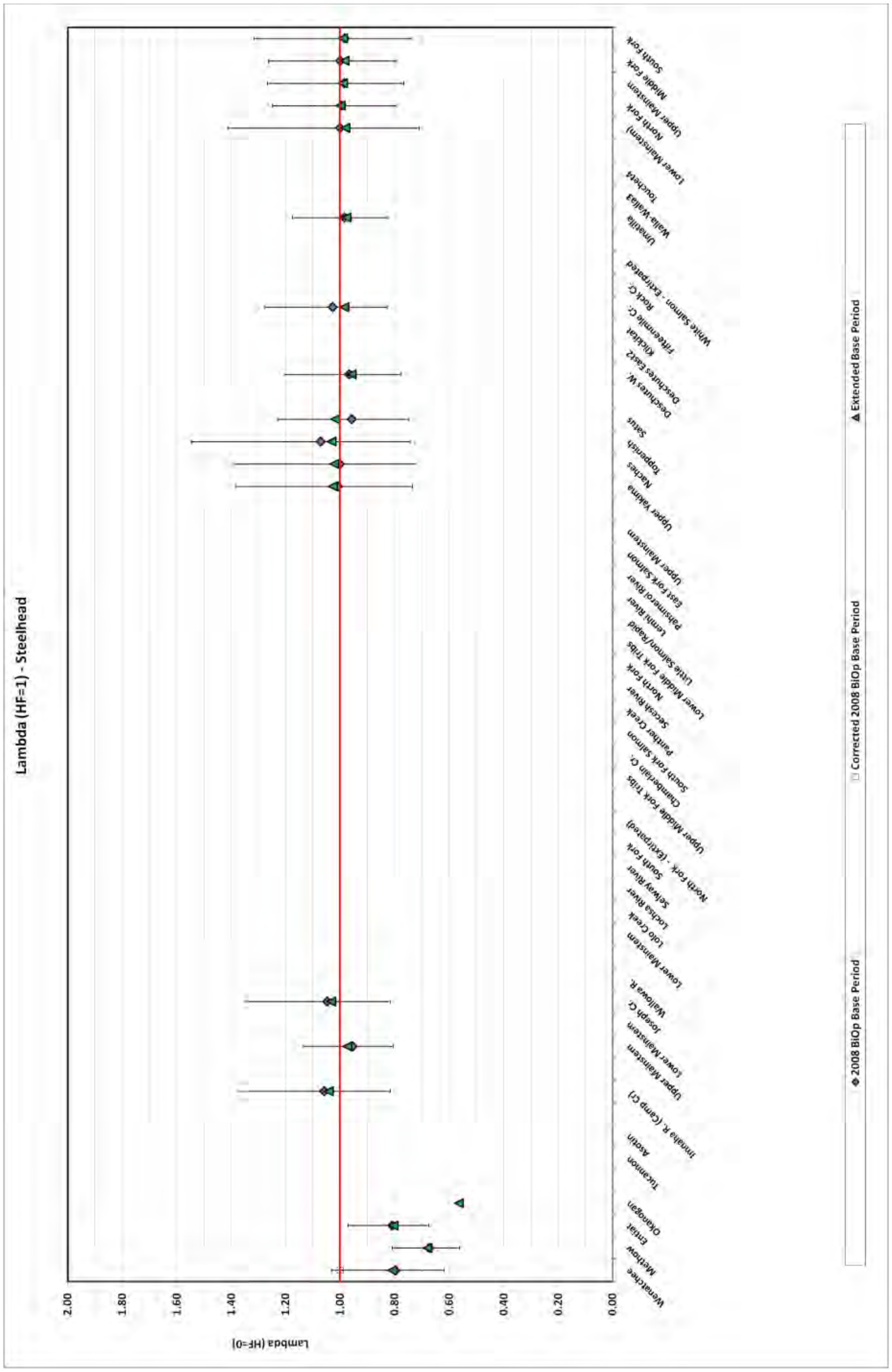

Figure 2.1-18. Steelhead median population growth rate (lambda) under the assumption that hatchery-origin spawners are as reproductively effective as natural-origin spawners (HF=1). Base Period estimates that were reported in the 2008 BiOp are compared with extended Base Period estimates based on new information in the NWFSC SPS database that has become available since the 2008 BiOp. The 2008 BiOp's goal for prospective actions for this metric is lambda greater than 1.0 (red line).

Productivity: Trend of ln(Abundance+1) (BRT Trend)

BRT abundance trends were estimated as described in the 2008 BiOp Chapter 7.1 using new information in the SPS database for the extended Base Period (Tables 2.1-15 and 2.1-16; Figures 2.1-19 and 2.1-20). As described in Section 2.1.1.4.1 (above), the 2008 BiOp's goal for prospective actions (including projected effects of the RPA and continuation of current management practices) for this metric is trend of ln(abundance+1) greater than 1.0. New point estimates of BRT trend were higher than estimates in the 2008 BiOp for most populations (19[20][23] of 26 Chinook and 16 of 18 steelhead populations). All but three new estimates were within the 2008 BiOp's 95% confidence intervals, indicating that the results are within the range of statistical uncertainty described in the 2008 BiOp. The Upper Grande Ronde Chinook estimate was 1% below the 2008 BiOp's lower confidence limit while the Wenaha and Imnaha Chinook population estimates were 2% to 3% above the higher confidence limit. Although BRT trend declined for a few populations, nearly all continued to exhibit base-period estimates that were greater than 1.0: 5 of 6 [or 6 of 7][20] Chinook populations and both of the two steelhead populations.

[23] Snake River fall Chinook metrics were calculated using two different methods, as in the 2008 BiOp and ICTRT (2007b) survival gap analyses, and the results differed for the two methods.

Table 2.1-15. Comparison of Chinook Base Period BRT abundance trend reported in the 2008 BiOp and extended Base Period estimates based on new information in the NWFSC SPS database that has become available since the 2008 BiOp. The 2008 BiOp's goal for prospective actions for this metric is BRT trend greater than 1.0. Extended Base Period BRT abundance trend estimates are higher than the 2008 BiOp estimates for most Chinook populations. All but one new estimate is within or above the 2008 BiOp's 95% confidence limits.

ESU	MPG	Population	2008 BiOp			New Information			
			Base Period BRT Trend	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Extended Base Period BRT Trend	Probability BRT Trend >1.0	Lower 95% Confidence Limit	Upper 95% Confidence Limit
Snake River Spring/ Summer Chinook Salmon	Lower Snake	Tucannon	0.92	0.85	0.99	0.98	0.25	0.92	1.04
		Asotin - Functionally Extirpated							
	Grande Ronde / Imnaha	Catherine Creek	0.92	0.87	0.98	0.96	0.06	0.92	1.01
		Upper Grande Ronde	1.01	0.96	1.06	0.95	0.01	0.91	0.99
		Minam River	1.02	0.97	1.07	1.04	0.99	1.01	1.07
		Wenaha River	0.98	0.94	1.02	1.05	1.00	1.02	1.08
		Lostine/Wallowa Rivers	1.04	0.99	1.10	1.02	0.87	0.98	1.06
		Imnaha River	0.92	0.87	0.97	0.99	0.22	0.96	1.02
		Big Sheep Creek - Functionally Extirpated							
		Lookingglass- Functionally Extirpated							
	South Fork Salmon	South Fork Salmon Mainstem	1.05	1.01	1.10	1.03	1.00	1.01	1.05
		Secesh River	1.05	1.01	1.09	1.04	1.00	1.02	1.07
		East Fork S. Fork Salmon (including Johnson)	1.02	0.97	1.08	1.01	0.76	0.98	1.04
		Little Salmon River (including Rapid R.)							
	Middle Fork Salmon	Big Creek	1.02	0.94	1.10	1.03	0.90	0.98	1.08
		Bear Valley/Elk Creek	1.05	0.98	1.13	1.05	1.00	1.01	1.09
		Marsh Creek	1.01	0.92	1.10	1.03	0.95	0.99	1.07
		Sulphur Creek	1.02	0.94	1.11	1.03	0.88	0.98	1.07
		Camas Creek	1.00	0.93	1.07	1.00	0.42	0.95	1.04
		Loon Creek	1.07	0.98	1.16	1.04	0.96	0.99	1.09
		Chamberlain Creek				1.06	0.99	1.01	1.11
		Lower Middle Fork Salmon (below Ind. Cr.)							
		Upper Middle Fork Salmon (above Ind. Cr.)							
	Upper Salmon	Lemhi River	0.98	0.92	1.05	0.99	0.27	0.96	1.02
		Valley Creek	1.03	0.96	1.11	1.04	0.98	1.00	1.08
		Yankee Fork	1.05	0.96	1.15	1.01	0.62	0.96	1.06
		Upper Salmon River (above Redfish L.)	1.01	0.95	1.06	1.03	0.94	0.99	1.06
		North Fork Salmon River							
		Lower Salmon River (below Redfish L.)	1.00	0.95	1.05	1.01	0.75	0.98	1.04
		East Fork Salmon River	1.01	0.94	1.09	1.04	0.95	0.99	1.09
		Pahsimeroi River				1.24	1.00	1.19	1.30
		Panther - Extirpated							
Upper Columbia Spring Chinook Salmon	Eastern Cascades	Wenatchee R.	0.89	0.83	0.95	0.95	0.00	0.91	0.98
		Methow R.	0.90	0.80	1.01	0.96	0.03	0.91	1.00
		Entiat R.	0.93	0.89	0.98	0.98	0.11	0.95	1.01
		Okanogan R. (extirpated)							
Snake River Fall Chinook Salmon	Main Stem and Lower Tributaries	Lower Mainstem Fall Chinook 1977-Most Recent BY	1.09	1.06	1.13	1.12	1.00	1.09	1.14
		Lower Mainstem Fall Chinook 1990-Most Recent BY	1.23	1.16	1.31	1.19	1.00	1.15	1.23

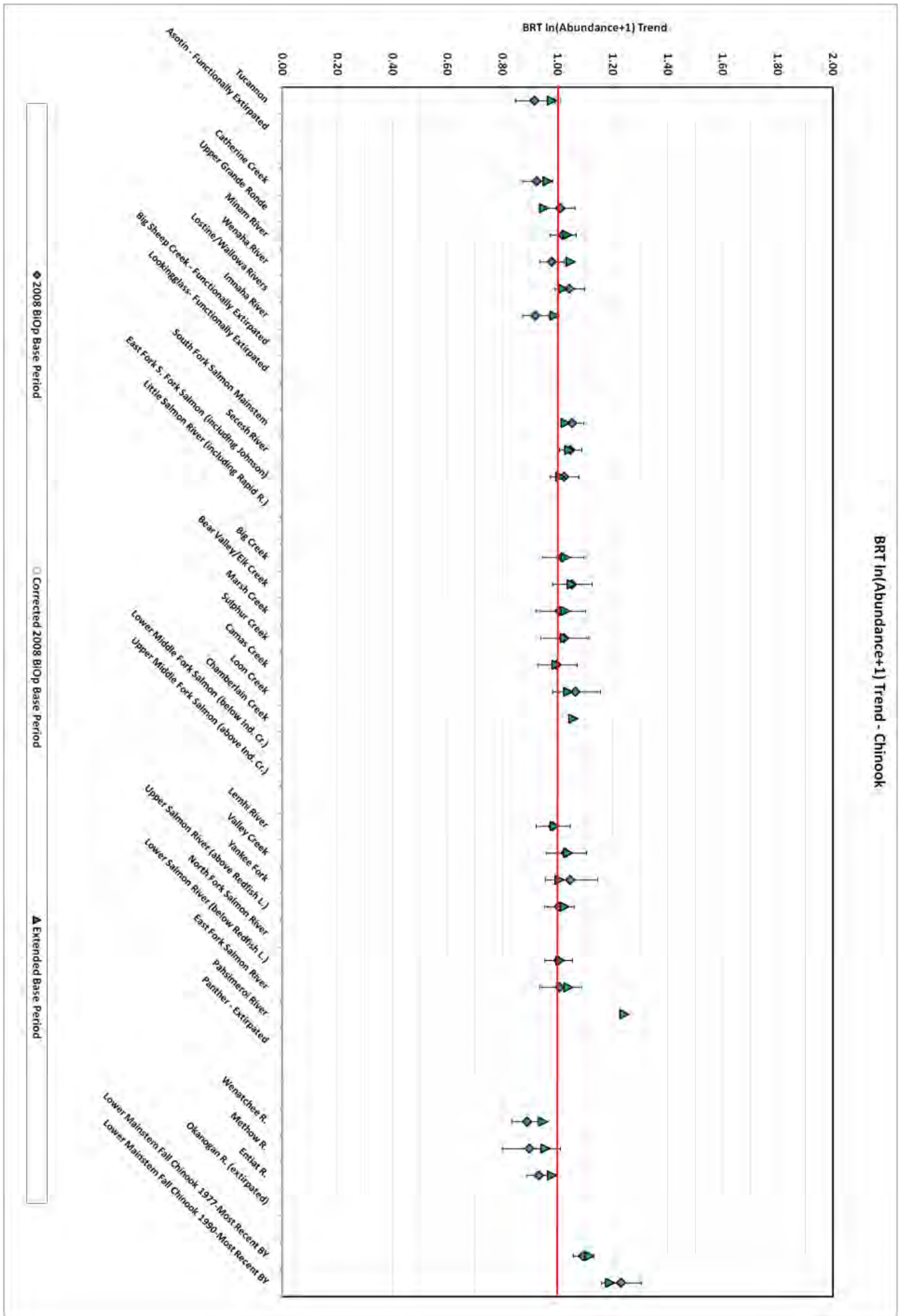

Figure 2.1-19. Comparison of Chinook Base Period BRT abundance trend reported in the 2008 BiOp and extended Base Period estimates based on new information in the NWFSC SPS database that has become available since the 2008 BiOp. The 2008 BiOp's goal for prospective actions for this metric is R/S greater than 1.0 (red line).

Table 2.1-16. Comparison of steelhead Base Period BRT abundance trend reported in the 2008 BiOp and extended Base Period estimates based on new information in the NWFSC SPS database that has become available since the 2008 BiOp. The 2008 BiOp's goal for prospective actions for this metric is BRT trend greater than 1.0. Extended Base Period BRT abundance trend estimates are higher than the 2008 BiOp estimates for most Chinook populations; however, all new estimates are within or above the 2008 BiOp's 95% confidence limits.

ESU	MPG	Population	2008 BiOp			New Information			
			Base Period BRT Trend	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Extended Base Period BRT Trend	Probability BRT Trend >1.0	Lower 95% Confidence Limit	Upper 95% Confidence Limit
Upper Columbia River Steelhead	Eastern Cascades	Wenatchee	1.04	1.00	1.11	1.04	1.00	1.02	1.07
		Methow	1.07	1.03	1.14	1.07	1.00	1.05	1.10
		Entiat	1.04	1.01	1.12	1.05	1.00	1.02	1.07
		Okanogan				1.04	0.99	1.01	1.07
Snake River Steelhead[1]	Lower Snake	Tucannon							
		Asotin							
	Imnaha River	Imnaha R. (Camp Cr)	1.03	0.99	1.14	1.03	0.98	1.00	1.06
	Grande Ronde	Upper Mainstem	0.99	0.95	1.07	1.00	0.34	0.97	1.02
		Lower Mainstem							
		Joseph Cr.	1.01	0.97	1.11	1.01	0.70	0.98	1.04
		Wallowa R.							
	Clearwater River	Lower Mainstem							
		Lolo Creek							
		Lochsa River							
		Selway River							
		South Fork							
		North Fork - (Extirpated)							
	Salmon River	Upper Middle Fork Tribs							
		Chamberlain Cr.							
		South Fork Salmon							
		Panther Creek							
		Secesh River							
		North Fork							
		Lower Middle Fork Tribs							
		Little Salmon/Rapid							
		Lemhi River							
		Pahsimeroi River							
		East Fork Salmon							
		Upper Mainstem							
Mid Columbia Steelhead	Yakima	Upper Yakima	1.01	0.95	1.17	1.05	1.00	1.02	1.08
		Naches	1.02	0.96	1.18	1.05	1.00	1.02	1.08
		Toppenish	1.09	1.02	1.32	1.07	1.00	1.04	1.11
		Satus	0.98	0.93	1.12	1.04	0.99	1.01	1.07
	Eastern Cascades	Deschutes W.	0.99	0.96	1.17	1.01	0.65	0.98	1.03
		Deschutes East[2]							
		Klickitat							
		Fifteenmile Cr.	1.03	0.98	1.15	1.01	0.63	0.97	1.04
		Rock Cr.							
		White Salmon - Extirpated							
	Umatilla/Walla Walla	Umatilla	1.01	0.98	1.13	1.02	0.97	1.00	1.04
		Walla-Walla[3]							
		Touchet[4]							
	John Day	Lower Mainstem)	0.98	0.94	1.14	0.98	0.07	0.95	1.01
		North Fork	0.99	0.95	1.16	1.00	0.53	0.97	1.03
		Upper Mainstem	0.95	0.92	1.03	0.96	0.01	0.94	0.99
		Middle Fork	0.97	0.93	1.06	0.97	0.01	0.94	0.99
		South Fork	0.95	0.91	1.09	0.98	0.07	0.95	1.01

[1] Only the populations with empirical estimates are shown, as in the 2008 BiOp. In the 2008 BiOp, other populations were analyzed using "average A- and B-run" estimates, as understood at the time.

[2] Deschutes East populationwas not included in 2008 BiOp "1980-present" metrics because data set doesn't begin until 1990. As in 2008 BiOp, it is included in shorter-term estimates in an appendix.

[3] Walla Walla population data not available for 2008 BiOp. New data, beginning in 1993, is included in appendix with shorter-term estimates.

[4] Touchet population data not available for 2008 BiOp. New data, beginning in 1987, are included in appendix with shorter-term estimates.

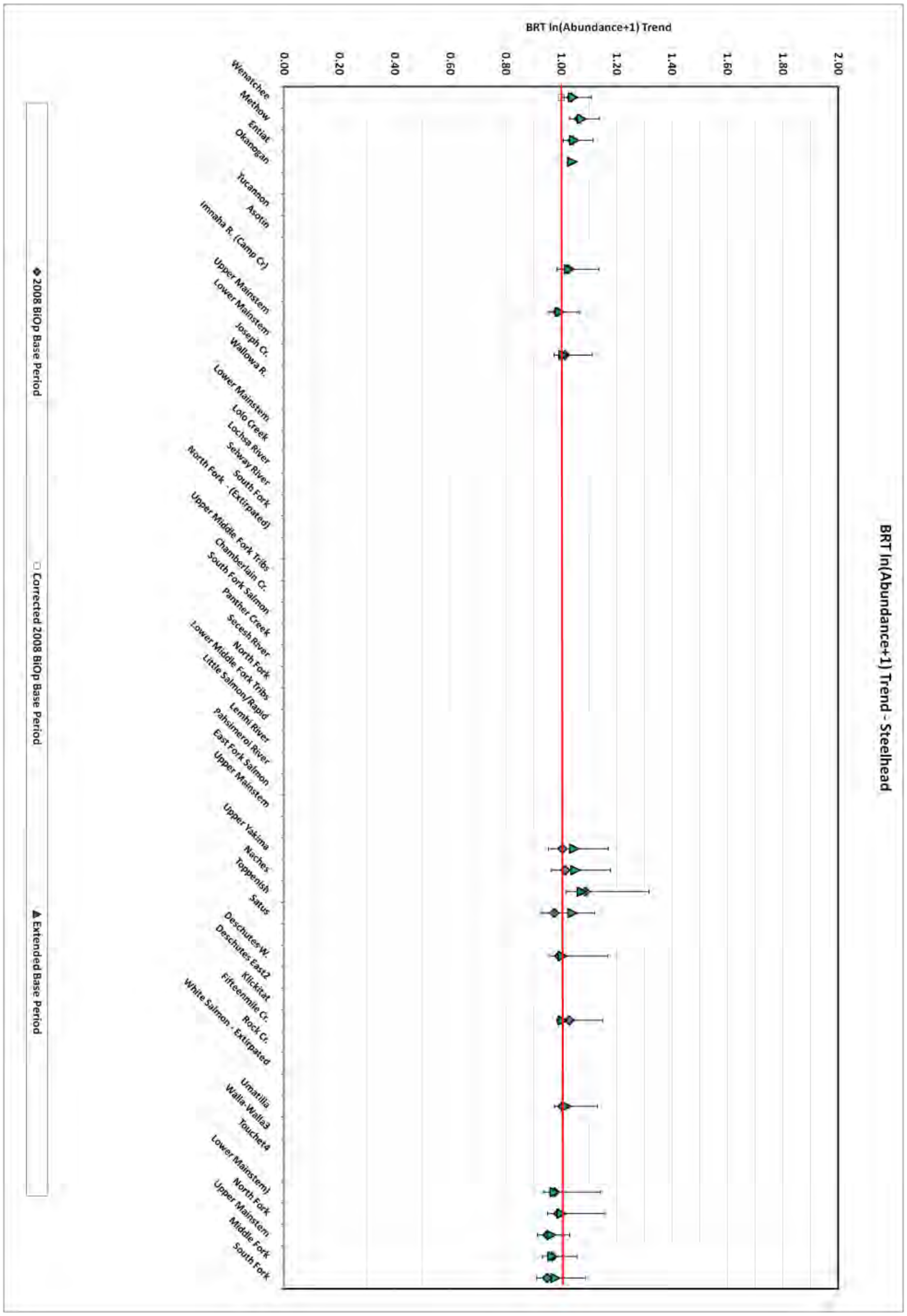

Figure 2.1-20. Comparison of steelhead Base Period BRT abundance trend reported in the 2008 BiOp and extended Base Period estimates based on new information in the NWFSC SPS database that has become available since the 2008 BiOp. The 2008 BiOp's goal for prospective actions for this metric is R/S greater than 1.0 (red line).

2.1.1.4.4 Comparison of Extended Base Period Metrics with Estimates in the 2008 BiOp

Overview of Patterns of Abundance and Productivity

When the 2008 BiOp's Base Period indicator metrics are corrected based on new information and extended to include additional years with new empirical estimates of population performance, virtually all of the new extended Base Period estimates fall within the statistical confidence limits of the previous estimates. This is in part due to many of the annual estimates being common to both the original and extended Base Periods; the relatively small changes in most point estimates; and the variability inherent in the original data set. The lack of statistically significant changes is consistent with the 2012 GPRA Report described in Section 2.1.1.3—which concluded that no statistically significant trends can be detected for most populations—and with the Ford (2011) status review, which made almost no changes to the relative risk and recovery status of these interior Columbia populations based on information available since the previous status review.

While the new information indicates no statistically significant changes in Base Period metrics, some of the point estimates did change, with point estimates of abundance and BRT abundance trend generally higher, and estimates associated with productivity generally lower, than those in the 2008 BiOp were.

The 2010 Supplemental BiOp (e.g., Section 4, p. 8) pointed out that annual variations are to be expected based on the historical record and the statistical variance associated with the original estimates. The 2010 Supplemental BiOp also described the observed pattern in the abundance and productivity point estimates as being consistent with an expectation that interference or competition for resources is likely to occur at high abundance and density, resulting in fewer returns (also referred to as "recruits") produced per spawner. Such density-dependent mortality in Pacific salmonids is a well-established principle in fishery population dynamics (e.g., Ricker 1975; Hilborn and Walters 1992; Zabel et al. 2006). Matrix model projections displayed in Chapter 7.1 of the 2008 BiOp showed how abundance and productivity are expected to interact over time in response to a survival improvement in a single life stage, such as one expected from an RPA action. Due to time limitations of the 2010 voluntary remand, this pattern of observed abundance and productivity was not analyzed in detail. The following discussion further elaborates on the pattern of abundance and productivity indicator metrics since the 2008 BiOp.

Figure 2.1-21 shows the pattern of abundance for natural-origin Snake River spring/summer Chinook salmon populations as an indicator of the general pattern of abundance for interior Columbia basin salmonids. Figure 2.1-22 shows the same information for total spawners, including hatchery-origin fish that spawn naturally along with the natural-origin spawners for some populations (especially those in the Lower Salmon, Grande Ronde, and South Fork MPGs). The abundances are expressed as a percentage of each population's ICTRT abundance threshold (ICTRT 2007a) so that the same figure can display large and small populations. These thresholds also are relevant because they are the abundance levels associated with population viability and, as a rule of thumb, density-dependent effects would be expected as the number of total spawners approaches approximately 75% of the threshold (Cooney 2012).

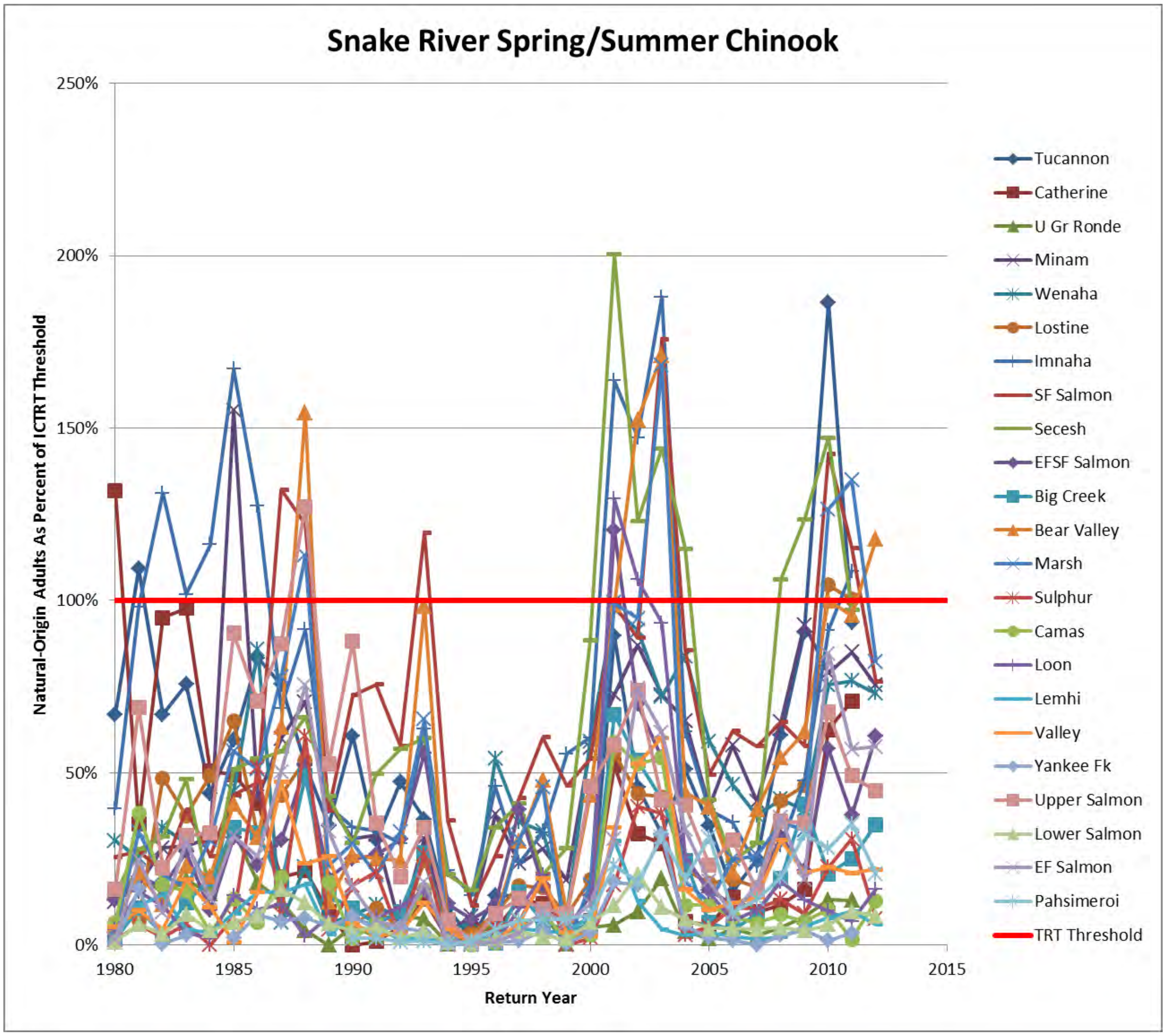

Figure 2.1-21. Annual abundance of natural-origin spawners, expressed as a percentage of ICTRT abundance thresholds.

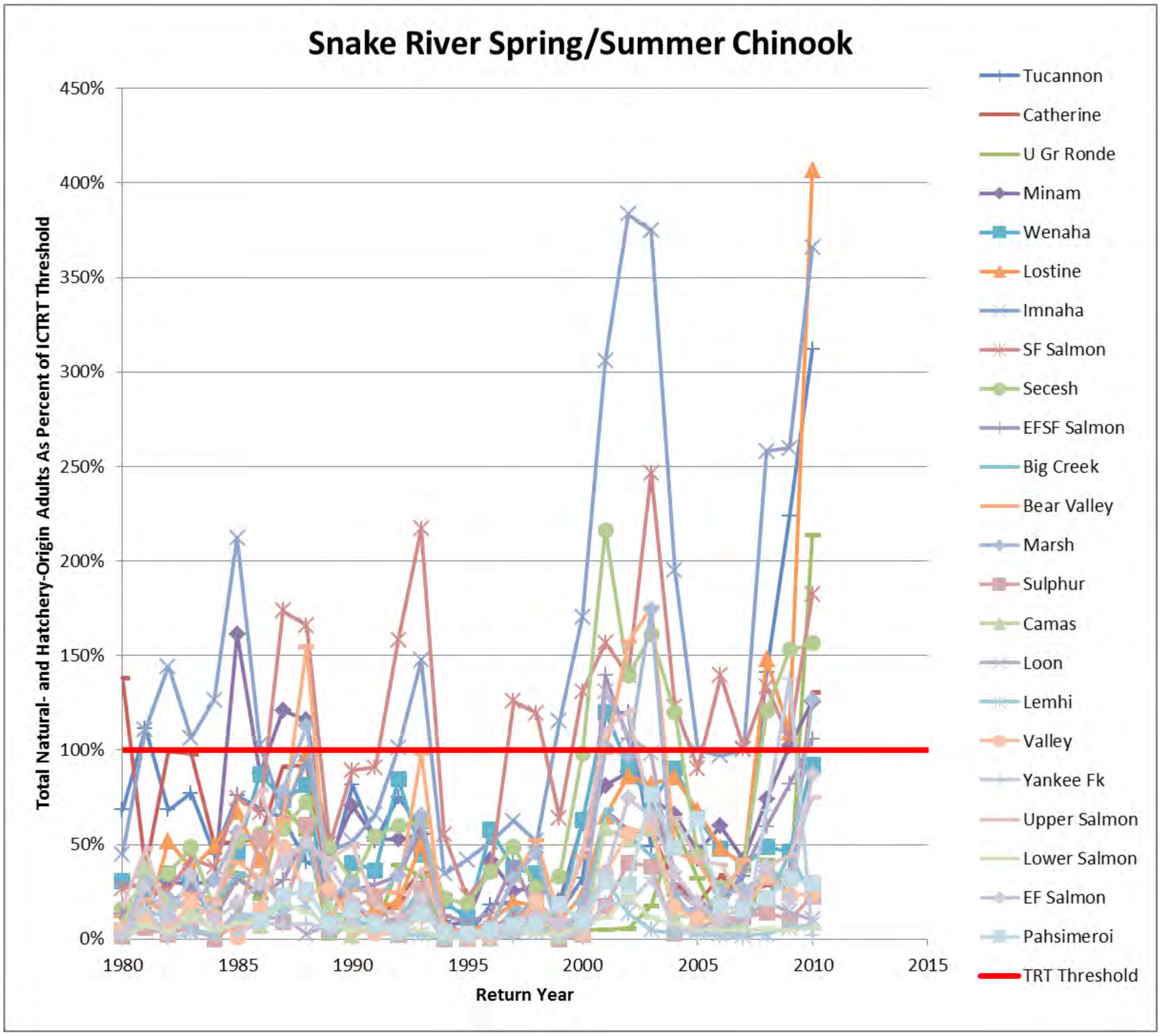

Figure 2.1-22. Annual abundance of total natural-origin and hatchery-origin spawners, expressed as a percentage of ICTRT abundance thresholds.

The Base Period for the 2008 BiOp generally included spawners through 2003 or 2004, depending upon the population, and new observations go through 2010, 2011, or 2012 for most populations. During this period, abundance was

- variable during the 1980s and early 1990s,
- consistently low from 1994 to 1999,
- generally high to very high from about 2001 to 2003 or 2004,
- consistently low from about 2005 to 2008 or 2009, and
- generally high to very high since that time.

The abundance of returning natural-origin progeny (mostly at age 4 and age 5 for the SR spring/summer Chinook example) resulted in the pattern of R/S displayed in Figure 2.1-23. Most populations had natural returns that more than replaced the parents (i.e., leading to population growth) for early 1980s, late 1990s, and mid- to late-2000s brood years. Conversely, populations generally did not replace themselves through natural production (i.e., declined) for the late 1980s, early 1990s, and early 2000s brood years.

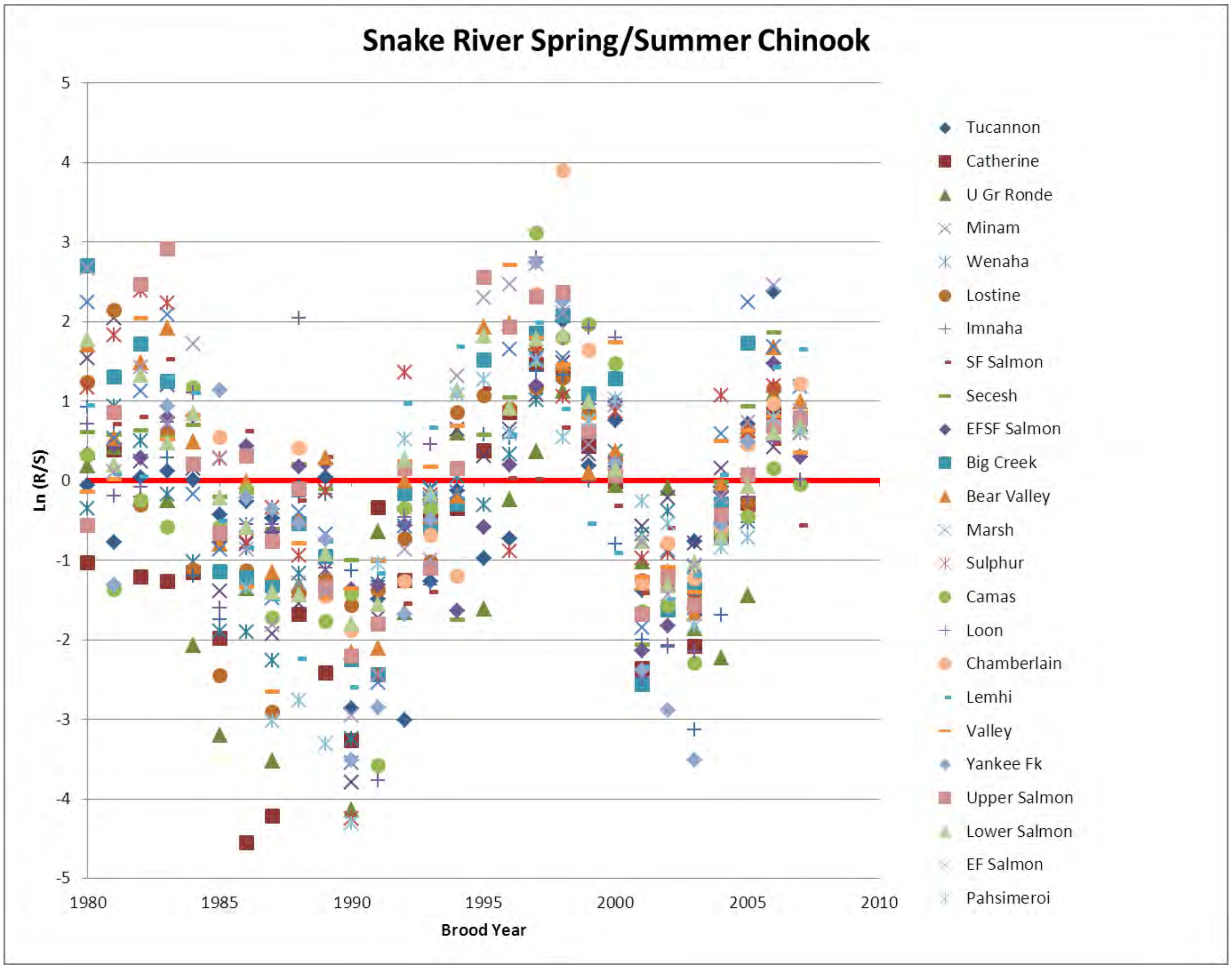

Figure 2.1-23. Brood year R/S expressed on a logarithmic scale (0 is equivalent to the 2008 BiOp goal of an average of one returning adult per spawner).

When the patterns of spawner abundance and R/S are compared with the pattern of environmental conditions described in Section 2.1.4.1.4 (*Ocean Ecosystem Indicators and Overall Pattern of Ocean Conditions*; particularly Table 2.1-20), it appears that ocean conditions may have reduced marine survival, adding to the reduced freshwater survival caused by density dependence in some years (Table 2.1-17). For example, 2001–2003 spawner abundance was relatively high for many SR spring/summer Chinook populations, suggesting that effects of density may have reduced survival of progeny. When the progeny of those brood years entered the ocean in 2003–2005, they encountered poor conditions, further reducing survival. The result was low R/S productivity for the 2001–2003 brood years. The low productivity of the 2001–2003 brood years was the main factor influencing lower extended Base Period average productivities, compared to the original Base Period averages.

Table 2.1-17. Qualitative summary of factors influencing survival of brood years comprising the 2008 BiOp's Base Period and more recent years for Snake River spring/summer Chinook.[1]

Spawner Years (= Brood Years)	Natural Spawner Abundance[2]	Ocean Entry Conditions (+2 years)	Abundance of Returning Progeny (+4 to +5 years)	R/S for Brood Years
1994–1999	Very Low (*weaker density dependence*)	1996–97: N/A 98: Poor 1999–2000: Good 2001: Intermediate	1998–99: Low 2000: Mixed 2001–04: High	1994–96: Mixed 1997–99: High
2000	Mixed	2002: Good	2004: High 2005: Low	2000: Mostly High
2001–2004	High to Very High (*stronger density dependence*)	2003–05: Poor 2006: Intermediate	2005–08: Low 2009: Low/Mixed	2001–03: Very Low 2004: Mixed
2005–2008	Low to Very Low (*weaker density dependence*)	2007: Intermediate 2008: Good 2009: Intermediate 2010: Poor	2009: Low/Mixed 2010–12: High 2013: N/A	2005–08: High
2009	Low to Mixed (*relatively weak density dependence*)	2011: Intermediate	2013–14: N/A	N/A
2010–2012	High (*stronger density dependence*)	2012: Good	2014–17: N/A	N/A

[1] The qualitative descriptions of abundance and R/S are derived from the patterns for most populations, based on Figures 2.1-21 and 2.1-23, while the general characterization of ocean entry conditions is based on Table 2.1-20.

[2] Note that R/S is determined by the combination of natural- and hatchery-origin spawners, which exacerbates the high spawner abundances for some populations per Figure 2.1-23.

The Influence of Density Dependence

In the previous section, we described the patterns of abundance, productivity, and environmental conditions during the 2008 BiOp's Base Period and the extended Base Period. As in the 2010 Supplemental BiOp, we proposed that density dependence affecting brood years with high spawner abundance contributed to lower average productivity in the extended Base Period, as would be expected from the scientific literature regarding salmon population dynamics and the discussion of results from matrix modeling analyses presented in the 2008 BiOp. In this section, we further explain the influence of density dependence on the results and summarize an analysis performed by the NWFSC (Zabel and Cooney 2013; included as Appendix C) to quantitatively test whether the productivity observed in recent years is within the expectations of the 2008 BiOp.

First, it is useful to rearrange annual estimates of R/S so that, instead of plotting R/S by year as displayed in Figure 2.1-7 for Tucannon River spring Chinook, it is plotted against the number of parental spawners. An example is displayed for the Secesh River population of SR spring/summer Chinook (Figure 2.1-24), which (unlike the Tucannon River population) had a lower point estimate of average R/S for the extended Base Period than the 2008 BiOp's point estimate for the Base Period (Table 2.1-9). Figure 2.1-24 presents the natural logarithm of R/S (ln[R/S]) because this results in a linear arrangement of points, rather than a more complicated curved relationship. The spawners on the horizontal axis are total spawners, since both natural-origin and hatchery-origin adults that spawned naturally contribute to the returning natural-origin progeny. In the Secesh River example, hatchery-origin spawners made up 1% to 9% of the total spawners in recent years.

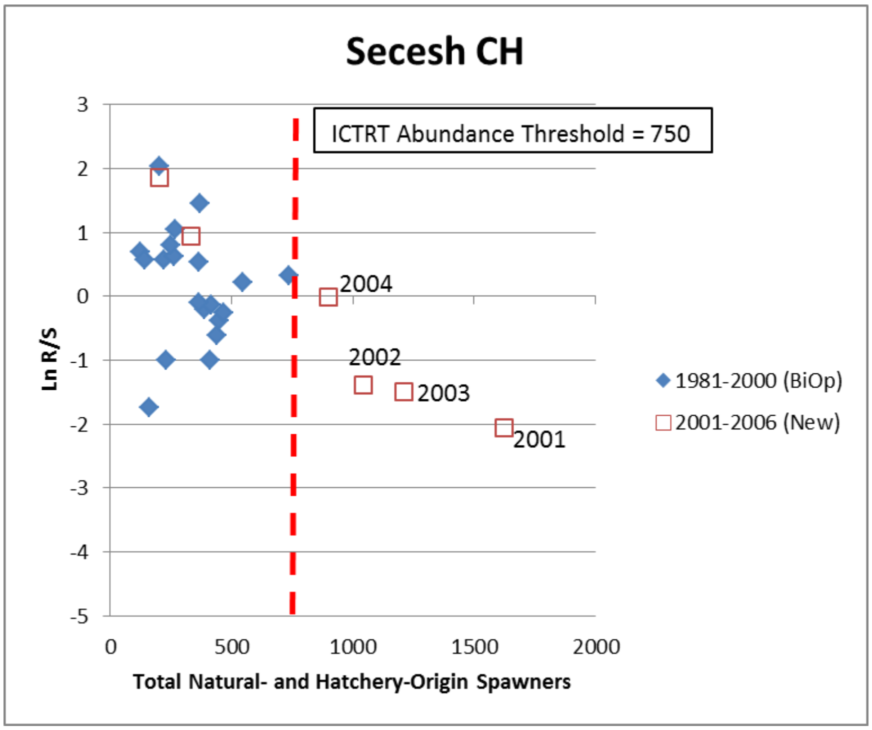

Figure 2.1-24. Example of natural logarithms of returns-per-spawner (ln[R/S]) versus total adult spawners for the Secesh River population of SR spring/summer Chinook. Dashed line represents the ICTRT (2007a) viability abundance threshold of 750 spawners. Hatchery-origin spawners made up approximately 1% to 9% of total spawners in these years.

Figure 2.1-24 shows that at relatively low total spawner levels, most R/S estimates are above replacement (ln[R/S] = 0, which is equivalent to R/S = 1), although there was considerable variability during the 2008 BiOp's Base Period. In contrast, four of the new brood years included in the extended Base Period had parental spawner abundances that were greater than the ICTRT abundance threshold and R/S estimates that were well below replacement. Those four years are the 2001–2004 brood years described above and in Table 2.1-17 as having high abundance and low productivity, driving down the extended Base Period average R/S estimates. Density dependence was hypothesized as a key factor explaining the low productivity for those brood years.

The pattern of decreasing productivity with increasing abundance over a range of environmental conditions suggests that density dependent mortality is occurring. Zabel and Cooney (2013;

Appendix C) statistically tested whether the pattern of ln(R/S) versus spawner abundance during the Base Period was consistent with a density-dependent model commonly used in fisheries management (Ricker 1954), and whether the new estimates contributing to the extended Base Period were within the prediction limits generated from the model using the Base Period data. If so, the new R/S estimates can be considered consistent with the Base Period R/S estimates for a given abundance of spawners.

As described in Appendix C, 20 out of 26 Chinook populations demonstrated statistically significant density-dependent relationships using Base Period data (Figures 2.1-25 and 2.1-26). When the more recent data points were plotted against the 95% prediction intervals, only one point fell below the interval and four points fell above, "providing no support for the hypothesis that recent conditions are less productive than those experienced during the Base Period" (Zabel and Cooney 2013). Eighteen out of 18 steelhead populations demonstrated statistically significant density-dependent relationships using Base Period data; only three points fell below the prediction intervals and 14 points fell above (Figures 2.1-27 and 2.1-28). The steelhead results provided "little support for the hypothesis that recent conditions are less productive than those experienced during the Base Period" (Zabel and Cooney 2013; included as Appendix C).

Zabel and Cooney (2013; included as Appendix C) concluded that these analyses provide strong support for the hypothesis that density-dependent recruitment is occurring in these populations. Further, when "recent" data points were plotted onto relationships derived from the Base Period data, the vast majority of these points fell with the 95% prediction intervals, providing strong support for the hypothesis that productivity has not decreased for these populations when comparing base to recent time periods but that the decreased R/S resulted from density-dependent processes as a result of the increased abundance observed recently.

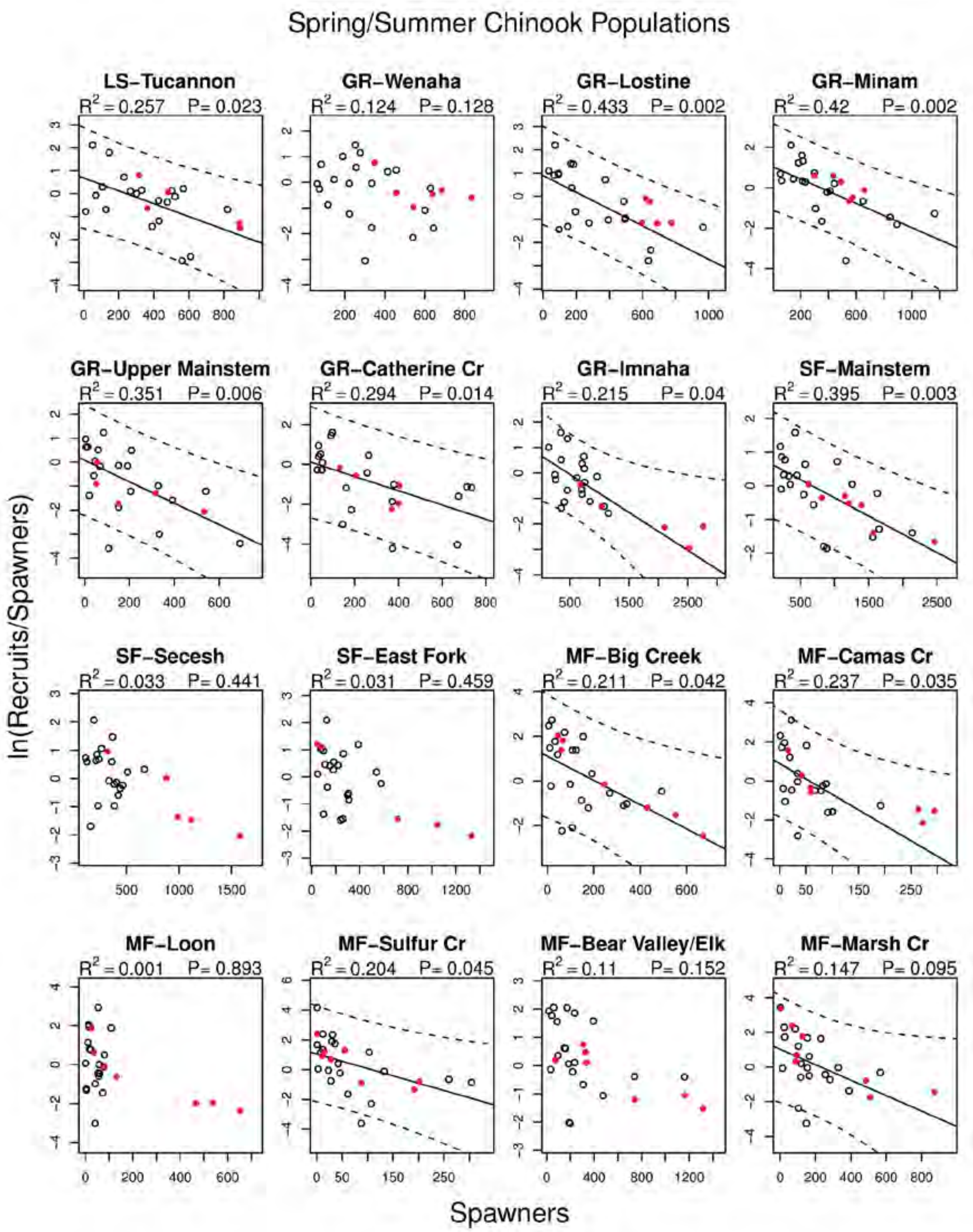

Figure 2.1-25. Ln(Recruits/Spawner) versus spawners for interior Columbia basin spring and summer Chinook populations. Open black points represent the 2008 BiOp Base Period (approximately 1980 to 2000 brood years) and red points represent the recent period. Based on linear regression, if *P*<0.10, the black line is the best fit and the dashed lines are the 95% prediction interval for the data. Figure reproduced from Zabel and Cooney (2013; Appendix C).

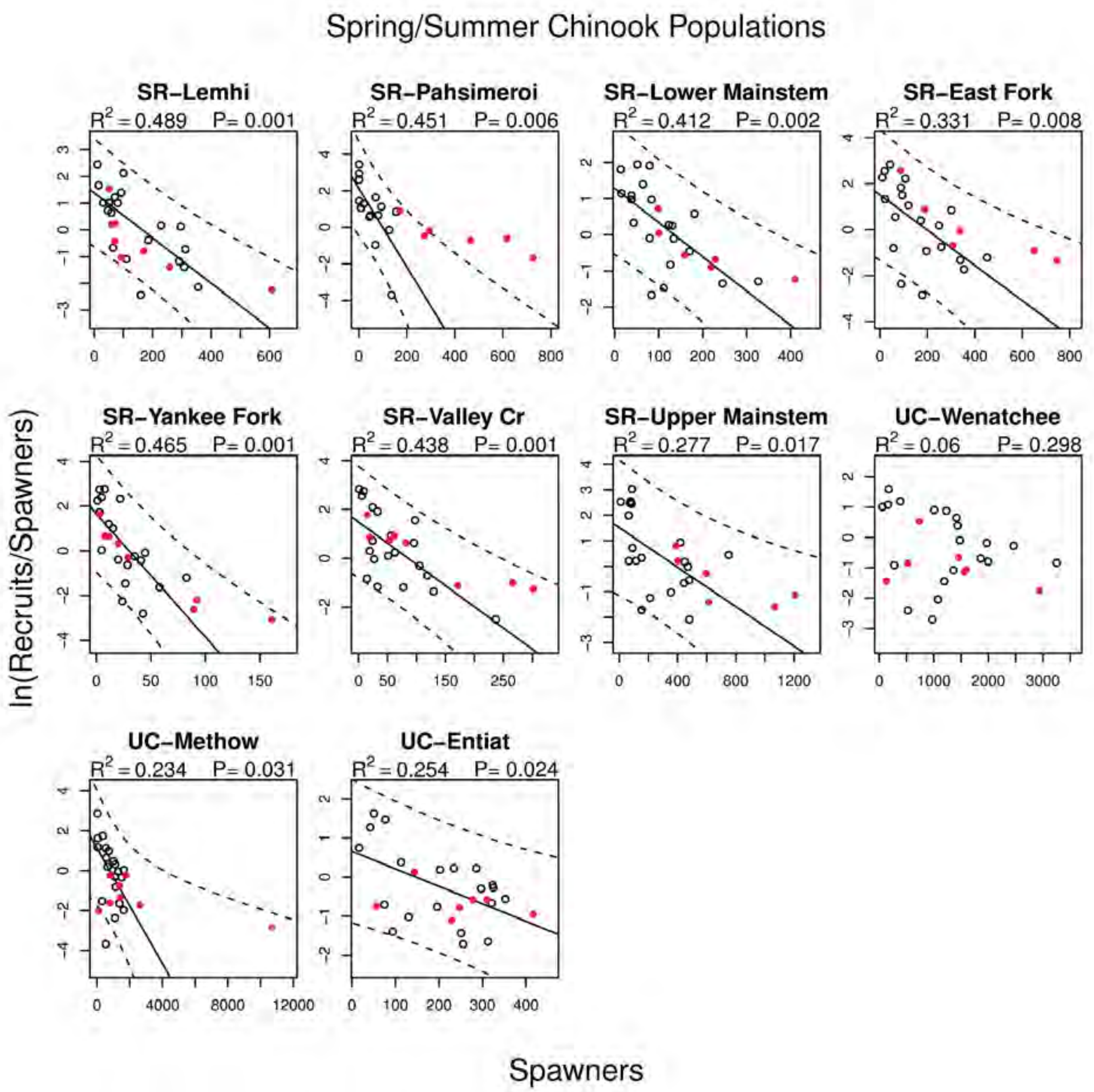

Figure 2.1-26. Ln(Recruits/Spawner) versus spawners for interior Columbia basin spring and summer Chinook populations, continued.

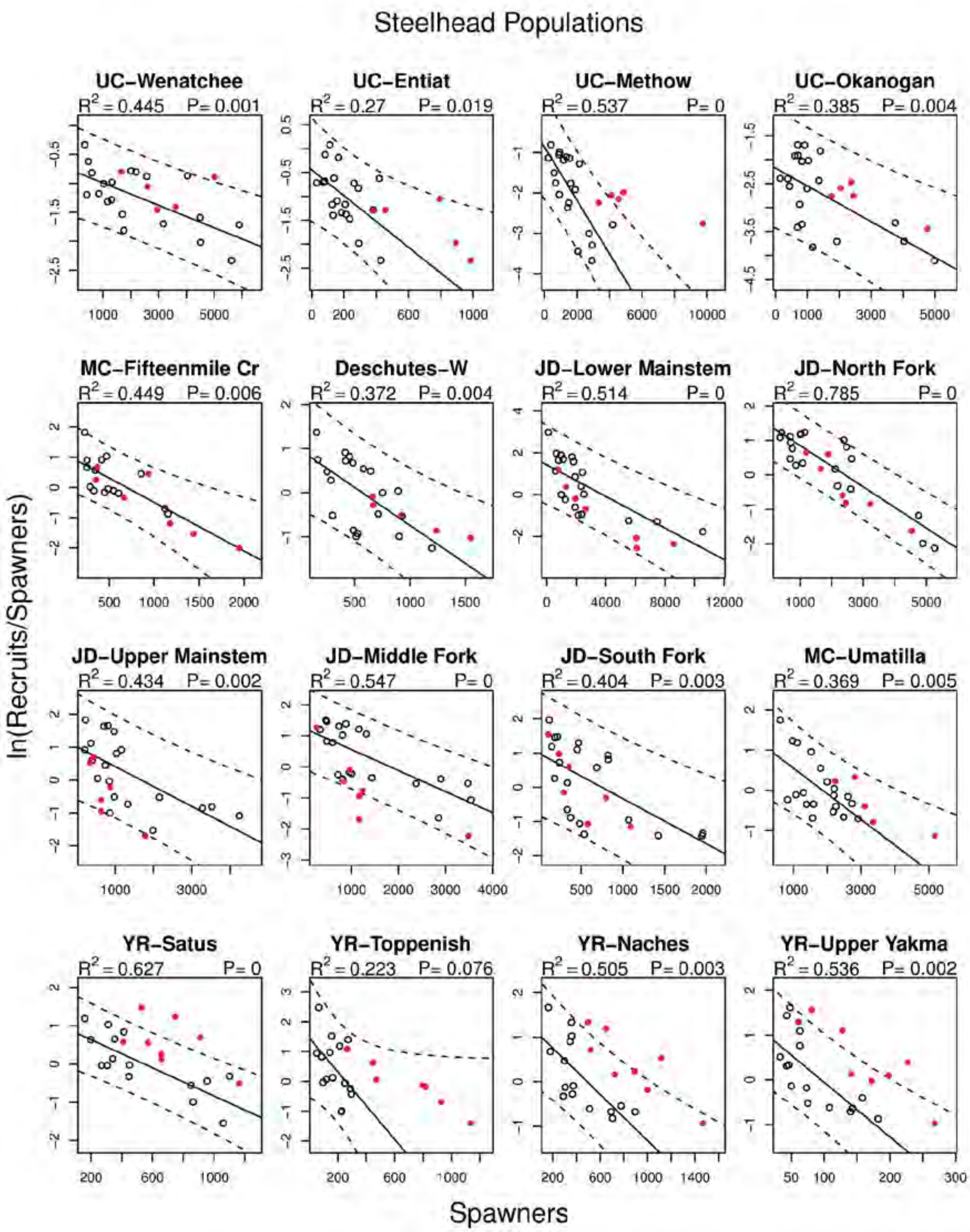

Figure 2.1-27. Ln(Recruits/Spawner) versus spawners for interior Columbia basin steelhead populations. Open black points represent the 2008 BiOp Base Period (approximately 1980 to 2000 brood years) and red points represent the recent period. Based on linear regression, if *P*<0.10, the black line is the best fit and the dashed lines are the 95% prediction interval for the data. Figure reproduced from Zabel and Cooney (2013; Appendix C).

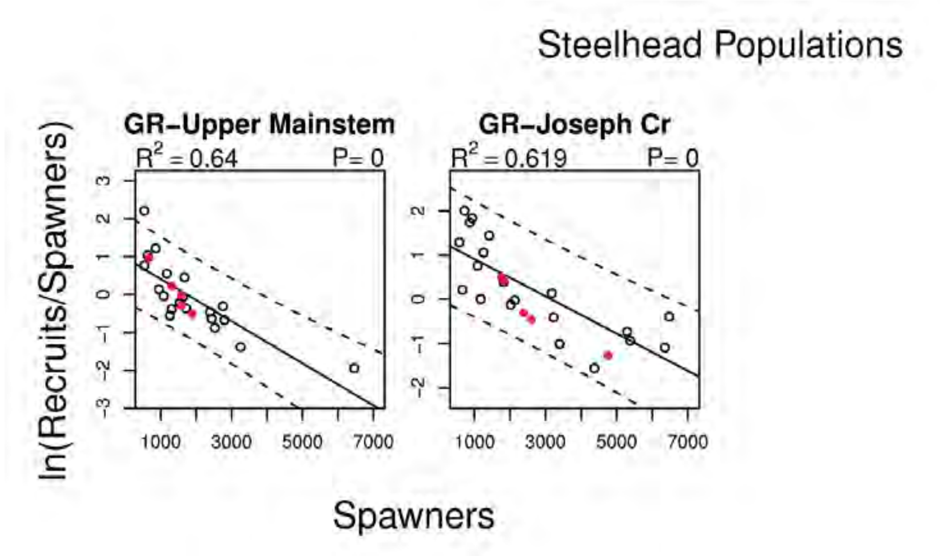

Figure 2.1-28. Ln(Recruits/Spawner) versus spawners for interior Columbia basin steelhead populations, continued.

2.1.1.5 Other Information on the Abundance of Interior Columbia Basin Salmon and Steelhead

The preceding four subsections present retrospective population status information, which is generally based on empirical estimates of spawners reaching each population's spawning ground. It is also useful to consider very recent aggregate population estimates derived from dam counts, which may include more up-to-date data than that available for individual populations; projections of returning spawners in future years based on observations of cohorts at earlier life stages; and on environmental conditions likely to affect their survival to adults.

2.1.1.5.1 AMIP Dam Count Data for the Most Recent Years

The AMIP developed a set of triggers for declines that were not anticipated in the 2008 BiOp, which are evaluated using aggregate population data derived from dam counts (Section 3.7.1, *Early Warning Indicator and Significant Decline Trigger* in this document). Aggregate population information is used because it is more immediately available than population-level data. The Action Agencies' 2013 Draft CE presents the most recent aggregate population data in Section 1: 2008–2012 *Fish Status and Environmental Conditions, Fish Status, Adult Fish Returns and Trends*. The following is a brief overview of information additional to the population-level data presented in preceding subsections of this supplemental opinion.

SR Fall Chinook

Information available for SR fall Chinook in the SPS database ends in 2012. The 2013 Draft CE also includes preliminary abundance estimates of this species' single extant population through 2012. Both sources of information indicate that natural-origin SR fall Chinook abundance has been very high since 2008, with returns among the highest recorded in decades.

SR Spring/Summer Chinook

Information available for SR spring/summer Chinook in the SPS database extends through either 2011 or 2012, depending upon population. The 2013 Draft CE includes aggregate dam counts of natural-origin spring and summer Chinook at Lower Granite Dam through 2012. These estimates indicated that 2010 through 2012 aggregate population estimates were similar and at a higher level than abundances during 2005 through 2008. Therefore, for populations that were only updated through 2011, it is likely that 2012 abundance will be relatively high and similar to 2011, reinforcing the increasing abundance trends reported in previous subsections.

SR Steelhead

As described in Section 2.1.1.4.2, information is only available for three SR steelhead populations in the SPS database, and that information extends through 2010. The approach used to apply dam count estimates to uncensused populations in the 2008 BiOp is no longer valid (Cooney 2013a), so until an alternative approach is developed, the aggregate dam count is the main information available for most populations. The aggregate population abundance was high in the early 2000s, low in the mid-2000s, increased again to high levels in 2009 and 2010, and has again been declining in 2011 and 2012. The abundance in 2011 and 2012, while declining, is still much higher than in the 1990s and mid-2000s. The 2013 Draft CE reports that the abundance trend has been positive based on 1990 through 2012 estimates. No information is presented for the trend beginning in 1980.

UCR Spring Chinook

Information available for UCR spring Chinook in the SPS database extends through 2011, while the 2013 Draft CE includes aggregate abundance of natural-origin spring Chinook at Rock Island Dam through 2012. The aggregate abundance in 2012 increased above levels observed during the previous 10 years, approaching the high abundances of 2000 and 2001. This suggests there will be an increase in the abundance trend once 2012 returns are added to the database.

UCR Steelhead

Information available for UCR steelhead in the SPS database extends through 2011, while the 2013 Draft CE includes aggregate abundance of natural-origin spring Chinook at Rock Island Dam through 2012. The aggregate abundance in 2012 is similar to the aggregate abundance in 2011, which is about half the aggregate abundance in 2009 and 2010. This pattern does not match the abundance pattern in the SPS database through 2011, which indicates for the three available populations that 2010 and 2011 were about twice as high 2008 and 2009. Because the patterns do not appear to match for years in common, it is difficult to determine how to interpret the aggregate abundance data relative to the population-level data.

MCR Steelhead

Information available for MCR steelhead in the SPS database extends through 2011 or 2012, depending upon population. Data for the Yakima MPG populations extended through 2012. The 2013 Draft CE includes aggregate abundance of Yakima MPG natural-origin steelhead at Prosser Dam through 2012. Because the aggregate population count covers the same period, it does not inform future returns of MCR steelhead.

2.1.1.5.2 US v Oregon Projections for Future Years

The Washington Department of Fish and Wildlife (WDFW) and the Oregon Department of Fish and Wildlife (WDFW and ODFW 2013) fisheries managers forecast the 2013 run of natural-origin Snake River fall Chinook at the Columbia River mouth at 31,600 fish, 272% of the 2003–2012 average. This would be the highest return on record (since construction of the lower Snake River Dams).

2.1.1.5.3 NWFSC Ocean Indicators and the AMIP Projection Model for Future Years

Two methods predicted that Chinook abundance would be relatively high in 2013, and one of two methods predicts relatively high abundance for 2014 as well.

The ocean ecosystem indicators described in Section 2.1.4.1.4 allow for projections of the relative abundance of adult spring Chinook returns one to two years after the ocean conditions associated with juvenile ocean entry are observed (Peterson et al. 2012). Based on observed ocean indicators through 2012, returns of adult spring Chinook salmon to the Columbia River in 2013 and 2014 are expected to be well above average.[24] These projections apply to multiple species and populations, including SR spring/summer Chinook and UCR spring Chinook. They also include both hatchery-origin and natural-origin fish. Estimates of returning adult fall Chinook, including SR fall Chinook, are also projected to be well above average in 2013 and 2014.

A related projection is generated using the method of Burke et al. (2013). This method uses a broader suite of 32 indicators in a maximum covariance analysis, and is able to project adult returns at a finer taxonomic scale. The Burke et al. (2013) approach predicted that approximately 97,000 SR spring/summer Chinook, expanded for harvest,[25] will return to Ice Harbor Dam in 2013. This estimate is slightly above the most recent 10-year average. They also predicted that 19,500 UCR spring Chinook, expanded for harvest, will return to Priest Rapids Dam in 2013. Confidence limits on these predictions are very wide.

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[24] Web site http://www.nwfsc.noaa.gov/research/divisions/fed/oeip/g-forecast.cfm accessed on May 15, 2013.
[25] "Expanded for harvest" means that the adult return predictions are adjusted to reflect pre-harvest numbers.

As described in Section 2.1.1.5.1 above, preliminary estimates of 2013 combined natural-origin and hatchery-origin Snake River spring/summer Chinook salmon returns are much lower than the 10-year average, while corresponding estimates for UCR spring Chinook are higher than the 10-year average. Therefore, the predictions for the 2013 fall Chinook run and 2014 returns should be viewed with caution. Scientists are currently exploring additional variables indicative of survival at other points in the ocean life phase, such as zooplankton and larval/juvenile fish abundances in the Gulf of Alaska, which may improve predictions (see Section 2.2.3.1: *Plume conditions—bottom-up control of salmon survival (food webs))*.

2.1.1.6 Rangewide Status of Snake River Sockeye Salmon

The endangered SR sockeye ESU includes populations of anadromous sockeye salmon in the Snake River basin, Idaho (the single extant population occurs in the Sawtooth Valley), as well as residual sockeye salmon in Redfish Lake, Idaho, and one captive propagation hatchery program. Four of the historical populations are extirpated (Alturas Lake, Pettit Lake, Yellowbelly Lake and Stanley Lake; NMFS 2011a).

Between 1991 and 1998, all 16 of the natural-origin adult sockeye salmon that returned to the weir at Redfish Lake were incorporated into the captive broodstock program, as well as outmigrating smolts captured between 1991 and 1993, and residual sockeye captured between 1992 and 1995 (Hebdon et al. 2004). The program has used multiple rearing sites to minimize chances of catastrophic loss of broodstock and has produced several million eggs and juveniles, as well as several thousand adults, for release into the wild.

Estimates of annual returns are now available through 2012 (Table 2.1-18). Between 1999 and 2007, more than 355 adults returned from the ocean from captive broodstock releases (Flagg et al. 2004), primarily due to large return (257 fish) in the year 2000. Returns for 2003 through 2007 were lower, but increased beginning in 2008. The return of 257 adults in 2012 was lower than in 2008 through 2011, but still the fifth highest return since the captive broodstock program began. Adults returning in 2012 were released as smolts in 2010 when survival from the Sawtooth Valley through the Salmon and lower Snake rivers and Lower Granite Reservoir was very low (about 18% compared with an average for 2006 through 2012 of about 50%). In addition, average annual survival rates of adults in the mainstem reach from Bonneville to McNary dams were lower in 2010 through 2012 than in 2006 and 2007 (Section 3.3.3.1). Other factors, such as an unknown effect of ocean conditions, may have influenced the size of the 2012 adult return.

Table 2.1-18. Hatchery and natural sockeye returns to Sawtooth Basin, 1999–2012 (Source: Baker 2013).

Return Year	Total Return	Natural Return[1]	Hatchery Return	Observed (Not Trapped)
1999	7	0	7	0
2000	257	10	233	14
2001	26	4	19	3
2002	22	6	9	7
2003	3	0	2	1
2004	27	4	20	3
2005	6	2	4	0
2006	3	1	2	0
2007	4	3	1	0
2008	650	142	457	51
2009	833	85	732	16
2010	1,355	179	1,143	33
2011	1,118	146	955	17
2012	257	52	190	15

[1] Adult returns from natural production from Redfish, Alturus, and Pettit lakes.

The increased production from the captive broodstock program resulted in sufficient numbers of fry for initial evaluations of alternative supplementation strategies (Hebdon et al. 2004), i.e., acclimating some fry to natural waters and allowing them to emigrate to the ocean and return to spawn naturally.

Monitoring and evaluation focus on identifying and prioritizing the most successful reintroduction strategies. Sawtooth Basin to Sawtooth Basin smolt-to-adult return rates for anadromous adults from the 2004 through 2006 brood years varied by release strategies. Averaged across all release strategies, SARs ranged from a low of 0.29% for brood year 2004 to a high of 0.74% for brood year 2006 releases (NMFS 2013b). Within brood year 2006, SARs ranged from a low of 0.35% for adults produced from outplanted pre-smolts returning to the Redfish Lake trap to a high of 2.48% for adults from naturally produced smolts that emigrated from Redfish Lake.

2.1.1.6.1 Limiting Factors and Threats

Snake River sockeye salmon have been—and continue to be—affected by hydropower impacts; low abundance (making the single extant population vulnerable to catastrophic loss and posing significant risks to genetic diversity); water quality impairment in the upper Salmon River drainage; predation by birds, pinnipeds, and fish; and the effects of climate change.

2.1.1.6.2 ESU Risk Summary

The captive propagation program has likely forestalled extinction of this population and the ESU. This program has increased the total number of anadromous adults and has preserved what genetic diversity remained after the decline. However, the longer this program relies on captive broodstock to maintain the population, the greater the risks of domestication become. Although the program has increased the number of anadromous adults in some years, it has only begun to yield large numbers of returning adults (in part due to larger smolt releases and in part because of out-of-basin effects such as improved ocean conditions).

In recent years, sufficient numbers of returning hatchery adults and their eggs and smolts have been available to make it feasible to use supplementation strategies to increase the abundance of natural spawners. Limnological studies and direct experimental releases are being conducted to learn more about production potential in the three Sawtooth Valley lakes that are candidates for sockeye restoration. Lake habitat rearing potential, juvenile downstream passage survivals, and adult upstream survivals are also being studied. However, substantial increases in survival rates across all life history stages must occur in order to reestablish sustainable natural production (e.g., Hebdon et al. 2004; Keefer et al. 2008). Although the risk status of the Snake River sockeye salmon ESU appears to be on an improving trend, the risk of extinction is still high and the ESU continues to be listed as endangered (Ford 2011).

2.1.1.7 Relevance of Updated Status of Interior Columbia Basin Salmon and Steelhead to the 2008/2010 BiOps' Analyses

New information in Section 2.1.1 regarding the status of interior Columbia basin species is very similar to that described in the 2010 Supplemental BiOp. Additional years of data and new analyses provide support for NOAA Fisheries' continued reliance on the 2008 BiOp's description of the rangewide status of these species and the Base Period metrics applied in the 2008 BiOp's quantitative aggregate analysis. As described in the introduction to Section 2.1.1, this conclusion is significant because the Base Period metrics were the starting point for all subsequent calculations in the 2008 BiOp's quantitative analysis for six interior Columbia basin species. The following is a review of information reviewed in earlier subsections of Section 2.1.1, which supports this conclusion.

New information in Sections 2.1.1.1 through 2.1.1.3 regarding recovery goals and the status of species and their constituent populations relative to those recovery goals is nearly identical to the recovery status in the 2008 BiOp, as updated by the 2010 Supplemental BiOp.

- Recovery plans and goals have not changed since the 2008/2010 BiOps.
- NOAA Fisheries completed 5-year status reviews for interior Columbia basin species in 2011 and concluded that the listing status of all species was unchanged from the 2005 status review, which was relied upon in the 2008/2010 BiOps.
- NOAA Fisheries' latest report to Congress concluded that the trends of six of seven interior Columbia species have been stable, while the SR sockeye trend is described as "mixed" because of the high level of artificial propagation necessary to maintain the species. This is identical to the conclusions of the 2009 report to Congress, which was described in the 2010 Supplemental BiOp.

- When the trends of individual populations were evaluated, NOAA's report to Congress indicated that 47 populations of interior Columbia Chinook and steelhead were stable, two were decreasing, and two were increasing.
- When individual populations of Chinook and steelhead were evaluated relative to recovery criteria, the new 5-year status review indicated that most populations had increased abundance, decreased intrinsic productivity, and little or no change in spatial structure or diversity compared to population risk metrics at the time of the previous 5-year review. These are the same characteristics described in the 2010 Supplemental BiOp, and they are discussed in more detail below relative to the 2008 BiOp metrics.
    - ◊ Overall risk ratings continued to be "high" for all populations of UCR Chinook, UCR steelhead, and SR spring/summer Chinook. There was a mixture of risk categories for SR steelhead, while most populations of MCR steelhead and the single population of SR fall Chinook were rated either "Maintained" or "Viable."
    - ◊ For SR sockeye salmon, it was not possible to quantify the risk rating, although this species appears to be on an improving trend.

New information in Section 2.1.1.4 regarding 2008 BiOp indicator metrics, which have been updated and extended to reflect the most recent return years, are consistent with the expectations of the 2008 BiOp, as updated by the 2010 Supplemental BiOp. These metrics apply to six interior Columbia basin species with sufficient information to conduct a quantitative analysis. The extended Base Period estimates include four to nine additional years of return data beyond the years included in the 2008 BiOp for most populations.

- Virtually all of the new extended Base Period estimates fall within the statistical confidence limits of the 2008 BiOp Base Period metric estimates.
- While the new information indicates no statistically significant changes in Base Period metrics, some of the point estimates did change. Point estimates of abundance and BRT abundance trend were generally higher, estimates of extinction risk were generally lower, and estimates associated with productivity were generally lower, than those in the 2008 BiOp were. This pattern is nearly identical to that described in the 2010 Supplemental BiOp.
    - ◊ Mean abundance point estimates for the most recent 10-year period were higher than estimates in the 2008 BiOp for all populations of Chinook and nearly all populations of steelhead.
    - ◊ Extinction risk (24-years, QET 50) point estimates were unchanged or lower than estimated in the 2008 BiOp for nearly all populations.

- ◊ Mean R/S productivity point estimates were lower than estimates in the 2008 BiOp for most populations (although over 1/3 of the populations that were lower still had average Base Period R/S greater than 1.0, the 2008 BiOp's goal for prospective actions);
- ◊ Median population growth rate (lambda) point estimates, under the assumption that hatchery-origin spawners do not contribute to productivity (HF=0), were lower than in the 2008 BiOp for most populations of Chinook but higher than in the 2008 BiOp for most populations of steelhead. For those populations with lower estimates, over two-thirds still had average Base Period lambda greater than 1.0.
- ◊ Median population growth rate (lambda) point estimates, under the assumption that hatchery-origin spawners are as effective as natural-origin spawners (HF=1), were lower than in the 2008 BiOp for most populations of Chinook, but half of the steelhead populations were higher and half were lower. For those populations with lower estimates, over two-thirds still had average Base Period lambda greater than 1.0, the 2008 BiOp's goal for prospective actions.
- ◊ BRT abundance-trend point estimates were higher than in the 2008 BiOp for most populations. For the few populations with lower estimates, all but one still had a trend greater than 1.0.

- The observed pattern in the abundance and productivity point estimates is consistent with an expectation that interference or competition for resources is likely to occur at high abundance and density, resulting in fewer returns produced per spawner. Such density-dependent mortality was anticipated in the 2008 BiOp; described as the explanation for lower productivity point estimates in the 2010 Supplemental BiOp; and confirmed in this supplemental biological opinion.
  - ◊ Section 2.1.1.1.4 (*Comparison of Extended Base Period Metrics with Estimates in the 2008 BiOp*) includes a detailed review of the patterns of abundance, productivity, and climate factors affecting brood years in the extended Base Period, which shows the likely effects of density dependence on a brood-year basis. The total spawner abundances in brood years contributing to low average productivity estimates were in many cases the highest in the Base Period and near or above the ICTRT abundance thresholds.
  - ◊ Section 2.1.1.4.4 (*The Influence of Density Dependence*; see also Appendix C) includes a quantitative test of whether the productivity observed in recent years is within the expectations of the 2008 BiOp.

- Most Chinook populations demonstrated statistically significant density-dependent relationships using Base Period data. When the more recent data points were plotted against the 95% prediction intervals, only one point fell below the interval and four points fell above, "providing no support for the hypothesis that recent conditions are less productive than those experienced during the Base Period."
- All steelhead populations with sufficient data for the analysis demonstrated statistically significant density-dependent relationships using Base Period data; only three points fell below the prediction intervals and 14 points fell above. The steelhead results provided "little support for the hypothesis that recent conditions are less productive than those experienced during the Base Period."

- In summary, these results provide "strong support for the hypothesis that density-dependent recruitment is occurring in these populations" and "strong support for the hypothesis that productivity has not decreased for these populations when comparing base to recent time periods but that the decreased R/S resulted from density-dependent processes as a result of the increased abundance observed recently."

More recent aggregate population dam counts and predictions from factors influencing earlier ages of some cohorts (Section 2.1.1.5) indicate that:

- abundance of SR fall Chinook, SR spring/summer Chinook, and UCR Chinook (which end in 2012, 2011 [some populations], and 2011 [all populations], respectively, in the SPS database) has remained high through 2012.
- abundance of SR steelhead (which ends in 2010 in the SPS population-specific database) has declined from recent peaks in 2011 and 2012, but still remains above average.
- in spite of predictions of above-average SR spring/summer Chinook returns in 2013, preliminary information indicates that returns this year were below average for the first time in several years. Above-average returns are still predicted for 2014, based on ocean indicators.
- UCR Chinook are predicted to have higher than average returns in 2013 and 2014 and preliminary information for 2013 indicates that this is the case.
- predictions for SR fall Chinook are for much higher than average returns in 2013 and higher than average returns in 2014.

In addition to the description of the recovery status of SR sockeye salmon (above), a review of the captive broodstock and reintroduction programs in Section 2.1.1.6 indicates that these aspects of SR sockeye status are functioning the same or better than as anticipated in the 2008/2010 BiOps.

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2.1.2 Rangewide Status of Lower Columbia Basin Salmon and Steelhead

NOAA Fisheries has updated its status assessments for lower Columbia basin salmon and steelhead (Table 2.1) since the 2008/2010 BiOps. The following sections summarize the updated information for each species of lower Columbia basin (including the upper Willamette River) salmon and steelhead.

Hydrosystem Effects on Rangewide Status of Lower Columbia Basin Salmon and Steelhead

Flow management operations at large storage reservoirs in the interior of the Columbia basin (Grand Coulee, Dworshak, etc.) affect all juvenile Columbia River salmon and steelhead in the lower mainstem and estuary, and potentially in the plume—primarily by altering flow volume and timing. These alterations impair sediment routing, influence habitat forming processes, reduce access to peripheral habitat, and change the dynamics of the Columbia River plume and the estuarine food web. The reservoirs associated with the run-of-river mainstem dams contribute to elevated water temperatures below Bonneville Dam in late summer and fall, which affects each ESU and DPS to a different degree depending on the timing of its juvenile and adult migrations, as described in the following sections. These lower basin species are substantially less affected by the FCRPS compared to listed species that range into the interior Columbia basin, and therefore migrate past multiple FCRPS projects. The generally poor status of the lower Columbia species is primarily the result of other limiting factors and threats, as described below.

2.1.2.1 Columbia River Chum Salmon

The threatened Columbia River chum (CR chum) salmon ESU consists of 17 historical populations in the three eco-geographic strata, Coastal, Cascade, and Gorge, plus three artificial propagation programs.

At the time of the 2008 BiOp, we thought that the Grays River and Lower Gorge were the only chum salmon populations with consistent natural spawning. However, there is new information (i.e., not previously considered in NOAA Fisheries' 5-year status reviews or the 2008/2010 BiOps) that indicates there has been consistent spawning, predominantly by natural-origin fish, since at least 2002 in the Washougal population in the Cascade stratum. Based on recent mark-recapture studies, the estimated numbers of spawners during 2009 through 2012 (including those in the mainstem near Interstate Highway 205) has ranged from 1,132 to 4,947 (Table 2.1-19). Spawner estimates for the Grays River and Lower Gorge populations also have been moderately high (Table 2.1-19).

Small numbers of adult chum salmon are found in other Washington and Oregon streams, but numbers are too sparse to convert to estimates of abundance (Ford 2011). For example, ODFW survey crews reported a peak count of 12 adults in Big Creek and another four adults in Little Creek, one of Big Creek's tributaries, during 2012 (Jacobson 2013). The origin of these fish is not known; the first fry raised at ODFW's Big Creek Hatchery were released during spring 2010 and adult returns are not expected until fall 2013.

Table 2.1-19. Preliminary estimates of abundance for the Grays River, Washougal, and Lower Gorge fall-run chum salmon populations (Hillson 2013).

Population	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
Grays River[1]	12,041	16,974	15,157	4,327	6,232	3,966	2,807	2,833	6,399	11,519	10,114
Washougal[2]	3,468	2,844	2,102	1,009	862	544	626	1,132	2,105	4,947	2,483
Lower Gorge[3]	7,883	4,480	1,857	944	1,564	432	458	534	1,404	2,594	1,255

[1] The Grays River population includes spawners in Crazy Johnson Creek, the West Fork Grays, and the mainstem Grays River.
[2] The Washougal population includes the mainstem spawners near I-205, Rivershore, and Woods Landing.
[3] The Lower Gorge population incudes spawners in the mainstem Columbia near Multnomah Falls, St. Cloud, and Horsetail creeks, near Ives Island, and tributary spawners in Duncan, Hardy, and Hamilton creeks and Hamilton Spring Channel.

In the 2008 BiOp, we assumed that the Upper Gorge population was extirpated by inundation behind Bonneville Dam. However, a total of 177 chum fry have been recorded by the Smolt Monitoring Program between spring 2010 and 2013 (Fish Passage Center 2013), indicating spawning in the reservoir reach. The fry seen at Bonneville Dam could have originated in the White Salmon River where WDFW has recovered a few chum carcasses (Hillson 2013). Alternately, these fry could be the progeny of spawners in Eagle Creek, which is less than one mile above Bonneville Dam (Hillson 2013).

In NOAA Fisheries' report to Congress on GPRA performance measures for listed species as of 2012, Ford (2012) categorized the overall ESU trend as "unknown" because due to lack of hatchery fraction data, the trends for the two populations with available data (Gray River and Lower Gorge) were both unknown.

Limiting Factors and Threats

NOAA Fisheries (NMFS 2013c) has finalized its ESA recovery plan for lower Columbia basin species including CR chum salmon. This species has been affected by the loss and degradation of spawning and rearing habitat, the impacts of mainstem hydropower dams on upstream access and downstream habitats, and the legacy effects of historical harvest. Together, these factors have reduced the risk of extinction of all populations. Although we now know that there are three populations with consistent natural spawning, the constrained spatial structure of the ESU, which is related to conversion, degradation, and inundation of habitat, contributes to very low abundance and low genetic diversity in most populations, thereby increasing the risk to the ESU from local disturbances (NMFS 2013c).

With respect to the hydrosystem, passage at Bonneville Dam and the inundation of historical habitat under Bonneville Reservoir is a primary limiting factor for the Upper Gorge Tributaries chum salmon population (Table 8-3 in NMFS 2013c). Juvenile chum salmon are rearing in and migrating through the mainstem in February through July (peak during May) and adults are migrating during November and December, so it is unlikely that elevated mainstem temperatures have a significant impact on this ESU. For the Lower Gorge population, the availability of tailrace spawning habitat is affected by flows from the Columbia River hydropower system during fall and winter and early spring flows are critical to prevent dewatering of redds before emergence.

ESU Risk Summary

None of the CR chum salmon ESU's three strata meet recovery criteria: most (15 out of 17) remain at very high risk (NMFS 2011b). The Grays River and Lower Gorge populations showed sharp increases in adult abundance in 2002, declined back to relatively low levels, and then increased again in recent years. A focused look at the Washougal population could alter the biological risk category for that population and the Cascade stratum at the time of NOAA Fisheries' next status review. In any case, there is no new information to indicate that extinction risk for the CR chum salmon ESU has increased significantly compared to our understanding in 2008 and 2010.

2.1.2.2 Lower Columbia River Chinook Salmon

The threatened LCR Chinook salmon ESU consists of 32 historical populations in six strata: Coastal fall-run, Cascade spring-run, Cascade fall-run, Cascade late fall-run, Gorge fall-run, and Gorge spring-run, plus 17 artificial propagation programs.

The last status review included abundance data for most LCR Chinook salmon populations up to the year 2001. For the more recent review, Ford (2011) compiled data through 2008 or 2009 for most populations.[26] Abundance of all LCR Chinook salmon populations increased during the early 2000s but has since declined back to levels close to those in 2000 for all but one population. Abundance of the Sandy spring Chinook salmon population has declined from levels in the early 2000s but remains higher than its 2000 level. In general, abundance of LCR Chinook salmon populations has not changed considerably since the previous status review (Ford 2011).

Assessments conducted as part of recovery planning indicate that most LCR tule fall Chinook salmon populations are at high to moderate risk for issues related to diversity and at relatively low risk for issues related to spatial structure (Ford 2011). The two LCR late fall Chinook salmon populations are at moderate to low risk for issues related to diversity and spatial structure. Lower Columbia River spring Chinook salmon populations range from very high to moderate risk because of diversity, and most are at very high risk due to spatial structure concerns.

In NOAA Fisheries' report to Congress on GPRA performance measures for listed species as of 2012, Ford (2012) categorized the overall ESU trend as "stable."

Limiting Factors and Threats

The spring-run component of the LCR Chinook salmon ESU has been—and continues to be—affected by habitat degradation, hydropower impacts, harvest, and hatchery production that, together, have reduced the persistence probability of all populations. One of the largest factors limiting the spring-run component has been the existence of tributary dams that block access to core headwater spawning areas in upper subbasins. Spatial structure, productive potential, and survival are further constrained by widespread degradation of tributary habitat in downstream areas. In addition, the high historical harvest rates and the effects of hatchery fish on natural populations have undermined the genetic and life history diversity of spring Chinook salmon populations and contributed to significant losses in production and abundance (NMFS 2013c).

The tule fall Chinook salmon component of the LCR Chinook salmon ESU is limited by a combination of factors: widespread habitat degradation both in tributaries and the Columbia

[26] Data were available only through 2006 for the Clatskanie fall and Sandy late fall Chinook salmon populations.

River estuary; a history of high harvest rates and large scale hatchery production with associated population depletions, reductions in productivity, and loss of genetic diversity; the effects of tributary dams and the FCRPS on habitat; and predation by native fish, birds, and marine mammals. In addition, the ongoing straying of hatchery fish continues to affect productivity and diversity of fall Chinook salmon, and harvest impacts continue to be significant. For some populations, spatial structure is constrained by tributary dams; for many more populations, urban, agricultural, and transportation development in lowland areas constrains spatial structure; and development contributes to losses in abundance as habitat quality is reduced.

With respect to the hydrosystem, the reservoirs associated with the mainstem run-of-river dams contribute to elevated water temperatures downstream in late summer and fall when adults from tule and late fall Chinook populations are moving upstream to tributary spawning areas. Juveniles move downstream to the ocean in the spring or to rearing habitat in the estuary throughout the year. For populations above Bonneville Dam, NOAA Fisheries identifies the passage issues at Bonneville as a secondary limiting factor for the White Salmon and Hood populations and inundation of historical spawning habitat by Bonneville Reservoir as a secondary limiting factor for the Hood population[27] in its proposed recovery plan (NMFS 2013c).

ESU Risk Summary

Three recent evaluations of LCR Chinook salmon status, all based on the criteria developed by the Willamette Lower Columbia Technical Recovery Team's (W/LCTRT), have been conducted as part of the recovery planning process (McElhany et al. 2007; LCFRB 2010, Vol. 1, Ch. 2; ODFW 2010). All three evaluations concluded that none of the ESU's six strata meet recovery criteria. Of the 32 historical populations in the ESU, 28 are considered at very high risk (and some may be extirpated or nearly so) and only two populations are considered viable.

Overall, the new information did not indicate a change in the biological risk category since NOAA Fisheries' last status review. Although this ESU has made little progress toward meeting its recovery criteria, there is no new information to indicate that its extinction risk has increased significantly.

[27] The exact extent to which Bonneville Reservoir inundated habitats for any species is unknown. Some biologists have hypothesized impacts to spring Chinook salmon as a result of inundation. Based on spawning habitat preferences, it is likely that impacts of inundation were greatest on fall Chinook and chum salmon (NMFS 2013 = final LCR recovery plan).

2.1.2.3 Lower Columbia River Coho Salmon

The threatened LCR coho salmon ESU consists of 24 historical populations in three strata: Coastal, Cascade, and Gorge, plus 25 artificial propagation programs.

The 2005 BRT status evaluation (Good et al. 2005) included abundance data for the Clackamas population for the years 1957 to 2002 and for the Sandy population from 1977 to 2002. Spawner data for Oregon LCR coho salmon populations from 2002 through 2004 indicated relatively low numbers of natural-origin fish (averaging less than 500 spawners) for all Oregon populations except the Clackamas and Sandy. Despite these low abundances, it appears that there is also some natural production in the Clatskanie and Scappoose populations. Neither the Clackamas or Sandy population shows a clear long-term trend in natural-origin abundance over that full time series, but both indicate a positive trend over the years 1995 to 2008. Ford (2011) observed a negative growth rate for the Clackamas and Sandy populations when considering the entire time series and assuming that hatchery-origin fish have the same reproductive success as natural-origin fish.

Spawner surveys have been conducted for Washington's Mill/Germany/Abernathy population since 2005. Data for the 2006 spawning year show an estimated 3,150 spawners—over half of them hatchery-origin fish. This large fraction of hatchery-origin spawners in a population with no direct hatchery releases suggests that those with direct hatchery releases are not likely to be self-sustaining.[28] Data on smolt production in the Mill/Germany/Abernathy population indicate some natural production (Ford 2011).

Assessments conducted as part of recovery planning since the last status review indicate that Oregon LCR coho salmon populations are at moderate to low risk as a result of spatial structure and at high to moderate risk from issues related to diversity (Ford 2011). Similar assessments for Washington LCR coho salmon populations also indicate moderate to low risk from spatial structure and, in general, high risk from issues related to diversity (Ford 2011). Hatchery releases have remained relatively steady since the previous review. Overall hatchery production remains relatively high, and most populations in the ESU are likely to have a substantial fraction of hatchery-origin spawners (although data are limited, particularly for Washington populations). Efforts to shift hatchery production to certain areas (e.g., Youngs Bay and Big Creek) to reduce hatchery-origin spawners in other populations (e.g., the Scappoose and Clatskanie) are relatively recent, and their success is unknown (Ford 2011).

In NOAA Fisheries' report to Congress on GPRA performance measures for listed species as of 2012, Ford (2012) categorized the overall ESU trend as "stable."

[28] Direct data on the fraction of hatchery-origin spawners are available for only one of Washington's 17 coho salmon populations (Mill/Germany/Abernathy) for a single year (2006) (Ford 2011).

Limiting Factors and Threats

Lower Columbia River coho salmon have been—and continue to be—affected by habitat degradation, hydropower impacts, harvest, and hatchery production. The combined effects of these factors have reduced the persistence probability of all LCR coho salmon populations. Extensive channelization, diking, wetland conversion, stream clearing, and, in some subbasins, gravel extraction have significant negative impacts on juvenile coho salmon throughout the ESU and are identified as primary limiting factors (NMFS 2013c). Land uses both past and present have created sediment issues in the mainstem Columbia. The ongoing straying of hatchery fish has affected the productivity and diversity of LCR coho salmon, and harvest impacts continue to be significant for some populations (e.g., Youngs Bay and Big Creek).

With respect to the hydrosystem, the reservoirs associated with the mainstem run-of-river dams contribute to elevated water temperatures in late summer and fall when adult coho are moving to their tributary spawning areas. The downstream migration of juveniles peaks in mid-April through mid-July before mainstem temperatures become elevated enough to have a significant impact. For populations above Bonneville Dam—the Upper Gorge/Hood and Upper Gorge/White Salmon populations—NOAA Fisheries (NMFS 2013c) identified passage issues at Bonneville and inundation of historical spawning habitat by Bonneville Reservoir as secondary limiting factors.

ESU Risk Summary

Three evaluations of LCR coho salmon status, all based on W/LCTRT criteria, have been conducted since the last status review, as part of the recovery planning process (McElhany et al. 2007; LCFRB 2010; ODFW 2010). All three evaluations concluded that none of the ESU's three strata meet recovery criteria. Of the 24 historical populations in the ESU, 21 are considered at very high risk. The remaining three (Sandy, Clackamas, and Scappoose) are considered at high to moderate risk. All of the Washington populations are considered at very high risk because the limited studies available suggest most of the populations have returns that are greater than 90% hatchery fish. However, uncertainty about population status is high because of a lack of regular, comprehensive adult spawner surveys. Smolt traps indicate some natural production in Washington populations, though given the high fraction of hatchery-origin spawners suspected to occur in these populations, it is not clear that any are self-sustaining.

Overall, the new information considered does not indicate a change in the biological risk category since the time of the last status review. Although this ESU has made little progress toward meeting its recovery criteria, there is no new information to indicate that its extinction risk has increased significantly.

2.1.2.4 Lower Columbia River Steelhead

The threatened LCR steelhead DPS consists of 23 historical populations in four strata: Cascade winter-run, Cascade summer-run, Gorge winter-run, and Gorge summer-run, plus 10 artificial propagation programs.

All LCR steelhead populations increased in abundance during the early 2000s, generally peaking in 2004, but the abundance of most populations has since declined back to levels close to the long-term mean. However, across the DPS, LCR steelhead populations do not show any sustained, dramatic changes in abundance since the 2005 status review (Ford 2011).

Total releases of hatchery steelhead in the LCR steelhead DPS have increased since the last status review (Good et al. 2005), from about 2 million to around 3 million fish per year. Some populations (e.g., Hood River and Kalama) have relatively high fractions of hatchery-origin spawners, whereas others (e.g., Wind) have relatively few (Ford 2011). Assessments since the last status review indicate that Oregon LCR steelhead populations are generally at moderate risk because of diversity issues and low risk because of spatial structure (Ford 2011). Similar assessments for Washington LCR steelhead populations also indicate moderate risk because of diversity issues, in general, and moderate to low risk because of spatial structure (Ford 2011).

In NOAA Fisheries' report to Congress on GPRA performance measures for listed species as of 2012, Ford (2012) categorized the overall DPS trend as "stable."

Limiting Factors and Threats

Lower Columbia River steelhead are affected by a legacy of habitat degradation, harvest, hatchery production, and hydropower development that together have reduced the persistence probability of almost every population. Historically, high harvest rates contributed to population depletions, while stock transfers and straying of hatchery-origin fish reduced productivity and genetic and life history diversity (NMFS 2013c). Construction of tributary and mainstem dams has constrained the spatial structure of some steelhead populations by blocking or impairing access to historical spawning areas. Over time, tributary and mainstem habitat alterations have reduced population abundance and productivity. Habitat alterations in the Columbia River estuary also have contributed to increased predation on steelhead juveniles. Today, widespread habitat degradation, predation, and the lingering effects of hatchery-origin fish continue to be significant limiting factors for most steelhead populations.

With respect to the hydrosystem, the reservoirs associated with the mainstem run-of-river dams contribute to elevated water temperatures in late summer and fall when some adults are moving to their tributary spawning areas. Juveniles move downstream to the ocean primarily in April through June so that elevated mainstem temperatures are unlikely to have a significant impact on that life stage. For populations above Bonneville Dam—the Upper Gorge winter steelhead, Wind summer steelhead, and both populations of Hood steelhead—NOAA Fisheries (NMFS 2013c) identified the impacts of Bonneville Dam on passage and habitat quantity as secondary limiting factors.

DPS Risk Summary

Three evaluations of LCR steelhead status, all based on W/LCTRT criteria, have been conducted as part of recovery planning since the last status review (McElhany et al. 2007; LCFRB 2010, Vol. 1, Ch. 2; ODFW 2010). All three evaluations concluded that none of the DPS's four strata meet recovery criteria. Of the 23 historical populations in the DPS, 16 are considered at high or very high risk.

Overall, the new information considered does not indicate a change in the biological risk category since the 2005 status review. Although this DPS has made little progress toward meeting its recovery criteria, there is no new information to indicate that its extinction risk has increased significantly.

2.1.2.5 Upper Willamette River Chinook Salmon

The threatened Upper Willamette River (UWR) Chinook salmon ESU includes all naturally spawned populations of spring-run Chinook salmon in the Clackamas River and in the Willamette River and its tributaries above Willamette Falls, Oregon. Fish produced in six artificial propagation programs are included in the ESU.[29]

The W/LCTRT consider the Clackamas and McKenzie populations to be at moderate to low risk of extinction for abundance and productivity; the remaining five are in the very high risk category (NMFS 2011c). Returns at the North Fork Dam on the Clackamas River peaked in 2004 at over 12,000 hatchery- and natural-origin fish, but dropped to approximately 2,000 in 2009 and 2010 (Ford 2011). The geometric mean number of natural-origin spawners for the last five years (ending in 2010) is 850 fish per year. Returns to the McKenzie population increased in abundance, peaking in 2004, but dropped to previous levels of little more than 1,000 unmarked fish crossing Leaburg Dam and remained flat in 2010. NOAA Fisheries (NMFS 2011c) stated its concern that this signaled a failure of the natural population to respond to improved ocean conditions, but noted that not all factors had been completely evaluated. The Willamette Falls count averaged about 40,000 fish (hatchery- and natural-origin) and the estimated number of unmarked (mostly natural-origin) spawners above Leaburg Dam has recently averaged about 2,000 fish.

The Clackamas population is at very low risk of extinction for spatial structure, the Molalla and McKenzie populations are at low to moderate risk, while the remaining four populations are at very high risk due to lack of access to historical habitat above Willamette Project dams. The majority of natural production in the Clackamas occurs upstream of the North Fork Dam in historically accessible habitat, although there is some spawning, primarily by hatchery-origin fish, downstream of the dam. Most of the natural-origin spawning in the McKenzie population occurs above Leaburg Dam.

[29] Seven artificial propagation programs were considered part of the ESU at the time of listing, but the South Santiam hatchery adult outplanting program ended in 2005 (NMFS 2011 = 5-yr review for UWR spp.).

The Clackamas and McKenzie rivers contain the only two populations in the ESU that have substantial natural production and both are at moderate risk of extinction for the diversity metric. The other five populations are at moderate to high risk for diversity. The Molalla, North Santiam, South Santiam, Calapooia, and Middle Fork Willamette spawning populations continue to be dominated by hatchery-origin fish and are not likely to be self-sustaining (McElhany et al. 2007; Schroeder et al. 2007; ODFW 2010). In addition, these populations appear to be experiencing significant risks from pre-spawning mortality of adults (Schroeder et al. 2005, 2007; McElhany et al. 2007).

In NOAA Fisheries' report to Congress on GPRA performance measures for listed species as of 2012, Ford (2012) categorized the overall ESU trend as "stable."

Limiting Factors and Threats

Upper Willamette River Chinook salmon are threatened by the ongoing development of low-elevation habitats in private ownership; lack of access to spawning and rearing habitat above Willamette Project flood-control dams; altered flow levels and elevated water temperature below the dams; a high proportion (greater than 90%) of hatchery-origin fish on the spawning grounds; predation by birds, pinnipeds, and fish; and climate change impacts (NMFS 2011c). NOAA Fisheries completed consultation on the Willamette Project in 2008 (NMFS 2008d), providing an RPA that addresses many of the factors limiting the viability of this species. The Willamette Project action agencies have implemented a number of RPA measures of benefit to both UWR Chinook salmon and UWR steelhead, including the following, to date:

- New adult fish collection facilities
    - ◊ At the base of Cougar Dam in the South Fork McKenzie River (completed in 2010), allowing the safe collection and transport of naturally produced UWR Chinook salmon to historical spawning habitat above the reservoir. In its second full year of operation (2012), over 500 fish were collected, of which 350 were produced above the reservoir.
    - ◊ At Minto, below Big Cliff Dam on the North Santiam River (completed in April 2013), which now allows the collection, sorting, and handling of adult UWR Chinook and UWR winter steelhead, as well as hatchery broodstock, while reducing delay and stress for fish holding below Minto trap. Until downstream fish passage improves through Detroit Dam, only hatchery-origin adults are released above the dam.
    - ◊ At the base of Foster Dam on the South Santiam River (slated for completion in June 2014), which will allow the collection, sorting, and handling of adult UWR Chinook and UWR steelhead as well as hatchery broodstock (Chinook and summer steelhead). Unmarked adult Chinook and winter steelhead will be released above Foster Dam to access

spawning habitat in the South Santiam River and Middle Santiam below Green Peter Dam.

- Operational water temperature control
    - ◊ Improved water temperatures below Detroit and Big Cliff dams on the North Fork Santiam River (beginning in 2009) by passing water through the spillway and regulating outlets at Detroit Dam as well as the turbines to improve water temperatures in the North Santiam below Big Cliff Dam. Before this measure was implemented, water was cooler through the summer and warmer in the fall than under a normative condition. This regime caused UWR steelhead egg incubation to be protracted in the summer, reducing the growth period during fry and subyearling life stages. The cool water in the summer caused adult Chinook to delay upstream migration and the warm water in the fall after the spawning period caused accelerated egg incubation, resulting in early (winter) emergence when rearing conditions were less suitable. This operation has improved passage and incubation conditions for UWR Chinook and incubation and rearing for UWR steelhead. However, operations have not been able to maintain cooler temperatures throughout the fall. A structural temperature control facility, also called for in the Willamette Project RPA, which would achieve temperature goals throughout the year, is in the early design stages.
    - ◊ Improved water temperatures below Lookout Point and Dexter dams on the Middle Fork Willamette River (beginning in 2012) by passing water through the spillways and regulating outlets as well as the turbines. The previous temperature regime caused extremely high temperatures in early fall, resulting in high mortality of UWR Chinook eggs in redds below Dexter Dam. Even when temperatures did not exceed lethal levels, incubation was accelerated in the fall, resulting in early emergence in winter when rearing conditions are less suitable. Initial monitoring results from 2012 show that operations improved water temperatures through the summer, but that temperature targets were exceeded, although not above lethal levels, in the fall.
    - ◊ Improved water temperatures below Fall Creek Dam on Fall Creek, a tributary to the Middle Fork Willamette (beginning in 2009), by operating "fish horns,"[30] combined at times with the regulating outlets. Temperature targets were achieved for most of the spring and summer in 2012, but

[30] The fish horns are water intakes for the adult fish trap located at the base of the dam, but because they are located at three different reservoir elevations, they can draw water from different elevations and take advantage of the water temperature stratification in the reservoir.

temperatures were elevated during part of September and all of October. This operation appears to create more normative passage conditions for adult UWR Chinook salmon to spawning areas above Fall Creek Dam through the summer.

◊ Constructing new or improving adult release sites (in 2013) for releasing adult Chinook into historical habitat above Cougar Dam on the South Fork McKenzie River; adult Chinook and steelhead into historical habitat above Detroit Dam on the North Santiam River; and adult Chinook into historical habitat above Fall Creek and Dexter dams on the Middle Fork Willamette River. Combined with the new adult trapping facilities, the release sites will reduce stress and injury to adult UWR Chinook and steelhead and are expected to reduce rates of prespawning mortality.

These measures, and others that will be implemented over the 15-year term of the Willamette Project RPA, are addressing many of the factors limiting the abundance, productivity, and spatial structure of this species.

With respect to effects of the Columbia River hydrosystem on the species' biological requirements, adult spring Chinook migrate to the mouth of the Willamette during spring and early summer before temperatures become elevated in the lower Columbia River. Juveniles move downstream to the ocean in the spring or to rearing habitat in the estuary throughout the year.

ESU Risk Summary

Two related status evaluations of UWR Chinook salmon have been conducted since the last status update (McElhany et al. 2007; ODFW 2010). Both evaluations concluded that the ESU is substantially below the viability criteria recommended by the W/LCTRT. Of the seven historical populations in the ESU, five are considered at very high risk. The remaining two (Clackamas and McKenzie) are considered at moderate to low risk. Recent data verify the high fraction of hatchery-origin fish (in some cases more than 90% of total returns). The new data also highlight the substantial risks associated with pre-spawning mortality of adults. Although recovery plans are targeting key limiting factors for future actions, there have been no significant on-the-ground actions to resolve the lack of access to historical habitat above dams since the last review; nor have there been substantial actions removing hatchery fish from the spawning grounds. Overall, new information considered does not indicate a change in the biological risk category since the time of the previous status review.

2.1.2.6 Upper Willamette River Steelhead

The threatened UWR steelhead DPS includes all naturally spawned populations of winter-run steelhead in the Willamette River, Oregon, and its tributaries upstream from Willamette Falls to (and including) the Calapooia River. This DPS does not include any artificially propagated steelhead.[31]

In the previous status review (Good et al. 2005), data were only available to the year 2002 when population abundance peaked. However, since then, population abundance has returned to the relatively low levels of the 1990s—with the total abundance of winter steelhead at Willamette Falls in 2008 reaching 4,915. In 2009, the late-returning abundance for the entire DPS was 2,110 fish. All four populations are in the moderate risk-of-extinction category for abundance and productivity (Ford 2011).

Winter steelhead hatchery releases within the boundary of the Upper Willamette River DPS ended in 1999. However, there is still a substantial hatchery program for non-native summer steelhead, and in recent years, the number of non-native summer steelhead returning to the upper Willamette outnumbered that of native winter-run steelhead, raising genetic (diversity) concerns. Thus, all four Upper Willamette River populations are considered to be in the moderate risk category for diversity. The W/LCTRT considers the Molalla population to be in the low risk category for spatial structure, and the other three populations to be in the moderate to high risk categories because Willamette Project dams block access to the upper watersheds in the North and South Santiam watersheds. Water quality problems in the Calapooia River limit spatial structure there. South Santiam steelhead have access to the upper basin via trap and haul at Foster Dam.

In NOAA Fisheries' report to Congress on GPRA performance measures for listed species as of 2012, Ford (2012) categorized the overall DPS trend as "stable."

Limiting Factors and Threats

Upper Willamette River steelhead are threatened by the ongoing development of low-elevation habitats in private ownership; lack of access to spawning and rearing habitat above Willamette Project flood control dams; altered flow levels and elevated water temperature below the dams; non-native summer steelhead hatchery releases; predation by birds, pinnipeds, and fish; and climate change impacts (NMFS 2011c). As described in Section 2.1.2.5 (UWR Chinook Salmon), NOAA Fisheries completed consultation on the Willamette Project in 2008, providing an RPA that addresses many of the factors limiting the viability of this species. The Willamette Project action agencies have implemented a number of RPA measures of benefit to both UWR Chinook salmon and UWR steelhead, including those described in Section 2.1.2.5, above. These and other measures that will be implemented over the 15-year term of the Willamette Project

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[31] Hatchery summer-run steelhead in the Willamette Basin are the progeny of an out-of-basin (Skamania) stock that is not part of the DPS.

RPA, are addressing many of the factors limiting the abundance, productivity, and spatial structure of this species.

DPS Risk Summary

Overall, the new information considered does not indicate a change in the biological risk category since the time of the last status review. Although direct biological performance measures for this DPS indicate little realized progress to date toward meeting its recovery criteria, there is no new information to indicate that its extinction risk has increased significantly. This DPS remains at a moderate risk of extinction.

2.1.2.7 Relevance of Updated Status of Lower Columbia Basin Salmon and Steelhead to the 2008/2010 BiOps' Analyses

NOAA Fisheries completed 5-year status reviews for lower Columbia basin species in 2011 and concluded that the listing status of all species was unchanged from the 2005 status review, which was relied upon in the 2008/2010 BiOps. We report some new information on spawning in the Gorge and Cascade strata of the CR chum ESU (Section 2.1.2.1), which could indicate that the status of this species is better than previously thought. This information will be considered in the next 5-year status review. Until then, we consider the status of CR chum salmon, LCR Chinook salmon, LCR coho salmon, LCR steelhead, UWR Chinook salmon, and UWR steelhead to be stable.

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2.1.3 Rangewide Status of Designated Critical Habitat

NOAA Fisheries described the rangewide status of critical habitat designated for 12 species of Columbia basin salmon and steelhead in Section 4.2 of the 2008 SCA. This included the primary constituent elements (PCEs) of critical habitat for each ESU and DPS and the conservation value ratings for the fifth field hydrologic units within the designated area. Those descriptions remain current without change for this consultation.

Habitat alterations that have resulted in the loss of important spawning and rearing habitat and the loss or degradation of migration corridors were described in Chapter 8 of the 2008 BiOp. In general, critical habitat is still not able to serve its conservation role in many of the designated watersheds.

2.1.3.1 Additional Critical Habitat Designation Proposed for LCR Coho Salmon

On January 14, 2013, NOAA Fisheries published a proposed rule for the designation of critical habitat for a thirteenth species of Columbia basin salmonid, LCR coho salmon (NMFS 2013d). NOAA Fisheries also published a draft biological report that includes habitat quality assessments for this designation (NMFS 2012a), that informs the proposed designation rule. Of the 55 occupied watersheds evaluated, 34 were assigned a conservation value of “high,” 18 a value of “medium,” and three a value of “low” (Table A-2 in NMFS 2012a). The specific areas proposed for designation include approximately 2,288 mi (3,681 km) of freshwater and estuarine habitat in Oregon and Washington. These overlap with existing critical habitat designations for LCR steelhead and Chinook, and CR chum, and in the case of the mainstem Columbia River below the confluence of the Big White Salmon River, Washington, and the Hood River, Oregon, with existing designations for salmonid species that spawn in the middle and upper Columbia rivers and in the Snake River (Figure 2.1-29). Given the shared general life history characteristics of these anadromous salmonids, the essential habitat features (“primary constituent elements” or “PCEs”) of critical habitat are also similar to those for the existing salmon and steelhead designations.

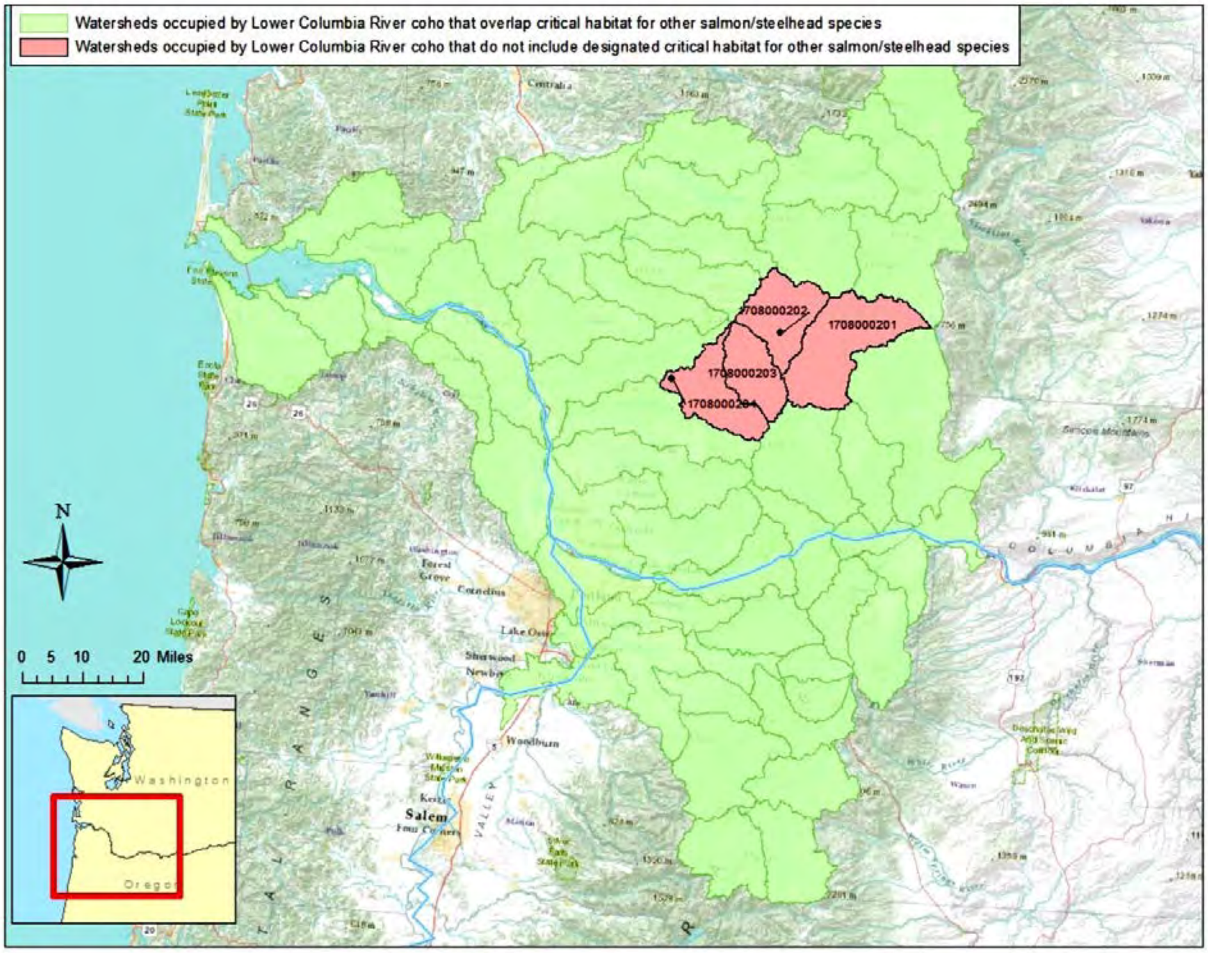

Figure 2.1-29. Overlap of proposed critical habitat designation for LCR coho with that previously designated for other species of salmon and steelhead (Source: Exhibit 2.1 in IEc 2012).

The four additional watersheds in Figure 2.1-29 that NMFS proposed as critical habitat for LCR coho are the Upper Lewis River, Muddy River, Swift Reservoir, and Yale Reservoir. All are located above PacifiCorps' Merwin Dam and are accessible to LCR coho salmon via trap and haul operations (NMFS 2007).

The PCEs (physical and biological features) of the critical habitat designations proposed for LCR coho salmon are identical to those for the other species in the overlapping areas. These are sites for spawning, rearing, migration, and foraging and are essential to support one or more life stages of the ESU. These sites in turn contain physical or biological features essential to the conservation of the ESU (e.g., spawning gravels, water quality and quantity, side channels, forage species). Specific types of sites and the features associated with them (both of which are referred to as "PCEs") include the following (NMFS 2013d):

> "1. Freshwater spawning sites with water quantity and quality conditions and substrate supporting spawning, incubation, and larval development.
>
> 2. Freshwater rearing sites with water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; water quality and forage supporting juvenile development; and natural cover such as shade, submerged and overhanging large wood, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks.
>
> 3. Freshwater migration corridors free of obstruction with water quantity and quality conditions and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival.
>
> 4. Estuarine areas free of obstruction with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh- and saltwater; natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels; and juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation.
>
> 5. Nearshore marine areas free of obstruction with water quality and quantity conditions and forage, including aquatic invertebrates and fishes, supporting growth and maturation; and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels."

Of these, freshwater rearing sites and migration corridors, and estuarine areas in the lower Columbia River below the Big White Salmon River, Washington, and the Hood River, Oregon, are within the action area for this consultation. The lower Columbia River received a conservation value rating of "high" for connectivity between designated areas (Table A-2 in NMFS 2012a).

2.1.3.2 Relevance of Updated Status of Designated Critical Habitat to the 2008/2010 BiOps' Analyses

With the exception of proposing to designate critical habitat for LCR coho salmon, NOAA Fisheries' determinations regarding the rangewide status of critical habitat for Columbia basin salmon and steelhead in Section 4.2 of the 2008 SCA continue to be appropriate in 2013. In general, habitat function is still not sufficient for critical habitat to serve its conservation role in many of the designated watersheds. The tributary areas proposed for designation for LCR coho salmon and the PCEs of critical habitat overlap with the existing designated areas and PCEs for LCR steelhead and Chinook, and CR chum salmon. Likewise, designated areas and PCEs in mainstem reaches of the lower Columbia River overlap with those for listed Upper Columbia River, Snake River, and Middle Columbia River salmon and steelhead.

2.1.4 Recent Climate Observations and New Climate Change Information

Qualitative considerations of weather and climate, as they affect salmon and steelhead survival, were described in Section 5.7 of the 2008 BiOp, and quantitative aspects were described in Section 7.1.1. Several indices of climate, such as the Pacific Decadal Oscillation (PDO), the El Niño-Southern Oscillation (ENSO), and freshwater flows (caused by precipitation and runoff patterns) are correlated with survival of listed salmon and steelhead (e.g., Logerwell et al. 2003; Scheuerell and Williams 2005; Petrosky and Schaller 2010; Haeseker et al. 2012; Peterson et al. 2012; Burke et al. 2013) and therefore affect the rangewide status of the species.

The 2008 BiOp applied three future climate scenarios to prospective quantitative estimates of interior Columbia basin salmon and steelhead extinction risk and productivity to capture a reasonable range of future ocean survivals based on recommendations of the Interior Columbia River Technical Recovery Team (ICTRT and Zabel 2007). Future climate scenarios explicitly incorporated the climate indicators described further in this section. The three climate scenarios were:

- 1980 through 2001 (“Recent” Climate, with mostly warm years and mostly poor survival);
- 1977 through 1997 (“Warm PDO” Climate, with almost exclusively warm years and poor survival); and
- 1946 through 2001 (“Historical” Climate, with a mixture of cool years with good survival and warm years with poor survival).

The 2008 BiOp gave the greatest weight to projections based on the Recent climate scenario.

To apply these scenarios to projections of future survival (e.g., to evaluate prospective actions in the 2008 BiOp), ICTRT and Zabel (2007) expressed combined estuary and ocean survival as functions of climate indices, such as upwelling and the PDO, because of significant correlations of these factors with survival. Each future climate scenario was therefore defined by specific climate variables, such as upwelling and the PDO, and the historical occurrence of those variables over the three periods described above.

The 2008 BiOp also included Comprehensive Fish Passage (COMPASS) model estimates of juvenile survival during mainstem migration. Survival projections using the COMPASS model were based in part on Snake and Columbia River flow rates over a wide range of conditions.

In Section 2.1.4.1, NOAA Fisheries examines recent climate patterns, with an emphasis on those relied upon in the 2008 BiOp analysis, and compares the observations with the 2008 BiOp’s analytical assumptions. Additionally, in Section 2.1.4.2, we review new information on climate change and its effects on salmon and steelhead, updating reviews in the 2008 and 2010 BiOps.

New information regarding our understanding of physical and biological processes in the Columbia River estuary and plume are reviewed separately in Section 2.2.3.1. Although most of the new information does not directly address climate and climate change, the new information regarding plume dynamics, fish behavior, and habitat use indicate the importance to plume dynamics of climate factors reviewed in this section, such as Columbia River outflow and wind-generated nearshore processes, including coastal upwelling.

Eulachon survival is associated with many of the same climate factors as salmon and steelhead (Gustafson et al. 2010). Although the discussion of climate in this section focuses on impacts to salmon and steelhead, we also consider it relevant to eulachon survival and productivity.

2.1.4.1 Recent Climate Observations

In this section, we highlight climate variables that have been discussed in previous FCRPS BiOps, especially those variables and indices that were used to calculate the three ocean climate scenarios that were incorporated into the 2008/2010 BiOps' analyses for interior Columbia basin salmonids (ICTRT and Zabel 2007; see discussion above). The primary purpose of this review is to determine if recent climate conditions have been within the range of climate conditions relied upon in the 2008/2010 BiOps' analyses.

2.1.4.1.1 Pacific Decadal Oscillation

The PDO is a measure of north Pacific sea-surface temperature variability, but the index is correlated with both terrestrial and oceanic climate effects (Mantua et al. 1997). Pacific Northwest salmon and steelhead survival is generally high when ocean temperatures are cooler (negative PDO) and survival is generally low when ocean temperatures are warm (positive PDO), although this pattern is reversed for Alaskan stocks (e.g., Hare et al. 1999; Peterson et al. 2012). While this pattern reflects a general correspondence, the PDO is not always a good indicator of salmon survival, as demonstrated by lower returns in 2013 than were predicted based on the PDO and other ocean indicators (see Section 2.1.1.5.3 *NWFSC Ocean Indicators and the AMIP Projection Model for Future Years*).

The 2008 BiOp included a general discussion of the PDO in Section 5.7.2 and Figure 5.7.1-2 displayed a time series of estimates through Jan 2008. The PDO during spring months of ocean entry relevant to salmon and steelhead ocean survival was one of the factors used to model the future climate scenarios in the 2008 BiOp, as described above. The 2010 Supplemental BiOp updated the PDO index through September 2009 and Figure 2.2.1.3.1.6 demonstrated that there had been a higher proportion of negative PDO years (cool, with presumably higher survival) since 2001 than would be predicted by the Recent climate scenario.

The 2008 BiOp Section 5.7.2 described a pattern of PDO cycles over the last century, with cool (negative: "good" Pacific Northwest salmon survival) PDO regimes prevailing in 1890–1924 and again in 1947–1976 and warm (positive: "poor" Pacific Northwest salmon survival) regimes from 1925–1946 and from 1977 through at least the late 1990s (Mantua and Hare 2002). It is now possible to further update the PDO observations and compare them with the 2008 BiOp's assumptions (Figures 2.1-30 and 2.1-31). Recently, the sign of the PDO has changed more frequently than in the past, with shifts since the late 1990s occurring on approximately 2- to 6-year intervals rather than on decadal or multi-decadal intervals. From 2002 to 2013, six years had a positive mean spring PDO (warm, lower survival), with 2003 through 2006 being the years with the highest values. Six years had a negative mean spring PDO (cold, higher survival). The distribution of 2002 through 2012 PDO observations is more similar to the Historical climate scenario, which resulted in a mixture of good and poor years for salmon survival, than to either the Recent or Warm PDO climate assumptions in the 2008 BiOp, which were both dominated by poor survival years. The overall mean spring PDO for the entire 2002 through 2013 time period is lower (i.e., cooler) when compared to multi-year means for the Recent ($P = 0.02$[32]) climate scenario and Warm PDO ($P < 0.01$) climate scenario described in the 2008 BiOp (Figure 2.1-31), but does not differ from the Historical climate scenario ($P = 0.88$).

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[32] The p-value (*P*), or probability value, is the probability of observing an outcome (in this case, that the 2002–2013 mean is different from the Recent period mean), given that the null hypothesis is true (i.e., that the two means are actually the same, which, if true, would be apparent if there was an infinitely large sample size or number of replicate samples). A small p-value indicates that it is unlikely that the two means are actually the same. Often a probability of 5% or less ($P \leq 0.05$) indicates that a difference in means can be considered "statistically significant." Probabilities greater than 5% do not necessarily prove that there is "no difference" between the means; these results have to be evaluated in the context of a power analysis to ensure that the sample size was sufficient to have detected a difference.

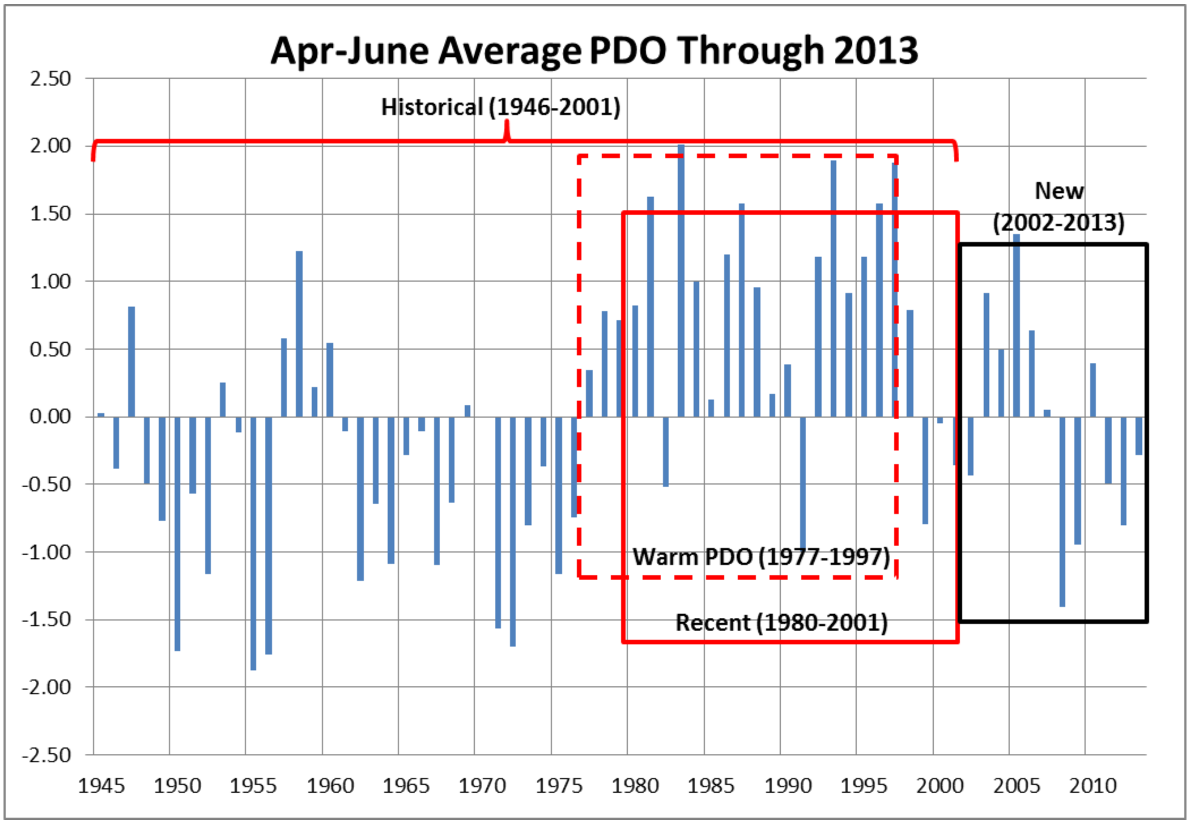

Figure 2.1-30. Pacific decadal oscillation (PDO) index 1946–2012. Positive values are warmer than average and are associated with poor survival of Pacific Northwest salmon and steelhead. Negative values are cooler than average and are associated with higher survival of salmon and steelhead (Source: University of Washington PDO web page: http://jisao.washington.edu/pdo/ - downloaded August 20, 2013.) Time periods corresponding to ocean climate scenarios in the 2008 BiOp are displayed.

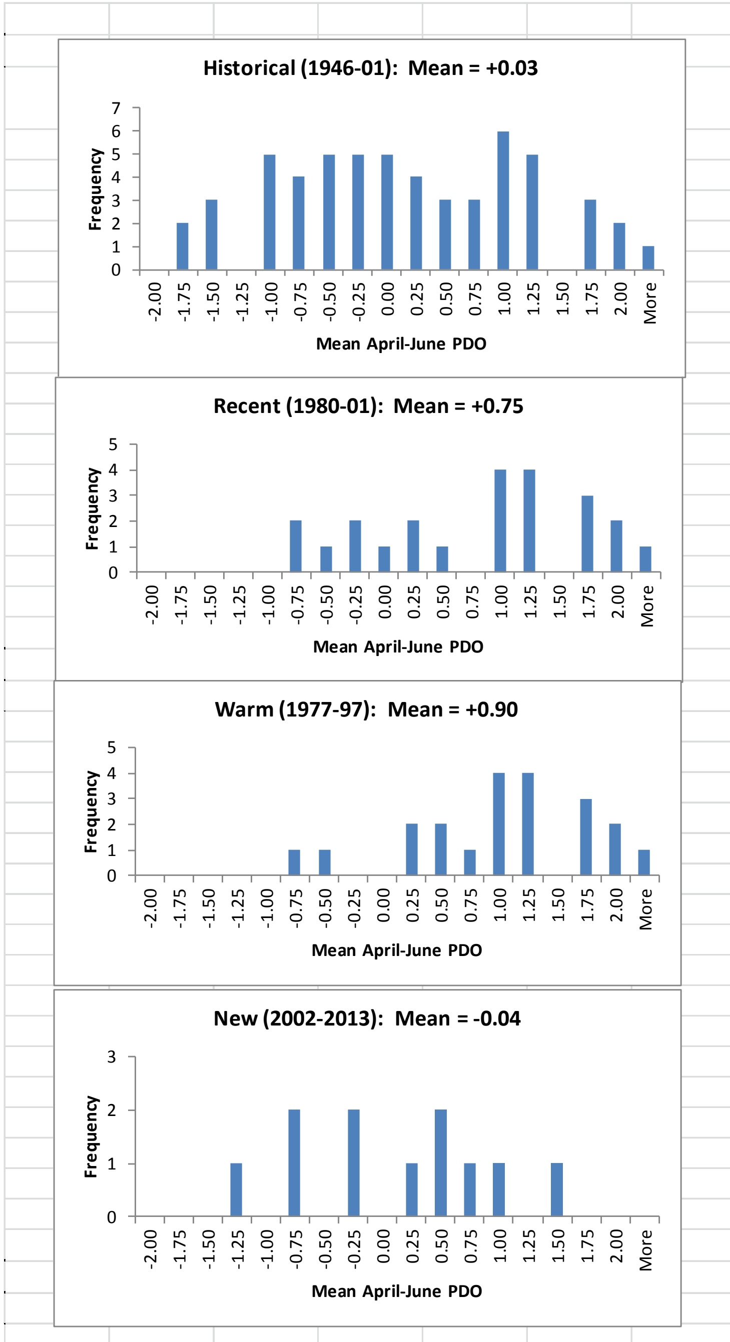

Figure 2.1-31. Histograms showing the frequency of mean spring (April through June) PDO indices. The distribution and mean of new observations since the 2008 BiOp (2002–2013) can be compared with PDO distributions and means represented by three sets of future climate assumptions considered in the 2008 BiOp. Positive values are warmer than average and are associated with poor survival of salmon and steelhead. Negative values are cooler than average and are associated with higher survival of salmon and steelhead (Source of data: University of Washington PDO web page: http://jisao.washington.edu/pdo/ accessed on August 20,2013).

2.1.4.1.2 El Niño - Southern Oscillation

Coastal waters off the Pacific Northwest are influenced by atmospheric and ocean conditions not only in the north Pacific Ocean (as indexed by the PDO), but also in equatorial waters, especially during El Niño events. Strong El Niño events result in the transport of warm equatorial waters northward along the coasts of Central America, Mexico, and California and into the coastal waters off Oregon and Washington. El Niño events are of shorter duration than PDO phases, generally lasting six to 18 months. El Niño conditions are generally associated with poor survival of salmon and steelhead (e.g., Scheuerell and Williams 2005; Peterson et al. 2012) due to lower productivity and changes in the distribution of predator and prey species. Unusually cool water (La Niña) conditions are generally beneficial to salmon and steelhead. El Niño and La Niña conditions also affect terrestrial climate and hydrology (e.g., Barlow et al. 2001).

The 2008 BiOp Section 5.7.1 described the ENSO in more detail and presented a time series of estimates through November 2007. The ENSO was not included as a predictor variable in modeling the three future climate scenarios in the 2008 BiOp; however, El Niño conditions are likely to have influenced salmonid marine survival during the climate scenario time periods. The 2010 Supplemental BiOp Section 2.2.1.3.1.6 extended the time series through April 2010 and compared conditions in the last decade with those during the time periods associated with the three climate scenarios considered in the 2008 BiOp. It concluded that El Niño conditions in the past decade had not been as strong as those predicted by either the Recent climate scenario or the Warm PDO climate scenario evaluated in the 2008 BiOp.

It is now possible to further update the ENSO observations and compare them with the 2008 BiOp's assumptions (Figure 2.1-32). During the time periods encompassed by the Recent and Warm PDO climate scenarios, the pattern is described by Peterson et al. (2012) as consisting of two "very large" El Niño events (1983–1984 and 1997–1998), two smaller events (1986 and 1987), and a prolonged event from 1990 to 1995. Since 2001, El Niño events of the same or lower magnitude as the 1986 and 1987 events occurred in 2002 through 2005 and from spring 2009 through May 2010. La Niña conditions occurred in many of the other years.

We used the National Weather Service Climate Prediction Center's definition of warm events[33] to objectively determine if the frequency of warm El Niño events has changed compared to the time periods represented by the 2008 BiOp's three climate assumptions. The frequency of warm event months, defined in this manner, was nearly identical for the time periods represented by the three climate scenarios (25% to 28%) and the period from 2002–2012 (24%). We also compared means of the Oceanic Niño Index (ONI) for all months encompassed by warm events in each of the four BiOp climate periods. We found that the average magnitude of warm events was lowest for the 2002–2012 period, the averages varied by only 0.3°C from the lowest (2002–

[33] Warm and cold episodes are based on a threshold of ± 0.5°C for the ONI (3 month running mean of ERSST.v3b SST anomalies in the Niño 3.4 region [5°N-5°S, 120°-170°W]), based on centered 30-year base periods updated every 5 years. For historical purposes cold and warm episodes are defined when the threshold is met for a minimum of 5 consecutive over-lapping seasons.
http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/ensostuff/ensoyears.shtml

2012; 0.9°C) to the highest (Recent; 1.2°C) climate periods. In summary, in years since those comprising the climate scenarios relied upon in the 2008 BiOp, El Niño conditions have not been stronger or more frequent than those implicitly captured in the 2008 BiOp's assumptions.

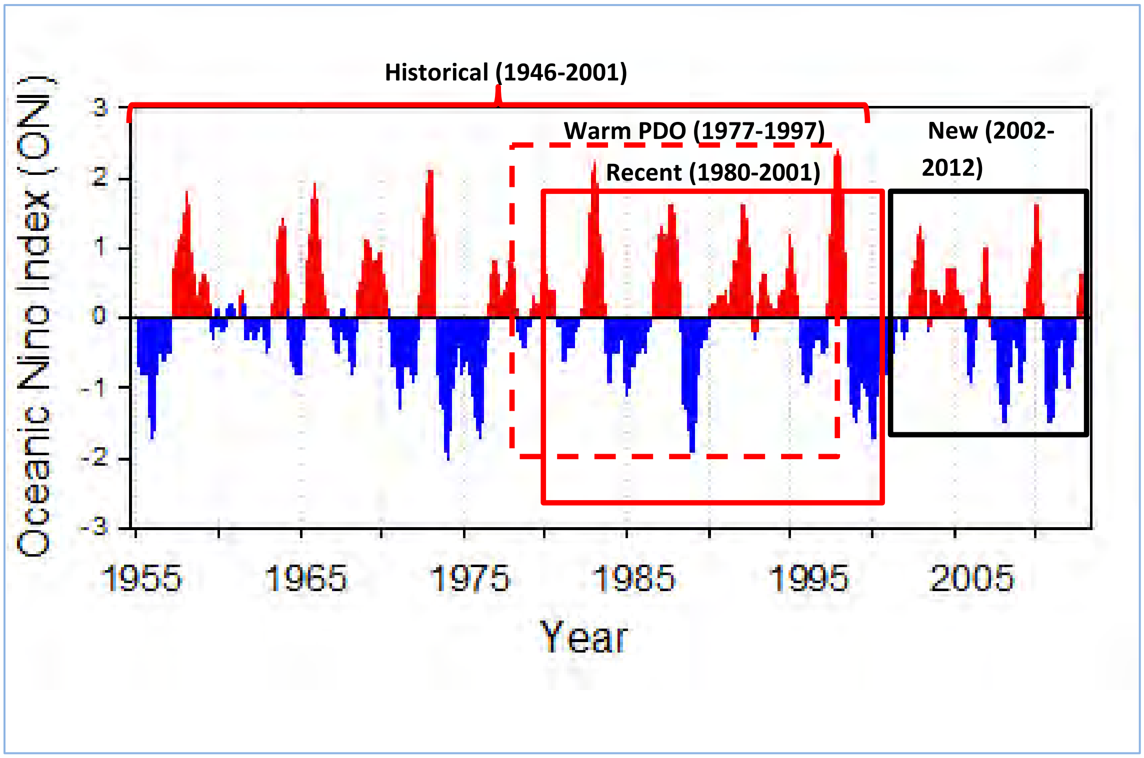

Figure 2.1-32. Values of the Oceanic Niño Index (ONI), 1955 through 2012. Red (positive) values indicate warm conditions in the equatorial Pacific; blue (negative) values indicate cool conditions in equatorial waters. Large and prolonged El Niño events are indicated by large, positive values of the index: note the ONI greater than +2 associated with the 1972, 1983, and 1998 events. Note cool anomalies (La Niña) during 1999–2002 and 2007–spring 2009. A La Niña event developed in equatorial waters from mid-2010 to June 2011, but transitioned to positive values in 2012. Figure and caption are reproduced from Peterson et al. (2012). Time periods corresponding to ocean climate scenarios in the 2008 BiOp have been added.

2.1.4.1.3 Upwelling Index

Upwelling is a wind-driven process that brings nutrients up from depth into the photic zone, increasing ocean productivity and the availability of food for juvenile salmon (Peterson et al. 2012). The 2008 BiOp included a general discussion of upwelling in Section 5.7.2. Salmon survival is generally higher when upwelling is more intense during months corresponding to early ocean growth of juvenile salmon (e.g., Scheuerell and Williams 2005; Petrosky and Schaller 2010), although Peterson et al. (2012) cautions that knowledge of upwelling intensity alone does not always provide good predictions of salmon survival. Factors such as the source of bottom water that is upwelled, and whether El Niño conditions are occurring, can influence the expected upwelling signal as well. Peterson et al. (2012) hypothesize that although upwelling is necessary to stimulate plankton production, its impact is greatest during negative phases of the

PDO. The onset and duration of the upwelling season are also important factors that influence salmon survival (Peterson et al. 2012).

Spring and summer upwelling (exact months dependent upon species) were among the factors used to model the 2008 BiOp's future climate scenarios. Spring (April–May) upwelling intensity was lower than the long-term average in most of the new years subsequent to those represented in the 2008 BiOp's future climate scenarios (Figure 2.1-33). Exceptions were 2007 through 2009, which were greater than the long-term average. The average intensity of spring upwelling in 2002 through 2012 (11.7 m^3/s/100 km) did not differ significantly ($P > 0.24$) from mean estimates associated with the 2008 BiOp's Recent and Warm PDO climate scenarios (11.9 and 10.9 m^3/s/100 km, respectively) but was lower than the Historical average (17.2 m^3/s/100 km, $P = 0.05$).

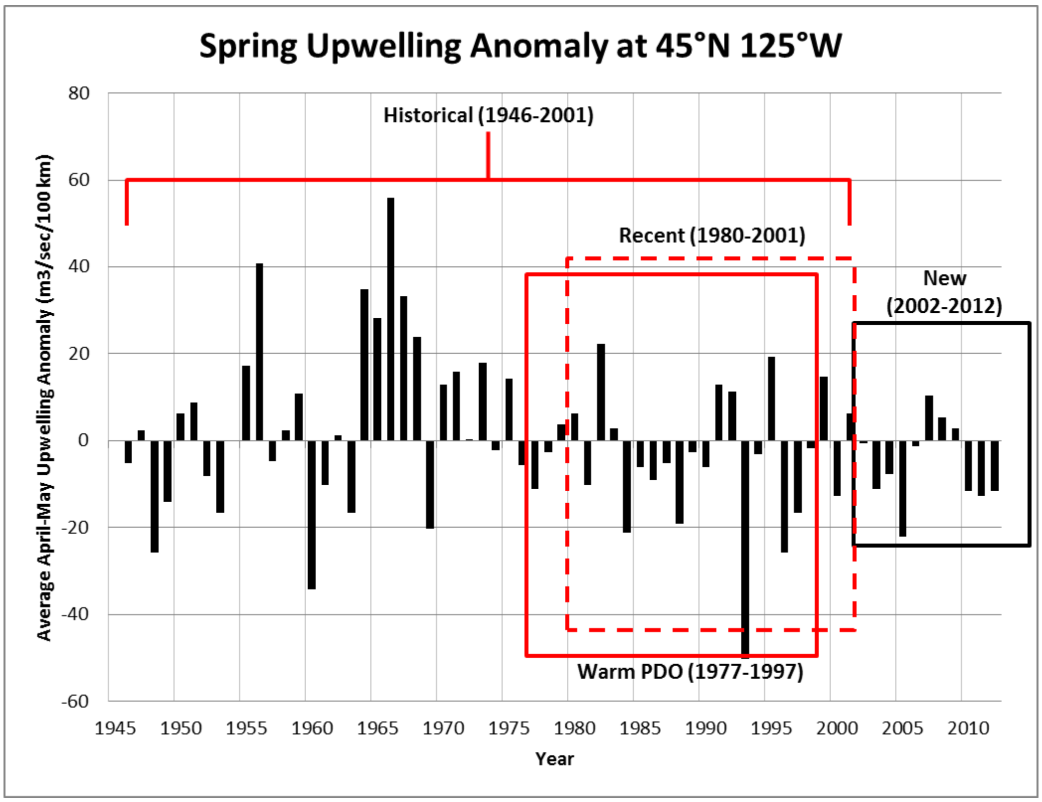

Figure 2.1-33 Anomalies (differences between the 1946–2012 mean and individual yearly values) of the average April and May coastal Upwelling Index, 1946–2012. Positive values represent above-average upwelling and negative values represent below-average upwelling. Units are m^3/s/100 km coastline. Data from NOAA Pacific Fisheries Environmental Laboratory http://www.pfeg.noaa.gov/products/pfel/modeled/indices/upwelling/upwelling.html. Time periods corresponding to ocean climate scenarios in the 2008 BiOp are displayed.

2.1.4.1.4 Ocean Ecosystem Indicators and Overall Pattern of Ocean Conditions

Peterson et al. (2012)—using data collected along the Newport Hydrographic Line and from other Oregon sites and broad areas affecting the Pacific northwest—developed a set of 18 marine indices that represent climatic and biological factors influencing survival of juvenile salmon and steelhead during their first year in the ocean. These indicators include large-scale climate factors described above (PDO, upwelling, and ONI); more local measures of temperature and salinity of coastal waters; and biological drivers such as the copepod community structure, and direct salmon measurements, which were the catches of juvenile Chinook and coho salmon in surveys conducted during their first summer at sea. The indicators are combined into a qualitative assessment of whether the ocean entry conditions in a given year are representative of "good" or "poor" survival of juvenile salmon and steelhead (Table 2.1-20).

Table 2.1-20. Ocean ecosystem indicators, 1998–2012, and rank scores (among the 15 years) upon which color-coding of ocean ecosystem indicators is based. Lower numbers indicate better ocean ecosystem conditions, or "green lights" for salmon growth and survival, with ranks 1–5 green/medium gray, 6–10 yellow/light gray, and 11–15 red/dark gray. To arrive at these rank scores, 15 years of sampling data were compared across years (within each row), and each year received a rank between 1 and 15 (Reproduced from Peterson et al. 2012).

Ecosystem Indicators	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
PDO (December-March)	14	6	3	10	7	15	9	13	11	8	5	1	12	4	2
PDO (May-September)	9	4	6	5	10	14	13	15	11	12	2	8	7	3	1
ONI Jan-June	15	1	1	6	11	12	10	13	7	9	3	8	14	4	5
46050 SST (May-Sept)	13	8	3	4	1	7	15	12	5	14	2	9	6	10	11
NH 05 Upper 20 m T winter prior (Nov-Mar)	15	9	6	8	5	12	13	10	11	4	1	7	14	3	2
NH 05 Upper 20 m T (May-Sept)	13	10	12	4	1	3	15	14	7	8	2	5	11	9	6
NH 05 Deep Temperature	15	4	8	3	1	11	12	13	14	5	2	10	9	6	7
NH 05 Deep Salinity	15	3	6	2	5	13	14	9	7	1	4	11	12	8	10
Copepod Richness Anomaly	15	2	1	6	5	11	10	14	12	9	7	8	13	3	4
N. Copepod Biomass Anomaly	14	10	6	7	4	13	12	15	11	9	3	8	5	1	2
S. Copepod Biomass Anomaly	15	3	5	4	2	10	12	14	11	9	1	7	13	8	6
Biological Transition	14	10	6	5	7	13	9	15	12	2	1	4	11	3	8
Winter Ichthyoplankton	15	7	2	4	5	14	13	9	12	11	1	8	3	10	6
Chinook Juv Catches (June)	14	3	4	12	8	10	13	15	9	7	1	5	6	11	2
Coho Juv Catches (Sept)	11	2	1	4	3	6	12	14	8	9	7	15	13	5	10
Mean of Ranks	13.8	5.5	4.7	5.6	5.0	10.9	12.1	13.0	9.9	7.8	2.8	7.6	9.9	5.9	5.5
RANK of the Mean Rank	15	4	2	6	3	12	13	14	10	9	1	8	11	7	4
Principle Component Scores (PC1)	6.56	-2.22	-2.95	-1.60	-2.12	2.08	3.12	4.21	1.10	-0.30	-4.39	-0.91	1.13	-1.76	-1.96
Principle Component Scores (PC2)	-0.51	0.04	-0.24	-0.76	-1.96	-1.53	2.55	-0.43	-0.66	1.07	-0.50	0.96	-0.74	1.36	1.35
Ecosystem Indicators not included in the mean of ranks or statistical analyses															
Physical Spring Trans (UI Based)	3	6	14	12	4	9	11	15	9	1	5	2	7	8	13
Upwelling Anomaly (Apr-May)	7	1	13	3	6	10	9	15	7	2	4	5	11	13	11
Length of Upwelling Season (UI Based)	6	2	14	9	1	10	8	15	5	3	7	3	11	13	11
NH 05 SST (May-Sept)	10	6	5	4	1	3	15	13	8	12	2	14	9	7	11
Copepod Community Structure	15	3	5	7	2	12	11	14	13	8	1	6	10	9	4

Based on the suite of ocean ecosystem indicators, 1998, 2003 through 2005, and 2010 were years in which ocean entry conditions were generally unfavorable for salmon survival. Favorable years were 1999 through 2000, 2002, 2008, and 2012. It is difficult to compare these qualitative assessments to those predicted by the 2008 BiOp's three future climate scenarios because the rankings are based on a 15-year period that is largely subsequent to the years represented by the scenarios.

This assessment, or a more quantitative model based on 32 indicators (Burke et al. 2013), has been used to predict adult returns 1–2 years in the future. The 2010 Supplemental BiOp discussed this index in Section 2.2.1.3.2.7 and predicted relatively high Chinook returns in 2010 and intermediate returns in 2011, based on the 2008 and 2009 ocean ecosystem indicators. As described in Section 2.1.1.4.4 (*Overview of Patterns of Abundance and Productivity*) and in Figure 2.1-21, Chinook returns were above average in these years, as predicted. Future predictions of the ocean ecosystem indicators are considered in Section 2.1.2.5 (*Other Information on the Abundance of Interior Columbia Basin Salmon and Steelhead*), including the need to investigate possible inclusion of additional factors to explain lower than predicted returns in 2013.

2.1.4.1.5 Freshwater Stream Flow

Tributary stream flow is relevant to survival of listed salmon and steelhead during the first 1–2 years of life when juvenile salmon and steelhead are rearing in freshwater and when mainstem flows are relevant to smolt survival during seaward migration and following ocean entry. We discuss each in more detail below and compare new observations with those considered directly or indirectly in the 2008 BiOp.

Tributary Stream Flow (Salmon River)

For interior Columbia basin salmon and steelhead that generally rear in snowmelt-fed streams, the lowest flow levels generally occur in late summer or early fall. The level of flow can affect available habitat area; the distribution and availability of prey; refuges from predators; water temperature; and other factors (e.g., Arthaud et al. 2010; Poff and Zimmerman 2010; Nislow and Armstrong 2012; Roni et al. 2013a). This can potentially affect growth and survival of juvenile salmonids. Consistent with these expectations, mean fall (September and October) flow levels in Salmon River tributaries correlate positively with parr-to-smolt survival of juvenile spring/summer Chinook salmon (Crozier and Zabel 2006; Crozier et al. 2008; Crozier and Zabel 2013 DRAFT). Tributary stream flow was not a factor in the ocean climate scenarios evaluated in the 2008 BiOp and previous FCRPS biological opinions have not presented empirical tributary flow observations.

We present streamflow from the Salmon River in Idaho (Figure 2.1-34) because that is the site used by Crozier and Zabel (2006, 2013 DRAFT) after they determined that it correlated strongly with stream flow within various tributaries of the Salmon River. This site also has a long historical flow record with few data gaps. Figure 2.1-37 indicates that the approximately 1980 through 2001 Base Period included a range of mean fall flows that were nearly equally distributed above and below the 1946 to 2012 long-term average. In contrast, most of the recent observations have been lower than the long-term average, with the mean fall flow level for the recent years (1,020 cfs) lower than the Base Period mean (1,158 cfs). This suggests that streamflow conditions have been less favorable to parr-to-smolt survival since the 2008 BiOp's Base Period, at least for interior Columbia basin spring/summer Chinook. Because of similarities in juvenile rearing requirements, this is likely true for juvenile steelhead in the interior Columbia basin as well.

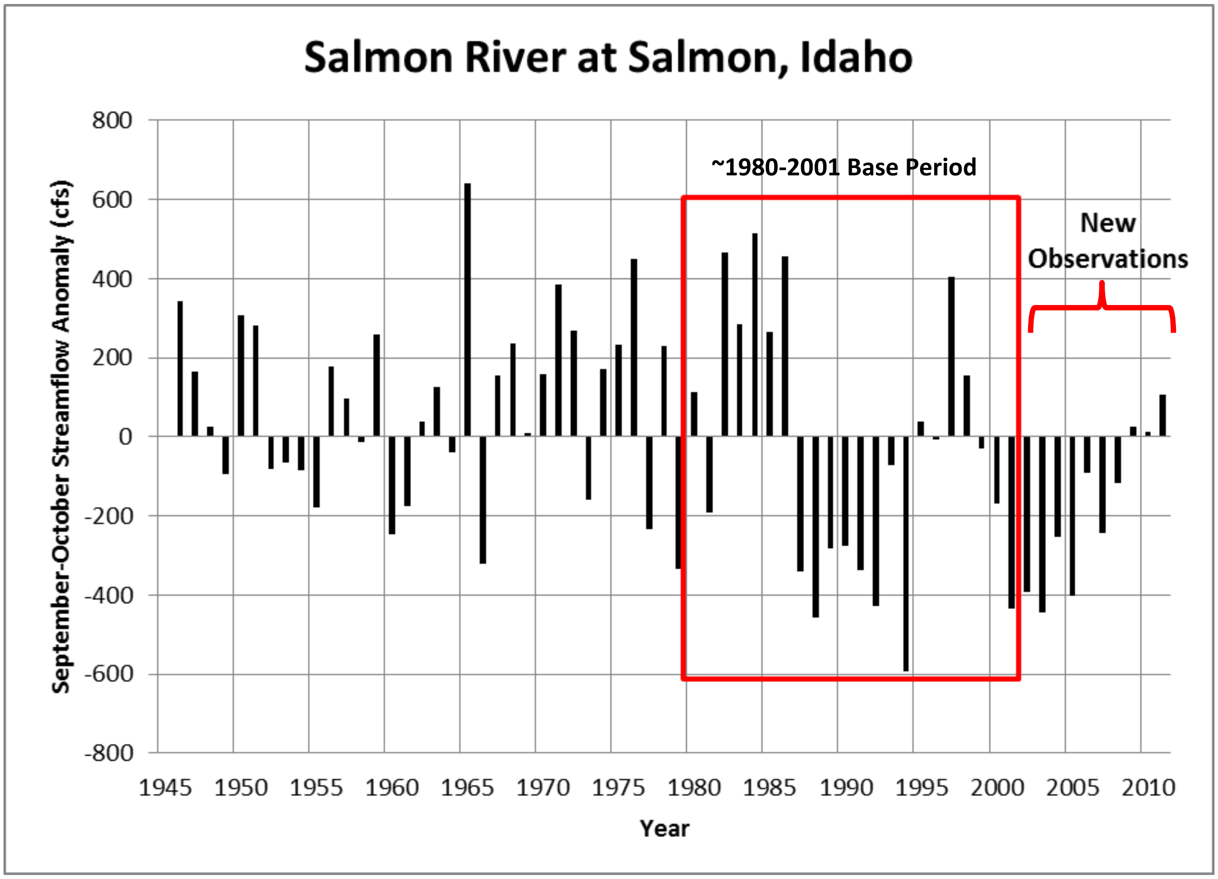

Figure 2.1-34. Anomalies (differences between the 1946–2011 mean and individual yearly values) of the average September and October streamflow in the Salmon River at Salmon, Idaho, 1946–2012. Positive values represent above-average flows and negative values represent below-average flows. Units are cubic feet per second (cfs). The 2008 BiOp's Base Period of approximately 1980–2000 is indicated by the red box, followed by new observations. Data are from U.S. Geological Survey Station 13302500, available from: http://waterdata.usgs.gov/id/nwis/uv/?site_no=13302500&PARAmeter_cd=00065,00060,00010

Mainstem Snake/Columbia Stream Flow

Section 5.1.3 of the 2008 BiOp describes several effects of mainstem Snake and Columbia River flow on survival of smolts during seaward migration. Increased flow generally increases migration speed, which decreases exposure to factors such as predation and temperature stress in reservoirs (e.g., Ferguson 1995), and it affects ocean entry timing and early ocean survival (Scheurell et al. 2009). Juvenile survival through the hydropower system is correlated with water travel time (Haeseker et al. 2012), which is in part a function of flow. Water travel time, derived from mean springtime Columbia River flow at Bonneville Dam, was included as a factor in determining the three future ocean climate conditions in the 2008 BiOp (ICTRT and Zabel 2007).

Consistent with ICTRT and Zabel (2007), we compared mean springtime flow at Bonneville Dam after 2001 with Columbia River flows during the 2008 BiOp's Base Period (Recent climate scenario) and the periods represented by the Historical and Warm PDO climate scenarios (Figure 2.1-35). Columbia River spring flows during the years since the 2008 BiOp (2002–2011) averaged 263 thousand cubic feet per second (kcfs), which was nearly identical to the mean flow of 262 kcfs during the 1980–2001 Base Period (and Recent climate scenario). Lowest Columbia River flows during the new years were in 2005 and 2010 (affecting smolt migration of the 2003 and 2008 brood years of spring Chinook and steelhead), while the highest flows were in 2006 and 2011 (2004 and 2009 brood years). Mean flows during the years corresponding to the Warm PDO climate scenario were lower (256 kcfs) than the more recent means; and the mean for the Historical climate scenario was higher (289 kcfs) than the more recent means.

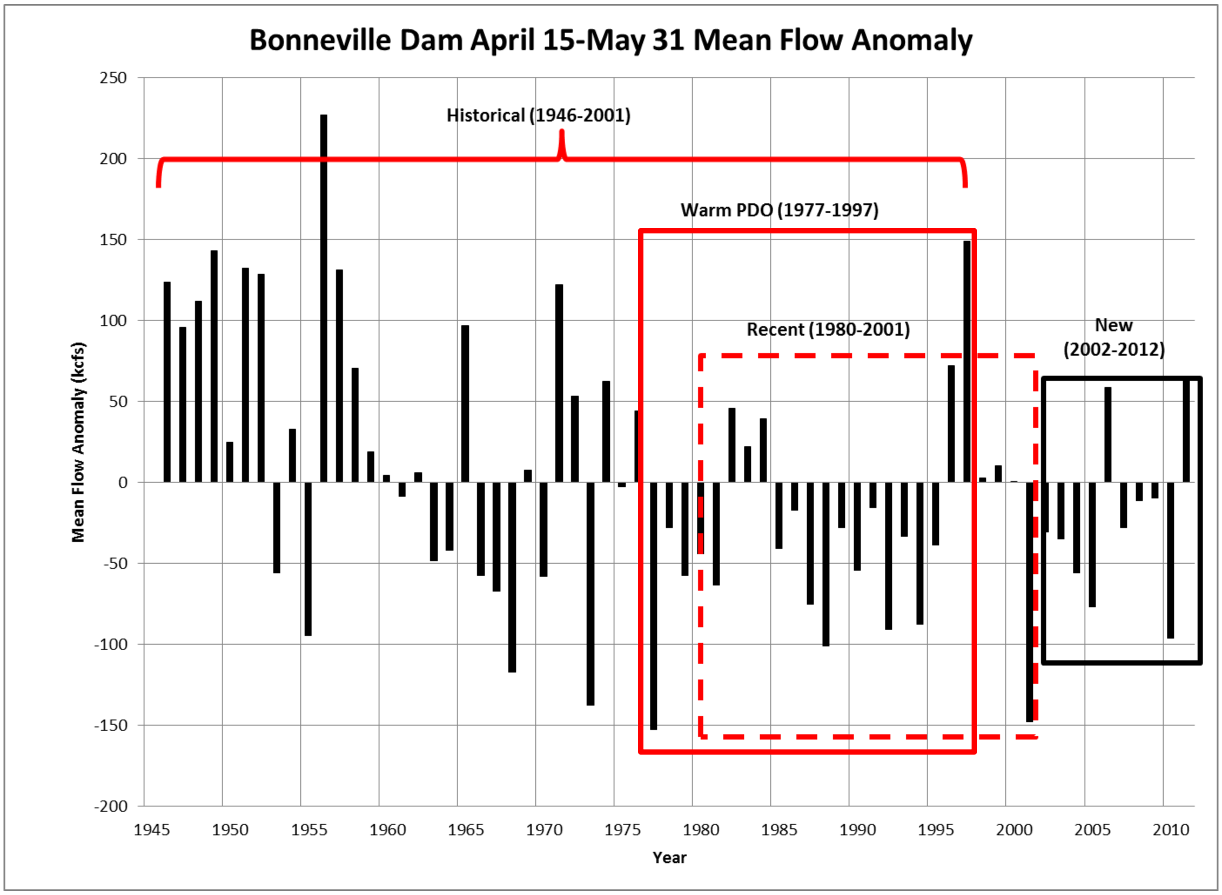

Figure 2.1-35. Anomalies (differences between the 1946–2011 mean and individual yearly values) of the average April 15 through May 31 Columbia River flow at Bonneville Dam in thousand cubic feet per second (kcfs). Periods corresponding to ocean climate scenarios in the 2008 BiOp are indicated. Raw data from Corps of Engineers, summarized by the Fish Passage Center (spreadsheet: WTT calcs 29-11 from cp w UC.xls).

2.1.4.1.6 Freshwater Stream Temperatures

Stream temperature can affect growth and survival of juvenile salmon and steelhead rearing in interior Columbia basin streams. The Independent Scientific Advisory Board (ISAB 2007) reviewed temperature effects on juvenile salmon, including

- excluding fish from reaches with temperatures at or near their thermal tolerance;
- increasing metabolism at higher temperatures, thereby either increasing or decreasing fish growth rate, depending upon the availability of food;
- increasing the metabolism of predators at higher temperatures, thereby increasing predation rates on salmonids;
- affecting susceptibility to pathogens and parasites, which increases when fish become thermally stressed;
- affecting migration timing; and
- affecting survival in subsequent life stages based on the fish size and migration timing determined in part by temperature during juvenile rearing.

Consistent with these expectations, mean summer (May through August) temperatures in Salmon River tributaries negatively correlate with parr-to-smolt survival of some populations of juvenile spring/summer Chinook salmon, while having a neutral or positive effect on other populations (Crozier et al. 2010; Crozier and Zabel 2013 DRAFT). Tributary temperature was not a factor in defining the ocean climate scenarios evaluated in the 2008 BiOp. Previous FCRPS biological opinions have not presented tributary temperature data.

Crozier et al. (2010) found that cumulative growing degree-days[34] measured in various streams in the Salmon River basin correlate strongly with mean May–August air temperature, which was also a strong predictor of fish length. An advantage of using air temperature, rather than stream temperature, is that most of the stream temperature data sets in the interior Columbia basin are of relatively short duration or of irregular length. We therefore present mean monthly air temperature in the Salmon River basin, as used by Crozier et al. (2010) and Crozier and Zabel (2013 Draft) in Figure 2.1-36.

[34] "Growing degree-days" are defined as the sum of daily mean temperatures in Celsius during the period of salmon growth.

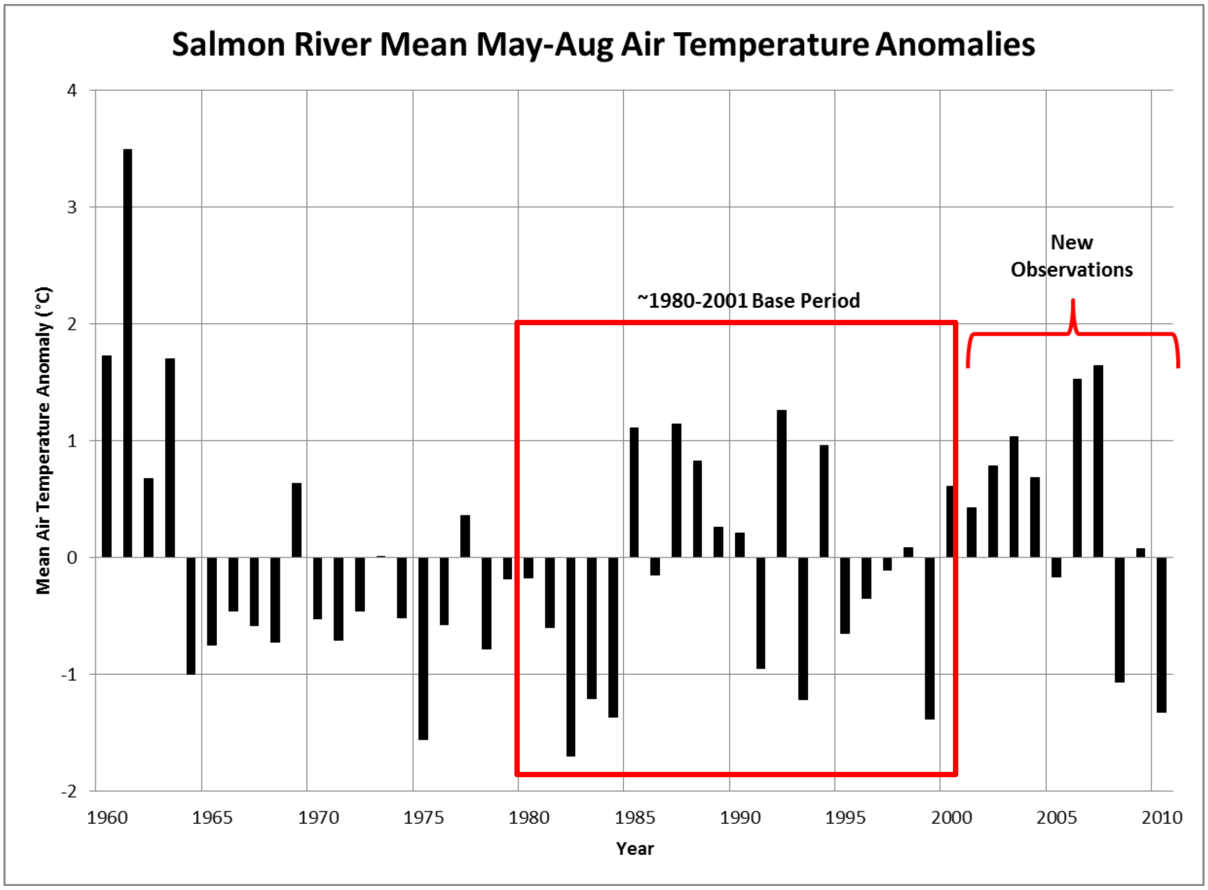

Figure 2.1-36. Anomalies (differences between the 1960–2010 mean and individual yearly values) of the average May through August air temperatures from meteorological stations in the Salmon River basin. As described in the text, air temperatures correlate strongly with stream temperatures and fish growth. Time periods corresponding to the 2008 BiOp's Base Period and more recent observations are indicated. Raw data provided by the NOAA Western Regional Climate Center (http://www.wrcc.dri.edu/climsum.html) and basin averages provided by L. Crozier, NOAA Fisheries.

Figure 2.1-36 indicates that new observations since the 2008 BiOp include a higher percentage of years with above-average mean temperatures than the percentage of above-average years in the 2008 BiOp's approximate Base Period. The mean temperature of all years in the new period was higher than that of the Base Period (12.1°C versus 11.7°C). Based on Crozier and Zabel (2013 DRAFT), these higher temperatures in recent years could be associated with lower parr-to-smolt survival for some Salmon River spring/summer Chinook populations. However, it could also have resulted in higher growth rates and larger smolt sizes—which would lead to higher survival rates in other life stages that could compensate for reduced survival at the parr-to-smolt life stage.

2.1.4.2 Recent Information Regarding Climate Change

The 2008 BiOp included information on climate change that was published through 2007. The primary sources of information were the ISAB's review of climate change impacts on Columbia River basin fish and wildlife (ISAB 2007), the ICTRT's ocean climate scenarios for use in quantitative analyses (ICTRT and Zabel 2007), and a modeling analysis of potential effects of climate change on freshwater stages of SR spring Chinook (Crozier et al. 2008). This information was used to assess effects of the RPA under climate change and to develop elements of the RPA that would implement climate change mitigation actions recommended by the ISAB (2007) in the 2008 BiOp Section 8.1.3.

Section 2.2.1.3 of the 2010 Supplemental BiOp reviewed subsequently available climate change literature (through 2009) that was relevant to Pacific Northwest salmonids and made the following conclusions:

- New observations and predictions regarding physical effects of climate change were within the range of assumptions considered in the 2008 BiOp and the AMIP.
- New studies of biological effects of climate change on salmon and steelhead provided additional details on effects previously considered and suggest that the adult life stage may need particular attention through monitoring and proactive actions envisioned in the AMIP. (The 2010 Supplemental BiOp included amendments to the AMIP to address this point).
- The types of potentially beneficial actions identified by ISAB (2007) and implemented through the RPA are consistent with the types of adaptation actions described in current literature.

This section briefly reviews the climate change effects considered in the 2008 BiOp and discusses additional information regarding climate change that has become available since the 2008 BiOp was issued. It concludes that, while additional details regarding observed and forecasted effects of climate change on Pacific Northwest salmonids have become available in recent years, the effects remain consistent with those described in the 2008 BiOp.

2.1.4.2.1 Review of Climate Change Effects Considered in the 2008 BiOp

The 2008 BiOp relied primarily upon the review of climate change effects on salmonids prepared by the Northwest Power and Conservation Council's (NPCC) Independent Scientific Advisory Board (ISAB 2007). This report summarized the key effects of climate change and related them to salmon life history in a figure that is reproduced here as Figure 2.1-37.

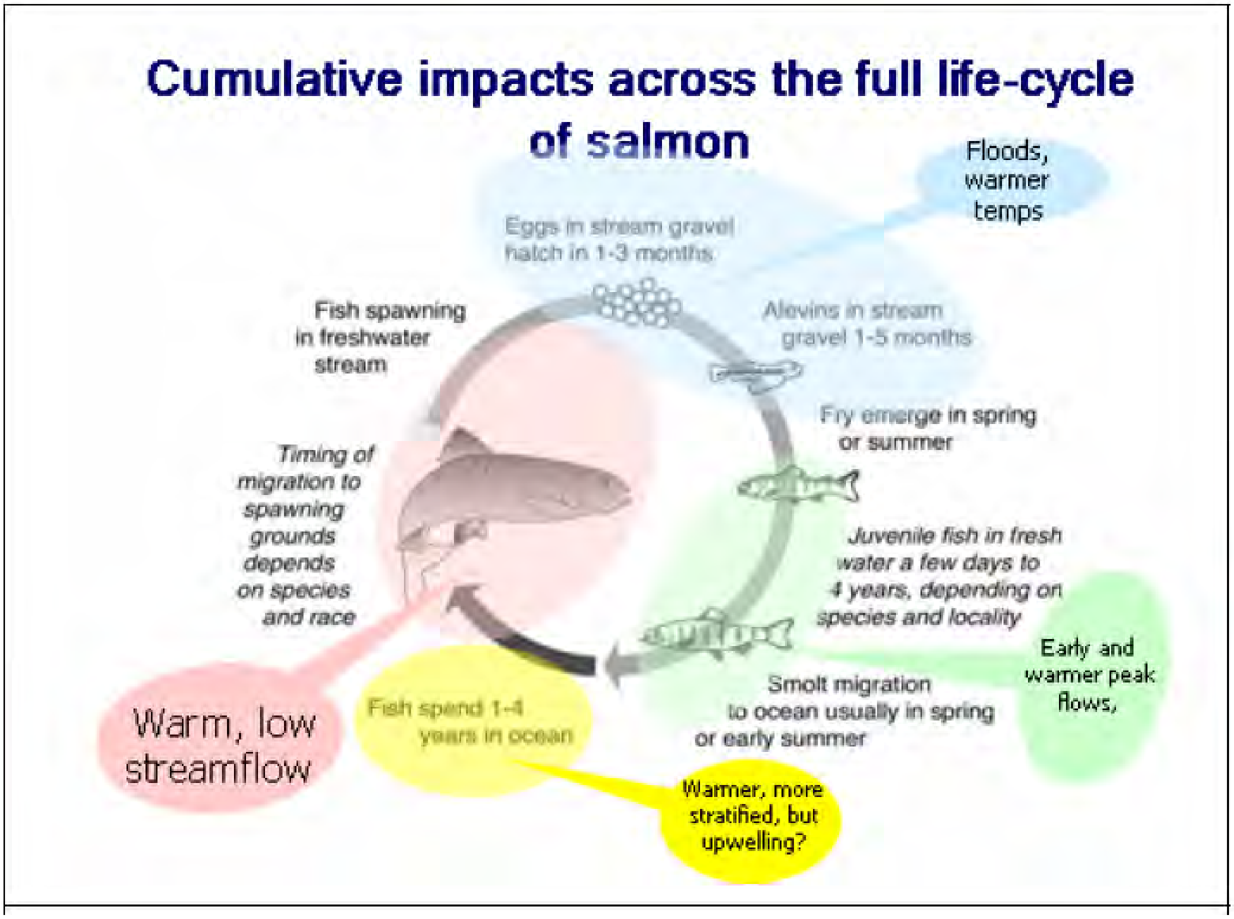

Figure 2.1-37. Illustration of the points in the salmon life history where climate change may have an effect. Reproduced from ISAB (2007) Figure 24.

The effects of climate change that were summarized from ISAB (2007) and other sources in the 2008 SCA Section 5.7.3, and incorporated by reference into the 2008 BiOp's description of the environmental baseline, included the following.

Freshwater Environment

Climate records show that the Pacific Northwest has warmed about 1.0°C since 1900 or about 50% more than the global average warming over the same period. The warming rate for the Pacific Northwest over the next century is projected to be in the range of 0.1°C to 0.6 °C per decade. Although total precipitation changes are predicted to be minor (+ 1% to 2%), increasing air temperature will alter the snowpack, stream flow timing and volume, and water temperature in the Columbia River basin. Climate experts predict the following physical changes to rivers and streams in the Columbia basin:

- Warmer temperatures will result in more precipitation falling as rain rather than snow.
- Snowpack will diminish, and stream flow volume and timing will be altered.
    - ◊ More winter flooding is expected in transient[35] and rainfall-dominated basins.
    - ◊ Historically transient watersheds will experience lower late summer flows.
- A trend towards loss of snowmelt-dominant and transitional basins is predicted.
- Summer and fall water temperatures will continue to rise.

These changes in air temperatures, river temperatures, and river flows are expected to cause changes in salmon and steelhead distribution, behavior, growth, and survival. Although the magnitude and timing of these changes currently are poorly understood and specific effects are likely to vary among populations, the following effects on listed salmon and steelhead in freshwater are likely:

- Winter flooding in transient and rainfall-dominated watersheds may scour redds, reducing egg survival.
- Warmer water temperatures during incubation may result in earlier fry emergence, which could be either beneficial or detrimental depending on location and prey availability.
- Reduced summer and fall flows may reduce the quality and quantity of juvenile rearing habitat, strand fish, or make fish more susceptible to predation and disease.
- Reduced flows and higher temperatures in late summer and fall may decrease parr-to-smolt survival.
- Warmer temperatures will increase metabolism, which may either increase or decrease juvenile growth rates and survival, depending on availability of food.
- Overwintering survival may be reduced if increased flooding reduces suitable habitat.
- Timing of smolt migration may be altered such that there is a mismatch with ocean conditions and predators.

[35] Transient watersheds have streamflow that is strongly influenced by both direct runoff from rainfall and springtime snowmelt because surface temperatures in winter typically fluctuate around the freezing point. Over the course of a given winter, precipitation in transient watersheds frequently fluctuates between snow and rain depending on relatively small changes in air temperature (Mantua et al. 2009).

- Higher temperatures during adult migration may lead to increased mortality or reduced spawning success as a result of lethal temperatures, delay, increased fallback at dams, or increased susceptibility to disease and pathogens.

The degree to which phenotypic or genetic adaptations may partially offset these effects is being studied but currently is poorly understood.

Estuarine Environment

Climate change also will affect salmon and steelhead in the estuarine and marine environments. Effects of climate change on salmon and steelhead in estuaries include the following:

- Warmer waters in shallow rearing habitat may alter growth, disease susceptibility, and direct lethal or sublethal effects.
- Increased sediment deposition and wave damage may reduce the quality of rearing habitat because of higher winter freshwater flows and higher sea level elevation.
- Lower freshwater flows in late spring and summer may lead to upstream extension of the salt wedge, possibly influencing the distribution of salmonid prey and predators.
- Increased temperature of freshwater inflows and seasonal expansion of freshwater habitats may extend the range of warm-adapted non-indigenous species that are normally found only in freshwater.

In all of these cases, the specific effects on salmon and steelhead abundance, productivity, spatial distribution and diversity are poorly understood.

Marine Environment

Effects of climate change in marine environments include increased ocean temperature, increased stratification of the water column, and changes in intensity and timing of coastal upwelling. Hypotheses differ regarding whether coastal upwelling will decrease or intensify but, even if it intensifies, the increased stratification of the water column may reduce the ability of upwelling to bring nutrient-rich water to the surface. There are also indications in climate models that future conditions in the North Pacific region will trend towards conditions during warm phases of the PDO. Hypoxic conditions observed along the continental shelf in recent years appear to be related to shifts in upwelling and wind patterns, which may be related to climate change.

These continuing changes are expected to alter primary and secondary productivity, the structure of marine communities (particularly the distribution of predators and prey), and in turn, the growth, productivity, survival, and migrations of salmonids, although the degree of impact on listed salmonids currently is poorly understood. A mismatch between earlier smolt migrations (because of earlier peak spring freshwater flows and decreased incubation period) and altered upwelling may reduce marine survival rates. Ocean warming also may change migration patterns, increasing distances to feeding areas.

In addition, rising atmospheric carbon dioxide concentrations drive changes in seawater chemistry, increasing the acidification of seawater. This reduces the availability of carbonate for shell-forming invertebrates (e.g., pteropods, which are prey for some species of salmon and prey for some forage fish that are consumed by salmon), reducing their growth and survival. This process of acidification is underway, has been well documented along the Pacific coast of the U.S, and is predicted to accelerate with increasing emissions.

2.1.4.3 Updated Climate Change Information Since the 2010 Supplemental BiOp

In addition to the 2007–2009 scientific literature on climate change that was reviewed in the 2010 Supplemental BiOp, NOAA Fisheries reviewed hundreds of scientific papers published from 2010 through 2012 that are relevant to effects of climate change on Pacific Northwest salmonids (Crozier 2011, 2012, 2013). The Crozier (2011 and 2012) reports were included as attachments to the Action Agencies' annual progress reports.[36] All three reviews (Crozier 2011, 2012, 2013) are included as Appendix D of this supplemental opinion.

Other recent reviews of ongoing and expected changes in Pacific Northwest climate that are relevant to listed salmon and steelhead include the U.S. Global Change Research Program's national climate change impacts assessment (Karl et al. 2009; NCADAC 2013 DRAFT), the Washington Climate Change Impacts Assessment (CIG 2009), and the Oregon Climate Assessment (OCCRI 2010). The NCADAC (2013) includes a chapter that specifically reviews physical and biological climate change impacts in the Pacific Northwest (Mote and Snover 2013). These climate change assessments include empirical observations and climate model projections. The regional climate assessments include projections from the International Panel on Climate Change global climate models (IPCC 2007), which were then downscaled to reflect regional terrestrial and aquatic conditions (e.g., Salathe 2005) and ocean conditions (e.g., Stock et al. 2011). A new IPCC global climate assessment is currently underway, with new global climate projections expected by 2014.

Recent information concerning climate impacts on oceans and coastal resources is reviewed in Griffis and Howard (2012). Additional reviews of marine climate effects relevant to the Pacific Northwest, such as ocean acidification and sea level change, are included in the Oregon and Washington climate assessments (Huppert et al. 2009; Mote et al. 2010; Ruggiero et al. 2010). Key research on ocean acidification is reviewed in Feely et al. (2012) and includes Feely et al. (2008). Mote et al. (2009), Ruggiero et al. (2010), and NRC (2012) described observed sea level height changes along the Pacific coast and reviewed literature projecting sea level changes in the Pacific Northwest, which can affect rearing habitat of salmonids. Various localized studies of projected sea level height changes are also available (e.g., Glick et al. 2007; Sharp et al. 2013).

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[36] These reviews are also available on the Northwest Fisheries Science Center web site: http://www.nwfsc.noaa.gov/trt/lcm/docs/Climate%20Literature%20Review_py2011.pdf and http://www.nwfsc.noaa.gov/trt/lcm/docs/Climate%20Literature%20Review_py2010.pdf

Recent reviews of the effects of climate change on the biology of salmon and steelhead in the Columbia River basin and the California Current region, subsequent to ISAB (2007) and additional to Crozier (2011, 2012, 2013) reviews, include sections of the Oregon and Washington climate assessments (Huppert et al. 2009; Mantua et al. 2009, 2010; Hixon et al. 2010), Stout et al. (2010) and Ford (2011). Adaptation strategies that contain measures to reduce impacts of climate change on Pacific Northwest salmon and steelhead include, in addition to ISAB (2007), the interim Washington Climate Change Response Strategy (WDOE 2011); the Oregon Climate Change Adaptation Framework (ODLCD 2010); the National Fish, Wildlife, and Plants Climate Adaptation Strategy (NFWPCAP 2012); and the North Pacific Landscape Conservation Cooperative's reviews of marine and freshwater adaptation strategies (Tillmann and Siemann 2011a,b). Beechie et al. (2012) produced an important description of best methods for restoring salmon and steelhead habitat in the face of climate change (see Section 2.1.4.5 for details).

Overall, new climate change information subsequent to the 2008 BiOp supports and adds detail to the information relied upon in that biological opinion. Crozier (2011, 2012, 2013; Appendix D in this supplemental opinion) describes results of hundreds of scientific papers relevant to effects of climate on Pacific Northwest salmon and steelhead that have been published since the literature reviewed in the 2008/2010 BiOps. *We refer the reader to those reviews for more information, but in the remainder of this section briefly describe <u>a few examples</u> of studies that are relevant to the current and future status of listed species, and relevant to expected effects of the RPA.*

2.1.4.4 Physical Effects of Climate Change

2.1.4.4.1 Recent Observations

Recent observations of climate trends are generally consistent with expectations in the 2008 BiOp, and the capacity for monitoring these trends in the Pacific Northwest is increasing. For example, a variety of recent studies found significant trends in temperature, precipitation, and flow both within the Columbia River basin and over broader spatial scales.

Arismendi et al. (2012) and Isaak et al. (2012) found stream temperatures getting warmer within the Columbia River basin, although results were dependent upon length of the time series and whether the rivers were regulated or not. Arismendi et al. (2012) found significant warming trends when longer records were available—roughly 44% of streams with records prior to 1987 had significant warming trends. However, cooling trends predominated in the shorter time series, despite significant warming of air temperature in many cases. The authors noted a correlation between base flow and riparian shading with these cooling trends. Human-impacted sites showed less variability over time, likely due to flow regulation and reservoir heat storage. Isaak et al. (2012) demonstrated statistically significant warming trends from 1980 to 2009 on seven unregulated streams in the Pacific Northwest in summer (0.22ºC per decade), fall, and winter, producing a net warming trend annually despite a cooling trend in spring. Stream temperature trends were strongly correlated with air temperature, showing the expected signal from regional climate warming. Trends in 11 regulated streams were in the same direction, but were not statistically significant, indicating that modified flows, in some cases explicitly for temperature management, can limit stream thermal response to climate drivers.

To increase the capability to monitor and project stream temperatures, Isaak and colleagues have assembled a Pacific Northwest stream temperature database[37] that was compiled from temperature records provided by hundreds of biologists and hydrologists working for numerous resource agencies. It contains more than 45,000,000 hourly temperature recordings at more than 15,000 unique stream sites. These temperature data are being used with spatial statistical stream network models to develop a more accurate and consistent baseline for describing current conditions and comparing the impact of future scenarios. NOAA Fisheries and Action Agency contributions to this regional database constitute the primary implementation of AMIP Amendment 3 (2010 Supplemental BiOp, Section 3.2; also see Section 3.9 of this supplemental biological opinion *RPA Implementation to Address the Effects of Climate Change*).

As another example, consistent with the expectation of changes in hydrology, Jefferson (2011) found that transitional areas in 29 watersheds in the Pacific Northwest demonstrate significant historical trends of increasing winter and decreasing summer discharge. Snow-dominated watersheds showed changes in the timing of runoff (22 to 27 days earlier) and lower low-flows (5% to 9% lower) than in 1962.

Crozier (2011, 2012, 2013) also reviewed studies of observed trends in the marine environment, including studies that:

- Reviewed the chemistry of offshore waters near Vancouver Island and the Strait of Juan de Fuca, that indicated increases in dissolved carbon dioxide levels (associated with ocean acidification), which correlated with increases in atmospheric carbon dioxide.
- Described variable reports of trends in coastal upwelling intensity along the Pacific coast, with one recent comprehensive study concluding that upwelling events have become less frequent, stronger, and longer in duration off Oregon and California.
- Tracked low-oxygen (hypoxic) conditions in the Columbia River estuary that are associated with upwelling and may be exacerbated with climate change, and documented decreased oxygen levels off Newport, Oregon and a thickening of the oxygen minimum zone.
- Described changes in sea level height along the Pacific coast, including the effects of local geology and other factors.

[37] NorWest: http://www.fs.fed.us/rm/boise/AWAE/projects/NorWeST.html

2.1.4.4.2 Climate Change Projections

In addition to the reviews of observed changes in climate to date, a considerable body of literature has developed that uses models to project continuing climate change in the Pacific Northwest. These projections are generally consistent with expectations in the 2008 BiOp.

A particularly relevant example is a projection of mainstem Columbia River hydrology under climate change (Brekke et al. 2010; USBR et al. 2011). The Action Agencies are using these projections to plan for flood control, power management, and fish impacts (e.g., summer flow targets per RPA 4) in response to effects of climate change. Hydroregulations based on these climate projections also are being considered in the ongoing Columbia River Treaty review. Numerous other climate projections produced since the 2008 BiOp are included in the state and national climate assessments described above and in Crozier (2011, 2012, 2013).

There have also been advances in projecting tributary temperature and hydrologic changes. A recent example is Wu et al. (2012), who projected decreased summer streamflow (19.3% in 2020s to 30.3% in 2080s) in Pacific Northwest streams and increases in mean summer stream temperatures from 0.92°C to 2.10°C. The simulations indicate that projected climate change will have greater impacts on snow dominant streams, with lower summer streamflows and warmer summer stream temperature changes relative to transient and rain dominant regimes. Lower summer flows combined with warmer stream temperatures suggest a future with widespread increased summertime thermal stress for cold-water fish in the Pacific Northwest region.

An example of new projections of marine effects is Gruber et al. (2012), who estimated changes in ocean acidification in the California Current under two climate change scenarios. Their model projected that by the 2050s, 70% of the euphotic zone (top 60m) of nearshore (within 10km of the coast) habitat will be undersaturated for aragonite (the form of calcium carbonate generally used in shell formation) during the entire summer, and over 50% will be undersaturated year-round, regardless of emissions scenario.

The Pacific Northwest has increased its capacity to both develop downscaled climate projections and to interpret and apply them in recent years. In particular, two consortiums of academic and agency researchers have been formed to address Pacific Northwest climate research and outreach needs: the Climate Impacts Research Consortium[38] and the Northwest Climate Science Center.[39] The Interior Department has formed two Landscape Conservation Cooperatives[40] that generate applied climate research, outreach, and management planning for the Columbia River basin; and

[38] The Climate Impacts Research Consortium is a NOAA-funded consortium of seven universities in Oregon, Washington, Idaho, and western Montana that provides information and tools for making decisions about landscape and watershed management in a changing climate. http://pnwclimate.org/

[39] The Northwest Climate Science Center is an Interior-Department–funded consortium of three universities in Washington, Oregon, and Idaho that develops climate science and decision support tools to address conservation and management issues in the Pacific Northwest Region. http://www.doi.gov/csc/northwest/index.cfm

[40] The Interior Department funds Landscape Conservation Cooperatives (LCC), which are public-private partnerships throughout the U.S. designed to respond to landscape-scale stressors, with an emphasis on climate change. Two LCCs cover most of the Columbia River basin: the Great Northern LCC (http://greatnorthernlcc.org/) and the North Pacific LCC (http://northpacificlcc.org/About).

a variety of other public and private entities are providing and applying climate projections to support adaptation planning in the region.

2.1.4.5 Biological Effects of Climate Change on Salmonids

Recent scientific studies regarding biological effects of climate change are generally consistent with expectations in the 2008 BiOp; however, some studies provide new details and have implications that are particularly relevant to listed salmonids in the Columbia River basin. A few examples follow—details are in Crozier (2011, 2012, 2013) and Crozier and Zabel (2013 DRAFT).

A key piece of new information regarding likely effects of climate change on juvenile salmonid survival is Crozier and Zabel (2013 DRAFT). The 2008 BiOp Section 7.1.1 discussed an earlier version of this analysis (Crozier et al. 2008), which predicted an 18% to 34% decline in parr-to-smolt survival for spring Chinook in the Salmon River Basin in 2040, compared to survival under current climate conditions, as well as a significant increase in extinction risk. We did not quantitatively apply these results to the 2008 BiOp analysis for reasons that included the time frame of the Crozier et al. (2008) analysis, but instead applied a qualitative approach to evaluating the adequacy of the RPA with respect to implementing ISAB (2007) recommendations for climate adaptation actions (2008 BiOp Sections 7.1.2.1 and 8.1.3). The new Crozier and Zabel (2013 DRAFT) analysis updates both the expected climate conditions and the relationship between juvenile survival, summer stream temperature, and fall stream flow. The most recent climate downscaling and hydrological models predict that, although summer stream temperatures will increase, fall precipitation may also increase in the Salmon River basin, reducing some of the impact from rising air temperatures. The analysis found that four of the nine populations evaluated responded negatively to warmer historical temperatures; four had neutral or slightly positive responses, and one population in a very cold stream showed a positive response in warmer years. In model projections that included climate change, abundance declined in five of the populations, but the remaining populations stayed about the same on average across models, or increased. The impact of population declines on the extinction risk within 25 years was minor for all but one population.

Crozier (2011, 2012, 2013) identifies many other recent studies relevant to effects of climate change on freshwater life stages of Pacific Northwest salmon and steelhead. These include studies elucidating effects of temperature and flow (coupled with density) on juvenile growth, survival, and migration timing, as well as projections of expected changes in response to climate change. Results of these studies add detail but are generally consistent with descriptions in ISAB (2007) and the 2008 BiOp. Additional information, particularly for the Fraser River, continues to accumulate for the effects of increasing temperature on adult salmon migration and prespawning survival. As described in the 2010 Supplemental BiOp, this is a key area of concern requiring ongoing monitoring and evaluation. Amendments to the AMIP in the 2010 Supplemental BiOp help to address these concerns.

New projections of the effects of ocean warming on salmon marine distributions are an example of an effect generally considered in the 2008 BiOp, but which new information indicates may be greater than previously anticipated. As described in ISAB (2007) and summarized in the 2008 BiOp, a major concern is the extent to which natural responses to climate change must include range shifts or range contractions, because the current habitat will become unsuitable. Abdul-Aziz et al. (2011) illustrate this point dramatically for Pacific Northwest salmon by showing that climate scenarios imply a large contraction (30%–50% by the 2080s) of the summer thermal range suitable for chum, pink, coho, sockeye, and steelhead in the marine environment, with an especially large contraction (86%–88%) of Chinook salmon summer range under two commonly-used IPCC (2007) greenhouse gas scenarios. Previous analyses focusing on sockeye salmon (Welch et al. 1998) came to similar conclusions, but updated climate change projections and the multi-species perspective make this a particularly relevant study.

As described above, a considerable body of literature regarding actions to allow salmon and steelhead to persist in the face of climate change ("adaptation") has become available since the 2008 BiOp (e.g., the Oregon and Washington climate adaptation plans and the National Climate Adaptation Plan, referenced above). Additionally, new research such as Beechie et al. (2012) describes the best methods to apply for restoring salmon habitat in particular types of environments (e.g., streams in which the hydrology is determined by rainfall, melting snowfall, or a combination of the two). They found that restoring floodplain connectivity, restoring stream flow regimes, and re-aggrading incised channels are the actions most likely to ameliorate stream flow and temperature changes and increase habitat diversity and population resilience. By contrast, they found that most restoration actions focused on instream rehabilitation[41] and controlling erosion and sediment delivery, while important for other reasons, are unlikely to ameliorate climate change effects. This study helps to focus our evaluation in Section 3.9 of the effectiveness of the RPA in promoting adaptation to climate change. Other studies such as Donley et al. (2012) suggest methods and provide case studies for prioritizing recovery actions, such as restoring instream flow, in the face of climate change.

2.1.4.6 Relevance of Climate Information to the 2008/2010 BiOp's Analysis

New observations and predictions regarding physical effects of climate change, as described in Sections 2.1.4.1 and 2.1.4.2, continue to be within the range of assumptions considered in the 2008 BiOp and 2010 Supplemental BiOp. This information applies to both interior and lower Columbia basin salmon and steelhead.

[41] Beechie et al. (2012) defined "instream rehabilitation" as adding stream meanders and channel realignment, addition of rock or wood structure, and adding gravel to streams. Although these are generally less effective at ameliorating climate change effects than other restoration actions, Beechie et al. (2012) did describe particular circumstances under which these actions could also contribute. In addition to the three most effective categories of restoration actions described above, other categories described by Beechie et al. (2010) that ameliorate effects of climate change include barrier removal and restoration of riparian functions (e.g., grazing removal and tree planting).

- Ocean conditions considered in the 2008 BiOp extended through approximately 2001 (e.g., the ICTRT [2007] "Recent" ocean climate scenario represented climate conditions between 1980 and 2001). Climate patterns reflected in the PDO, El Niño indices, upwelling indices, and other ocean ecosystem indicators between 2002 and 2012 are within the range of the three ocean-climate scenarios considered in the 2008 BiOp.
  - ◊ Average 2002 through 2012 conditions, as defined by the PDO, were more similar to the "Historical" climate scenario than to the "Recent" or "Warm PDO" scenarios, which are less favorable to salmon survival, for factors such as the PDO and El Niño indices. Recent El Niño and upwelling conditions either did not differ or were generally more favorable than the Recent and Warm PDO scenarios. Because the 2008 BiOp primarily relied upon the "Recent" climate scenario in the quantitative analysis for interior Columbia Basin species, average ocean conditions to date have been similar or more favorable for salmon survival than assumed in the 2008 BiOp.
  - ◊ Although the average ocean conditions between 2002 and 2012 have been similar or more favorable for salmon survival than Base Period assumptions under the Recent climate scenario, poor ocean conditions still occurred during this period, particularly in 2003, 2004, 2005, and 2010.
- Predictions of future ocean conditions as climate continues to change are also within the range of expectations in the 2008 BiOp. New information continues to add detail to the previous expectations, including predictions of northward-shifting isotherms, increasing ocean acidity, and higher sea levels. Some marine effects of climate change remain uncertain, such as the future pattern of upwelling (whether it will intensify or diminish) and the future pattern of broad-scale indices such as the PDO.
- The 2008 BiOp did not include freshwater climate change scenarios or estimate resulting changes in salmon and steelhead survival. Instead, continuing Base Period (through approximately 2001) freshwater climate conditions were implicit in quantitative analyses for interior Columbia basin salmonids and future freshwater climate change was considered qualitatively. Some freshwater climate factors have remained consistent with observations during the 2008 BiOp's Base Period, while others are more consistent with the 2008 BiOp's qualitative expectations for future climate.
  - ◊ Average flow in the mainstem Columbia River since 2001 has been nearly identical to average Columbia River flow during the 2008 BiOp's Base Period.

- ◊ Average fall streamflow in the Salmon River basin since 2001 has been lower than the average fall streamflow during the 2008 BiOp's Base Period, which is consistent with qualitative expectations under climate change in the 2008 BiOp.
- ◊ Average summer stream temperature (as inferred from air temperature per Section 2.1.4.1.5) in the Salmon River basin since 2001 has been higher than the average temperature during the 2008 BiOp's Base Period, although the difference is not statistically significant. The higher summer stream temperatures were anticipated as a result of climate change in the 2008 BiOp.

- ▪ More recent predictions of freshwater streamflow and temperature are generally unchanged from those included in the 2008 BiOp (e.g., increasing temperatures and changes in seasonal hydrology with higher winter and spring flows and lower summer and fall flows due to a decrease in the percentage of precipitation falling as snow).

New studies of biological effects of climate change on salmon and steelhead, as described in Section 2.1.4.2, are generally consistent with expectations in the 2008 BiOp, but provide additional details on those effects.

- ▪ The 2008 BiOp indicated that warming stream temperatures could have positive or negative effects on juvenile salmonid growth, depending on available food and density. New studies provide a greater understanding of the interactions between stream temperature, food availability, fish density, and growth of juvenile salmonids, indicating the situations under which increasing stream temperatures will be beneficial, detrimental, or have little effect.
- ▪ The 2008 BiOp generally assumed that parr-to-smolt survival of interior Columbia basin spring Chinook would decline substantially for most, if not all, populations. A new study indicates that this is most likely the case for populations with survival correlated primarily with summer stream temperatures. However, survival is likely to increase for populations more dependent upon fall stream flow. In this study, most of the Salmon River populations examined were in the first category. The impact of these projected survival changes on extinction risk was minor over the next 25 years for all but one of the nine populations in the study.
- ▪ Juvenile studies confirm general expectations in the 2008 BiOp of changes in mainstem migration timing and life history strategies in response to higher temperatures.
- ▪ The new information on non-indigenous fishes provides additional detail to the general response of warm-water predators considered in the 2008 BiOp: their ranges

are expected to expand and predation rates are likely to increase as temperatures warm.

- Most studies related to climate effects on estuary and ocean productivity offer new details on biological effects but do not differ substantively from factors previously considered in the 2008 BiOp. Examples include predictive modeling of reduced ocean salmon survival and a decline in fisheries as ocean temperatures warm and available marine habitat moves northward and becomes compressed and new predictive modeling of ocean acidification off Oregon and California.
- As described in the 2010 Supplemental BiOp, new studies document effects of higher temperatures on modified adult migration timing and on reduced adult survival and spawning success in the Snake and Columbia rivers. These factors were considered generally in the 2008 BiOp, but new studies provide greater detail. Tributaries in the lower Columbia are identified as containing thermal refugia for both steelhead and Chinook. Some new studies indicate that the utility of thermal refugia is reduced by harvest targeting fish in thermal refugia. Amendments added to the AMIP in the 2010 Supplemental BiOp help to address this growing concern with adult migration.

New research and plans for climate change adaptation are consistent with ISAB (2007) and expectations of the 2008 BiOp. The types of monitoring and adaptation actions identified by ISAB (2007) and implemented through the RPA are consistent with the types of adaptation actions described in current literature. New literature such as Beechie et al. (2012) provides additional guidance on the habitat restoration actions most likely to be effective in responding to climate change.

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2.2 Environmental Baseline

The environmental baseline includes "the past and present impacts of all Federal, state, or private actions and other human activities in the action area, including the anticipated impacts of all proposed Federal projects in the action area that have undergone Section 7 Consultation and the impacts of state and private actions that are contemporaneous with the consultation in progress" (50 CFR § 402.02, "effects of the action"). Chapter 5 of the 2008 Supplemental Comprehensive Analysis (SCA), which NOAA Fisheries incorporated by reference into Chapter 5 of the 2008 BiOp, discussed the environmental baseline in detail for multiple species. Additionally, individual species chapters (Chapters 8.2–8.14) discussed the effects of past and ongoing human and natural factors on the current status of each species and its habitats and ecosystems within the action area. That analysis included effects on designated critical habitat.

The 2008 BiOp considered environmental baseline effects qualitatively for all species. Additionally, for six interior Columbia basin salmonid species, NOAA Fisheries quantified expected changes in population survival, compared with average survival rates associated with the 2008 BiOp's Base Period (see Section 2.1.1.4.1: *Review of the 2008 BiOp Indicator Metrics and What They Represent*). As described in the 2008 BiOp, Section 7.1.1, quantitative analyses were based on the retrospective performance of populations during a historical Base Period (reviewed for a longer "extended Base Period" in Section 2.1.2). The fundamental assumption in the analyses is that all factors influencing population performance during the Base Period would continue into the future, within a range of observed variation, unless some factor affecting the survival or reproduction of the population has changed, or is expected to change, from the average historical condition.

The 2008 BiOp identified "current" management actions and other factors such as predation rates that had changed, relative to mean survival associated with that factor during the Base Period. Note that the survival rate changes associated with current actions were not necessarily those occurring at the time of the 2008 BiOp, but were expected after current actions were fully implemented and survival changes were expressed over the entire life cycle. For example, some types of habitat actions may take years before they are fully implemented if changes in vegetation or streambed morphology are expected, and all actions might take multiple generations before productivity changes resulting from the actions can be detected. In the 2008 BiOp's quantitative aggregate analysis (Figure 7.1-1 and Table 8.3.3-1 of the 2008 BiOp; Figure 2.2-1 in this supplemental opinion), the change from a factor's Base Period average survival rate to the Current action survival rate was expressed as a Base-to-Current survival multiplier. Section 7.1.1 of the 2008 BiOp describes the details of this calculation, which was based on the ICTRT (2007) "gap analysis" method.

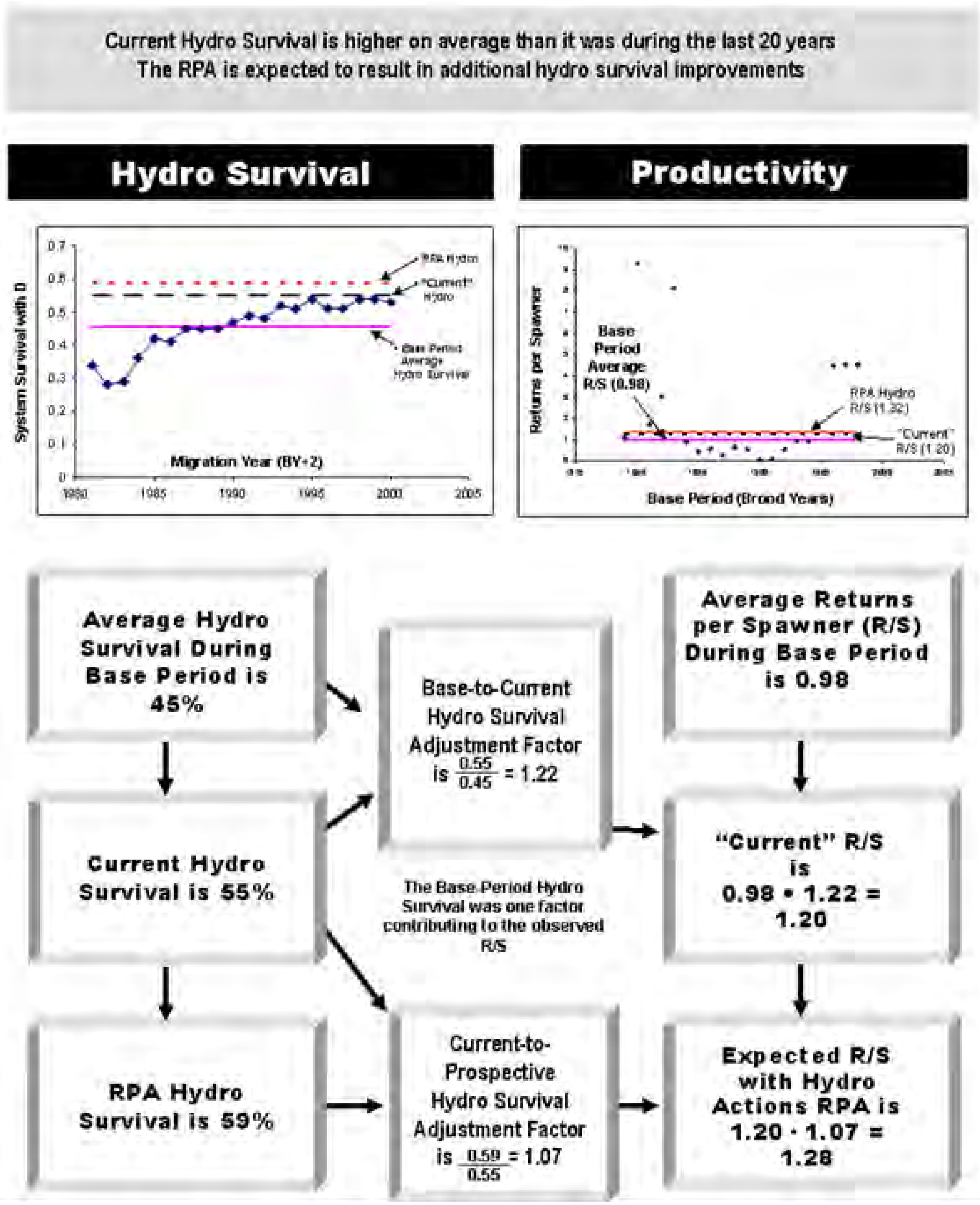

Figure 2.2-1. Schematic showing the method of applying survival changes that have occurred during the Base Period to a "Base-to-Current" productivity adjustment factor and method of applying expected prospective survival changes (i.e., RPA actions) to a "Current-to-Future" productivity adjustment factor. This example is reproduced from the 2008 BiOp Figure 7.1-1 and detailed methodology is described in the 2008 BiOp Section 7.1.1. This example uses average returns-per-spawner (R/S) as the productivity estimate, applied to the Marsh Creek population of Snake River spring/summer Chinook. Numbers reflect those available at the time of the 2008 BiOp.

Sections 2.2 through 2.7 of the 2010 Supplemental BiOp reviewed new information that was relevant to both the environmental baseline and implementation of the 2008 BiOp's RPA for each of the effects listed above. These reviews concluded that the new information was generally in accordance with the expectations, assumptions, and analyses of the 2008 BiOp. One area that was identified as needing further review was the historical pattern of cormorant predation and its potential effect on the 2008 BiOp's quantitative analysis for some species.

In this supplemental opinion, we again review new information relevant to the environmental baseline. We consider climate and climate change in Section 2.1.4 because it affects listed species and critical habitat both within and outside of the action area and it can significantly affect current and future status of the species. New information regarding effects of hydrosystem, tributary habitat, and estuary and plume habitat actions that have resulted from implementation of the 2008 BiOp's RPA are described in Section 3. In this section, we review new information regarding all of the factors influencing the environmental baseline that were discussed in the 2008 BiOp.

For the six interior Columbia basin species included in the 2008 BiOp's quantitative aggregate analysis, we review the methods and information used to calculate the Base-to-Current survival multipliers for each environmental baseline impact[42] included in the 2008 BiOp's aggregate analysis. Because we have concluded in Section 2.1.1.4.3 that the underlying Base Period status of each species has not changed with the inclusion of additional years of demographic data—and because all years of RPA implementation are included in effects of the RPA (rather than in the environmental baseline)—we did not recalculate Base-to-Current multipliers to reflect time periods that differed from those in the 2008 BiOp analysis. Instead, we reviewed Base Period and current management actions and their effects (at the time of the 2008 BiOp) to determine if new information suggested modifying the 2008 BiOp's Base-to-Current survival change estimates.

[42] Prospective effects of ongoing FCRPS operations are properly included only in the proposed action (RPA), rather than in prospective effects of the environmental baseline. However, because the 2008 BiOp's aggregate analysis is based on proportional changes from survival during the Base period for which salmonid demographic information was available, and because the Base-to-Current and Current-to-Prospective survival multipliers are cumulative, Base-to-Current FCRPS hydrosystem survival changes were described with other Base-to-Current survival changes in the environmental baseline sections of the 2008 BiOp (e.g., Section 8.3.3.1 for SR spring/summer Chinook). Mathematically, it makes no difference whether the FCRPS hydro effects are divided in this manner or if a single Base-to-Prospective survival multiplier is estimated for the effects of the RPA FCRPS hydro actions.

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2.2.1 Hydrosystem Effects

2.2.1.1 New Hydrosystem Environmental Baseline Effects

In January 2013, NOAA Fisheries issued a biological opinion (NMFS 2013e) on Reclamation's proposed Odessa Subarea Groundwater Replacement Project (OSGRP). The project entails replacing the groundwater source for irrigating 70,000 acres within the existing boundaries of the Columbia Basin Project with surface water from the Columbia River at Lake Roosevelt. Following full implementation, the OSGRP would withdraw an average of 164,000 acre-feet of water annually from Lake Roosevelt via the Keys Pumping Plant at Grand Coulee Dam. The project was substantially changed during the ESA consultation process to reduce impacts to ESA-listed salmon and steelhead. The project will divert water at the John W. Keys III Pump-Generating Plant primarily during October each year, with much smaller amounts (not more than 350 cfs) of diversions from November through March if it is not possible to divert the entire 164,000 acre-feet during October. The newly diverted water would be used to refill Banks Lake. During the irrigation season, Banks Lake would be drafted to serve lands receiving OSGRP water. No additional withdrawals of water from the Columbia River during the irrigation season (April through September) would occur.

Reclamation anticipates it will take over 10 years to fully implement the project and, as of May 2013, construction work had not yet begun. For this consultation, we are evaluating the environmental baseline as if this project were fully developed and operating as proposed. Adding this project changes the hydrologic conditions described in Section 5 of the 2008 SCA, thus it increases the total depletion of October flow at Bonneville Dam by 2,667 cfs, raising the total October depletion to 5,545 cfs—which would reduce the Current average flow for October to 110,350 cfs (see 2008 SCA, Table 5.1-3)—still substantially higher than estimated average unregulated flows of 87,115 cfs at Bonneville Dam (see 2008 SCA, Figure 5.1-2). Table 2.2-1 depicts the current hydrologic baseline conditions at Bonneville Dam for this supplemental opinion, including full build out of the OSGRP.

Table 2.2-1. Simulated mean monthly Columbia River flows at Bonneville Dam under current conditions including the full build-out of Reclamation's Odessa Subarea Groundwater Replacement Project (Sources: Figure 5.1.2 in NMFS 2008 SCA; NMFS 2013e).

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Current 2008 SCA	113017	128641	149403	189076	175921	172150	225689	293948	313930	218523	157935	109020
Odessa	-2667	0	0	0	0	0	0	0	0	0	0	0
New Baseline	110350	128641	149403	189076	175921	172150	225689	293948	313930	218523	157935	109020

The Corps estimated that a 2,700 cfs flow reduction at Grand Coulee Dam would change river stage at Portland by about two hundredths of a foot for short periods during the tidal cycle. The anticipated 2.4% flow reduction in October corresponds with active adult migration for fall-run Chinook salmon from the Snake and lower Columbia River ESUs, LCR coho salmon, and CR chum salmon. This small relative change in flow is not likely to affect the behavior of adult migrants, but could reduce, very slightly, the availability of suitable spawning habitat for early spawning chum salmon in shallow mainstem habitat used by the Lower Gorge and Washougal populations.[43]

Contingent withdrawals during November through January could reduce the availability of suitable spawning habitat or the ability to maintain flow over established, incubating redds in shallow mainstem habitat. The contingent withdrawals represent 0.26% to 0.19% of the average monthly flows in the lower Columbia River below Bonneville Dam during November through March. In the event that a contingent withdrawal for the Odessa Project occurred when chum spawning flows were already not being met under RPA 17, the Odessa Project withdrawal would be limited to 100 cfs, a 0.07% reduction, which would have negligible further effects on spawning and incubating chum.

Some juvenile salmon and steelhead from each interior and lower Columbia basin ESU and DPS could be in the mainstem during October through March. Effects on these individuals are likely to be limited to small lateral changes in position relative to the shoreline to maintain position in the preferred section of the flow field.

2.2.1.2 Review of the 2008 BiOp's Base-to-Current Estimates for Hydrosystem

The 2008 BiOp's Appendix E reported estimates of FCRPS juvenile "system survival" (combined inriver and transported fish survival), including post-Bonneville effects of transportation and estuary arrival timing on smolt-to-adult returns (SAR), for a Base Period of 1980 through 2001 outmigration years and a Current operation defined as 2004 FCRPS BiOp operations and actions implemented through 2006 (2008 BiOp Section 7.2.1.1). NOAA Fisheries used the COMPASS model (Zabel et al. 2007) to estimate juvenile survival under continuing Current operations (at the time of the 2008 BiOp), averaged across a range of hydrologic conditions. We used empirical estimates of historical inriver and transport percentages and juvenile survival rates to generate Base Period system survival estimates consistent with ICTRT analyses (ICTRT and Zabel 2007), and then factored in average post-Bonneville effects using the COMPASS-derived Current SARs (2008 BiOp, Appendix E, Footnotes 1 and 2). The 2008 BiOp's aggregate analysis for six interior Columbia basin species relied on the Appendix E Base-to-Current multipliers derived from these SAR estimates (e.g., 1.20 for SR spring/summer Chinook in first table of Appendix E and in Table 8.3.3-1). The conservative assumption inherent in this approach was that post-Bonneville Base-to-Current juvenile survival did not change, even though juvenile system survival improved (2008 BiOp Section 7.2.1.1, Footnote 3).

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[43] The Washougal population of CR chum salmon includes the mainstem spawners near the Interstate Highway 205 bridge.

Additionally, NOAA Fisheries implicitly assumed that adult survival through the FCRPS did not change from the Base to the Current condition.

NOAA Fisheries found no changes in the methods or data used to generate the hydro Base-to-Current estimates in the 2008 BiOp. The historical hydro survival estimates used by ICTRT and Zabel (2007) have not changed and the COMPASS model has not been modified in a manner that would change the estimates of survival associated with 2004 FCRPS BiOp operations. Therefore, NOAA Fisheries continues to rely on the hydro Base-to-Current estimates included in the 2008 BiOp.

2.2.1.3 Hydrosystem Effects on Critical Habitat under the Environmental Baseline

In the 2008 BiOp, we reviewed the effects of the Columbia basin development for hydropower, flood control, navigation, and irrigation, which includes water storage operations in Canada and the Columbia and upper Snake basins, as well as the past effects of the existence and operation of the mainstem run-of-river FCRPS and similar projects, on the PCEs of designated critical habitat (see species-specific discussions in the 2008 BiOp, such as in sections 8.2.3.3 for SR fall Chinook salmon, 8.3.3.3 for SR spring/summer Chinook salmon, 8.4.3.7 for SR sockeye salmon, etc.). These descriptions of the environmental baseline remain accurate for this consultation. Effects to critical habitat PCEs include:

- Juvenile and adult mortality in the mainstem lower Snake and lower Columbia River hydropower system (PCEs are juvenile and adult migration corridors with safe passage)
- Scarcity of cover in mainstem reservoirs as refuge from fish predators such as smallmouth bass and northern pikeminnows (PCEs are juvenile and adult migration corridors with safe passage)
- Altered seasonal flow and temperature regimes (PCEs are water quantity and quality)
- Reduced mainstem spawning/rearing habitat for SR fall Chinook salmon due to inundation by the reservoirs behind Lower Granite Dam and Idaho Power Company's Hells Canyon Complex and for the Lower Gorge population of CR chum salmon in the Bonneville tailrace (PCEs are spawning areas with gravel, water quality, cover/shelter, riparian vegetation, and space to support egg incubation and larval growth and development)

As described in the 2008 BiOp, the Action Agencies have taken a number of actions in recent years to improve the conservation value of PCEs in the migration corridor for all listed Columbia basin salmonids. For example, the essential feature of safe passage for ESA-listed outmigrating juvenile salmonids at FCRPS dams in the lower Snake and Columbia rivers has been improved by a number of structural improvements and operations described in Section 4.3.1.1 of the 2007 Comprehensive Analysis (USACE et al. 2007a, *hereafter* 2007 CA). These include the construction and operation of surface bypass routes at all eight projects and new spill patterns to provide attraction flows to surface bypass weirs.

With respect to flow management and water quality, Idaho Power Company began voluntarily stabilizing outflows from Hells Canyon Dam during late October and November in 1991, keeping SR fall Chinook redds established during that period "watered" through emergence in April. The functioning of mainstem spawning habitat for CR chum salmon has improved in recent years with FCRPS flow operations that provide fall and winter flows for spawning, incubation, and emergence in the tailrace of Bonneville Dam. These flows also provide access to spawning areas in Hardy and Hamilton creeks.

To improve water quality, the Corps began drafting Dworshak Reservoir in 1993 to add cooler water to the lower Snake juvenile migration corridor during summer. Reclamation also provides flow augmentation from the upper Snake basin that enhances flows (water quantity) in the lower Snake and Columbia rivers during July and August.

Hydrosystem effects on recently proposed critical habitat for LCR coho salmon are identical to those for other Columbia basin salmon and steelhead in the mainstem migration corridor below The Dalles Dam. Specifically, coho populations in the Columbia River gorge are subject to juvenile and adult mortality at Bonneville Dam (migration corridors with safe passage). The functioning of this PCE for all juvenile outmigrants, including LCR coho salmon, improved with the addition of the Bonneville Powerhouse 2 corner collector.

2.2.2 Tributary Habitat Effects

2.2.2.1 New Tributary Habitat Environmental Baseline Effects

In NMFS (2008), we reviewed the status of the listed species and their habitat in both the interior and lower Columbia basin tributaries under the environmental baseline.[44] Several dams that were previously licensed by the Federal Energy Regulatory Commission and had limited the spatial structure of Chinook, coho, and steelhead populations in lower Columbia tributaries are now removed (Portland General Electric’s Bull Run Project on the Sandy River—Marmot and Little Sandy dams; Powerdale Dam on the Hood River; and Condit Dam on the White Salmon River) as anticipated in the 2008 BiOp. These watersheds are now recovering their habitat function and are expected to produce natural-origin populations of LCR spring- and fall-run Chinook salmon, LCR coho salmon, and LCR steelhead in the coming years. With respect to UWR Chinook salmon and steelhead, the Willamette Project action agencies have implemented a number of measures since 2008 to address factors limiting the viability of these species (Section 2.1.2.5).

New information on the conditions of spawning populations and habitat within the interior Columbia basin tributaries is developed through the tributary habitat RME program (RPA Actions 56 and 57). This work includes “status and trends” monitoring through which the Action Agencies are characterizing fish–habitat relationships at the ESU/DPS, MPG, and population levels across the interior Columbia basin. This program (called the Columbia Habitat Monitoring Program or CHaMP) is under development with oversight by the NPCC and the Independent Science Review Panel. Preliminary results are available at this time and are discussed in Section 3.1. This program will inform future biological opinions on the FCRPS and other Federal actions.

With respect to NOAA Fisheries’ ongoing Section 7 consultation program, Federal agencies continue to implement projects within these areas such as forest thinning, grazing, bridge repairs, bank stabilization, and road construction/maintenance that have neutral or short- or even long-term adverse effects on viability. Other Federal actions benefit the viability of the affected populations by improving access to blocked habitat, preventing entrainment into irrigation pipes, increasing channel complexity, and creating thermal refuges. Some restoration actions have negative effects during construction, but these are expected to be minor, occur only at the project scale, and persist for a short time (no more and typically less than a few weeks). All of these actions have met the ESA standards for avoiding jeopardy.

These same types of projects continue to affect the functioning of the PCEs of safe passage, spawning gravel, substrate, water quantity, water quality, cover/shelter, food, and riparian vegetation. Projects implemented for purposes other than habitat restoration (forest thinning, grazing, bridge repairs, etc.) have neutral or have short- or even long-term adverse effects on

[44] Columbia basin tributaries are within the action area for this consultation because they are the locations where the RPA habitat and hatchery mitigation programs (RPA Actions 54 and 55 and 39 through 42, respectively) are implemented.

some of these PCEs. However, all of these actions have met the ESA standards for avoiding any adverse modification of critical habitat.

2.2.2.2 Review of 2008 BiOp's Base-to-Current Estimates for Tributary Habitat

NOAA Fisheries included Base-to-Current tributary habitat survival estimates ranging from 0% to 8.5% improvements (i.e., 1.00 to 1.085 survival multipliers) in the 2008 BiOp, Tables 8.2.3-1 (SR fall Chinook); 8.3.3-1 (SR spring/summer Chinook); 8.5.3-1 (SR steelhead); 8.6.3-1 (UCR spring Chinook); 8.7.3-1 (UCR steelhead); and 8.8.3-1 (MCR steelhead). These estimates represented the incremental (compared to pre-2000) survival improvements expected from tributary habitat projects implemented by the Action Agencies between 2000 and 2006. The Action Agencies estimated these survival changes using the methods described and reviewed in Section 3.1.1 of this supplemental opinion. Base-to-current estimates for most populations were based on what is referred to as the "updated method" in Section 3.1.1 (the "hybrid method" of the 2007 CA, Appendix C, Attachment C-1), which was developed by the Remand Collaboration Habitat Work Group, with estimates informed by a series of meetings with local experts in 2006 and 2007. Base-to-Current estimates for MCR steelhead were based on the "Appendix E method" described in Section 3.1.1, which NOAA Fisheries had applied in the 2004 FCRPS BiOp.

As described in Section 3.1 of this supplemental opinion, NOAA Fisheries finds the tributary habitat survival methodology applied in the 2008 BiOp used the best available scientific information for assessing the effects of actions occurring across the Columbia River basin and affecting multiple ESUs and DPSs. The expert panel process has not modified the original estimates of effects of 2000–2006 projects, so NOAA Fisheries continues to rely upon the tributary habitat Base-to-Current estimates included in the 2008 BiOp.

2.2.2.3 Tributary Habitat Effects on Critical Habitat under the Environmental Baseline

In the 2008 BiOp, we reviewed the effects of tributary habitat conditions, including human activities, on the PCEs of critical habitat used by stream-type fish for spawning and rearing (see species-specific discussion in the 2008 BiOp, sections 8.3.3.3 for SR spring/summer Chinook salmon, 8.4.3.7 for SR sockeye salmon, 3.5.3.3 for SR steelhead, etc.). These descriptions are still accurate today. Effects include

- physical passage barriers such as culverts, push-up dams, and low flows (PCEs are freshwater migration corridors free of obstruction);
- reduced usable stream area and altered channel morphology due to urban and rural development, low flows, bank hardening, and livestock use of riparian areas (PCEs are freshwater rearing sites with water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility) ;

- excess sediment in gravel due to roads, mining, agricultural practices, livestock use of riparian areas, and recreation (PCEs are freshwater spawning sites with substrate supporting spawning, incubation, and larval development); and
- elevated summer temperatures and, in some cases, chemical pollution from mining (PCEs are freshwater spawning sites with water quality supporting spawning, incubation, and larval development).

In recent years, the Action Agencies, in cooperation with numerous non-Federal partners, have implemented actions to address limiting factors for listed salmonids in spawning and rearing areas of their critical habitat. These include acquiring water to increase streamflow, installing or improving fish screens at irrigation facilities to prevent entrainment, removing passage barriers and improving access, improving channel complexity, and protecting and enhancing riparian areas to improve water quality and other habitat conditions.

Tributary habitat effects on recently proposed critical habitat for LCR coho salmon under the environmental baseline are identical to those for LCR Chinook salmon and steelhead. In addition to the general effects described above, dam removal actions at FERC-licensed hydroelectric projects in the White Salmon and Hood rivers have addressed key factors limiting the functioning of PCEs for LCR coho salmon, which has spawning populations in those tributary watersheds.

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2.2.3 Estuary and Plume Habitat Effects

2.2.3.1 New Estuary and Plume Habitat Environmental Baseline Effects

In NMFS (2008), we reviewed the status of the listed species and their habitat under the environmental baseline in the lower Columbia River estuary and the plume. New information on the conditions of juvenile salmonids and rearing and migration habitat is developed through the RME program (RPA Actions 58 through 61). The Action Agencies describe their results to date in the 2013 Draft CE with some important points summarized below.

Estuarine land use: New information since the 2010 Supplemental BiOp includes the Lower Columbia Estuary Partnership's (LCEP) characterization of net habitat change on the floodplain below Bonneville Dam. They compared land cover data for 2010 to Geographic Information System (GIS) interpretations of late-1800s survey maps; the first time that current habitat has been compared to the "pre-development" condition for the entire tidally-influenced lower Columbia River. The LCEP's objective was to identify the natural habitat diversity that existed previously in the lower Columbia and then those habitats for which significant coverage is now lost or rare. The comparison showed a 70% loss of vegetated tidal wetlands and 55% of forested uplands (Corbett 2013). There has also been a significant conversion of tidal wetlands to non-tidal wetlands. Most of these losses were due to the conversion of land for agriculture and urban development. The LCEP's goal is to prioritize the remaining intact areas of these habitat types for protection or for restoration where practical.

In addition, the Action Agencies are developing information on the status of estuary habitat through the RPA's RME program (Actions 58 through 61; see description of accomplishments in Section 2 of the 2013 Draft CE). As part of this work, Diefenderfer et al. (2013) measured trends in habitat condition on the estuary floodplain in the ten-year period between 1996 and 2006. Urbanization has reduced the floodplain habitat by 8.3 km^2 and loss of forest cover has altered habitat function in another 13.3 km^2.[45] In comparison, the Action Agencies' estuary habitat program has reconnected and improved the condition of about 10.8 km^2 of floodplain land area. Over the same time period, large areas of habitat in the watersheds that contribute to the lower Columbia River also were lost to urbanization (48.4 km^2) or altered by a decrease in forest cover (189.0 km^2). These losses may be having additional adverse effects on the condition of estuary habitat.

Estuarine water quality: In terms of changes in estuarine conditions away from the shoreline, Roegner et al. (2011) observed that low oxygen sea water intruded along the bottom of the lower estuary during the summers of 2006 through 2008, with minimum oxygen concentrations close to the hypoxic threshold of 2.0 mg/L. In contrast, concentrations in the overlying Columbia River water were within the normal range (from greater than 6 to about 9 mg oxygen/L). Low

[45] Conversion: 1 km = 0.621371 miles

oxygen water intruded the farther along the bottom in the estuary and stayed there longer during strong coastal upwelling events that coincided with neap (weak) tides.[46] Upwelled waters are naturally acidic (i.e., low pH) due to the respiration of marine organisms and the added contribution of anthropogenic carbon dioxide. Acidic marine waters can become corrosive to shell-forming organisms such as oyster larvae, clams, mussels, crabs, and pteropods.

Future effects of Federal actions in the Columbia River estuary with completed Section 7 consultations: With respect to NOAA Fisheries' ongoing Section 7 consultation program, Federal agencies continue to implement projects within the estuary such as maintenance dredging, bridge repairs, bank stabilization, and road construction/maintenance that have neutral or short- or even long-term adverse effects on viability. Other Federal actions benefit the viability of the affected populations by improving access to blocked habitat and creating thermal refuges. Some restoration actions have negative effects during construction, but these are expected to be minor, occur only at the project scale, and persist for a short time (no more and typically less than a few weeks). All of these actions have met the ESA standards for avoiding jeopardy.

These same types of projects continue to affect the functioning of the PCEs safe passage, substrate, water quantity, water quality, cover/shelter, food, and riparian vegetation. Projects implemented for purposes other than habitat restoration have neutral or have short- or even long-term adverse effects on some of these PCEs. However, all of these actions have met the ESA standards for avoiding any adverse modification of critical habitat.

Plume conditions—bottom-up control of salmon survival (food webs): Jacobson et al. (2012) describe new scientific information on conditions in the plume and nearshore ocean, developed in response to RPA Actions 58 through 61 (see description of Action Agency accomplishments in Section 2 of the 2013 Draft CE). Results suggest that juvenile salmon survival is set within the first year of marine residency and is partially related to food-web structure and growth conditions in the plume and coastal ocean. As salmon grow older (and larger) during their first summer at sea, the frequency of juvenile fishes in their stomachs tends to dominate over that of krill and other invertebrates. This shift to a fish-based diet appears to be important to the marine growth and survival of juvenile Chinook and coho salmon. The ocean projects have focused on understanding interannual variation in prey quantity and quality (lipid content). From 1999 to 2012, there was strong evidence that source waters for the Northern California Current drove the composition of the plankton community that anchored the food web and juvenile salmon growth and survival and thus adult returns. If the source waters originated from the north, then the plankton communities were dominated by "northern" copepods, which have a high fat content

[46] The physical structure within the estuary normally alternates between two conditions: one that is weakly stratified, occurring during low flow periods with strong tides, and one that has a salt-wedge, and thus stratification. The salt-wedge travels up and down the river, commensurate with the balance between river flow and tides (Newton et al. 2012). When the sun and moon are at right angles to each other, the Sun's effect on the tide partially cancels out the Moon's effect, producing moderate tides known as neap tides. (http://oceanservice.noaa.gov/education/kits/tides/media/supp_tide06a.html)

and high levels of omega-3 fatty acids. Conversely, if source waters originated from offshore, the plankton community was dominated by small "subtropical" species with low lipid content. Given that subtropical species are deficient in omega-3 fatty acids and rich in saturated fat, it is logical to assume that salmon growth and survival would be higher during years when lipid-rich northern copepods dominate, since they result in lipid-rich forage fish and krill upon which salmon feed. However, the 2013 spring Chinook return to the Columbia River was low, despite observations of a nearshore food web anchored by northern copepods in 2011 and good juvenile growth. Low zooplankton and larval/juvenile fish abundances in the Gulf of Alaska in 2011 may have resulted in this discrepancy (Beckman 2013), indicating that control of adult returns can happen at different points in the ocean life phase.

Plume conditions—top-down control of salmon survival (marine bird predation): Bird predators, especially common murres (*Uria aalge*) and sooty shearwaters (*Puffinus griseus*) are significantly more abundant in the plume than elsewhere on the Oregon or Washington continental shelf. Surveys along five transects radiating out from the mouth of the Columbia River showed that murres and shearwaters not only aggregated in the plume, but were typically within the region containing the most recently discharged river water (Zamon et al. 2013). There are no direct estimates of marine mortality caused by avian predators in the ocean.

2.2.3.2 Review of 2008 BiOp's Base-to-Current Estimates for Estuary Habitat

NOAA Fisheries included Base-to-Current estuary habitat survival estimates ranging from 0.7% for SR fall Chinook to 0.3% for the other five interior Columbia species included in the 2008 BiOp's quantitative aggregate analysis (2008 BiOp, Tables 8.2.3-1, 8.3.3-1, 8.5.3-1, 8.6.3-1, 8.7.3-1, and 8.8.3-1). These estimates represented the incremental (compared to pre-2000) survival improvements expected from 21 estuary habitat projects implemented by the Action Agencies between 2000 and 2006. The Action Agencies estimated these survival changes using the methods described in the 2007 CA, Appendix D, which were based on NOAA Fisheries' draft Columbia River Estuary Recovery Plan Module (NMFS 2006).

As described in Section 3.2 in this supplemental opinion, current methods for estimating survival improvements from estuary projects have been improved and NOAA Fisheries concludes that it represents the best available approach. Estimates based upon the earlier method used to characterize the projects implemented in 2000 to 2006 may be somewhat less certain, but no update of the estimates are available. Because the estimated Base-to-Current estuary improvements in the 2008 BiOp were extremely low, it is unlikely that recalculation using the new expert group and methodology would have a discernible impact on the 2008 BiOp's assumptions or analyses. Therefore, NOAA Fisheries continues to rely upon the estuary Base-to-Current survival estimates included in the 2008 BiOp.

2.2.3.3 Estuary Habitat[47] Effects on Critical Habitat under the Environmental Baseline

In the 2008 BiOp, we reviewed the effects of habitat conditions in the lower Columbia River estuary, including human activities, on the PCEs of critical habitat used by juvenile salmonids for rearing and migration (see sections 8.2.3.3 for SR fall Chinook salmon, 8.3.3.3 for SR spring/summer Chinook salmon, 8.4.3.7 for SR sockeye salmon, 3.5.3.3 for SR steelhead, etc.). The conditions described in 2008 and 2010 remain relevant without change for this 2013 consultation. The principal effects are the loss of shallow water, low velocity habitat that could provide sites used for rearing by some juveniles and export prey to the main channel for others. These changes are the result of diking for agriculture and urban/rural development and reduced spring flows from upper Columbia basin water management. Recent habitat improvement projects have restored riparian areas and breached or lowered dikes and levees to provide access to the cover/shelter, food, and riparian vegetation required by juvenile migrants. These effects also apply to recently proposed critical habitat for LCR coho.

[47] Although Columbia basin salmonids spend part of their first year in the ocean in the Columbia River plume, NOAA Fisheries has not designated critical habitat in marine waters.

2.2.4 Predation Effects

Section 5.4 of the 2008 BiOp described environmental baseline effects of predation by warm-water fish species, birds, and pinnipeds (seals and sea lions).

Because the RPA includes actions to address fish predation, this factor is discussed under RPA implementation in Section 3. No Base-to-Current survival changes were estimated for predation by predatory fish and we found no new information that would change this conclusion.

The 2008 BiOp described environmental baseline effects of predation by a number of bird species, including Caspian terns, double-crested cormorants, ring-billed and California gulls, and American white pelicans. All are addressed to some extent by the RPA, and Section 3 of this supplemental opinion describes progress on the relevant RPA Actions. Trends in predation by cormorants have particular relevance to the environmental baseline (see review in the 2010 Supplemental BiOp, Section 2.2.5.1) and to the 2008 BiOp's estimates of Base-to-Current survival changes, so these effects are detailed in this section.

The 2008 BiOp described environmental baseline effects of pinniped predation, including effects of the state and tribal sea lion removal program (2008 SCA, Section 5.4.1.3 and Appendix G). The 2010 Supplemental BiOp, Section 2.2.5.3, updated this information and we review the most recent scientific information in this section.

2.2.4.1 New Predation Environmental Baseline Effects

Avian Predation

New studies of cormorant predation since the 2008/2010 BiOps are described in Fredericks (2013) and summarized here. The number of double-crested cormorants inhabiting colonies in the Columbia River estuary increased from an estimated 150 pairs in the early 1980s to over 6,000 pairs in the late 1990s. Numbers increased in the early 2000s, but appear to have finally stabilized, varying between about 11,000 to 13,500 pairs during the past ten years (Fredricks 2013). Double-crested cormorant consumption rates of juvenile salmon and steelhead increased throughout this period as well, peaking in 2006, when double-crested cormorants are estimated to have consumed about 13% of the interior Columbia basin juvenile steelhead and over 4% of the juvenile yearling Chinook salmon. Juvenile subyearling Chinook salmon from the Lower Columbia and Upper Willamette River ESUs are also consumed at relatively high rates—more likely similar to rates estimated for steelhead than for yearling Chinook salmon assuming they spend more time rearing in the estuary than do interior basin yearling Chinook smolts. In contrast, SR fall Chinook salmon, which are typically larger than fall Chinook juveniles from lower Columbia basin ESUs when they enter the estuary, are assumed to spend relatively little time rearing as juveniles in the vicinity of the cormorant colonies. For these reasons, NOAA Fisheries assumes that the yearling Chinook salmon estimate (–1.1%) is the most appropriate estimate to use as a Base-to-Current adjustment for SR fall Chinook salmon.

There is new information on cormorant consumption of sockeye salmon smolts in the estuary, as well. These were taken at an average rate of 1.3% during 1998 to 2012 (Fredricks 2013).

NOAA Fisheries did not assume any compensatory mortality[48] for predation by Caspian terns in the estuary in the 2008 BiOp and has no clear indication that the case would be different, or substantial, for predation by double-crested cormorants. Thus, the increasing loss of juvenile salmon and steelhead in the estuary due to cormorant predation has likely reduced the productivity (i.e., Recruit-per-Spawner estimates, Lambda estimates, etc.) of all Columbia River basin populations since the 1980s and, absent human intervention, would be expected to continue into the future.

Pinniped Predation

Pinniped Population Status

NOAA Fisheries (NMFS 2010a) previously summarized information relating to predation by pinnipeds and its likely effect on ESA-listed salmon and steelhead adults in the lower Columbia River (from the river's mouth upstream to Bonneville Dam). This section evaluates new information available since May, 2010 to determine if NOAA Fisheries' previous conclusions regarding these effects can be reaffirmed or if the environmental baseline conditions have been substantially altered.

Lower Columbia River and Estuary

The eastern DPS of Steller sea lions[49] has increased from an estimated 18,040 animals in 1979 to an estimated 63,488 animals in 2009 with an overall rate of increase of 4.3% per year. Most of the overall increase in population abundance was due to increases in the northern portion of the range in Southeast Alaska and British Columbia, but the smaller population in the south (Oregon and California) also increased in abundance (NMFS 2012b).[50] Recent estimates of Steller sea lion abundance in the Columbia River estuary are lacking, however, increasing numbers throughout the eastern DPS indicates that numbers of Steller sea lions in the Columbia River estuary have likely also increased in recent years.

California sea lions in the U.S. are not listed as "endangered" or "threatened" under the ESA. Also, they are not listed as "depleted" or "strategic" under the Marine Mammal Protection Act because the human-caused mortality is less than the calculated potential biological removal and is considered insignificant (NMFS 2011d). The optimum sustainable population status of this population has not been formally determined, however, continued exponential growth indicated

[48] Mortality that would have occurred for another reason.

[49] Steller sea lions were listed under the ESA as threatened throughout their range on December 4, 1990. United States populations of Steller sea lions comprise the Western and Eastern DPSs. On June 4, 1997, the Western DPS was listed as an endangered DPS and the Eastern DPS remained listed as threatened.

[50] In 2012, after receiving two petitions to delist, NOAA Fisheries proposed to remove the eastern DPS of Steller sea lions from the list of Endangered and Threatened Wildlife. According to NOAA Fisheries' proposal, the delisting is warranted based on findings from a draft comprehensive status review indicating the DPS has recovered and no longer meets the definition of threatened species under the ESA (NMFS 2012b).

from the 2006 to 2008 pup counts suggests that the population is not yet at optimum sustainable population status (Scordino 2010). California sea lion pup counts continue to rise in recent years (Carretta et al. 2013) indicating recent management activities at FCRPS projects are not having substantial negative impacts on overall California sea lion population growth. Recent estimates of California sea lion abundance in the Columbia River estuary are lacking, however, increasing numbers throughout their range indicates that numbers of California sea lions in the Columbia River Estuary have likely also increased in recent years.

The total effect of marine mammals on the productivity and abundance of Columbia River basin ESA-listed salmon populations is still uncertain, but it is clear that adult Chinook salmon contribute considerably to the diets of pinnipeds in the lower Columbia River and estuary. A two-year study conducted by Rub et al. (2012a, 2012b) produced initial estimates of mortality attributed to pinnipeds, and unknown sources, for adult spring/summer Chinook salmon from Rice Island (river kilometer[51] [rkm] 45; river mile [RM] 28) to Bonneville Dam. Adult spring/summer Chinook salmon were collected, PIT tagged, and released back to the Columbia River estuary. Using genetic stock identification, it was determined that 174 PIT-tagged fish in 2010 and 445 PIT-tagged fish in 2011 were destined for tributaries above Bonneville Dam. After accounting for estimated gear harvest mortality, survival from release to Bonneville was estimated at 0.88 in 2010 (Rub et al. 2012a) and 0.85 in 2011 (Rub et al. 2012b). These estimates are inclusive of pinniped predation at the Bonneville Dam tailrace. Since adult spring/summer Chinook survival below rkm 45 (RM 28) was not accounted for in this study, this estimate may be biased high as an estimate of survival from river mouth to Bonneville Dam. Based on spring Chinook returns to Bonneville, these estimates suggest a minimum of 33,300 in 2010 and 29,500 in 2011 adult spring Chinook salmon from interior Columbia basin ESUs were removed by pinnipeds or other unknown factors in the Columbia River estuary and Bonneville Dam tailrace.

The pinniped abundance and diet composition information currently available is insufficient to accurately assess the Base-to-Current impact of California sea lions and Steller sea lions on listed salmonids in the lower Columbia River and estuary. Recent information clearly indicates region-wide numbers of California sea lions and Steller sea lions are increasing, and predation from the estuary to Bonneville Dam is substantial. It seems probable that a proportional increase in the number of California and Steller sea lions residing in the lower Columbia River is occurring, and thus, the overall consumption of salmon and steelhead (especially spring Chinook salmon and winter steelhead), eulachon, and green sturgeon in the lower river and estuary is increasing as well. However, losses in the estuary are spread amongst all of the Columbia River ESUs and DPSs, including lower Columbia basin species and the large numbers of hatchery produced adults spend substantial time in this area. Together, these factors should minimize proportional increases (beyond the 12% to 15% total losses estimated by Rub et al. (2012a, 2012 b) to natural-origin interior basin spring Chinook salmon ESUs and winter steelhead populations upstream of Bonneville Dam.

[51] Conversion: 1 km = 0.621371 mile

Bonneville Dam Tailrace and Upstream

The earliest returning spring Chinook salmon are most affected by pinniped predation (Naughton et al. 2011; Keefer et al. 2012). While they are the best information available, generic salmonid consumption estimates do not take into account these disproportionate impacts to specific populations within ESUs.[52] Further research may be necessary to evaluate if more intensive management strategies are required to protect these endangered ESUs. The proportion of fish with injuries too severe to migrate up the fish ladder to the observation window is still unknown; however, recent research indicates pinniped injuries on fish observed at Bonneville Dam do not consistently reduce adult survival to interior basin spawning tributaries (Naughton et al. 2011).

Standardized efforts to observe and document pinniped presence and predation have occurred in the immediate vicinity of Bonneville Dam since 2002. Stansell et al. (2011, 2013) summarize the recent information regarding the abundance of California sea lions and Steller sea lions in the tailrace of Bonneville Dam and their estimated consumption of salmonids. Minimum estimated numbers of California sea lions from years 2010–2012 were 89, 54, and 39 respectively. Minimum estimated number of Steller sea lions from years 2010–2012 were 75, 89, and 73 respectively. Minimum estimated numbers of Harbor seals from years 2010–2012 was 2, 1, and 0 respectively (Stansell et al. 2012). In 2013, 45 California sea lions and 77 individual Steller sea lions were observed up to May 2 (Stansell et al. 2013). These numbers are indicative of the recent annual trend of increasing numbers of Steller sea lions and decreasing numbers of California sea lions in the Bonneville Dam tailrace.

The estimated percentage of the adult salmonid run consumed from January 1 through May 31 in the Bonneville Dam tailrace has declined steadily in recent years from a high of 4.7% in 2007 to a low of 1.4% in 2012 (Stansell et al. 2012). The estimated percentage of adult salmonids consumed at the tailrace in 2010 and 2011 is 2.4% and 1.8% respectively. Preliminary estimates from 2013 indicate a continuing trend of declining numbers of California sea lions observed and fewer salmonids consumed (Stansell et al. 2013). Increased intensive hazing efforts in combination with lethal removal have coincided with these recent annual California sea lion declines and reduced salmon consumption.

The annual trend of proportionally fewer adult salmonids consumed has been observed despite numbers of Steller sea lions observed at the tailrace remaining relatively stable. Decreased impacts to salmonids are expected because a large portion of Steller sea lion diet at Bonneville Dam consists of white sturgeon. Potential explanations for this include: higher flow years, later spring Chinook runs, cleptoparasitism,[53] intense hazing, and lethal removal of California sea lions (Stansell et al. 2012). Limited monitoring indicates that Steller sea lions arrive at Bonneville Dam at increasing earlier dates during the October through May period, which could negatively affect populations of winter steelhead migrating past Bonneville Dam during this

[52] Spring Chinook and steelhead returning to the Hood, Big White Salmon, and Wind River subbasins in the upper gorge are also vulnerable to pinniped predation at the fish ladder entrances at Bonneville Dam.
[53] A form of feeding in which one animal takes prey or other food from another that has caught or collected the food.

period, and chum salmon spawning in November and December downstream of Bonneville Dam.

Between 2008 and 2010, 40 California sea lions were removed (30 lethal removals and 10 relocations; Carretta et al. 2013). In 2011, no California sea lions were euthanized at Bonneville Dam (Stansell et al. 2011). In 2012, Oregon and Washington's request for lethal removal authority of California sea lions under Section 120 of the Marine Mammal Protection Act was granted. The authorization allows the states to remove up to 93 California sea lions a year. In 2012, one California sea lion was relocated and 11 were euthanized (Stansell et al. 2012). As of May 2013, two California sea lions were relocated and one was euthanized (Stansell et al. 2013). From the available information, it appears the California sea lion removal program is contributing to the reduction in California sea lion abundance and associated predation on salmonids in the Bonneville Dam tailrace.

Multiple California sea lions have been identified upstream of Bonneville Dam. In April of 2011, a California sea lion was confirmed to have passed through the navigation lock (Stansell et al. 2012). This California sea lion was identified at The Dalles Dam and has resided in the Bonneville pool for multiple years. Several reports of other sea lions being observed in the Bonneville pool have been made, and it is likely that up to four California sea lions are currently upstream of Bonneville Dam. Efforts to remove pinnipeds from the Bonneville pool via trapping have been initiated (Stansell et al. 2013). The proportion of adult salmonids consumed by pinnipeds upstream of Bonneville Dam is currently unknown. Pinnipeds have been observed feeding on kelt[54] steelhead in the Bonneville forebay during winter months (Stansell et al. 2012). Pinniped predation upstream of Bonneville Dam should be eliminated through California sea lion removal by the states. If California sea lion removal upstream of Bonneville Dam is not successful, modification to project operations will be considered to reduce delay and impacts to downstream migrating steelhead ESUs.

[54] Steelhead that have spawned but may survive to spawn again, unlike most other anadromous fish.

2.2.4.2 Review of 2008 BiOp's Base-to-Current Estimates for Predation

Avian Predation

Following issuance of the 2008 BiOp, NOAA Fisheries found that a Base-to-Current adjustment was needed to capture the relative effect of the substantially increased double-crested cormorant populations in the estuary on the current (and, if no corrective action is taken, on the prospective) productivity of salmon and steelhead populations and ESUs/DPSs. Using annual smolt population, cormorant population, and smolt consumption estimates, NOAA Fisheries recently estimated the average losses of smolts during the Base (1983–2002) and Current (2003–2009) periods that resulted from double-crested cormorant predation in the estuary. Comparing these two indices (Current rate/Base rate) provides an estimate of the "gap" or negative multiplier indicating the average relative impact of these cormorants on current salmon and steelhead productivity (Fredricks 2013). NOAA Fisheries currently estimates that steelhead (–3.6%, multiplier of 0.964 = 0.935/0.971 [Current/Base]) have been the most affected by double-crested cormorant colonies in the estuary between the Base and Current time periods. Estimates for impacts to yearling Chinook salmon are substantially lower (–1.1%, multiplier of 0.989 = 0.978/0.988).

Based on the size of smolts when they reach Bonneville Dam, we assume that juvenile Snake River fall Chinook salmon spend relatively little time rearing in the lower estuary in the vicinity of cormorant colonies. These fish are typically substantially larger than fall Chinook juveniles from lower Columbia basin ESUs when they enter the estuary and more likely to be ocean-ready. For these reasons, NOAA Fisheries uses the estimate of predation rates for yearling Chinook salmon [–1.1%, multiplier of 0.989] as the Base-to-Current adjustment for SR fall Chinook salmon.

Juvenile subyearling Chinook salmon from the lower Columbia and Willamette River ESUs are likely to rear in shallow water areas within the estuary for many weeks or months, increasing their period of exposure to avian predators. We assume that the higher estimated predation rates for steelhead apply to these fish rather than the rates we estimate for yearling Chinook salmon.

Pinniped Predation

The 2008 SCA, Appendix G, did not include an estimate of changes in sea lion predation below Bonneville Dam in the Base-to-Current calculations.

Adult losses of spring Chinook and winter steelhead have been substantially reduced as the number of California sea lions has decreased substantially in the tailrace of Bonneville Dam as a result of lethal removal activities there. Thus, for populations and ESUs/DPSs returning to natal spawning areas upstream of Bonneville Dam, there has likely been an increase in survival (and correspondingly to productivity) in recent years. If current trends continue, survival rates may be less affected by pinnipeds in this area than was expected in the Base-to-Current assessment in the 2008 SCA (0.986 instead of 0.970). Similarly, populations of winter steelhead upstream of Bonneville dam may also be less affected than 2008 SCA estimates (0.964 instead of 0.924)

Overall, more information is needed to determine the specific effect of pinniped predators on ESA-listed species that are migrating through the lower Columbia River and estuary. However, given the available information concerning overall increases in coastwide pinniped populations, NOAA Fisheries deems it likely that average adult losses due to pinnipeds are increasing slightly.

These factors, taken together, would suggest that losses of adult interior Columbia basin spring Chinook ESUs and winter steelhead populations migrating upstream of Bonneville Dam as a result of pinniped predation are equivalent to, or possibly even less than NOAA Fisheries' estimates in the 2008 BiOp (2008 SCA). Thus, for SR spring/summer and UCR spring Chinook salmon and populations of LCR winter-run steelhead residing upstream of Bonneville Dam, NOAA Fisheries will continue to rely on the Base-to-Current estimates in the 2008 BiOp, rather than adjust them upwards based on the new Bonneville Dam data.

In contrast, Chinook salmon and steelhead ESUs from the lower Columbia River or Willamette River are likely experiencing slightly increasing losses of adults as pinniped populations increase in the lower Columbia River and estuary, and NOAA Fisheries will qualitatively assume that Base-to-Current impacts have increased slightly.

2.2.4.3 Predation Effects on Critical Habitat under the Environmental Baseline

In the 2008 BiOp, we reviewed the effects of predation on the PCEs of critical habitat (see sections 8.2.3.3 for SR fall Chinook salmon, 8.3.3.3 for SR spring/summer Chinook salmon, 8.4.3.7 for SR sockeye salmon, 3.5.3.3 for SR steelhead, etc.). These conditions have not significantly changed and thus remain relevant for this consultation. Effects on the PCE for safe passage in juvenile and adult migration corridors include

- pinniped predation on spring Chinook and winter steelhead in the estuary and in the tailrace at Bonneville Dam;
- habitat changes in the estuary that contributed to increased numbers of avian predators; and

- scarcity of cover in mainstem reservoirs that has increased the vulnerability of smolts in the juvenile migration corridor to piscivorous fishes (e.g., native pikeminnows and non-native smallmouth bass) and birds (Caspian terns and double-crested cormorants).

The safe passage of juvenile salmon and steelhead in the estuary improved beginning in 1999 when Caspian terns were relocated from Rice to East Sand Island, but the numbers of double-crested cormorants has grown since that time (see above). The hazing and lethal removal of certain individually identified California sea lions that prey on adult spring-run Chinook and winter steelhead in the tailrace of Bonneville Dam has improved the functioning of safe passage in the adult migration corridor.

For the most part, predation effects on proposed critical habitat for LCR coho salmon are identical to those for other Columbia basin salmon and steelhead in the mainstem migration corridor below The Dalles Dam. Specifically, the functioning of safe passage for juvenile migration is limited by fish and bird predation. Coho adults return to the lower Columbia during summer when California sea lions are in coastal areas.

2.2.5 Hatchery Effects

2.2.5.1 New Hatchery Environmental Baseline Effects

Most of the new hatchery actions affecting listed species are elements of the RPA, so are discussed in Section 3 of this supplemental opinion. New information regarding the 2008 SCA Appendix I assessment of effects of hatchery actions that occurred prior to the 2008 BiOp is discussed below in Section 2.2.5.2. This section discusses new hatchery actions in the action area that are not part of the RPA.

NOAA Fisheries expects to complete two ESA consultations in 2013 for issuance of permits for hatchery programs in the Wenatchee River basin that are funded by Chelan County Public Utility District (PUD) and Grant County PUD. These hatchery programs are not part of the RPA. The hatchery programs release steelhead into the Chiwawa River, the mainstem of the Wenatchee River, and Nason Creek; and they release spring Chinook salmon into the Chiwawa River, Nason Creek, and White River. These programs reduce short-term extinction risk for Wenatchee River steelhead and spring Chinook salmon populations. As a result of ESA consultation, these programs will reduce the proportion of hatchery-origin fish on the spawning grounds, which will increase the integrated productivity of the Wenatchee steelhead and spring Chinook salmon populations. Grant County PUD will discontinue their White River spring Chinook hatchery program in 2016.

In the two ESA consultations on PUD-funded hatchery programs in the Wenatchee River, we considered whether effects on other salmonid species in the mainstem Columbia River, the estuary, and the ocean should be included in the analysis. The potential concern was a relationship between hatchery production and density dependent interactions affecting the growth and survival of other ESUs and DPSs from the Snake, Mid-Columbia, Lower Columbia, and Upper Willamette subbasins. However, NMFS determined that, based on best available science, it was not possible to establish any meaningful causal connection between hatchery production on the scale anticipated in the proposed programs and any such effects (<*Placeholder: citations for biological opinion(s) when completed*>). Therefore, we assume that the consultations on the PUD programs in the Wenatchee River do not affect the environmental baseline for Snake, Mid-Columbia, Lower Columbia, and Upper Willamette salmon and steelhead.

2.2.5.2 Review of the 2008 BiOp's Base-to-Current Estimates for Hatchery Programs

In the 2008 BiOp, most benefits and risks from past and present hatchery practices were embedded in the environmental baseline. However, because estimates of productivity and extinction risk in the 2008 BiOp were based on the performance of populations during a 20-year Base Period that ended in most cases with the 1999 brood year (with adults returning through 2003–2006, depending on the population), the Environmental Baseline had to be adjusted to account for the effects of hatchery reform actions for which empirical data had not yet been gathered or did not yet exist. For example, the Base Period did not fully reflect the effects of hatchery reform actions taken in the latter portion of the Base Period or after the Base Period (e.g., elimination of an out-of-basin broodstock in the Upper Grande Ronde). The Stier and Hinrichsen (2008) methodology was used to make Base-to-Current adjustments in survival from *completed* hatchery reform actions. Survival adjustments were based on changes in the productivity of the entire naturally spawning population, which includes hatchery-origin fish when they spawn naturally. Therefore, hatchery management actions that improved the productivity of hatchery-origin fish spawning naturally affected the Base-to-Current adjustment. This methodology is described in Appendix I of the 2008 SCA.

In the 2008 BiOp, Base-to-Current adjustments for hatchery reform actions were only applied to populations in the UCR steelhead DPS and SR spring/summer Chinook in the Grande Ronde MPG (Table 2.2-2). NOAA Fisheries must determine whether there is new information that reveals a change in the Environmental Baseline that would affect the conclusions made in the 2008 BiOp. Therefore, NOAA Fisheries updated the data used in the Stier and Hinrichsen (2008) methodology to see if it affected the 2008 BiOp's Base-to-Current integrated productivity increase (See 2008 BiOp, Appendix E: 2013 *Update to Hatchery Effects in the Environmental Baseline*).

After reviewing assumptions in developing the Base-to-Current multipliers for the 2008 BiOp, NOAA Fisheries has determined that hatchery effects in the environmental baseline represent greater improvements from Base Period survival for most populations in the upper Columbia steelhead DPS and for some populations in the Grande Ronde MPG of the SR spring/summer Chinook salmon ESU (Table 2.2-2). The only exceptions would be (1) the Minam and Weneha spring/summer Chinook salmon populations, which had an increased number of strays in recent years, reducing integrated productivity below what was anticipated in the 2008 BiOp, and (2) the Entiat steelhead population, which falls within the range anticipated in the 2008 BiOp.

Table 2.2-2. Comparison of the Base-to-Current Integrated Productivity Increases (Appendix E: Update to Hatchery Effects in the Environmental Baseline).

ESU/DPS	Population	2008 BiOp's Base-to Current Integrated Productivity Increase as a Ratio[1]	2013 Supplemental BiOp's Base-to-Current Integrated Productivity Increase as a Ratio
Snake River spring/summer Chinook salmon			
	Upper Grande Ronde Spring/Summer Chinook Salmon	1.21	1.29
	Lostine River Spring/Summer Chinook Salmon	1.03	1.11
	Catherine Creek Spring/Summer Chinook Salmon	1.20	1.31
	Minam River Spring/Summer Chinook Salmon	1.22	1.16
	Wenaha River Spring/Summer Chinook Salmon	1.39	1.36
Upper Columbia River steelhead			
	Wenatchee River Steelhead	1.60	1.78
	Entiat River Steelhead	0.82 (low) 1.30 (high)	0.93
	Methow River Steelhead	1.17 (low) 1.55 (high)	1.84
	Okanogan River Steelhead	1.34 (low) 1.88 (high)	1.42 (low) 1.87 (high)

[1]Integrated productivity refers to the productivity resulting from the combination of both natural-origin and hatchery-origin spawners and is identical to R/S productivity described in the 2008 BiOp, Section 7.1.1.2.

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2.2.6 Harvest effects

2.2.6.1 New Harvest Environmental Baseline Effects

The 2008 SCA's Environmental Baseline Section 5.6, incorporated by reference into the 2008 BiOp's Chapter 5, described historical and ongoing harvest actions affecting listed species. By 2002, the overall exploitation rate on LCR tule Chinook was reduced to 49%. By 2008, at the time of the SCA, the exploitation rate limit was 41%. The 2010 Supplemental BiOp described an additional 3% reduction in the exploitation rate for LCR tule Chinook to 38%. The exploitation rate limit was further reduced in 2011 to 37%. Recently, NOAA Fisheries completed a new biological opinion regarding the harvest of LCR Chinook salmon that approved an abundance-based framework allowing the total annual exploitation rate to vary between 30% and 41% depending on the preseason forecast of Lower River Hatchery Chinook salmon (NMFS 2012c). Thus, risks to the LCR Chinook salmon ESU associated with harvest are reduced compared to our assumptions in the 2008 and 2010 BiOps.

New terminal harvest agreements since the 2010 Supplemental BiOp are also relevant to the environmental baseline and are described in the remainder of this section.

State and tribal fisheries in the Snake River basin are ongoing, and have occurred both prior to and since the ESA listing. Though not all fisheries in the basin have gone through a formal ESA review, ESA-listed fish have been exposed to these ongoing fisheries, which are therefore part of the environmental baseline. In the past, fisheries targeting SR spring/summer Chinook salmon and steelhead focused on the large numbers of hatchery-origin fish, but some harvest also has occurred in natural production areas where the tribes have continued their traditional fishing practices.

There is little historical tribal harvest information for SR spring/summer Chinook salmon and steelhead in the Snake River basin, although documentation of the magnitude of impacts on natural-origin fish has improved significantly in recent years. The abundance-based management frameworks that both the states and tribes developed and implemented over the last 10 to15 years for spring/summer Chinook salmon, for example, provide a more formal construct for managing fisheries in the Snake River basin. In terms of impacts on natural-origin fish, the fishing patterns that NOAA Fisheries considered in the 2008/2010 BiOps continue to emphasize fisheries in areas of high hatchery-origin abundance (i.e., limiting fisheries impacts on natural-origin populations that are relatively depressed).

In 2011, NOAA Fisheries completed consultation on a Fisheries Management and Evaluation Plan (FMEP) for SR steelhead in southeast Washington tributaries submitted by the WDFW (NMFS 2011e), and on an FMEP for SR spring/summer Chinook salmon for the Salmon River basin (NMFS 2011f) submitted by the IDFG. Washington Department of Fish and Wildlife's FMEP provides ESA coverage for fisheries that have been ongoing as part of the environmental baseline. The IDFG's FMEP improves fishery management compared to the environmental baseline by the inclusion of additional abundance-based management frameworks that emphasize recreational fisheries in areas with high numbers of hatchery-origin fish as described above. The IDFG's FMEP now also uses a natural-origin "population aggregate" approach to shaping their more terminal area fisheries. The ESA take resulting from the implementation of SR spring/summer Chinook salmon fisheries is apportioned by population proportional to its respective contribution to the natural-origin aggregate abundance affected by each of IDFG's fisheries in the Salmon River basin. Ultimately, population-specific ESA take limits constrain fisheries by area and time.

In 2013, NOAA Fisheries completed consultation on a Tribal Resource Management Plan submitted by the Shoshone-Bannock Tribes for spring/summer Chinook salmon fisheries in the Salmon River basin (NMFS 2013f), most of which are ongoing and were thus part of the environmental baseline in the 2008 BiOp. The Shoshone-Bannock Tribes' Tribal Resource Management Plan uses generic abundance-based harvest frameworks applied to each of the affected populations separately. Table 2.2-3 presents the abundance-based schedule to be used for natural-origin populations; Table 2.2-4 presents the abundance-based schedule to be used for populations with active integrated supplementation hatchery programs. Both schedules are used to calculate total allowable ESA take by population; and to account for ESA take by IDFG's fisheries and any other fisheries that may be considered in the future (i.e., Nez Perce Tribes Salmon Basin Tribal Resource Management Plan, which is currently under development). Table 2.2-5 presents Critical Abundance and Minimal Abundance Thresholds to be used in conjunction with Table 2.2-3 and Table 2.2-4.

Although there has been no recorded catch of sockeye salmon in the fishery since monitoring began in 1979, the Shoshone-Bannock Tribe proposed a harvest rate limit of 1% of the Lower Granite Dam escapement number in recognition of the fact that some sockeye could be caught incidental to the fishery in the future (NMFS 2013f).

In 2013, NOAA Fisheries also completed consultation on a package of spring/summer Chinook salmon fishery proposals for the Grande Ronde and Imnaha rivers (NMFS 2013g), most of which are ongoing and thus were part of the environmental baseline in the 2008 BiOp. Grande Ronde/Imnaha spring/summer Chinook salmon fisheries are now managed according to a population-specific abundance-based schedule (Table 2.2-6). Table 2.2-6 is used to calculate total allowable ESA take by population accounting for ESA take of all fisheries in the basins. Table 2.2-6 presents Critical Abundance and Minimal Abundance Thresholds to be used in conjunction with Table 2.2-7.

Table 2.2-3. Harvest rate for natural-origin populations of Snake River spring/summer Chinook salmon in the Middle Fork Salmon, South Fork Salmon, or the Upper Salmon MPGs.

Percent of Minimum Abundance Threshold	Harvest Rate
0–30%	1%
30.1–50%	3%
50.1–75%	5%
75.1–108%	8%
>108.1%	8% + 35% of the margin

Table 2.2-4. Harvest rate for supplemented populations of Snake River spring/summer Chinook salmon in the Middle Fork Salmon, South Fork Salmon, or the Upper Salmon MPGs.

Percent of Minimum Abundance Threshold	Harvest Rate
0–30%	1%
30.1–50%	4%
50.1–75%	9%
75.1–108%	12%
>108.1%	12% + 42% of the margin

Table 2.2-5. List of the natural fish populations, Critical Abundance Thresholds, and Minimum Abundance Thresholds for the Middle Fork Salmon, South Fork Salmon, and the Upper Salmon MPGs.

Name	Critical Abundance Threshold (adults/year)	Minimum Abundance Threshold (adults/year)
South Fork Salmon MPG		
Little Salmon River	225	750
South Fork Salmon River	300	1,000
Secesh River	225	750
East Fork South Fork Salmon River	300	1,000
Middle Fork Salmon MPG		
Chamberlain Creek	225	750
Middle Fork Lower Main	150	500
Big Creek	300	1,000
Camas Creek	150	500
Loon Creek	150	500
Middle Fork Upper Main	225	750
Sulphur Creek	150	500
Bear Valley Creek	225	750
Marsh Creek	150	500
Upper Salmon MPG		
Panther Creek [1]	150	500
North Fork Salmon River	150	500
Lemhi River [2]	300	1,000
Salmon River Lower Main	300	2,000
Pahsimeroi River[1]	300	500
East Fork Salmon River	300	1,000
Yankee Fork Salmon River	150	500
Valley Creek	150	500
Salmon River Upper Main	300	1,000

Table 2.2-6. Harvest rate for natural-origin populations of Snake River spring/summer Chinook salmon in the Grande Ronde/Imnaha MPG.

Fishery Scenario	Expected return of natural-origin fish	Total collective natural-origin mortality
A	Below Critical Threshold	1%[1]
B	Critical to Minimum Abundance Threshold (MAT)	A + 11% of margin above A[1]
C	MAT to 1.5X MAT	B + 22% of margin above B
D	1.5X MAT to 2X MAT	C + 25% of margin above C
E	Greater than 2X MAT	D + 40% of margin above D

[1] For Lookingglass Creek fisheries will be managed more liberally under fishery scenarios A and B: A = 10% total harvest (tribal 8% and sport 2%); B = A + 16% of margin above critical (tribal 12% and sport 4%).

Table 2.2-7. List of the natural fish populations, Critical Abundance Thresholds, and Minimum Abundance Thresholds for the Grande Ronde/Imnaha MPG

Population	Critical Thresholds (adults/year)	Minimum Abundance Thresholds (MAT) (adults/year)
Wallowa/Lostine	300	1000
Catherine/Indian[1]	300	1000
Upper Grande Ronde R	300	1000
Wenaha R	225	750
Minam R	225	750
Lookingglass Cr	150	500

[1]When fisheries target only the Catherine Creek portion of the Catherine/Indian Population, then the fisheries will be managed based on a Critical Threshold of 225 with a MAT of 750 as for an Intermediate-sized population.

2.2.6.2 Review of the 2008 BiOp's Base-to-Current Estimates for Harvest

The harvest-related Base-to-Current multipliers in the 2008 BiOp did not explicitly incorporate tributary harvest into the calculations (2008 SCA, Appendix G), but implicitly assumed that effects on listed species of ongoing tributary harvest practices would be equivalent to those that occurred during the Base Period. Because of the abundance-based nature of the harvest frameworks described above, average fishery-related mortality rates for SR spring/summer Chinook salmon populations could be higher or lower when compared with Base Period fishing mortality rates, depending on run size. That is, in years of low natural-origin abundance, allowable population-specific ESA take limits will be lower than during the Base Period, and in years of high natural-origin abundance, allowable population-specific ESA take limits will be higher. Because of the current status of the affected populations, which would favor the lower harvest rates, and the potential balance between the effects at different run sizes, NOAA

Fisheries continues to rely upon the 2008 BiOp’s harvest Base-to-Current survival changes for SR spring/summer Chinook.

Additionally, because average fishery-related mortality rates for SR steelhead populations have not changed compared with the baseline, NOAA Fisheries continues to rely upon the 2008 BiOp’s harvest Base-to-Current survival changes for SR steelhead.

2.2.7 Climate and Climate Change Effects

This factor, while included in the 2008 BiOp's environmental baseline section, is discussed under rangewide status in Section 2.1.4 of this supplemental opinion because of its importance both within and outside of the action area.

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2.2.8 Overall Relevance of New Environmental Baseline Information to the 2008/2010 BiOps' Analyses

Sections 2.2.2 through 2.2.7 of this supplemental opinion described new information relevant to the environmental baseline, which is summarized in Table 2.2-8.

Table 2.2-8. New information relevant to effects of the environmental baseline, summarized from Sections 2.2.2 through 2.2.7.

Environmental Baseline Effect(2008 BiOp Ch. 5)	New Action or Information	Qualitative Effect	Quantitative Effect on Interior Columbia Species Analysis
Hydro effects	Odessa Subarea Groundwater Replacement Project	Could slightly reduce the availability of suitable spawning habitat for early spawning CR chum salmon	N/A
	FCRPS pre-RPA effects	No change in Base or Current (pre-RPA) estimates	No change in hydro Base-to-Current survival multipliers
Tributary habitat effects	No significant new non-RPA tributary habitat actions.	N/A	N/A
	Pre-RPA tributary habitat actions	No change in Base or Current (pre-RPA) estimates	No change in tributary Base-to-Current survival multipliers
Estuary and plume habitat effects	No significant new non-RPA estuary habitat actions.	N/A	N/A
	Pre-RPA estuary habitat actions	No change in Base or Current (pre-RPA) estimates	No change in estuary Base-to-Current survival multipliers
Predation and disease effects - Avian	Cormorant predation	Increase in predation since Base Period higher than 2008 BiOp's implicit assumption of no change for Chinook and steelhead. May also apply to sockeye but no Base Period estimates for comparison.	New avian Base-to-Current estimate 0.96 (-3.6%) for steelhead and 0.99 (-1.1%) for stream-type Chinook and SR fall Chinook.
	Other avian predation—no change	N/A	N/A
Predation and disease	New information on	Magnitude of predation still	*Probable reduced Base-to-*

Environmental Baseline Effect(2008 BiOp Ch. 5)	New Action or Information	Qualitative Effect	Quantitative Effect on Interior Columbia Species Analysis
effects – Pinniped	pinniped predation on spring Chinook and winter steelhead in estuary	unknown, but populations increasing so likely higher mortality in recent years than in Base Period	*Current survival multipliers compared to 2008 BiOp implicit assumption of 1.0 (no change).*
	Updated pinniped predation estimates on spring Chinook and winter steelhead at Bonneville Dam	Reduced predation compared to 2008 BiOp estimates	*Base-to-current multi-plier increased from 0.97 in the 2008 BiOp to 0.986 for SR and UCR spring Chinook and from 0.78 in the BiOp to 0.8 for MCR steelhead (1 pop)*
	Combined lower Columbia and Bonneville predation	**Mixture of higher- and lower-than-expected estimates**	**No change in Base-to-Current survival multipliers**
Hatchery effects	Issuance of new permits for PUD-funded hatchery programs for spring Chinook salmon and steelhead in the Wenatchee river basin	Will reduce proportion of hatchery-origin spawners in Wenatchee River and its tributaries	Unquantifiable increase in productivity for Wenatchee populations of UCR spring Chinook salmon and steelhead
	Pre-RPA hatchery actions	Higher fraction of natural-origin spawners or higher effectiveness of hatchery-origin spawners than estimated in 2008 BiOp, leading to higher productivity for some populations of SR spring/summer Chinook and UCR steelhead.	Increased Base-to-Current survival estimates for 3 populations of Grande Ronde/Imnaha MPG SR spring/summer Chinook : Catherine Creek (+10%)[1] Upper Grande Ronde (+6%) Lostine (+8%) and for three populations of UCR steelhead: Wenatchee (+11%) Methow (+19-57%) Okanogan (+6%)
		Lower productivity for some populations of SR spring/summer Chinook	Decreased Base-to-current survival estimates for 2 populations of Grande Ronde/Imnaha MPG SR spring/summer Chinook: Minam (-5%) Wenaha (-2%)
Harvest effects	LCR Chinook harvest management plan	Lower than described in 2008 BiOp (-3% for some populations)	N/A – no quantitative analyses for LCR Chinook

Environmental Baseline Effect(2008 BiOp Ch. 5)	New Action or Information	Qualitative Effect	Quantitative Effect on Interior Columbia Species Analysis
	WA steelhead terminal fishery mgmt. plan	SR Steelhead – no change from historical harvest (so no change to baseline)	No change in harvest Base-to-Current multipliers
	ID spring/summer Chinook terminal fishery mgmt. plan Tribal spring/summer Chinook terminal fishery management plan	SR spring/summer Chinook – reduced from historical harvest at low run sizes but can increase above historical harvest rates at higher run sizes approaching ICTRT recovery thresholds. No change for rare sockeye catch.	No change in harvest Base-to-Current multipliers
	Pre-RPA BiOp harvest rates for other fisheries	No change in Base or Current estimates	No change in harvest Base-to-Current multipliers
Large-scale environmental variation (climate and climate change)	Considered in Section 2.1.1 (Rangewide Status)	See Section 2.1.1	N/A

[1] Hatchery Base-to-Current proportional survival changes from 2008 BiOp estimates. Source: Appendix E, Tables E2–E11.

In general, new information indicates that effects of most factors influencing the environmental baseline remain similar to those considered in the 2008 BiOp and that NOAA Fisheries should continue to rely on most Base-to-Current survival estimates in the 2008 BiOp for the quantitative analysis applied to six interior Columbia basin species. However, effects of some factors influencing the environmental baseline differ in a manner that could affect the overall analysis of effects of the action for some species:

Environmental baseline effects that are more favorable to listed salmon and steelhead than those described in the 2008 BiOp:

- Updated estimates based on new information increase the 2008 BiOp's hatchery Base-to-Current survival estimates for three populations of Grande Ronde/Imnaha MPG SR spring/summer Chinook and all populations of UCR steelhead.
- As described in the 2010 Supplemental BiOp, LCR Chinook harvest rates are lower than described for some populations, resulting in higher survival than anticipated in the 2008 BiOp.

Environmental baseline effects that are less favorable to listed salmon and steelhead than those described or implicitly assumed in the 2008 BiOp:

- As previously described in the 2010 Supplemental BiOp, the 2008 BiOp implicitly assumed that the average Current Period cormorant predation rate was, and would remain, unchanged from predation rates during the Base Period. New information indicates that the average Current Period cormorant predation rate has been higher (and therefore salmon and steelhead survival has been lower) than that occurring in the 2008 BiOp Base Period for some species. The higher cormorant impact mainly applies to steelhead, but results in a small change for Chinook.
- Updated estimates based on new information decrease the 2008 BiOp's Base-to-Current survival estimates for two populations of Grande Ronde/Imnaha MPG SR spring/summer Chinook (Wenaha and Lostine).
- A new water management action may have a minor effect on the amount of CR chum salmon spawning habitat. This action was the subject of a formal Section 7 consultation and was found to meet the ESA standards for avoiding jeopardy and the destruction or adverse modification of critical habitat.

Relevance of New Environmental Baseline Information for Lower Columbia Basin Species

Effects of the new environmental baseline information on lower Columbia basin salmon and steelhead, especially with respect to conditions or activities in the mainstem below The Dalles Dam and in the estuary and plume, are similar to those described above for interior ESUs and DPSs. However, there are some differential effects as well. The Odessa Subarea Groundwater Replacement Project (Section 2.2.1.1) is expected to reduce, very slightly, the availability of suitable spawning habitat for early (i.e., October) spawning chum salmon in shallow mainstem areas used by the Lower Gorge and Washougal populations. Avian predation rates on fish from lower Columbia and upper Willamette populations may be higher than those on fish from interior populations based on the amount of time spent rearing in the lower Columbia River. Our recent biological opinion on the harvest of LCR Chinook salmon approved an abundance based framework that allows the total annual exploitation rate to vary between 30% and 41%, further reducing risks to the LCR Chinook salmon ESU under the environmental baseline compared to our assumptions in the 2008 and 2010 opinions.

Relevance of New Environmental Baseline Information for Designated Critical Habitat

In general, the conditions identified in the 2008 BiOp that limit the functioning of designated critical habitat for Columbia basin salmonids still continue today. Effects on PCEs of critical habitat recently proposed for LCR coho salmon are identical to those for other Columbia basin salmon and steelhead in the migration corridor below The Dalles Dam and in tributaries to the lower Columbia used by LCR Chinook and coho salmon and LCR steelhead for spawning and rearing.

2.3 Cumulative Effects

In the 2008 BiOp, NOAA Fisheries described information provided by the states of Oregon, Washington, and Idaho on ongoing, future, or expected projects that were reasonably certain to occur and that were expected to benefit recovery efforts in the interior Columbia basin (see list in Chapter 17, USACE et al. 2007b). All of those actions were either completed or ongoing and were thus part of the environmental baseline, or were reasonably certain to occur and therefore qualified as cumulative effects. They address the protection of adequately functioning habitat and the restoration of degraded fish habitat including improvements to instream flows, water quality, fish passage and access, and watershed or floodplain conditions that affect downstream habitat. Significant actions and programs include growth management programs (planning and regulation); a variety of stream and riparian habitat projects; watershed planning and implementation; acquisition of water rights for instream purposes and sensitive areas; instream flow rules; stormwater and discharge regulation; Total Maximum Daily Load implementation to achieve water quality standards; and hydraulic project permitting. Responsible entities include cities, counties, and various state agencies. NOAA Fisheries determined that many of these actions would have positive effects on the viability (abundance, productivity, spatial structure, and/or diversity) of listed salmon and steelhead populations and the functioning of PCEs in designated critical habitat. Therefore, these activities were likely to have cumulative effects that will significantly improve conditions for the species considered in that consultation.

NOAA Fisheries also noted that some types of human activities that contribute to cumulative effects are expected to have negative effects on populations and PCEs, many of which were activities that occurred in the recent past and were an effect of the environmental baseline. NOAA Fisheries considered these to be reasonably certain to occur in the future because they occurred frequently in the recent past—especially if authorizations or permits had not yet expired. Within the freshwater portion of the action area for the Prospective Actions, non-Federal actions were likely to include human population growth, water withdrawals (i.e., those pursuant to senior state water rights), and land use practices. In coastal waters within the action area, state, tribal, and local government actions were likely to be in the form of fishing permits. Private activities are likely to be continuing commercial and sport fisheries, which have some incidental catch of listed species, and resource extraction. All of these activities can contaminate local or larger areas of the coastal ocean with hydrocarbon-based materials.

All of these factors are still ongoing to some extent and likely to continue in the future, although the continuing level of activity depends on whether there are economic, administrative, and legal impediments (or in the case of contaminants, safeguards). We are not aware of any non-Federal actions that change our expectations for cumulative effects, whether beneficial or adverse. Therefore, NOAA Fisheries finds that the analysis of cumulative effects in the 2008 BiOp is still accurate for this supplemental opinion.

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Section 3: RPA Implementation Through 2018 for Salmon and Steelhead

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3 RPA Implementation for Salmon and Steelhead

In this section, NOAA Fisheries reviews the progress made in implementing the RPA to date, the certainty regarding the effects of remaining RPA action implementation through 2018, and new information regarding effectiveness of RPA actions, with a particular emphasis on habitat mitigation measures, as directed by the Remand Order. We compare this information with expectations in the 2008 BiOp to determine if the findings and analyses in the 2008 BiOp continue to be supported by best available science and information.

As described in Section 1.1, this review of RPA implementation serves two functions. The first is to address the 2011 court remand order, which requires a more detailed implementation plan for habitat mitigation projects for the 2014 through 2018 period. In this section, NOAA Fisheries evaluates the habitat mitigation projects the Action Agencies have now identified in the 2013 Draft CE and the 2014–2018 Draft IP for implementation in 2014 through 2018. Based upon this review, NOAA Fisheries addresses the following questions in Sections 3.1 and 3.2:

- whether effects of the newly developed projects are reasonably certain to occur;
- whether the projects the Action Agencies have so identified for implementation after 2014, when added to projects implemented since 2007, are sufficient to achieve the RPA's Habitat Quality Improvement objectives set forth in RPA Action 35, Table 5, and the associated survival improvements for listed salmonids in tributary habitat, as well as the estuary survival improvements objectives set forth in RPA Action 36; and
- whether the methodology used by the Action Agencies to determine the efficacy of the habitat actions uses the best science available.

The second purpose of this section is to support NOAA Fisheries' evaluation of the current validity of the ESA analysis contained in the 2008/2010 BiOps. To do so NOAA Fisheries considers

- Whether there is new data concerning the status of the listed species, changes to the environmental baseline, and cumulative effects. NOAA Fisheries also considers the information about effectiveness of the RPA's implementation to date. These determinations are informed by the current development of the RPA's Research, Monitoring, and Evaluation (RME) program.
- Whether the Action Agencies have implemented the RPA as intended, or whether any significant discrepancies deviate from the effects expected to result from the RPA actions.

As described in Section 1.2, effects of the action are added to the environmental baseline and cumulative effects and viewed in the context of the status of the species and of critical habitat. These aggregated effects are discussed in Section 4, *Conclusions for Salmon and Steelhead*.

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3.1 Tributary Habitat RPA Actions

The 2008 BiOp includes two RPA Actions to improve tributary habitat. Both require the Action Agencies to provide funding and technical assistance to implement actions designed to improve the quality and quantity of spawning and rearing habitat for specific populations of Snake River and upper Columbia River Chinook and steelhead and middle Columbia steelhead. RPA Action 34 required that specific habitat improvement actions incorporated into the 2008 BiOp be implemented during 2007 to 2009. RPA Action 35 requires implementation of habitat improvement actions during 2010 to 2018. Table 5 of RPA Action 35 includes performance standards for 56 salmon and steelhead populations.[55] These performance standards identify specific habitat quality improvements (HQIs), which correspond to survival improvements, that the Action Agencies are responsible for meeting for the 56 populations. RPA Action 35 also includes specific direction to the Action Agencies on identification of habitat improvement actions; use of expert panels to evaluate change in habitat function resulting from habitat improvement actions; the use of replacement actions if necessary based on new information or actions that prove infeasible to implement; and the reporting of implementation progress.

Other RPA Actions in the 2008 BiOp require the Action Agencies to ensure comprehensive monitoring and evaluation to assess tributary habitat program progress and effectiveness. RPA Actions 56 and 57 direct them to develop and implement a program to monitor and evaluate tributary habitat conditions, limiting factors, and habitat-improvement action effectiveness. RPA Action 50 requires them to conduct corresponding fish population monitoring designed to help establish relationships between habitat improvement actions and fish population responses. RPA Action 71 requires the Action Agencies to coordinate research, monitoring, and evaluation activities with appropriate entities; RPA Action 72 requires them to ensure the use of appropriate data management systems; and RPA Action 73 requires them to monitor action implementation and maintain an implementation tracking system using specified metrics (2008 BiOp, Appendix, Reasonable and Prudent Alternative Table).

In the 2008 BiOp, NOAA Fisheries determined that the approach the Action Agencies used to estimate benefits of habitat improvement actions and the corresponding survival improvements used the best science available for assessing the effects of actions occurring across the diverse watersheds of the Columbia River basin, affecting a variety of listed salmonid ESUs/DPSs, and that could consistently be applied over the Columbia River basin (2008 BiOp, Section 7.2.2). We also determined that the identified survival improvements were likely to be realized (2008 BiOp,

[55] In this section, NOAA Fisheries uses the term "performance standard" to describe the population habitat quality improvement, and associated survival improvement, commitments identified in RPA Action 35 Table 5 of the 2008 BiOp. In their 2013 Draft CE and 2014–2018 Draft IP, the Action Agencies generally refer simply to "habitat quality improvements," or "HQIs." The Action Agencies calculated HQIs for actions evaluated by expert panels using the Collaboration Habitat Workgroup method described in Appendix C of the 2007 CA and summarized below in Section 3.1.1.7.

Section 7.2.2), and incorporated those expectations into the aggregate analysis in the 2008 BiOp (e.g., 2008 BiOp, Table 8.3.5-1 for Snake River spring/summer Chinook).

In the Section 2.2.3 of the 2010 Supplemental BiOp, NOAA Fisheries reviewed new scientific information regarding the best methods for achieving the benefits needed from tributary habitat improvement. Through our review, we found that the information supported the Action Agencies' approach to implementing the tributary habitat program. We concluded that the tributary habitat RPA actions sufficiently addressed factors that had limited the functioning and conservation value of spawning and rearing habitat and would increase the survival of the affected populations to meet the BiOp RPA objectives.

In this supplemental opinion, we update our review of scientific information on the best methods for achieving the survival benefits needed from tributary habitat improvement and conclude that the information supports the Action Agencies' approach to implementing the tributary habitat program. We also review the Action Agencies' method and implementation of the program to date and conclude it represents the best science available for assessing the effects of actions occurring across the diverse watersheds of the Columbia River basin, affecting a variety of listed salmonid ESUs/DPSs, and that could consistently be applied over the Columbia River basin.

Section 3.1.1 below discusses the scientific foundation of and analytical methods used in the tributary habitat program. Section 3.1.2 discusses implementation and effects of the program. Sections 3.1.2.1 and 3.1.2.2 describe implementation of the program and effects on the interior Columbia ESUs and DPSs generally. Sections 3.1.2.3 through 3.1.2.7 describe the effects of the program individually on SR spring/summer Chinook salmon, UCR Chinook salmon, SR steelhead, UCR steelhead, and MCR steelhead. We conclude that, overall, the tributary habitat program established under RPA Actions 34 and 35 is directing resources to actions that sufficiently address the limiting factors identified as most significant through a process based on sound science and technical input, and that it is reasonably certain that the performance standards in RPA Action 35 Table 5 will be met.

3.1.1 Tributary Habitat Analytical Methods

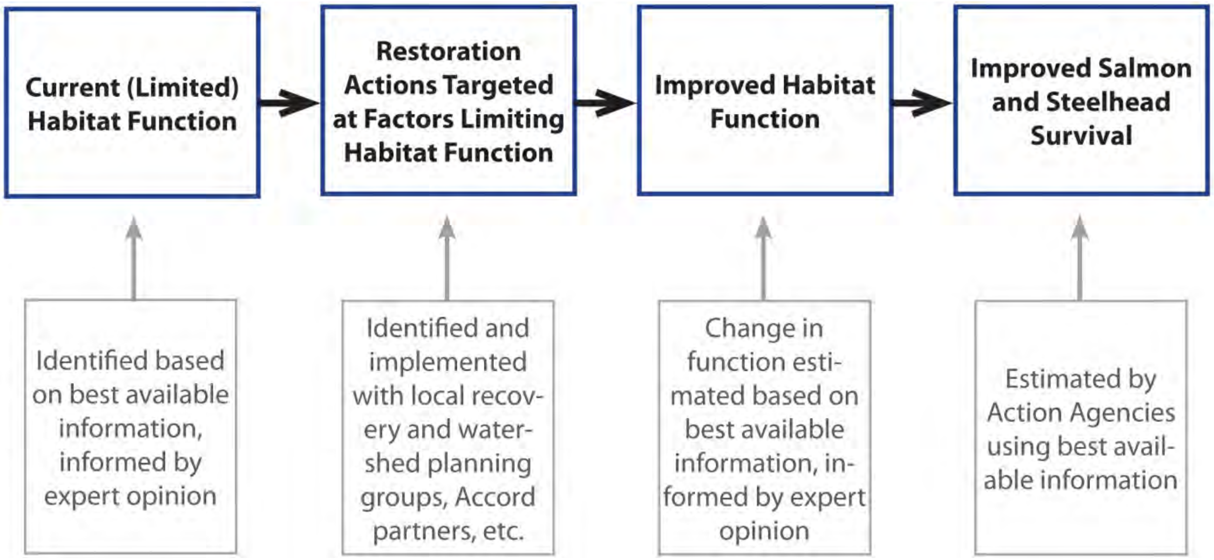
This section begins with a brief introduction to the tributary habitat program analytical methods. Sections 3.1.1.2, 3.1.1.3, and 3.1.1.4 then summarize the scientific foundation of the tributary habitat program—our knowledge of basic relationships between fish and their habitat and what the scientific literature tells us about how changes in fish habitat affect fish populations. We conclude that there is a strong basis for our expectation that habitat improvement actions such as those carried out to implement the RPA, which are designed to decrease the impact of “limiting factors” (or habitat constraints on fish survival), are likely to improve fish population status to meet the BiOp RPA objectives. In Section 3.1.1.4, we summarize a review of the information available from the monitoring and evaluation program associated with the RPA’s tributary habitat improvement program. Although available data are preliminary, they support our expectation that the RPA habitat actions will result in increased fish population abundance and productivity.

In Sections 3.1.1.5 through 3.1.1.8 we review the rationale for the methods the Action Agencies used to predict changes in habitat condition and fish survival resulting from implementation of RPA Actions 34 and 35. In Section 3.1.1.5 we review the feasibility of reaching the survival improvements identified in RPA Action 35, Table 5. In Section 3.1.1.6 we describe the method and rationale the Action Agencies use to estimate changes in habitat function expected from implementing habitat improvement actions. We first describe the use of expert opinion in conservation biology, and then briefly describe the method the Action Agencies use for determining changes in habitat function as a result of implementing improvement actions. We also reference alternative methods considered and the rationale for selecting the methods currently applied. In Section 3.1.1.7 we describe the method and rationale the Action Agencies use to estimate changes in population survival resulting from the estimated changes in habitat function. In 3.1.1.8 we describe the evolution of the analytical methods, including improvements in methods and procedures since the 2008 BiOp was completed and additional improvements anticipated through 2018.

3.1.1.1 Introduction to Tributary Habitat Analytical Methods

The fundamental logic of the tributary habitat analytical approach is that by identifying the factors limiting habitat productivity, and by implementing actions that alleviate those limiting factors, habitat function will improve, and, ultimately, the freshwater survival of salmon and steelhead will improve as well (see Figure 3.1-1).

Figure 3.1-1. Fundamental logic of and primary inputs for tributary habitat analytical methods



The technical foundation of the tributary habitat program established under RPA Actions 34 and 35 is a method for estimating (1) the changes in habitat quality likely to result from implementation of habitat improvement actions and (2) the corresponding change in fish survival that is likely to occur as the productive capacity of habitat changes. The approach relies on identifying the factors that limit the productivity of salmon and steelhead habitat; identifying actions that would reduce the magnitude of those limiting factors, thereby improving the quality and function of habitat; using expert judgment to estimate the change in habitat function as a result of implementing those actions; and then using an empirically based model to estimate the overall change in habitat quality and a corresponding change in egg-to-smolt survival that would result from that change in habitat quality and function. A monitoring and evaluation program is in place to track the effects of the program and to provide input for the adaptive management framework within which the Action Agencies implement the program. As new data and tools become available to inform estimates of habitat benefits of actions and resulting changes in survival, the Action Agencies will continue to incorporate them into the program, in compliance with RPA Action 35 (2008 BiOp, RPA Action 35a).

The Action Agencies have used two applications of the general approach described above. One method, referred to as the "Appendix E method," was first used by NOAA Fisheries in the 2004 BiOp to estimate benefits of tributary habitat improvements (NMFS 2004, Appendix E). This approach used qualitative ratings (i.e., low, medium, high) and approximate ranges of survival improvements associated with each qualitative category (e.g., "low" was approximately a 1% survival change) to provide approximate survival improvements associated with tributary habitat improvement actions. In their 2007 CA, the Action Agencies (sometimes in consultation with local experts, although not through a formal expert panel process) used the Appendix E method to estimate benefits of tributary habitat improvement actions for a subset of populations (see 2007 CA, Appendix C, Attachment C-1, Tables 1-5). Populations evaluated using the Appendix

E method generally had relatively small HQI performance standards and little influence on the life-cycle analysis in the 2007 CA's Appendix A. In addition, implementation of most tributary habitat improvement actions for these populations was underway at the time the 2008 BiOp was finalized and was expected to be complete by 2009.

For most populations, however, in their 2007 CA the Action Agencies used an updated method (see 2007 CA Appendix C, Attachment C-1, Tables 1–5). The Action Agencies applied the updated method to the populations with the "greatest needs" and most relevance to the life-cycle analysis (2007 CA, Appendix C, Section 1.2; 2007 CA, Appendix C, Annex 1, Section 2.2; the Action Agencies refer to these as "priority populations").[56] Subsequently, they have applied the updated method to all populations with the exception of middle Columbia steelhead populations (see 2013 Draft CE, Section 2, Table 35), since those populations all had small habitat improvement commitments and actions projected to achieve the commitments generally had been implemented by 2009.[57]

The updated method relies on both empirical data and expert opinion. It is summarized below in Section 3.1.1.6 and more fully in Appendix C of the 2007 CA (Attachment C-1 and Annexes 1–3) and in Appendix C of Milstein et al. (2013). The method was developed by the Remand Collaboration Habitat Workgroup (CHW), which was convened in 2006 at the request of the Policy Work Group formed as part of the court-ordered remand of NOAA Fisheries' 2004 FCRPS BiOp. Members of the CHW represented the states, tribes, and Federal agencies (including NOAA Fisheries) involved in the remand collaboration process and were selected for their technical expertise. The group met regularly in 2006 to review and update the "Appendix E" method NOAA Fisheries used to estimate the potential improvement from tributary habitat mitigation actions in the 2004 FCRPS Biological Opinion. In developing its method, the CHW considered multiple approaches, additional analyses, and information from recovery plans and other efforts that had become available after the 2004 BiOp was issued (2007 CA, Appendix C, Attachment C-1, and Annexes 1–3).

The workgroup developed methods based upon both expert opinion and review of scientific information, such as known egg-to-smolt survival relationships for Chinook salmon and steelhead, that could be applied consistently to all populations. Given the lack of adequate quantitative data for many populations across the basin, it was not feasible to apply more formal models and quantitative approaches across all populations. However, the CHW recommended that where relevant model results or empirical data were available, panels should consider them in developing estimates of habitat function and action effects (2007 CA, Appendix C, Annexes 1–2).

[56] In the Action Agencies' 2007 CA, the populations designated "priority populations," and also referred to as "populations of greatest need," were those for which the life-cycle analysis in the Comprehensive Analysis indicated that the specified tributary habitat survival improvements were needed to produce increased adult returns per spawner to the spawning grounds (i.e., to achieve productivity metrics of returns per spawner >1).

[57] The Action Agencies have continued to implement habitat improvement actions for these populations to further reduce risk.

3.1.1.2 Scientific Basis of Tributary Habitat Program

At its most basic level, the tributary habitat program relies on the relationship between fish and their habitat, and on our understanding of how habitat restoration actions affect habitat quantity, quality, and function, and ultimately egg-to-smolt survival. There is a strong relationship between freshwater habitat quantity and quality and salmon and steelhead survival and productivity in freshwater—and this relationship is fundamental to the persistence of salmon and steelhead over time (Roni et al. 2013a). Habitat quantity and quality requirements for Pacific salmonids by life stage and species have been well documented in scientific literature. Roni et al. (2013a) summarize these requirements for adult upstream migration and spawning, egg-to-fry survival, and juvenile rearing in freshwater.

It is also well documented that anthropogenic activities can reduce habitat quantity or degrade habitat quality, and that these changes in turn can adversely affect salmonid populations. Habitat loss or isolation has greatly reduced the amount of salmon habitat available in the Columbia basin as a result of blockages to fish migration, disconnection of river and floodplain habitats through the construction of levees or bank revetments, and filling of floodplain channels through the conversion of lands to agricultural or residential and urban uses. By reducing habitat capacity, such actions can result in decreased abundance of, and other deleterious effects on, salmon populations. Similarly, human actions such as logging, development, mining, road building, and agriculture can degrade habitat quality through various mechanisms. For example, road building increases sediment supply, and increased sediment can reduce egg-to-fry survival; removal of riparian vegetation can reduce in-channel stream structure needed for spawning and rearing, and increase water temperature. Reduced stream flow, as a result of water withdrawals can lead to reduced survival and productivity (Roni et al. 2013a).

In reviewing available scientific information regarding the best methods for achieving the benefits needed from tributary habitat improvement, we looked at several lines of evidence. These include literature on the physical and biological effectiveness of restoration actions in the Columbia River basin, as well as in other parts of the Pacific Northwest or the world; correlation analyses; and preliminary results from intensively monitored watersheds[58] (IMWs) underway within the Columbia River basin to evaluate the effects of different actions on limiting factors and on salmon and steelhead survival.

To understand how habitat affects fish, it is helpful to know something about the biological structure of salmon and steelhead ESUs and DPSs and the range of habitats they occupy. Each ESU or DPS consists of multiple independent populations that spawn in different watersheds throughout the range of the ESU or DPS. Additionally, within an ESU or DPS, independent populations are organized into larger groups known as major population groups (MPGs). MPGs

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[58] See Section 3.1.1.4, *Overview of Research, Monitoring, and Evaluation Program*, for more information about intensively monitored watersheds.

are groups of populations that share similarities within the ESU or DPS. They are defined on the basis of genetic, geographic (hydrographic), and habitat considerations (ICTRT 2005).[59]

3.1.1.3 Scientific Basis of Tributary Habitat Program: Effects of Habitat Restoration

The outcomes of habitat restoration are well documented and support the basis of the tributary habitat program. Numerous studies have been published on the physical and biological effectiveness of restoration actions in the Pacific Northwest and elsewhere. Roni et al. (2002, 2008, 2013a) have reviewed over 400 papers or readily available technical reports on the effectiveness of habitat restoration actions, including 61 studies published since 2008. The majority of published evaluations of habitat improvement are from North America (70%), with most studies from the western United States and Canada (Roni et al. 2013a). In cases where papers examine restoration efforts outside of the Columbia River basin and the Pacific Northwest, the techniques used are similar to those used in the Columbia River basin, and in many cases focus on salmonid fishes (Roni et al. 2013a). The results of these evaluations are summarized below.

In addition, several long-term studies are underway within the Columbia River Basin, including several IMWs being implemented under the BiOp, to evaluate the effects of different habitat restoration actions on limiting factors and on salmon and steelhead survival. These efforts are, however, relatively early in the implementation process, and only preliminary information on the effects of actions on survival and productivity is available at this time (see Section 3.1.1.4 below for discussion of preliminary results).

3.1.1.3.1 Effects at Stream Reach Scale

Habitat restoration actions have been well documented to provide benefits to fish at the stream reach scale.[60] Roni et al. (2013a) summarized conclusions from the literature on the effects of the types of restoration actions used in the BiOp RPA Actions 34 and 35 tributary habitat program. They found that many studies have reported improvements in physical habitat, particularly at a stream reach scale, for various restoration techniques. While fewer studies have focused on quantifying biological responses, Roni et al. (2013a) found that studies have shown reach-scale increases in fish abundance, size, or growth in response to passage improvements, placement of instream structures, and reconnection of tributary and floodplain habitat.

Some types of actions have been shown to have relatively immediate benefits. Removal of barriers or installation of fish passage has consistently been reported as effective for increasing fish numbers. Most studies evaluating the effectiveness of placement of instream structures such

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[59] The ESA Section 7(a)(2) standards are applied at the ESU or DPS level, and not at the MPG or population level.

[60] The term "stream reach" refers to a length of stream between two points. Reaches can be defined for various purposes. For instance, a reach can refer to a length of stream treated with a particular habitat improvement action, such as placement of boulders and large wood to improve instream structure. This is contrasted with a watershed, which refers to the drainage area of a stream or stream system (http://water.usgs.gov/wsc/glossary.html#D).

as logs, logjams, cover structure, or boulders and gravel (to increase pool area, habitat complexity, and spawning habitat) have also shown increased abundance of juvenile salmonids after treatment.[61] Studies of off-channel and floodplain habitat restoration have also consistently shown rapid recolonization of newly accessible habitats by salmonids and other fishes and, in some cases, have shown improved overwinter survival. Fish rearing in floodplain habitats created or reconnected following levee removal or setbacks often have higher growth rates than those in the mainstem. The literature has also shown that increases in base stream flow lead to increases in fish and macroinvertebrate production, with responses most dramatic in stream reaches that were previously dewatered or too warm to support fish due to water withdrawals (Roni et al. 2013a). For example, while data are not published, ongoing studies in the Lemhi River show increased spawner and juvenile fish numbers following restoration of instream flows in tributaries (Roni et al. 2013a). Studies have also shown rapid recolonization of stream habitats modified by reintroduced beaver. Recent studies have also shown that "beaver support structures," such as those constructed on Bridge Creek in the John Day watershed, can lead to construction of beaver dams and aggradation of incised channels (Pollock et al. 2012 and DeVries et al. 2012, cited in Roni et al. 2013a). Unpublished evidence from Bridge Creek also indicates improvements in juvenile steelhead abundance and survival following placement of beaver enhancement structures (Roni et al. 2013a).

Most monitoring of screening projects is compliance monitoring rather than effectiveness monitoring, focusing on whether installing or upgrading screens has reduced entrainment of fish into irrigation or water withdrawal systems. A modeling study in the Lemhi basin, however, suggests that the screening of most diversions encountered by Chinook salmon in that basin has potentially reduced mortality due to entrainment from 71.1% to 1.9% (Walters et al. 2012, cited in Roni et al. 2013a).

Riparian treatments and restoration of the riparian zone, including riparian planting, fencing, and removal of invasive species, lead to increased shade and bank stability, reduced fine sediment and water temperature, and improved water quality and are often critical to the success of other project types (e.g., projects to restore instream structure or floodplain function). Their effects, however, are less direct or occur over a longer term. Monitoring of riparian planting has focused on survival of plantings and has included monitoring of several BPA-funded projects, which generally has shown relatively high survival rates of plantings and increases in shade in the first few years following planting. Few studies have examined the response of instream habitat or fish to riparian planting or thinning, in part because of the long time period between planting and change in channel conditions or delivery of large wood. A few short-term studies have examined the response of fish or other instream biota to various riparian treatments and have produced variable results; however, response in the project area may be limited since most riparian

[61] The lack of a response or small decrease in abundance reported in some studies is large because watershed processes (e.g., sediment, water quality, etc.) were not addressed, monitoring had not occurred long enough to show results, or the treatments resulted in little change in physical habitat (Roni et al. 2013a).

treatments influence reach-scale conditions and processes while in-channel conditions are generally more affected by upstream or watershed-scale features (Roni et al. 2013a).

Similar to riparian planting, studies examining the removal of invasive vegetation have focused on the short-term response of vegetation changes. Roni et al. (2013a) found no published studies that examined the effects on channel conditions or fish and aquatic biota. They note that the success of projects to remove invasive species is highly dependent on the species in question, local site conditions, and follow-up maintenance.

The effectiveness of riparian fencing to exclude livestock and of rest-rotation grazing (in which livestock are excluded from certain areas for periods of time) has been the subject of several studies. Improvements in riparian vegetation, bank erosion, channel width, depth, width:depth ratios, and fine sediment levels have been well documented in most, particularly for complete livestock exclusion. Fish response to rest-rotation grazing systems has been highly variable (Roni et al. 2013a).

Efforts to reduce sediment delivery to streams fall into two major categories: (1) road restoration or modifications and (2) agricultural treatments to reduce sediment. Most evaluations of road treatments have focused on physical monitoring of landslides, fine sediment, and runoff. Little monitoring has been done to examine fish or other biota response to road treatments. Likewise, while the impacts of agriculture practices on streams and water quality have been well documented, relatively little information exists on the effectiveness of different agriculture practices in reducing fine sediment and improving salmon habitat (Roni et al. 2013a).

Studies examining changes in salmon or steelhead survival are much less numerous, in part because directly measuring survival is complex. Of the nearly 400 studies that Roni et al. (2013a) examined, 19 reported on changes in survival, rather than changes in fish numbers, density, size, or growth. The studies that document survival benefits focused on treatments that create or reconnect ponds or side channels and improve instream habitat. Of the 19 studies that Roni et al. (2013a) evaluated, about 13 suggested that survival improved post-restoration or was equivalent to that found in high-quality reference sites. Roni et al. (2013a) concluded that, in general, it appears that floodplain creation or reconnection leads to survival rates for coho and Chinook salmon that are equivalent to that found in natural floodplain habitats. They note that several researchers have determined that placement of large wood and instream structures can lead to increased survival for salmon and trout (Roni et al. 2013a).[62] Roni et al. (2013a) also note that studies have found that improvement of spawning habitat through the addition of gravel or of gravel retention structures appears to lead to some improvements in egg-to-fry survival for salmon and trout.

[62] Most of the evidence on which this conclusion is based was for coho salmon.

3.1.1.3.2 Effects at Watershed or Population Scale

Establishing relationships between habitat improvement and fish response at the watershed or population scale is also complex. For example, if there are 20 stream reaches in a watershed and only two are treated with restoration actions, the overall signal in the watershed would likely still be dominated by the untreated reaches. This makes detecting a change difficult, and researchers must look for situations where they can treat enough of a watershed to measure an effect. For this reason, completed population-scale assessments of the effectiveness of restoration actions are rare, although this scale is most meaningful for understanding relationships between habitat improvement and fish population response. The simplest such studies are of barrier removals, and a number of studies show dramatic population-level responses to reopening access to large amounts of habitat (Roni et al. 2013a). These studies clearly indicate that where habitat capacity has been reduced, restoring lost capacity results in relatively large and rapid population increases (Roni et al. 2013a). Most of the evidence for increases that resulted from restoring lost capacity comes from areas where downstream survivals are sufficient to allow for replacement (i.e., for spawner-to-recruit ratios of 1:1) on average over a period of years. For some ESUs and DPSs in the Columbia River basin this is not necessarily the case, and achieving “large and rapid” population increases from restoring capacity may also require improving survivals in other life stages.

Of studies looking at other types of restoration actions, Roni et al. (2013a) consider Solazzi et al. (2000) the most robust to date. Solazzi et al. (2000) demonstrated that creation of winter rearing habitat increased winter survival for coho salmon as well as the number of smolts leaving the stream in spring. In these experiments, construction of wood-formed pools and excavated alcoves increased winter rearing area by roughly 700%, and overwinter survival and number of smolts increased by about 200%.

For another study in the Strait of Juan de Fuca IMW in northwestern Washington, although the population abundance analyses have not yet been completed, early results show that increased pool area due to restoration activities may have increased coho salmon survival in the treated watershed (Roni et al. unpublished, cited in Roni et al. 2013a).

3.1.1.3.3 Correlation Analyses

Correlation analyses are another way to examine relationships between habitat quality and fish abundance. These analyses do not prove cause and effect, but they do provide associations and linkages that are helpful in evaluating whether multiple habitat improvements gain enough cumulative influence to have a positive effect on entire populations or species. The results of these analyses demonstrate that protected lands, high-quality stream habitat, and habitat improvement actions such as those proceeding under the 2008 BiOp are associated with significantly higher juvenile fish survival (BPA and Reclamation 2013a).

Paulsen and Fisher (2001, cited in BPA and Reclamation 2013a) compared the survival of fish from 20 different watersheds, each with different land-use characteristics, to evaluate relationships between the parr-to-smolt survival of wild Snake River spring/summer Chinook salmon and two indices of land use: mean road density and land use classifications such as agricultural or wilderness. The study found that fish from areas of reduced human development survived at a higher rate than those from areas of more intensive land use.

In another correlation analysis, Paulsen and Fisher (2005, cited in BPA and Reclamation 2013a) found that habitat improvements accounted for significantly higher survival for fish from areas with the most actions. This evidence emerged from the analysis of data from 33 wild juvenile fish tagging sites in the Snake River basin. The study compared the proportion of fish from each site that survived to reach Lower Granite Dam, the first dam they would pass on their migration to the ocean. Paulsen and Fisher correlated survival with numbers of the kind of habitat improvements they considered most likely to affect juvenile salmon survival. The analysis showed that juvenile fish from areas with large numbers of habitat actions survived at as much as 20% higher rates compared with those from areas with fewer actions. The authors concluded that if the relationship between habitat and fish survival was indeed causal, substantial increases in juvenile survival rates might be feasible for many of the stocks considered in the analysis (BPA and Reclamation 2013a).

In 2011, Paulsen and Fisher updated their 2005 analysis with new data through 2009 and found that the same relationships held true. They also expanded the analysis to detect relationships between habitat improvements and the number of juvenile fish that survive to return as adults. They found that the influence of habitat improvements carried through to adulthood, and that fish from areas with the most habitat actions survived their downstream migration and years at sea and returned as adults at a higher rate than those from areas with fewer actions (Paulsen and Fisher, unpublished manuscript, 2011, cited in BPA and Reclamation 2013a). The results of this study indicate that large numbers of habitat improvements such as those underway through the BiOp may benefit salmon not only in their early life as juveniles, but also through their return to spawning streams as adults (BPA and Reclamation 2013a).

Other correlations appeared to explain the relationship between habitat actions and increased survival. Relatively higher numbers of habitat actions were associated with larger juvenile fish, suggesting that fish rearing in streams with more habitat improvements grow faster and begin their migration downstream earlier. Larger fish that begin the trip to the ocean sooner were, in turn, more likely to survive their trip down the river and their years in the ocean to return as adults (Paulsen and Fisher, unpublished manuscript, 2011, cited in BPA and Reclamation 2013a).

Other analyses (McHugh et al. 2004 and Budy and Schaller 2007, cited in BPA and Reclamation 2013a) modeled the potential for habitat improvements to benefit Snake River salmon populations. Budy and Schaller (2007) found potential for an average of 104% increase in total life cycle survival from tributary habitat improvements, but concluded that was not enough—in the absence of survival increases in other parts of the life cycle—to ensure the viability of most populations. They noted that the analysis considered only physical factors associated with stream degradation that influences temperature and substrate, excluding factors such as irrigation diversions and exotic species. Still, the finding underscores the purpose of the All-H, life-cycle approach to salmon protection that includes major improvements and performance standards at dams. The authors noted that all populations are at risk of habitat degradation and that access to adequate habitat has likely kept some populations from going extinct. They suggested that similar modeling could help focus habitat actions on populations where they will make the most difference.

Another analysis by Roni et al. (2010, cited in BPA and Reclamation 2013a) used results from evaluations of habitat actions in western Washington and Oregon to predict how different concentrations of restoration actions would affect juvenile coho salmon and steelhead in the Puget Sound basin. The results generally agreed with other estimates of how habitat improvements increased fish numbers. Simulations by Roni et al. showed that habitat restoration across a watershed could considerably increase juvenile fish numbers, which is generally consistent with the findings of Paulsen and Fisher (2005). Roni et al. concluded that about 20% of floodplain and in-channel habitat would have to be restored to produce a 25% increase in juvenile fish, the minimum increase considered detectable under most monitoring programs, and that additional habitat improvements would provide greater certainty of a detectable increase in fish numbers.

3.1.1.4 Preliminary Results from the 2008 BiOp Tributary Habitat Monitoring Program

Although large-scale studies and reviews have provided evidence for the benefits of habitat improvement, they have consistently called for more detailed and long-term research to further our understanding of the mechanics of fish–habitat relationships and, in turn, to better inform and guide the planning and execution of future habitat improvement actions (BPA and Reclamation 2013a). Under the 2008 BiOp and the FCRPS AMIP (adopted as part of the 2008 BiOp and its 2010 Supplement; see Section 1.1), the Action Agencies are implementing an extensive tributary habitat monitoring program (under RPA Actions 56 and 57), paired with fish population status monitoring (under RPA Action 50), to define the benefits of habitat improvements (2008 BiOp, 2010 BiOp, AMIP). This research, monitoring, and evaluation (RME) program is part of an adaptive management approach designed to inform and shape future habitat actions so they deliver increasingly meaningful and cost-effective results (BPA and Reclamation 2013a). The program is described briefly below (and in more detail in the 2013 Draft CE, BPA 2013, and BPA and Reclamation 2013a). While data from the program are still preliminary, the habitat status and trend data and paired fish status monitoring results have added to our knowledge regarding important relationships between habitat treatments and effects on fish.

3.1.1.4.1 Overview of Research, Monitoring, and Evaluation Program

Monitoring to evaluate the fish response to cumulative effects of multiple habitat actions at the watershed or population scale is underway through the BiOp’s Integrated Status and

Effectiveness Monitoring Program (ISEMP), which includes IMWs that undergo detailed monitoring and tracking of adult and juvenile fish. IMWs may test specific hypotheses through before-after-control-impact experiments, which monitor stream reaches before and after habitat-improvement actions are implemented, so that results between reaches with improvements and reaches without improvements can be compared. The use of comparisons can help researchers more clearly gauge the benefits of habitat improvements. Researchers examine and analyze the data for evidence of the most important habitat variables, for the details of how improvement actions can reshape those variables and, finally, for how future actions might influence fish populations. Additional data is supplied by monitoring conducted using the Columbia Habitat Monitoring Protocol (CHaMP), which monitors habitat conditions at hundreds of sites across the Columbia basin and is strategically paired with population status monitoring (BPA and Reclamation 2013a; BPA 2013).

Such programs must have robust experimental design, including data of sufficient size, duration, and spatial scale and resolution, to detect change despite environmental variation (i.e., the designs must have sufficient statistical power). Otherwise, for example, a positive change in habitat could result in an increase in juvenile abundance, but could go undetected without an adequate level of accuracy and precision in estimating fish abundance. For this reason, adult and juvenile status and trend monitoring (under RPA Action 50) in IMWs, and in additional watersheds being monitored under the CHaMP, has been a key element in pairing "fish in/fish out" numbers with the overall status of habitat in a watershed. As the monitoring program evolves, the Action Agencies, based in part on input from the Independent Scientific Review Panel (ISRP), will continue to look for opportunities to improve collaboration with other habitat monitoring efforts to improve sampling efficiencies and promote coordination (e.g., with the PACFISH/INFISH Biological Opinion Effectiveness Monitoring Program).

The CHaMP sites will be distributed across the Columbia basin such that at least one population per MPG is monitored for both habitat and fish abundance. The intent is to obtain sufficient data to calibrate mathematical models simulating the overall effects of habitat improvement on changes in habitat condition and, in turn, the effects of changes in habitat condition on fish abundance and productivity within each MPG and each ESU or DPS within the interior Columbia basin. The models would provide information on change in habitat and fish population status for many of the watersheds where RPA Action 35, Table 5, identified major habitat quality improvement (and corresponding survival improvement) needs. Over time, these data would augment the analytical approaches used to evaluate changes in habitat condition and fish population response by providing quantitative data for specific watersheds and for extrapolation to other watersheds.[63] The information would also help detect trends in habitat condition over broader geographic scales, including effects of climate change. Fish population and habitat status

[63] For more detailed discussion of methods currently used to evaluate changes in habitat and fish population response, see the 2007 CA, Appendix C, and Sections 3.1.1.6 and 3.1.1.7 below.

information is now being collected for the seven Chinook salmon populations and eight of the 11 steelhead populations identified as priorities in Table 5 of RPA Action 35 of the 2008 BiOp. CHaMP monitoring is being conducted for another 11 steelhead populations and seven Chinook salmon populations included in Table 5 of RPA Action 35.

In addition to monitoring designed to detect changes at the watershed and fish population level, research and monitoring of specific actions (under RPA Action 73) or limited reaches is also under way. Such efforts operate under more controlled conditions with fewer variables and can more clearly expose the relationships between actions and results. The monitoring can take different forms, from basic implementation monitoring that determines whether actions have been completed properly and are functioning as anticipated, to experiments that compare the results of specific habitat actions to control areas that are left alone (BPA and Reclamation 2013a).

3.1.1.4.2 Preliminary Results

Data from the 2008 BiOp RME program are preliminary but appear to be confirming that implementation of tributary habitat improvement actions under RPA Actions 34 and 35 is contributing to improvements in fish population abundance and productivity. Example results are noted below. For a more extensive summary of preliminary results, see BPA and Reclamation 2013a):

- In the Entiat River, the IMW is being used to assess whether engineered log structures added to streams, channels, and other habitat improvements increase habitat complexity and diversity enough to produce a population-level increase in salmon abundance or productivity. Preliminary findings include increased numbers of pools and greater densities of juvenile Chinook and steelhead in pools created by the log structures during early summer (Dretke et al. 2012, cited in BPA and Reclamation 2013a).
- The Methow River IMW design focuses on how actions influence habitat over a watershed scale to increase available food supply to salmonids. The design strategy uses models to guide the planning of field work as well as to support analysis. The effects of habitat actions on fish growth rates and survival will be placed in the context of a full life-cycle model (USBOR 2013). An analysis of recent smolts-per-redd data indicates that freshwater habitat is limiting juvenile salmon. Two monitoring studies conducted under the 2008 BiOp have shown positive trends in fish abundance as a result of habitat improvement actions. An extensive monitoring effort in Beaver Creek (Weigel et al. 2013) after a fish barrier was removed has demonstrated recolonization by wild steelhead spawners above the barrier. Monitoring of a levee removal and side channel reconstruction project at Elbow Coulee in the Twisp River shows an increased abundance of listed spring Chinook and steelhead (Crandall 2009, 2010, 2013). Results of these and other actions will be analyzed for watershed-level effects.
- In the Upper Middle Fork John Day watershed, steelhead spawner abundance increased in the treatment area from 2008 to 2011 (primary actions included re-meandering and placement of wood revetments to provide bank stability and reduce sediment loading) compared to abundance in the South Fork of the John Day, which is the control watershed (Abraham and Curry 2012). Further monitoring may more clearly indicate whether the increases result from the restoration actions.

Overall, these site-specific and large-scale studies are confirming the scientific basis for protecting and improving habitat to promote salmon and steelhead survival and abundance. The evidence comes not from a single study but rather from the increasing weight of the literature, supported by preliminary data from monitoring at various spatial scales and emerging results of experimental studies in the Columbia River Basin. The preliminary results from the RME program also provide confidence that the program can detect and gauge improvements in habitat conditions and fish populations.

Research is establishing relationships between habitat quality and fish survival and is identifying the factors that most influence juvenile salmon and steelhead productivity. An understanding of those relationships, combined with detailed watershed and population assessments, is helping biologists and managers target the most critical habitat issues and more accurately estimate the benefits for fish. This in turn is helping the Action Agencies better focus the location, types, and distribution of tributary habitat improvement actions to achieve greater benefits. The above information supplements the information summarized in Appendix C of the 2007 CA and in the 2008 and 2010 BiOps, and further supports the efficacy of the tributary habitat program.

3.1.1.5 Feasibility of Achieving Survival Improvements

In addition to describing the theoretical and empirical support for the tributary habitat program in the 2008 BiOp and the 2010 Supplemental BiOp, NOAA Fisheries discussed the feasibility of meeting the specific habitat quality improvement (HQI) performance standards, and their associated survival improvements, identified in Table 5 of RPA 35, noting that the performance standards were within the range of potential survival benefits identified in already completed or developing recovery plans (2008 BiOp, Section 7.2.2).

The Action Agencies have further demonstrated the feasibility of meeting the HQI performance standards by estimating the benefits of habitat improvement actions implemented through 2011 or identified for implementation through 2018. Their analysis, using results from expert panel evaluations and other methods developed through the collaborative BiOp remand process, indicates that implementation of actions through 2011 was sufficient to meet or exceed the HQI performance standards for 35 of the 56 populations in Table 5 of RPA Action 35.[64,65] For the remaining 21 populations, the Action Agencies worked with local partners to identify actions for implementation through 2018. In 2012 they convened expert panels to evaluate the changes in limiting factors that implementation of these actions would be projected to achieve. Using the methods described below (see Sections 3.1.1.6 and 3.1.1.7; also see Section 3.1.2.2 for more detail on the Action Agencies' 2012 process), the Action Agencies converted the expert panel results to the HQI and associated survival improvement expected from implementation of those actions.[66] Their analysis indicates that implementation of the actions evaluated would meet or exceed the HQI performance standard for all but one population in Table 5 of RPA Action 35. For the one exception, the Catherine Creek spring Chinook salmon population, the Action

[64] The HQI performance standards for these populations were generally small (less than 5%), with the exception of the Lemhi spring Chinook, Pahsimeroi spring Chinook, and Pahsimeroi steelhead populations.

[65] Note that there are actually 58 "populations" listed in Table 5 of RPA Action 35; however, the Joseph Creek (OR) and Joseph Creek (WA) populations are considered a single population, parts of which are managed by two states, and there is no target for the Hells Canyon steelhead population—so there are 56 populations with targets.

[66] As also discussed below, in Section 3.1.2.2,for some actions identified and evaluated after the 2012 expert panels had met, the Action Agencies did a preliminary evaluation of benefits; benefits for these projects will be re-evaluated by the expert panels in 2015.

Agencies have outlined a strategy for selecting additional actions that is reasonably certain to achieve the HQI performance standard.

This further demonstrates that the habitat response potential exists to meet the HQI performance standards. In addition, as discussed in Section 3.1.2.2, the Action Agencies have established momentum in the tributary habitat program, developed institutional capacity and local relationships, and demonstrated the ability to implement the needed actions by the end of 2018. They have implemented actions sufficient to achieve or exceed, or that demonstrate significant progress toward achieving, the HQI performance standards for most of the RPA Action 35 Table 5 populations. Finally, they have outlined plans for implementing the program in an adaptive management context to achieve the HQI performance standards for all the RPA Action 35 Table 5 populations (2013 Draft CE).

3.1.1.6 Methods for Estimating Habitat Benefits

In this section, we describe the use of expert panels in conservation science generally and then the use of expert panels by the Action Agencies, including the method used by the panels to estimate benefits of tributary habitat improvement actions, the qualifications of expert panel members, and their use of best available science and information.

In compliance with RPA 35 in the 2008 BiOp, the Action Agencies convened expert panels, in collaboration with regional partners, to identify and weight the significance of tributary habitat limiting factors and to evaluate the change in limiting factor function that would be expected at the population scale from completed and proposed actions, using methods consistent with the CHW recommendations. The Action Agencies worked with regional partners to convene seven panels to evaluate actions, initially for all Table 5 populations they had designated as priority populations, grouped in the following geographic areas:

- Upper Columbia River
- Lower Snake River
- Lower Grande Ronde, Wallowa, and Imnaha rivers
- Upper Grande Ronde River
- Lower Salmon River
- Upper Salmon River
- Clearwater River

The expert panels also evaluated actions affecting the other RPA Action 35 Table 5 populations that occurred in these geographic areas.[67] The Upper Columbia River expert panel addressed the

[67] There is no expert panel in the geographic range of the MCR Steelhead DPS; HQIs and corresponding survival improvements for populations in that DPS were evaluated using the so-called Appendix E method. In addition, the Appendix E method was used for some populations up until 2009, when it was replaced by and the CHW method (see Section 3.1.1.1).

UCR spring Chinook ESU and the UCR steelhead DPS. The six other expert panels addressed populations within the Snake River spring/summer Chinook ESU and the Snake River steelhead DPS (2013 Draft CE, Section 1). The panels met in 2007,[68] 2009, and 2012, and will be convened again in 2015,[69] to collaboratively evaluate limiting factors and the changes to limiting factors expected to result from implementation of habitat improvement actions (BPA and Reclamation 2013b). Panels evaluate changes to limiting factor function expected to result from actions proposed for implementation, and then retrospectively evaluate actions once they have been implemented to capture any changes in proposed actions or in knowledge regarding action effects (Milstein et al. 2013, Appendix C).

3.1.1.6.1 Use of Expert Opinion in Conservation Science

Expert opinions are judgments used as a form of scientific evidence, in contrast to evidence derived from direct empirical observation or to model driven extrapolation based on empirical evidence. Expert knowledge is used widely in conservation science, particularly where data are scarce, problems are complex, and decisions are needed in a short time frame (Martin et al. 2011).

Marcot et al. (2012) note numerous natural resource modeling, management, planning, and impact assessment processes that have used expert opinion. Examples include evaluation of a habitat model for elk; development of faunal distribution models; modeling of the potential occurrence of rare species; evaluation of adaptive management options; development of computer programs for advising on species and habitat conservation; predicting extinction probabilities of marine fishes; evaluating effects of land use on biodiversity; and evaluating the conservation status of rivers.

One critical step in eliciting expert opinion is the solicitation and representation of expert knowledge in a reliable, rigorous, and unbiased fashion, especially from multiple experts. One major approach to this involves conducting expert panels. Expert panels as a means of eliciting expert opinion have been used extensively by natural resource and land management agencies for a wide variety of problems, including evaluating potential effects on species viability from an array of forest and land management planning options; determining the appropriate conservation status for a wide variety of potentially at-risk species under the Northwest Forest Plan; and developing a management plan for a national forest in Alaska (Marcot et al. 2012).

[68] The Action Agencies convened expert panels in 2007 to evaluate actions identified in their 2007 Biological Assessment for implementation in 2007–2009.
[69] NOAA Fisheries and the Action Agencies are still in discussion regarding the final schedule for convening expert panels in the remaining period of the 2008 BiOp.

3.1.1.6.2 Qualifications of Expert Panel Members

FCRPS expert panel members are highly qualified for the task they carry out. Membership varies by location but in general includes technical staff from Federal natural resource agencies, tribes, state resource management agencies, salmon recovery boards and their technical teams, soil and water conservation districts, non-profit groups, and private consultants. They are trained in disciplines including biology, hydrology, and engineering, and have direct knowledge of watershed processes, habitat conditions, and fish populations in the particular area being evaluated (BPA and BOR 2013b). Many have been involved in or are intimately familiar with habitat assessments and analysis conducted as part of the NPCC's subbasin planning process, NOAA Fisheries' ESA recovery planning process, other assessment work, and RME results.

Names of attendees at expert panel meetings are posted on the website maintained by Reclamation as a resource for the expert panels.[70] This includes both expert panel members and observers or ad hoc participants in meetings.

3.1.1.6.3 Method and Rationale for Biological Opinion Expert Panel Decisions

The expert panel method, which is consistent with guidance developed by the CHW, represents a cause-and-effect chain of events that links the completion of habitat improvement actions to changes in habitat functions. As discussed above in Section 3.1.1.3, there is a sound scientific foundation for this cause-and-effect chain. To predict the magnitude of those changes, it is first necessary to predict how habitat improvement actions will change habitat. To make those predictions, the CHW developed an approach that involves using expert opinion and empirical data when available. That recommendation was based on the fact that empirical data were not available everywhere for use in predicting changes in habitat as a result of implementing improvement actions (2007 CA, Appendix C, attachment C-1).

The CHW method that the Action Agencies have adopted for predicting changes in habitat function that will result from implementation of habitat improvement actions involves the following steps (2007 CA, Appendix C, Attachment C-1 and Milstein et al. 2013, Appendix C):

1. **Identify and weight assessment units within each population**. Assessment units are subareas of a population's freshwater habitat that share similar geography and limiting factors. This unit of analysis is useful because it recognizes important variation of habitat conditions within the population and makes the population-level analysis more sensitive to and reflective of that diversity. Because some assessment units have greater intrinsic productive potential than others, they are weighted to reflect their influence within a population. Expert panels define and weight the assessment units based on an intrinsic-potential analysis by the Interior Columbia Technical Recovery Team and other available information, including recovery plans and subbasin plans. Expert panels can adjust assessment unit weights based on new information. For example, in certain cases, the expert panels adjusted relative

[70] http://www.usbr.gov/pn/fcrps/habitat/panels/meetings/index.html

assessment unit weight to better align with current habitat use, so as not to overestimate the influence of some assessment units that historically were productive but currently are underutilized.

2. **Identify limiting factors**. Tributary habitat limiting factors are the habitat characteristics that negatively affect spawning, redds (nests of fish eggs), emergence of salmon fry from eggs, summer and winter juvenile fish growth and rearing, and smolting of salmon and steelhead in tributaries to the main stem of the Columbia and Snake rivers. Examples of these limiting factors are lack of instream structural complexity, decreased water quantity, impaired side channel and wetland conditions, and high water temperature. Limiting factors may differ in different parts of each tributary. As part of the pre-work for the expert panels, the Action Agencies assembled limiting factors information for each assessment unit, using recovery plans or draft recovery plans where available, as well as NPCC subbasin plans and other available information. Expert panels confirmed the identification of limiting factors for each assessment unit.

3. **Identify limiting factor function**. Expert panels assign numbers between zero and one to represent limiting factor function relative to properly functioning condition in several timeframes.[71] Low values indicate relatively poorer condition; higher values indicate conditions closer to proper function. The score that describes the current function of a limiting factor is referred to as the "low bookend." Two additional values—referred to as "high bookends"— describe the potential function of each limiting factor by 2018 (the end of the 2008 BiOp) and by 2033 (25 years after the end of the 2008 BiOp), assuming implementation of all technically feasible habitat improvement actions within the term of the 2008 BiOp. The high bookends indicate the potential for improvement in function of a limiting factor relative to its current function (i.e., its low bookend). Consistent with the CHW recommendations, the expert panels assigned these values based on best available information, including model results and empirical data where available, as well as on their best professional judgment.

4. **Identify limiting factor weights**. The relative influence of some limiting factors on salmon or steelhead productivity can vary among assessment units as a function of the particular combinations of habitat conditions. As a result, some limiting factors in each assessment may affect salmon and steelhead productivity more than others. Expert Panels weight limiting factors to recognize the relative importance of each in each assessment unit by assigning a weight between zero and one to each limiting factor. The sum of all limiting factor weights for an assessment unit must equal one. So, for example, an expert panel might assign a weight of 0.6 to streamflow, 0.2 to

[71] For a discussion of the term *properly functioning condition* as used in implementation of the 2008 FCRPS BiOp tributary habitat program, see Spinazola 2012.

riparian condition, and 0.2 to in-stream channel complexity if streamflow has a greater relative effect on conditions for salmon and steelhead than the other two factors.

5. **Evaluate changes in limiting factor status resulting from completed and planned actions**. Panels evaluate the change in each limiting factor associated with a group of habitat actions that affect that limiting factor in each assessment unit. Consistent with the CHW recommendations, the expert panels estimated these changes based on best available empirical, modeling, and assessment information as well as best professional judgment. Panels evaluate changes to limiting factors expected to result from actions proposed for implementation and then retrospectively evaluate actions once they have been implemented to capture any changes in proposed actions or in knowledge regarding action effects. They estimate changes through 2018 (the end of the 2008 BiOp) and through 2033 (25 years after the end of the 2008 BiOp).

   In making their decisions regarding changes in limiting factor function likely to result from habitat actions, expert panels consider synergy among actions and the need for sequencing of actions within a watershed. They also consider the possibility that future habitat conditions will degrade and that upstream influences may reduce habitat treatment effectiveness. These kinds of considerations were explicitly incorporated into guidance for the expert panels on estimating habitat improvement potential; panels were directed to consider whether the following variables might cause a substantially lower estimate of the degree of change for each environmental attribute that can be expected from the entire set of actions:

   - Any existing estimates from recovery or subbasin plans or other sources
   - Context and location of actions
   - Extent of the actions and resulting treatment of limiting factors
   - Effectiveness of methods used in implementing the actions
   - Interdependence of limiting factors treated by the actions with other factors and extent to which these other factors are also treated
   - Degree of certainty that actions will have the expected effect on limiting factors
   - Risk of effects from other threats that would confound or reduce the positive effects of the actions (2008 Kratz Declaration, *NWF v. NMFS*, Doc. No. 1564, cv-01-640-SI [D. Oregon]).

Once the expert panels have completed the steps described above, the Action Agencies use the expert panel results to identify overall changes in habitat quality and corresponding changes in survival (see Section 3.1.1.7 below).

3.1.1.6.4 Use of Best Available Information in Expert Panel Decisions

Expert panel members base their decisions not only on professional expertise and personal knowledge of habitats in the area, but also on the best available scientific information, including data on the status of fish runs; subbasin plans developed for the NPCC's subbasin planning process; NOAA Fisheries' ESA recovery plans and draft recovery plans; Reclamation's tributary and reach assessments; results of relevant research and monitoring; and other sources(including modeling such as Ecosystem Diagnostic and Treatment modeling, where it has been developed for the populations in question) (2013 Draft CE; BPA and Reclamation 2013b).

To make a core set of information readily available to expert panels, the Action Agencies developed a website[72] on which they made background information available to the expert panels. Information posted includes instructions; maps and graphical tools for use in evaluating assessment unit boundaries and in identifying and weighting limiting factors; recent monitoring reports; and the latest scientific information on climate change, invasive species, and toxins. The website ensures that information is uniformly available among the seven expert panels. The website also includes meeting agendas, lists of attendees, presentations by the Action Agencies on the expert panel process, presentations by NOAA's NWFSC staff on the effects of habitat actions on different salmonid life history stages, and information from meetings that the Action Agencies held with regional, state, and tribal partners in preparation for the 2012 expert panel workshops (2013 Draft CE).

3.1.1.7 Methods for Estimating Survival Benefits

Once they developed a method for estimating changes in habitat condition that would result from implementation of habitat improvement actions, the CHW needed to determine how to estimate survival benefits associated with those proposed actions. "Survival benefits" refers to increases in the proportion of salmon or steelhead surviving from one life stage to another, e.g., from eggs to fry emerging from eggs, or numbers of juveniles surviving in their overwintering habitat. These life stage specific survival benefits can ultimately be reflected in improved productivity at the population scale. Estimating the relationship between changes in habitat condition and changes in survival essentially involved characterizing the "shape" of the relationship between habitat quality (expressed in terms of percent of optimal function) and survival (2007 CA, Appendix C, Attachment C-1).

The CHW explored a number of options, including existing life-cycle models that could be used to guide professional judgment. After considering these options, the group decided that the most transparent approach that could credibly be applied across populations was to use a set of commonly used empirical relationships that characterize relationships between temperature, fine sediment, flows, and cover for different juvenile life stages and prespawning adults. These functions describe the relationship between specific habitat attributes and survival. Combining

[72] http://www.usbr.gov/pn/fcrps/habitat/panels/reference/index.html

these functions with professional judgment, the CHW developed a method to translate changes in habitat into survival changes (2007 CA, Appendix C, Attachment C-1).

To develop this method, the workgroup plotted the available empirical relationships, looking for a common functional shape among them that could be used to relate survival changes to relative change in an overall index of habitat function. The group explored several approaches to find this shape of central tendency among the various empirical relationships. They also compared the results using the alternative approaches with other modeling results where available. The CHW collectively agreed that given data currently available, a linear function was the most “realistic” and should be used to guide professional judgment (a linear relationship means that survival would be expected to improve at the same rate as habitat quality improves.) The linear relationship provided estimates of survival changes close to Ecosystem Diagnostic and Treatment modeling results where they were available, and fit well with published literature that indicates that more intensive and extensive restoration actions result in greater survival benefits (e.g., Paulsen and Fisher 2001) (2007 CA, Appendix C, Attachment C-1).

To calculate the survival improvements expected to result from implementation of a suite of actions, the Action Agencies use the output generated by the expert panels as described above in Section 3.1.1.6: specifically, consistent with the CHW method, they use the expert panels’ estimates of changes in limiting factor function to carry out the following steps (2007 CA, Appendix C, Attachment C-1; Milstein et al. 2013, Appendix C):

1. **Calculate current and updated habitat function for each assessment unit and population**. The Action Agencies multiply limiting factor weight by limiting factor status (under both current and changed conditions predicted as a result of implementation of habitat improvement actions through 2018) and sum all limiting factors to determine an overall habitat function for each assessment unit for both current and updated conditions.[73] If any limiting factor in an assessment unit was considered “lethal” (i.e., functioning at less than 20% of properly functioning condition), the entire assessment unit was not factored in to overall population-level habitat or survival improvements until the function of all limiting factors in the assessment unit was above the 20% threshold. The CHW considered multiple approaches to deriving a composite score for habitat quality and decided that this approach was the most reasonable. The Action Agencies then sum the estimates for all assessment units to the population level for both the current and updated habitat condition to derive population-level habitat condition.

[73] “Updated conditions” is used here generally to refer to what in reality is two separate evaluations by the expert panels: the so-called “look back,” in which the panels evaluate actions as actually implemented and estimate the effects, and the so-called “look forward,” in which the panels evaluate actions identified for future implementation and estimate their benefits.

2. **Calculate current and updated habitat condition (i.e., survival) for each population**. The Action Agencies then calculate current and updated habitat condition (i.e., survival) for each population by multiplying the current and updated habitat function for each population by the slope of the linear egg-to-smolt survival function developed by the CHW for Chinook salmon and steelhead. The Action Agencies refer to the resulting survival rate estimate as a "habitat quality index," or "habitat quality improvement," and NOAA Fisheries incorporated the terminology into the 2008 RPA and in this supplemental opinion.
3. **Calculate change in population-level survival estimates**. The ratio of survival under the two habitat conditions (current and updated) represents the proportional change in population survival expected from implementing the habitat improvement actions. Because the functions for each species are defined as linear, the proportional changes in habitat condition are equivalent to the proportional changes in survival for each species. This standardized approach for translating changes in habitat quality into survival changes eliminates the need to derive specific survival estimates for each reach and action.

3.1.1.8 Refinements to Tributary Habitat Analytical Methods

As with any science-based analytical approach, NOAA Fisheries and the Action Agencies intended for the methods used in the tributary habitat program to evolve through learning and adaptive management, and based on experiences with implementation, acquisition of monitoring data, new research findings, and improved tools and processes. The Action Agencies have refined the expert panel process to take advantage of this learning since its inception, and these refinements will continue. The Action Agencies have also initiated the tributary habitat monitoring and evaluation program described above and are utilizing preliminary results. In addition, NOAA Fisheries and the Action Agencies have reviewed relevant new research and are in the process of developing tributary habitat components for life-cycle models. They will continue to explore how to incorporate new research, monitoring information, and models in the 2015 expert panel process and beyond.

Described below are refinements to date and discussion of how the Action Agencies will continue to refine the tributary habitat program in the remaining term of the 2008 BiOp. These refinements demonstrate that the Action Agencies are using, and will continue to use, the best available science.

3.1.1.8.1 Refinements to Expert Panels

The Action Agencies have made a number of refinements to the expert panel process as well as to the process of identifying habitat improvement actions since the 2008 BiOp was completed. These refinements are largely based on the lessons learned to date from the initial expert panel reviews and the ongoing RME program. These refinements improve the focus of habitat improvement actions on the limiting factors and locations that will yield the greatest habitat quality improvement and associated survival benefit; address knowledge gaps; and improve the rigor, transparency, consistency, and repeatability of the expert panel process.

These refinements include:

- **Additional Tributary and Reach Assessments.** Tributary and reach assessments describe the geomorphic, hydraulic, and biological processes that influence the success of potential habitat improvement actions; describe historical conditions and factors that limit biotic production; establish environmental baseline conditions for comparison to post-implementation physical and biological conditions; and identify priority areas for habitat protection and improvement actions. Since 2008 the Action Agencies have completed 20 assessments with input and involvement from local scientists and other public participants.[74] In these assessments, the Action Agencies use an approach and methodology consistent with findings and recommendations of the process-based habitat improvement strategy advocated by NOAA Fisheries and presented in Roni et al. (2002, 2008) and Beechie et al. (2008, 2010; 2013 Draft CE, Section 2 and Appendix A).
- **Limiting Factor Pie Charts.** The Action Agencies developed maps showing assessment units within each population and corresponding pie charts depicting limiting factors for each assessment unit.[75] The maps and pie charts represent the expert panels' conclusions regarding limiting factors for each assessment unit within a population and also reflect data sources such as recovery plans, available modeling results, the Interior Columbia Technical Recovery Team's intrinsic potential analysis, and research. They also demonstrate the extent to which limiting factors remain to be addressed. These visual representations are useful in identifying potential actions and in expert panel workshops. The Action Agencies generated pie charts for use in the 2012 expert panel workshops that documented conclusions from the 2009 expert panel workshops. These were useful in evaluating potential impacts of actions—for example, they could be used to visualize whether an action addressed a highly weighted limiting factor in a highly weighted assessment unit that had a high potential for change. The Action Agencies updated the pie charts to reflect the outcomes of the 2012 expert panel workshops, and these will be available to the Action Agencies and their implementing partners as they plan, prioritize, and refine

[74] Examples of these assessments are available at http://www.usbr.gov/pn/programs/fcrps/thp/index.html
[75] http://www.usbr.gov/pn/fcrps/habitat/panels/piemaps/index.html

actions for implementation. The NPCC plans to use the maps and pie charts in future program reviews and to support funding recommendations (2013 Draft CE, Section 2 and Appendix A).

- **Use of RME Information.** The Action Agencies oversee an RME program to evaluate the effectiveness of implemented actions, inform development of future actions, and inform understanding of and assumptions about fish-habitat relationships and the adequacy of tributary habitat improvement actions for achieving HQIs and associated survival improvements. The Action Agencies work to incorporate RME information into decision making, administrative processes, action prioritization, and action implementation. This occurs in various ways, depending on timing and the level of analysis or data and report development necessary to share results and preliminary conclusions. For example, in January 2013 monitoring results for the Intensively Monitored Watersheds and elsewhere were presented at Reclamation's annual program meeting for the Columbia/Snake Salmon Recovery Office. Representatives from the Action Agencies and NOAA's NWFSC attended. In March 2013, the Pacific Northwest Aquatic Monitoring Partnership convened a meeting for presentation and discussion of the most recent results from Intensively Monitored Watersheds. As this information becomes available, the Action Agencies and other regional monitoring partners work to ensure it is shared through professional channels. The Action Agencies endeavor to deliver updated science and RME findings to partners and stakeholders so that they are brought to bear on decision processes. Recently, the Action Agencies have described preliminary RME results in a document titled "Benefits of Tributary Habitat Improvement in the Columbia River Basin; Results of Research, Monitoring, and Evaluation, 2001–2012" (BPA and Reclamation 2013a). This report will support implementation planning, expert panel processes, and action development, prioritization, and implementation for tributary habitat improvement actions. RME results from 2007–2012 also are described in the 2013 Draft CE, Sections 1–3.
- **Enhancing Action Agency Organizational Capacity.** The Action Agencies have hired staff with expertise in fish biology, geomorphology, geology, hydrology, environmental compliance and cultural resources, and hydraulic engineering and modeling to participate in local planning processes and other efforts to develop products that enhance implementation of the tributary habitat program. These staff members contribute to the planning, prioritization, and selection discourse that precedes action implementation, and to the evaluation of whether actions function as intended after they are completed. These evaluations in turn contribute to adaptive management, allowing local partners and the Action Agencies to identify and correct for unanticipated deficiencies or make improvements to existing and future actions (2013 Draft CE, Section 2 and Appendix A).

- **Ensuring availability of information.** As described above in Section 3.1.1.6.4, the Action Agencies developed a website[76] to make a core set of information readily available to the expert panels (2013 Draft CE, Section 2 and Appendix A). Information posted includes instructions; assessment unit maps and limiting factor pie charts; recent monitoring reports; and the latest scientific information on climate change, invasive species, and toxins.
- **Web-accessible system to manage data sets from Expert Panels.** To better manage the expert panel process data sets, the Action Agencies developed and use a web-accessible system to store and manage the material compiled, reviewed, and analyzed through the expert panel process. This system has improved the recording and tracking of the expert panel data sets, and it provides increased consistency across the expert panels (2013 Draft CE, Section 2).
- **Integrating expert panel and other watershed planning processes.** A number of other processes that involve watershed planning and improvement to enhance salmon survival have been underway throughout the Columbia River basin for over 30 years. These include the NPCC's subbasin planning process and NOAA Fisheries' ESA recovery planning process for salmon and steelhead. The Action Agencies have worked with the local groups involved in those processes to integrate FCRPS planning, prioritization, and implementation with these other processes. This enhanced regional collaboration ensures that the expert panels have access to information and analyses of habitat limiting factors and restoration strategies developed through those efforts, leading to more effective and efficient use of resources throughout the region and among these various processes (2013 Draft CE, Section 2 and Appendix A). (For more detailed descriptions of the integration of these processes in the Upper Columbia and the Southeast Washington portion of the Snake River basin, see Appendices A and B in Milstein et al. 2013).
- **Documentation of Expert Panels**: For the 2012 expert panels, the Action Agencies improved the process of documentation. For instance, note takers attended each meeting in an effort to capture more of the expert panel rationales for decisions than had been captured for previous expert panels. Documenting not only the results of the expert panels evaluations but also the key considerations behind their conclusions provides for more effective exchanges among panels and enhances the potential for constructive feedback from outside technical reviewers. Both of these elements are important to an effective adaptive management approach. Notes are incorporated in the expert panel data sets (Spinazola 2013)

Scientists from NOAA's NWFSC attended 2012 expert panel meetings and provided their observations and recommendations on the process to the NOAA Fisheries Northwest Regional

[76] http://www.usbr.gov/pn/fcrps/habitat/panels/reference/index.html

Office. They noted that the Action Agencies and expert panel members made an effort to standardize the criteria used to make judgments on habitat conditions and percent improvement, although the groups varied in how detailed their descriptions were and how much documentation they provided. The reviewers noted that, based on observing the panels' deliberations and conclusions and on their own knowledge of fish–habitat relationships, the panels were conscientious and conservative about their estimates of percent habitat improvement (Roni et al. 2013b).

These NWFSC scientists also made several recommendations for continuing to improve the expert panel process (Roni et al. 2013b). Those recommendations, along with steps the Action Agencies have taken to address the recommendations, and NOAA Fisheries' conclusions regarding the need for continued refinements, are discussed below.

> *Recommendation:* The Action Agencies need to better document and describe how the expert panels arrive at their estimates of habitat improvements, including documentation of the type and quality of information used to make each estimate. Defining where data and/or professional opinion are used will help clarify the process.
>
> *Response:* The Action Agencies have taken steps to facilitate consistency among expert panels and to document panels' conclusions. To make a consistent set of information available to panels, they developed the website described above. They also have begun using NOAA Fisheries' standard terms and definitions for limiting factors (Hamm, n.d.). NOAA Fisheries developed these after the 2009 expert panels had met, and the Action Agencies converted the 2009 limiting factors to the standard terms and definitions to provide consistency throughout the Columbia River basin for the 2012 expert panels. In addition, in 2012, they enhanced the extent to which notes documenting the rationale for expert panel decisions were incorporated into the database of expert panel results, and they provided staff specifically to take notes during most of the 2012 expert panel workshops (see Spinazola 2013).
>
> The Action Agencies will continue the process of improving the documentation of expert panel decisions that began in 2007 and continued in 2009 and 2012. NOAA Fisheries and the Action Agencies are discussing language that will be incorporated into the final supplemental opinion and the 2014–2018 Draft IP to describe specific steps that will be taken.
>
> *Recommendation:* The limiting factors identified for each assessment unit seem reasonable, but additional analysis confirming which factors are actually limiting each population would be helpful in prioritizing actions.
>
> *Response:* The Action Agencies note that in expert panel meetings preceding the workshops at which the panels evaluate the benefits of habitat improvement actions, the panels confirm which factors are most limiting, using best available information informed by expert opinion. They note that in doing so, the panels rely upon limiting factor and other analyses in NOAA Fisheries' recovery plans (Puckett 2013). The Action Agencies

will continue to ensure that expert panels have access to best available information on limiting factors and that the panels have an opportunity to confirm and, where needed, update their limiting factor weightings and assessment of function. NOAA Fisheries and the Action Agencies are discussing language that will be incorporated into the final supplemental opinion and the 2014–2018 Draft IP to describe specific steps that will be taken.

Recommendation: The estimates of baseline percent function for each limiting factor come from a variety of sources, including empirical data, other planning documents, modeling, and professional judgment. The panels used the best data available, although data quality varied within and among basins. Converting measures of habitat condition to a percent of properly functioning condition is, for the most part, subjective. The Action Agencies should provide guidelines to the expert panels on how to determine a percent of optimal condition so that it is done consistently across populations and expert panels.

Response: The Action Agencies note that expert panels use the best data available, including available data from monitoring programs. They also note that there were guidelines provided to the expert panels for estimating percent function .[77] The Action Agencies welcome NOAA Fisheries' participation, in collaboration with other partners, in developing additional guidance for expert panels in 2015 (Puckett 2013). The Action Agencies will continue to provide guidelines for expert panels based on best available information so that the process is more transparent, consistent, and repeatable. NOAA Fisheries and the Action Agencies are discussing language that will be incorporated into the final supplemental opinion and the 2014–2018 Draft IP to describe specific steps that will be taken.

Recommendation: In developing estimates of how limiting factor function will improve as a result of implementing actions, the expert panels should use the range of responses reported in the literature to bracket and help estimate restoration response.

Response: The Action Agencies note that they agree there is considerable literature on the effectiveness of habitat improvement actions and that they anticipate continuing to make it available to the panels via the website they maintain for that purpose (Puckett 2013). NOAA Fisheries and the Action Agencies are discussing language that will be incorporated into the final supplemental opinion and the 2014–2018 Draft IP to describe specific steps that will be taken.

Recommendation: Expert panels should include independent scientists from outside the basin in question to help ensure objective evaluation of habitat actions.

In March 2009, the Action Agencies and NOAA Fisheries discussed the potential for conflict of local interests affecting expert panel determinations and outlined a series of steps to address this valid concern (see Puckett 2013). NOAA Fisheries agrees with the Action Agencies that there is a need to balance the potential for conflict of interest with

[77] See, e.g., Spinazola 2012.

ensuring that habitat improvement action benefits are estimated by experts with an appropriate level of local knowledge. The risk is also reduced by the relative diversity in composition of most panels and by the public nature of the process.

3.1.1.8.2 Refinements in Methods for Predicting Survival Improvements

RPA Action 57.5 directed the Action Agencies to expand and refine models that relate habitat actions to ecosystem function and salmon survival. The Action Agencies continue to support the NOAA NWFSC life-cycle modeling effort, which includes the development and testing of several habitat models in collaboration with key state and tribal scientists (2013 Draft CE, Section 2). No single functional model would be expected to address all needs for estimating restoration benefits and priorities. In many cases, comparing results from two or more alternative functional models will increase the likelihood of properly rating the potential benefits of implementing a particular action. Models are population specific due to the unique characteristics of each watershed and population; while extrapolating model findings from one watershed or population to another is common, it must be done with caution (Roni et al. 2013a). Augmenting such extrapolations with more detailed functional models reflecting the specific characteristics of the particular watershed or population in question should improve confidence in the outcome. In addition, reviewing the workings of more detailed functional modeling applications can provide valuable insights into designing effective adaptive monitoring efforts that will give early feedback on response to implementation of actions.

RPA Action 57.5 directed the Action Agencies to convene a regional technical group annually to expand and refine models that relate habitat actions to ecosystem function and salmon survival by incorporating research and monitoring results and other relevant information. The NOAA/Action Agency RME Workgroup has identified general, conceptual modeling approaches and discussed them with ISAB/ISRP on multiple occasions between 2008 and 2012 (2013 Draft CE, Section 2).

Reclamation funded and co-sponsored a modeling workshop in February 2011 with the U.S. Geological Survey, NWFSC, and Columbia River Inter-tribal Fish Commission. The workshop identified a wide variety of habitat–fish models currently in use. BPA is funding work on modeling through projects in the Grande Ronde, Okanagon Basin Monitoring and Evaluation Program (OBMEP), CHaMP, and ISEMP IMWs. This work is largely designed to test current assumptions regarding functional relationships between habitat conditions, fish life-stage productivity, or habitat capacity. The efforts are also designed to further explore potential fish-habitat relationships and to identify relationships not currently understood. For example, Reclamation is developing a Methow River life-cycle model and a fish population and habitat processes mechanistic model in a system-dynamics framework. Additional investigation of regression model approaches at the direction of the NOAA/Action Agency RME Workgroup is ongoing. In several cases, the ongoing work to confirm or further elucidate fish–habitat relationships in these monitoring programs is being incorporated into full life-cycle models. The Action Agencies continue to support the NWFSC life-cycle modeling, which includes the development and testing of several habitat models in collaboration with key state and tribal scientists (2013 Draft CE, Section 2).

The Action Agencies state that collaborative development of more explicit and quantitative models and relationships remains limited by the need for more detailed fish and habitat data. The pilot research and monitoring projects that the Action Agencies have implemented should help to identify appropriate fish and habitat metrics and monitoring designs for this needed information. The ongoing implementation and collaboration of ISEMP, CHaMP, and the Reclamation monitoring programs, in coordination with Federal, state, and tribal collaborative habitat and life cycle modeling effort led by the NWFSC, should substantially advance the development and application of habitat and fish relationships during the 2014 to 2018 implementation period (2013 Draft CE, Section 2).

The Action Agencies will ensure that usable results from any models available in 2015 and beyond that would support the work of the expert panels are brought to the attention of the panels. Also, if models provide usable new information relevant to relating habitat change to change in egg-to-smolt survival, the Action Agencies will consider how that information relates to the CHW method currently in use and how it can be used as additional information in estimating relationships between change in habitat and change in survival. In addition, once empirical survival estimates become available from IMWs and other studies, they may further inform the methodology used to convert habitat improvements into changes in survival.

3.1.1.8.3 Refinements in Research, Monitoring, and Evaluation

The RME program (summarized above in Section 3.1.1.4.1) that is implemented under the 2008 BiOp has begun to yield data, although analysis based on the data is still preliminary. Several IMW studies are underway to quantify population-level responses to restoration and to quantify the effects of multiple restoration techniques throughout a watershed on salmon survival and production. Initial results from these studies are promising; however, results will not be available for most of these studies for 5 years or more, and results may not be directly transferable to other populations and watersheds (Roni et al. 2013a).

There is uncertainty regarding the precise effects that tributary habitat actions will have on habitat productivity and on salmon and steelhead survival. The RME program put in place under the 2008 BiOp and the AMIP was rigorously designed to provide statistically meaningful results on the effects of the program in a manner that could be used in an adaptive management framework for the program. The monitoring components set into motion in 2010 to obtain accurate spawner abundance information, juvenile migrant information, and watershed-scale habitat status/trend information have begun to build a picture of watershed productivity and of the way in which specific watersheds throughout the Columbia River basin are responding to habitat restoration in terms of fish produced. In some watersheds, such as the Lemhi River, where tributaries disconnected for a century for irrigation purposes have been reconnected, habitat restoration actions have begun to exhibit immediate results. Salmon and steelhead have already been documented using streams that have not been used for 100 years. By 2015, some watersheds will have collected habitat and fish data for four or five years, enough to be able to demonstrate whether habitat conditions have changed. By 2018 another three years of data will have been recorded for juveniles, and returning spawners will have been recorded. As additional information is collected, the habitat improvements completed can be better evaluated and the effects of proposed actions more specifically identified and predicted.

The information generated by the integrated tributary habitat and fish production monitoring programs will be an important driver in future adaptive management decisions in support of achieving BiOp objectives. In some cases sufficient information may be generated to directly link results from fish-in and fish-out studies to changes in habitat measured in direct response to specific actions. However, given the high level of year-to-year environmental variability in fish density and survival, it is more likely that further insights into fish responses to particular classes of actions will come from statistical analyses across treatment and control watersheds or populations. It is also likely that action effects on direct measures of habitat condition will be detectable in a relatively shorter period of time than will fish response to habitat actions. For example, the effect of actions intended to improve summer rearing conditions (e.g., restoration of stream structure, flow, and riparian habitat) may be more apparent in terms of their effect on habitat conditions in a shorter time frame than their effects on fish response. The resulting refinements in our assessment of the potential effects of specific restoration actions in particular habitat settings will feed directly into future adaptive implementation efforts.

Where little or no response is observed in fish production, adaptive management decisions will be possible to alter the restoration strategy toward the revealed limiting factors or to reassess the overall production capability of the watersheds thereby improving the methods of the expert panels. It is also anticipated that where intensive monitoring has not been possible that the information gathered will allow for predictive models that will have a much greater possibility of accurately predicting and confirming the effectiveness of management actions in those watersheds as well as the effectiveness of the overall tributary habitat strategy.

As noted above in Section 3.1.1.4.1, as the monitoring program evolves, the Action Agencies, based in part on input from the ISRP, will continue to identify opportunities to enhance collaboration and coordinate with other habitat monitoring efforts to improve sampling efficiencies and promote coordination (e.g., with the PACFISH/INFISH Biological Opinion Effectiveness Monitoring Program). NOAA Fisheries supports these efforts. As the Action Agencies continue these efforts, they will ensure that the objectives established for habitat status and trends monitoring in the AMIP of the 2010 BiOp are met, including

- status and trend monitoring of habitat condition coupled with adult and juvenile monitoring to allow the agencies to assess fish survival and habitat productivity improvements expected from FCRPS actions (including monitoring of at least one population per MPG)
- improved modeling of the expected benefits of habitat actions,

- ensure monitoring of appropriate habitat metrics (e.g., flow and temperature) across a diversity of ecological regions and habitat types to assess responses to climate change, and
- clarify the connections between restoration actions and freshwater survival of salmonids.

3.1.1.9 Tributary Habitat Analytical Methods: Conclusion

The analytical approach described above uses the best available scientific information for assessing the effects of actions occurring across the diverse watersheds of the Columbia River basin and affecting multiple ESUs and DPSs. Best available scientific literature on the subject of habitat restoration indicates that many habitat restoration actions can improve salmon survival over relatively short periods. Examples include increasing instream flow, improving access to blocked habitat, reducing mortality from entrainment at water diversion screens, placing of logs and other structures to improve stream structure, and restoring off-channel and floodplain habitat (see Section 3.1.1.3). Other habitat improvements, such as sediment reduction in spawning areas and the restoration of riparian vegetation, may take decades to realize their full benefit (see Section 3.1.1.3; Roni et al. 2013a, Beechie et al. 2003).

The best available scientific literature also supports the RPA approach of improving tributary habitat to increase survival of salmon and steelhead at the population scale (see Section 3.1.1.3). Preliminary results from the tributary habitat monitoring and evaluation program (see Section 3.1.1.4) provide evidence that the Action Agencies' habitat improvements are correctly targeting and improving degraded conditions and that fish are responding through increased abundance, density, and survival.

The approach used to estimate changes in habitat as a result of implementing tributary habitat actions and the corresponding survival improvements is based on the best available scientific information from fish and habitat experts and on general empirical relationships between habitat quality and salmonid survival. Professional judgment by experts provided a large part of the determination of habitat function in all locations given the limited extent of readily available empirical data and information. Although empirical data and information provide the best insight for determining habitat function and corresponding salmonid survival, the extent of readily available empirical data was not adequate to make a precise determination of habitat function and salmonid response uniformly throughout the Columbia River basin. NOAA Fisheries finds that the approach developed and information gathered through the CHW, and subsequently applied here, represents the best available scientific information that can be consistently applied over the larger Columbia basin to estimate the survival response of salmonids to habitat mitigation actions.

Literature reviewed in the 2010 Supplemental BiOp, Section 2.2.3.1, and in this supplemental opinion (see Sections 3.1.1.2 and 3.1.1.3), emphasizes the need to incorporate proper planning, sequencing, and prioritization into decision frameworks to best achieve habitat program objectives. This literature recommends that planners assess the natural potential of a system and use the information to direct action location, design, and selection. Beechie et al. (2010) outlined four principles that would ensure river restoration was guided toward sustainable actions:

- Address the root causes of degradation
- Be consistent with the physical and biological potential of the site
- Scale actions to be commensurate with the environmental problems
- Clearly articulate the expected outcomes

This approach corresponds with the approach taken in the RPA as implemented by the Action Agencies. For instance, Reclamation's effort to develop tributary and reach assessments is designed to evaluate the physical processes acting on a watershed and to identify limiting factors at a finer scale than is available from subbasin plans and recovery plans.

In summary, the information reviewed above in Sections 3.1.1.2 through 3.1.1.7 supports NOAA Fisheries' assumptions in the 2008 BiOp that the RPA tributary habitat program will sufficiently address factors that limit the functioning and conservation value of habitat that interior Columbia River basin salmon and steelhead use for spawning and rearing and that implementation of actions through 2018 is reasonably certain to achieve the survival improvements identified in Table 5 of RPA Action 35.

3.1.2 Effects of the RPA Tributary Habitat Program on Interior Columbia ESUs/DPSs

As noted above, the 2008 BiOp includes two RPA Actions (numbers 34 and 35) to improve tributary habitat. Both require the Action Agencies to provide funding and technical assistance to implement tributary habitat actions that improve the quality and quantity of spawning and rearing habitat for specific populations of Snake River and UCR Chinook and steelhead and MCR steelhead. The main goal of the program implemented under these RPA Actions is to increase population survival by decreasing the impact of key habitat factors that limit spawning and freshwater rearing success. Table 5 of RPA Action 35 in the 2008 BiOp contains specific habitat quality improvement (HQI) performance standards, which correspond to survival improvements, for 56 populations of Chinook salmon and steelhead.

The preceding section described the analytical approach upon which the tributary habitat program is based and NOAA Fisheries' conclusion that the program represents best available science. The sections below describe implementation and effects of the tributary habitat program and NOAA Fisheries' conclusions regarding the effects of the program. Sections 3.1.2.1 and 3.1.2.2 describe effects of the program generally on multiple ESUs/DPSs. Section 3.1.2.1 describes the Action Agencies' implementation of, and the effects of, RPA Action 34, implementation of which was completed in 2009. Section 3.1.2.2 describes the Action Agencies' implementation of, and the effects of, RPA Action 35. This discussion includes the effects of actions implemented through 2011 and the projected effects of specific actions identified and evaluated for implementation through 2018. Also discussed are the Action Agencies' institutional capacity to implement the program, and the adaptive management framework within which they will implement the program through 2018. Sections 3.1.2.3 through 3.1.2.7 describe in more detail the effects of implementation of the tributary habitat program on the Snake River spring/summer Chinook salmon ESU, the UCR spring Chinook salmon ESU, the Snake River steelhead DPS, the UCR steelhead DPS, and the MCR steelhead DPS. Our conclusions regarding the effects of the tributary habitat program are found in Section 3.1.2.9.

In the 2008 BiOp and the 2010 Supplemental BiOp, NOAA Fisheries concluded that the RPA addressed factors limiting the functioning and conservation value of spawning and rearing habitat sufficiently to increase the survival of the affected populations to meet the BiOp RPA objectives (2008 BiOp, Section 7.2.2; 2010 Supplemental BiOp, Section 2.2.3). In this supplemental biological opinion, we reaffirm that conclusion for the reasons outlined below. Our analysis of the effects of the tributary habitat program is based on the reasonable expectation that all estimated life stage and population-specific survival benefits estimated by the Action Agencies using the CHW process will be realized as a result of implementing actions to improve overall habitat quality and quantity, with a focus on improving the function of the factors limiting fish survival. NOAA Fisheries' confidence in this expectation is supported by the discussion above in Section 3.1.1.

3.1.2.1 Tributary Habitat Program: RPA Action 34

RPA Action 34 required implementation during 2007 to 2009 of specific actions identified in the Action Agencies' 2007 FCRPS Biological Assessment (USACE et al. 2007b) and incorporated into the 2008 BiOp. The Action Agencies completed implementation of RPA 34 in 2009 and reported accomplishments in the FCRPS Annual Progress Reports for 2006–2007, 2008, and 2009 (USACE et al. 2008, 2009a, 2009b).[78] Reporting included annual accomplishments for the actions identified in the 2007 FCRPS Biological Assessment (USACE et al. 2007b), which served as the 2007–2009 Implementation Plan, plus any additional actions or actions implemented in place of those that proved infeasible (2013 Draft CE, Section 2). The 2013 Draft CE (Section 3, Attachment 2, Tables 1–3) summarizes metrics by population for RPA 34 actions completed in the period from 2007 through 2009. Cumulatively, tributary habitat metrics achieved from 2007 through 2009 to benefit UCR, SR, and MCR Chinook salmon and steelhead resulted in (2013 Draft CE, Section 2):

- 119,619 acre-feet of water protected
- 82 miles of stream habitat treated to enhance complexity
- 4,130 acres of riparian habitat improved for better function
- 15 locations with fish screens installed or addressed for fish protection
- 696 miles of improved access to fish habitat

The 2013 Draft CE Section 2 Table 35 column headed "Estimated Percentage Habitat Quality Improvement of 2007-2009 Actions" summarizes the HQIs projected to be achieved from implementing the specific actions incorporated into RPA Action 34 (these HQIs represent a portion of the 2018 HQI performance standards).[79] As indicated in the 2013 Draft CE Section 2 Table 35 column headed "Habitat Quality Improvement Achieved through 2009," actions implemented in 2007–2009 were sufficient to meet or exceed those projections for 35 of the 56 populations in RPA Action 35 Table 5.[80] In addition, for 32 of the 56 populations in RPA Action 35 Table 5, the actions implemented through 2009 were sufficient to meet or exceed the actual 2018 HQI performance standard.

[78] Available at www.salmonrecovery.gov

[79] The Action Agencies developed these HQI projections using methods developed through the BiOp regional collaboration process.

[80] The HQIs shown in this column represent benefits of habitat improvement actions that were completed by 2009 as planned in 2007, planned in 2007 but completed with modifications by 2009, and completed by 2009 but not planned in 2007. Actions planned for implementation in 2007–2009 but not implemented in that time period were completed in a subsequent implementation cycle or, if they proved infeasible, replaced with other actions.

3.1.2.2 Tributary Habitat Program: RPA Action 35

RPA Action 35 of the 2008 BiOp requires implementation during 2010 to 2018. Table 5 of RPA Action 35 includes performance standards for 56 salmon and steelhead populations. These performance standards identify specific HQIs, which correspond to survival improvements, for 56 populations, 18 of which are designated priority populations (2013 Draft CE, Section 1; 2008 BiOp). Actions projected to achieve the performance standards are to be implemented by the end of 2018. RPA Action 35 also includes specific direction to the Action Agencies on action identification, use of expert panels to evaluate change in habitat function from implementation of actions, and the potential use of replacement actions if necessary (2008 BiOp, Appendix, Reasonable and Prudent Alternative Table).

The technical foundation of and analytical methods used in the tributary habitat program were discussed in detail in Section 3.1.1. In brief, the Action Agencies, working with regional partners, convene expert panels in areas with priority populations to estimate changes to limiting factor function expected to result from implementation of actions developed in collaboration with local recovery planning and watershed groups and targeted at key limiting factors (2013 Draft CE Sections 1 and 2). Expert panels also review actions implemented or planned for implementation for non-priority populations in the same geographic area. Using the expert panel results and a method developed by the CHW, the Action Agencies estimate overall habitat quality improvement, and corresponding survival improvements, expected from implementation of actions.

Working with local partners, the Action Agencies then fund, implement, and track hundreds of actions. In most cases, habitat improvement actions implemented under the BiOp are developed based on NPCC subbasin plans and NOAA Fisheries' draft and final recovery plans. They are identified and developed with the participation of the local groups, generally including the groups that provide local guidance for development and implementation of subbasin and recovery plans. Complementing these processes are efforts such as the tributary and reach assessments developed by the Action Agencies and described above in Section 3.1.1.8. The overlapping of subbasin planning, recovery planning, tributary and reach assessments, and BiOp implementation is intentional and facilitates coordination and efficient use of resources. (For examples of locally based approaches to identifying and prioritizing habitat actions consistent with subbasin and recovery plan goals and BiOp priorities in the Upper Columbia and the Southeast Washington portion of the Snake River basin, see Appendices A and B of Milstein et al. 2013.)

The NPCC's Fish and Wildlife Program, which was designed to guide funding by BPA of mitigation for the effects of Federal dams, provides additional review of many projects that ultimately are implemented to support BiOp objectives and the tributary habitat program (Milstein et al. 2013). Under the NPCC's Fish and Wildlife Program geographic review process, projects are reviewed by the ISRP. The NPCC then makes recommendations regarding project implementation based on consistency with the Fish and Wildlife Program, BiOp priorities, and satisfactory science review by the ISRP. Following ISRP review and NPCC recommendations, BPA makes multiyear funding decisions. In addition, BPA's "Taurus" and "Pisces" business management systems facilitate tracking of implementation and accomplishments for BiOp and other (e.g., Fish Accord) actions, providing additional accountability and transparency in implementation (see additional discussion in Milstein et al. 2013).[81]

Under the 2008 BiOp, the 2010 Supplemental BiOp, and the AMIP, the Action Agencies also are directed to monitor action implementation and to evaluate effectiveness of actions and determine fish population response. The program is designed to produce information on habitat and fish response to action implementation at the watershed/population scale. In addition to monitoring response to particular actions in specific populations, results from monitoring habitats subject to particular action types (e.g., enhanced stream structure) across populations should increase the statistical power to detect responses.

The Action Agencies have implemented and will continue to implement the program in an adaptive management context, identifying and implementing improvements to refine the process for selecting, evaluating, and sequencing implementation of tributary habitat improvement actions (2013 Draft CE).

3.1.2.2.1 Implementation through 2011

The tributary habitat program put in place by RPA Action 35 represents a large and complex undertaking, a significant advance in the tributary habitat work that had been underway in the Columbia River basin in previous decades. Overall, the Action Agencies' implementation of the RPA 34 and 35 tributary habitat program is directing resources to actions that are targeting the limiting factors identified as most significant through a process based on sound science and technical input. The Action Agencies are also implementing the program in a manner that has helped to coalesce support among local implementing partners for habitat improvement actions focused on significant limiting factors in locations that will yield high benefits.

The Action Agencies have made significant progress toward achieving the HQI performance standards in Table 5 of RPA Action 35. The Action Agencies' analysis, using the CHW method and based on expert panel evaluations of tributary habitat improvement actions implemented through 2011, indicates that those actions were sufficient to either met or exceed the 2018 HQI performance standard for 35 of the 56 populations in Table 5 of RPA Action 35.[82] These same analyses also indicate that the Action Agencies have implemented actions sufficient to make significant progress toward achieving the 2018 HQI performance standards for another 13 populations (2013 Draft CE, Section 2).

For the remaining eight populations, including some with large 2018 HQI performance standards, the Action Agencies have made more limited progress. In one case (the Yankee Fork

[81] For publicly available components of these business management systems, see http://www.cbfish.org.
[82] The HQI performance standards for these populations were generally small (less than 5%), with the exception of the Lemhi spring Chinook, Pahsimeroi spring Chinook, and Pahsimeroi steelhead populations.

spring Chinook salmon population), the Action Agencies had not completed implementation of any actions as of 2011). The Action Agencies note instances in which limited implementation progress through 2011 was because their efforts were directed initially at conducting assessments to better identify limiting factors and project opportunities, developing local relationships and support for implementation, and addressing other implementation obstacles (2013 Draft CE, Section 2 and Appendix A).

In addition, for all populations, the Action Agencies have demonstrated the ability to achieve the HQI performance standard (it is also possible that the HQI performance standard will be exceeded for some additional populations). For all populations but one (Catherine Creek Chinook salmon), the Action Agencies have demonstrated this based on (1) the identification of specific actions that have been evaluated either by an expert panel or preliminarily by the Action Agencies, using a method based on the 2012 expert panel results; (2) their ability to mobilize Action Agency resources and stakeholder support to implement actions; (3) the development of assessments and other tools to improve the focus of projects on the most significant limiting factors and locations; and (4) the adaptive management framework within which they will implement the tributary habitat program. For the Catherine Creek spring Chinook salmon population, although actions identified and evaluated to date are not projected to meet the 2018 HQI performance standard, the Action Agencies have described a credible process and demonstrated the ability to develop additional actions sufficient to meet the performance standard (see discussion below in Section 3.1.2.3.1).

Since 2007, the Action Agencies have implemented hundreds of actions affecting 56 populations under RPA Action 35. Cumulative metrics for RPA Actions 34 and 35 include:

- Securing water rights for and protecting approximately 177,227 acre feet of instream water in the Columbia River basin
- Improving 206 miles of instream habitat to improve channel complexity and floodplain connectivity
- Improving approximately 6,812 acres of riparian habitat and protecting almost 37,000 acres
- Installing fish screens on 247 irrigation diversions
- Improving access to approximately 2,053 miles of spawning and rearing habitat (2013 Draft CE Section 1)

While these cumulative metrics do not demonstrate benefits to any particular population or inform the extent of improvements to habitat productivity, they do provide an indication of the scope and scale of the program the Action Agencies have implemented to date.

The Action Agencies' 2013 Draft CE, Section 3, Attachment 2, Tables 1 through 3, display summary information on actions completed from 2007–2012. Table 1 summarizes metrics for all completed actions by population in the 2007–2009 implementation period (i.e., RPA Action 34);

the 2010–2012 implementation period; and total cumulative completed metrics by population for the implementation period of 2007–2012. Rather than being reported at the action scale (i.e., at the scale of specific tributary habitat improvement actions implemented on the ground), metrics are summarized in this table under BPA projects used to fund the actions. (In some cases, these projects include a number of contracts, each with detailed work elements and associated metrics. In essence, multiple specific "actions" are implemented on the ground under each of these "projects." This system allows BPA to track progress in addressing limiting factors as well as other details related to contract administration.)

Table 1 of the 2013 Draft CE, Section 3, Attachment 2, includes hyperlinks to BPA's contract management system, where BPA tracks and records planned and actual work administered under BPA contracts. The "Pisces" and "Taurus" databases that BPA uses in its contract management system house data for each of the specific actions identified in the 2007 Biological Assessment (i.e., for implementation of RPA Action 34) and the 2010–2013 Implementation Plan and managed under a BPA contract. Information available in the contract management database includes project summaries, annual progress reports, timelines, implementation metrics, and budget information. Start and end dates of project milestones are displayed in the work elements section. Additional detail on projects supported or funded entirely by Reclamation and completed in 2007–2012 is displayed in Tables 2 and 3, respectively, of the Action Agencies' 2013 Draft CE, Section 3, Attachment 2 (2013 Draft CE, Section 2; also see Milstein et al. 2013, Appendix D).

All actions completed from 2007–2011 that affect a population in Table 5 of RPA Action 35 have been evaluated by an expert panel to estimate resulting changes in habitat function,[83] and the Action Agencies have converted those habitat changes into HQIs (i.e., survival improvements). The Action Agencies' conclusions regarding HQIs estimated to result from actions implemented through 2011 are shown in the 2013 Draft CE, Section 2, Table 35, and summarized below in Table 3-1.

[83] The Middle Columbia Steelhead DPS is an exception; HQIs and corresponding survival improvements for populations in that DPS were evaluated using the so-called Appendix E method. In addition, the Appendix E method was used for some populations up until 2009, when it was replaced by the CHW method. See discussion in Section 3.1.1.

Table 3.1-1. HQIs estimated from actions implemented through 2011 and projected from actions to be implemented through 2018. Numbers represent percent changes in survival. Resulting survival multipliers included in the 2008 BiOp aggregate analysis (e.g., Table 8.3.5-1 for Snake River spring/summer Chinook) are calculated as 1+(HQI/100). Bolded populations indicate priority populations from RPA Action 35 Table 5.Shaded cells indicate populations for which actions implemented through 2011 were sufficient to meet or exceed the HQI performance standard.

			From RPA Action 35, Table 5	Based on Expert Panel Results		Based on Expert Panel Results + Action Agency Estimates for Supplemental Projects[1]
ESU	**MPG**	**Population**	**Habitat Quality Improvement (Survival Improvement) Performance Standard 2007-2018**	**Habitat Quality Improvement (Survival Improvement) estimated from actions implemented through 2011**	**Cumulative Habitat Quality Improvement (Survival Improvement) projected from actions to be implemented through 2018**	**Cumulative Projected Habitat Quality Improvement (Survival Improvement) including Supplemental Actions implemented through 2018**
Snake River Spring/Summer Chinook	Lower Snake	**Tucannon River**	**17**	**2**	**29**	**29**
	Grande Ronde/ Imnaha	**Catherine Creek**	**23**	**5**	**11**	**15**[2]
		Grande Ronde River upper mainstem	**23**	**4**	**5**	**23**[2]
		**Lostine/ Wallowa River	2	3	7	7
		**Imnaha River mainstem	1	1	1	1
	South Fork Salmon River	Secesh River	1	5	6	6
		South Fork Salmon River Mainstem	<1	2	5	5
	Middle Fork Salmon River	Big Creek	1	0.4	4	4
	Upper Salmon River	Lemhi River	7	28	32	32
		Valley Creek	1	13	19	19
		Yankee Fork	**30**	**0**	**21**	**43**[2]
		Salmon River upper mainstem above Redfish Lake	14	5	13	14[2]

ESU	MPG	Population	From RPA Action 35, Table 5: Habitat Quality Improvement (Survival Improvement) Performance Standard 2007-2018	Based on Expert Panel Results: Habitat Quality Improvement (Survival Improvement) estimated from actions implemented through 2011	Based on Expert Panel Results: Cumulative Habitat Quality Improvement (Survival Improvement) projected from actions to be implemented through 2018	Based on Expert Panel Results + Action Agency Estimates for Supplemental Projects[1]: Cumulative Projected Habitat Quality Improvement (Survival Improvement) including Supplemental Actions implemented through 2018
		Salmon River lower mainstem below Redfish Lake	1	3	3	3
		East Fork Salmon River	1	2	6	6
		Pahsimeroi River	41	62	70	70
Upper Columbia Spring Chinook	Upper Columbia Below Chief Joseph	**Wenatchee River**	**3**	**1**	**5**	**5**
		Methow River	**6**	**2**	**8**	**8**
		Entiat River	**22**	**3**	**9**	**24**[2]
Upper Columbia River Steelhead	Upper Columbia River – Below Chief Joe	**Wenatchee River**	**4**	**2**	**6**	**6**
		Methow River	**4**	**2**	**7**	**7**
		Entiat River	**8**	**3**	**8**	**8**
		Okanogan River	**14**	**7**	**17**	**17**
Snake River Steelhead	Lower Snake	Tucannon River	5	3	47	47
		Asotin Creek	4	5	5	5
	Imnaha River	Imnaha River	<1	1	3	3
	Grande Ronde River	Grande Ronde River upper mainstem	4	3	4	4
		**Grande Ronde River lower mainstem tributaries	<1	0.01	0.4	0.4

ESU	MPG	Population	From RPA Action 35, Table 5: Habitat Quality Improvement (Survival Improvement) Performance Standard 2007-2018	Based on Expert Panel Results: Habitat Quality Improvement (Survival Improvement) estimated from actions implemented through 2011	Based on Expert Panel Results: Cumulative Habitat Quality Improvement (Survival Improvement) projected from actions to be implemented through 2018	Based on Expert Panel Results + Action Agency Estimates for Supplemental Projects[1]: Cumulative Projected Habitat Quality Improvement (Survival Improvement) including Supplemental Actions implemented through 2018
		**Joseph Creek (OR)	<1	0.4	1	1
		*Joseph Creek (WA)	4	4	4	4
		**Wallowa River	<1	2	3	3
	Clearwater River	**Lolo Creek**	**12**	**3**	**18**	**18**
		Lochsa River	**16**	**6**	**8**	**17**[2]
		Selway River	**<1**	**0.01**	**1**	**1**
		South Fork Clearwater River	**14**	**4**	**13**	**17**[2]
	Salmon River	**South Fork Salmon River**	**1**	**1**	**5**	**5**
		Secesh River	**6**	**5**	**6**	**6**
		Lower Middle Fork mainstem and tributaries (Big, Camas, and Loon Creeks)	**2**	**0.4**	**3**	**3**
		Lemhi River	3	23	27	27
		Pahsimeroi River	9	27	37	37
		East Fork Salmon River	2	2	4	4
		Salmon River upper mainstem	6	4	8	8
	Hells Canyon	Hells Canyon				
Middle Columbia Steelhead	Yakima River Group	*Yakima River upper mainstem	4	4	4	4
		*Naches River	4	4	4	4
		*Toppenish	4	4	4	4

ESU	MPG	Population	From RPA Action 35, Table 5: Habitat Quality Improvement (Survival Improvement) Performance Standard 2007-2018	Based on Expert Panel Results: Habitat Quality Improvement (Survival Improvement) estimated from actions implemented through 2011	Based on Expert Panel Results: Cumulative Habitat Quality Improvement (Survival Improvement) projected from actions to be implemented through 2018	Based on Expert Panel Results + Action Agency Estimates for Supplemental Projects[1]: Cumulative Projected Habitat Quality Improvement (Survival Improvement) including Supplemental Actions implemented through 2018
		*Satus Creek	4	4	4	4
	Cascade Eastern Slope Tributaries	*Deschutes River – Westside	<1	1	1	1
		*Deschutes River – eastside	1	1	1	1
		*Klickitat River	4	4	4	4
		*Fifteen mile Creek (winter run)	<1	1	1	1
	Umatilla and Walla Walla River	*Umatilla River	4	4	4	4
		*Walla Walla	4	4	4	4
		*Touchet	4	4	4	4
	John Day River	*John Day River lower mainstem tributaries	<1	1	1	1
		*North Fork John Day River	<1	1	1	1
		*John Day River upper mainstem	<1	1	1	1
		*Middle Fork John Day River	<1	1	1	1
		*South Fork John Day River	1	1	1	1

[1] This column represents results of 2012 expert panel evaluations and, for seven populations, the Action Agencies' estimates of benefits for "supplemental" actions identified after the 2012 expert panels were concluded. Benefits for these supplemental actions will be reevaluated by the expert panels in 2015. See additional discussion in text below (under "Supplemental Actions for Seven Populations").

[2] Includes estimated HQI from supplemental actions. HQI for actions evaluated by expert panels, supplemental actions, and Fish Accord actions are shown separately in Section 3, Appendices A and B of the draft 2014-2018 FCRPS BiOp Implementation Plan (USACE et al. 2013).

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The Action Agencies' analysis, using the CHW method and based on expert panel evaluations of tributary habitat improvement actions implemented through 2011, indicates that those actions were sufficient to meet or exceed the HQI performance standard for 34 of the 56 populations with an HQI performance standard in Table 5 of RPA Action 35.[84] For 12 of those populations, the analysis indicates that actions implemented through 2011 were sufficient to exceed the HQI performance standard and, for another 22 populations, were sufficient to meet the HQI performance standard. The HQI performance standards for these populations were generally small (less than 5%), with the exception of Lemhi spring Chinook (7% HQI performance standard; actions implemented through 2011 sufficient to achieve 28% HQI), Pahsimeroi spring Chinook (41% HQI performance standard; actions implemented through 2011 sufficient to achieve 62% HQI), and Pahsimeroi steelhead (9% HQI performance standard; actions implemented through 2011 sufficient to achieve 27% HQI).

The Action Agencies' analysis, using the CHW method and based on expert panel evaluations of tributary habitat improvement actions implemented through 2011, also indicates that those actions were sufficient to achieve ≥50% of the HQI performance standard for an additional seven populations (see Table 3.1-2). The ≥50% benchmark is significant because the year 2011 is roughly 50% of the 2008 BiOp implementation timeframe of 2007–2018. Therefore, having implemented actions by 2011 sufficient to achieve ≥50% of the survival improvement standard is a good indicator that the Action Agencies are on track with implementation of the tributary habitat program for those populations and that achieving the HQI performance standard, and associated survival improvement, for those populations is reasonably certain, where the Action Agencies' analysis using CHW methods and based on expert panel results also indicates that implementation of actions through 2018 will meet the HQI performance standard.

[84] Note that the populations listed above in Table 3.1-1 (and in RPA Action 35 Table 5) as Joseph Creek (OR) and Joseph Creek (WA) are considered one population (managed by two states), hence the total of 35 rather than 36 populations for which actions implemented through 2011 were sufficient to meet HQI performance standards.

Table 3.1-2. Populations for which implementation of actions through 2011 was sufficient to achieve ≥50% of the HQI performance standard.[1]

ESU/DPS	Population	HQI Performance Standard (from RPA Action 35 Table 5)	HQI estimated from actions implemented through 2011(based on expert panel results)	% of HQI performance standard estimated from actions implemented through 2011
Snake River Steelhead DPS	**Grande Ronde River Upper Mainstem**	4%	3%	75%
	Tucannon River	5%	3%	60%
	Salmon River Upper Mainstem	6%	4%	67%
	Secesh River	6%	5%	83%
Upper Columbia Steelhead DPS	**Methow River**	4%	2%	50%
	Okanogan River	14%	7%	50%
	Wenatchee River	4%	2%	50%

[1] **Bold** = priority populations from RPA Action 35 Table 5.

In addition, the Action Agencies have made significant progress (i.e., analysis indicates that actions implemented through 2011 were sufficient to achieve ≥33% of HQI performance standard) on 6 other populations (see Table 3.1-3). The benchmark of ≥33% to define significant progress, while somewhat subjective, is reasonable because it indicates that the Action Agencies have demonstrated the ability to implement habitat improvement actions with significant benefits, and, where the Action Agencies' analysis using CHW methods and based on expert panel results also indicates that implementation of actions through 2018 is projected to meet the HQI performance standards, it is reasonably certain that the Action Agencies will achieve those performance standards.

Table 3.1-3. Populations for which implementation of actions through 2011 was sufficient to achieve ≥33% of the HQI performance standard.[1]

ESU/DPS	Population	HQI Performance Standard (from RPA Action 35 Table 5)	HQI estimated from actions implemented through 2011 (based on expert panel results)	% of HQI performance standard estimated from actions implemented through 2011
Snake River Spring/Summer Chinook ESU	**Big Creek**	**1%**	**0.4%**	**40%**
	Salmon River Upper Mainstem above Redfish Lake	**14%**	**3%**	**36%**
Upper Columbia Spring Chinook ESU	**Methow River**	**6%**	**2%**	**33%**
	Wenatchee River	**3%**	**1%**	**33%**
Snake River Steelhead DPS	**Lochsa River**	**16%**	**6%**	**38%**
Upper Columbia River Steelhead DPS	**Entiat River**	**8%**	**3%**	**38%**

[1]**Bold** = priority populations from RPA Action 35 Table 5.

For the remaining populations in Table 5 of RPA Action 35, implementation of actions through 2011 was sufficient to achieve <33% of the HQI performance standard (see Table 3.1-4). In some cases the Action Agencies describe circumstances that slowed or delayed progress on these populations initially, such as the need to direct efforts initially toward conducting assessments to better identify limiting factors and habitat improvement action opportunities; to develop local relationships and support for implementation; or to address other implementation obstacles (2013 Draft CE, Section 2 and Appendix A).

Table 3.1-4. Populations for which implementation of actions through 2011 was sufficient to achieve <33% of the HQI performance standard.[1]

ESU/DPS	Population	HQI Performance Standard (from RPA Action 35 Table 5)	HQI estimated from actions implemented through 2011 (based on expert panel results)	% of HQI performance standard estimated from actions implemented through 2011
Snake River spring/summer Chinook ESU	**Catherine Creek spring Chinook**	23%	5%	22%
Snake River Spring/Summer Chinook ESU	**Grande Ronde River Upper Mainstem**	23%	4%	17%
	Tucannon River	17%	2%	12%
	Yankee Fork	30%	0%	0%
Upper Columbia Spring Chinook ESU	**Entiat River**	22%	3%	14%
Snake River Steelhead DPS	**Lolo Creek**	12%	3%	25%
	South Fork Clearwater	14%	4%	29%
	Lower Middle Fork Clearwater	2%	0.4%	21%

[1] **Bold** = priority populations from RPA Action 35 Table 5.

The Action Agencies also note that after evaluating results from the 2009 expert panel workshops, they took steps to accelerate implementation of tributary habitat improvement actions or to ensure that actions implemented yielded higher benefits in areas where progress did not appear to be on track. For example, they completed tributary assessments for Catherine Creek, the Yankee Fork, and the Entiat, and one or more reach assessments within each of these areas.[85] These assessments identified numerous habitat improvement action opportunities. Some actions based on those assessments have been completed, but they were completed after the 2012 expert panel workshops, so their benefits are not reflected yet in population HQI totals (2013 Draft CE, Section 2 and Appendix A).

The Action Agencies note that the strategies initiated after the 2009 expert panel workshops are continuing to accelerate progress toward meeting the RPA Action 35 Table 5 HQI performance standards. The Action Agencies continue to develop or refine adaptive management strategies to ensure that RPA Action 35, Table 5, HQI performance standards are

[85] For a complete list of reach assessments completed as of the summer of 2013, see the 2013 Draft CE, Section 3, Attachment 2, Table 4.

achieved. For the RPA 35 Table 5 priority populations in the upper Columbia, Clearwater, Lower Snake, Grande Ronde, upper Salmon, and lower Salmon rivers, the Action Agencies are working intensively with watershed groups, project sponsors, and Fish Accord partners to refine and implement high priority habitat improvement actions to meet or exceed RPA Action 35, Table 5, HQI performance standards (2013 Draft CE, Section 2 and Appendix A).

Because of the less substantial progress through 2011 on these populations, however, NOAA Fisheries evaluated more closely the Action Agencies' strategies for implementation of actions affecting these populations through 2018 (see Sections 3.1.2.3 through 3.1.2.7).

3.1.2.2.2 Identification of Actions for Implementation through 2018

The 2008 BiOp included specific actions for implementation from 2007–2009. For 2010–2018, the 2008 BiOp required the Action Agencies to commit to specific habitat quality improvement (HQI) performance standards and associated survival improvements for certain populations, but it did not require them to identify specific actions to achieve those improvements at the time the BiOp was issued. Instead, it relied on a process to define actions in 3-year implementation cycles (2008 BiOp, RPA Actions 34 and 35).

In 2012, however, the Action Agencies worked with local partners to identify specific actions for implementation through 2018 and, with regional partners, convened expert panels to evaluate these actions. As described above, in Section 3.1.1.6, the Action Agencies use the expert panels' estimates of changes in limiting factor function as a result of implementing actions to determine habitat quality improvement (and associated survival improvements) at the population level. Projected HQIs based on the 2012 expert panel evaluations are summarized in the Action Agencies' 2013 Draft CE, Section 2, Table 35.

Appendix A of the 2014–2018 Draft IP summarizes by population the actions for implementation through 2018 that contribute to meeting or exceeding the RPA Action 35 Table 5 2018 HQI performance standards, including limiting factors addressed and metrics expected to be achieved. (Instead of reporting each specific action evaluated by the expert panels, the metrics for the actions are summarized at the population level, and the table shows the projects in BPA's program management system under which the actions will be implemented.)[86]

In their 2013 Draft CE and 2014-2018 Draft IP, the Action Agencies also lay out an adaptive management framework (described in more detail below) within which they intend to continue to implement the tributary habitat program through 2018. This adaptive management program includes menus of specific actions in addition to a number of assessment tools and prioritization frameworks that the Action Agencies will use to refine selection, design, and sequencing of habitat improvement actions within watersheds to enhance the habitat benefits attained (2013 Draft CE).

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[86] The 2014–2018 Draft IP includes actions to be implemented in 2013, since implementation timeframes did not allow them to be incorporated in to the 2013 Draft CE.

Using the CHW method, and based on the results of the expert panels' evaluation of actions for implementation through 2018, the Action Agencies determined that the actions evaluated by the expert panels, when implemented, were projected to meet or exceed the Table 5 HQI performance standard and associated survival improvement for all but seven populations (see 2013 Draft CE, Section 2, Table 25) These seven populations are shown below in Table 3.1-5.

Table 3.1-5. Populations not projected to meet HQI performance standards based on 2012 expert panel evaluation of actions for implementation through 2018.[1]

ESU/DPS	Population	HQI Performance Standard (from RPA Action 35 Table 5)	HQI estimated from actions implemented through 2011 (based on expert panel results)	Cumulative HQI projected from actions implemented through 2018
Snake River Spring/Summer Chinook ESU	**Catherine Creek**	23%	5%	11%
	Grande Ronde Upper Mainstem	23%	4%	5%
	Yankee Fork	30%	0%	21%
	Salmon River upper mainstem above Redfish Lake	14%	5%	13%
Upper Columbia Spring Chinook ESU	**Entiat**	22%	3%	9%
Snake River Steelhead DPS	**Lochsa River**	16%	6%	8%
	South Fork Clearwater	14%	4%	13%

[1] **Bold** = priority populations from RPA Action 35 Table 5.

As noted above, the Action Agencies have reviewed the specific reasons for delay in progress toward the HQI performance standards for these populations and taken steps tailored to each circumstance to achieve the HQI performance standards. For instance, in some areas, such as Catherine Creek and the Yankee Fork, institutional infrastructure or institutional relationships were inadequate to fully implement actions that had been identified previously, or barriers to implementation needed to be addressed before efforts to deliver the Table 5 HQIs could accelerate. The Action Agencies note that since 2007 they have improved stakeholder engagement and support for actions that target key limiting factors and have helped to enhance local capacity to implement those actions. Further, they note that new assessment tools and increased understanding of limiting factors and priority reaches are providing greater assurance that the habitat improvement actions with the potential to provide the most benefit will be implemented in a timely manner (2013 Draft CE, Section 2 and Appendix A).

When the expert panels met in 2012, some NOAA Fisheries regional office staff participated on the panels and other staff attended the meetings as observers. Staff from NOAA's NWFSC also attended the meetings as observers. In addition, NOAA Fisheries staff reviewed spreadsheets assembled from the database in which the Action Agencies record the results of the expert panel deliberations (see Spinazola 2013). These spreadsheets document the expert panels' weighting of assessment units, identification and weighting of limiting factors by assessment unit, their assignment of values for current function of each limiting factors by assessment unit, and their estimates of how the function of each limiting factor would change as a result of implementation of actions through 2013. They also include notes documenting the expert panels' rationale for certain decisions, and they contain detail on specific actions evaluated that is not found in the 2014–2018 Draft IP. NOAA Fisheries' review was not exhaustive, nor was it a reanalysis of the expert panels' assessments. Rather it was a means for NOAA Fisheries staff to expand understanding of the Action Agencies' implementation of the tributary habitat program, spot-check information for certain assessment units and populations, provide constructive feedback to the Action Agencies, and, ultimately, increase NOAA's confidence that the Action Agencies' were implementing the tributary habitat program in a manner likely to achieve the RPA Action 35 Table 5 HQI performance standards.

3.1.2.2.3 Supplemental Actions for Seven Populations

Based on the Action Agencies' analysis, using the CHW method and the results of the expert panels' evaluation of tributary habitat improvement actions for implementation through 2011, the seven populations in Table 3.1-5, above, are not projected to meet their HQI performance standard without an increase in the pace and/or focus of action implementation. For these populations, the Action Agencies worked with local implementing partners to identify and evaluate supplemental tributary habitat actions. Partners included tribal partners who identified habitat improvement actions that, if implemented, would be funded with Fish Accord funding. For the Fish Accord partners that contributed to the list of supplemental actions, the actions represent part of their negotiated commitment to deliver a component of the Table 5 HQI performance standards. In some cases, these tribal partners have submitted their supplemental actions as part of projects being reviewed under the NPCC's geographic review process. Under this process, projects are reviewed by the ISRP. The NPCC then makes recommendations regarding project implementation based on consistency with the Fish and Wildlife Program, BiOp priorities, and satisfactory science review by the ISRP. Following ISRP review and NPCC recommendations, BPA makes multiyear funding decisions. .

All the supplemental actions are informed by limiting factors analyses, tributary and reach assessments, and other studies developed by local technical teams, tribes, or Federal agencies. Some supplemental actions are expansions of action evaluated by the 2012 expert panels.

The supplemental actions are summarized by population in the 2014–2018 Draft IP, Appendix B. The appendix includes limiting factors addressed and metrics expected to be achieved.

(Rather than being reported at the specific action scale, this information is summarized under the projects that BPA will use to implement specific actions, and metrics for the actions are summarized at the population scale.)

The supplemental actions will be evaluated by the expert panels when the Action Agencies next convene them in 2015, but to develop an interim estimate, the Action Agencies estimated the benefits of the supplemental habitat actions using a method based on the results from the 2012 expert panels (2013 Draft CE, Appendix B). The Action Agencies based their estimates of benefits on proposed treatment types and the estimated benefit determined by the expert panels for similar treatments. For example, if a large wood installation of a certain size or dimension was determined by the expert panel to result in some “x” measure of habitat improvement, the logic followed that a supplemental large wood installation of a certain size or dimension would likewise result in a proportional measure of “x” habitat improvement. For all but one population (Catherine Creek spring Chinook salmon), the Action Agencies’ assessment was that implementation of these supplemental actions would be sufficient to meet or exceed the Table 5 HQI performance standards and associated survival improvements (2013 Draft CE, Section 2, Table 35).

Because these actions had not yet been reviewed by an expert panel, NOAA Fisheries gave additional scrutiny to the Action Agencies’ strategies for populations for which supplemental actions were identified. This scrutiny included discussion with Action Agency staff to ensure our understanding of the actions and implementation strategies. Based on that additional review, NOAA Fisheries concluded that it is reasonably certain that the HQI performance standard for the populations for which supplemental actions were identified will be achieved (including the Catherine Creek spring Chinook salmon population). The basis for our conclusion differed among populations. General considerations included actions previously reviewed by expert panels and not implemented but that the Action Agencies now are likely to implement ; additional actions that paralleled actions in particular assessment units that would proportionately increase the benefits the expert panels had previously identified for similar actions in specific assessment units; additional actions identified based upon results from recently completed tributary and reach assessments; the extent to which actions targeted the most heavily weighted limiting factors in the most heavily weighted assessment units; and the extent to which implementation strategies appeared to be consistent with accepted watershed restoration principles (e.g., Beechie et al. 2010, Roni et al. 2002, Roni et al. 2008). See Sections 3.1.2.3 through 3.1.2.7 for more detailed population discussions.

3.1.2.2.4 Replacement Projects to Provide Benefits at MPG or ESU Level

RPA Action 35 also contains a provision that if actions identified for implementation prove infeasible, in whole or in part, the Action Agencies will implement comparable replacement projects to maintain estimated HQIs and achieve equivalent survival benefits at the population level. If infeasible at the population level, then alternatively, RPA Action 35 provides that the Action Agencies will find replacement projects to provide benefits at the MPG or ESU/DPS level. The 2008 BiOp did not include a specific method for evaluating benefits of such replacement projects at the MPG or ESU level. The Action Agencies have incorporated into their adaptive management strategy a plan to employ replacement projects if necessary (2013 Draft CE, Section 2). The method by which replacement projects would be used to “credit” survival improvements is described in Appendix D of the 2014–2018 Draft IP.

NOAA Fisheries Northwest Regional Office staff has reviewed the method proposed by the Action Agencies and agree that it is a reasonable approach for evaluating equivalent benefits at the MPG or ESU level. NOAA Fisheries will evaluate any proposed use of replacement projects to provide benefits at the MPG or ESU level on a case-by-case basis, including consideration of the Action Agencies’ approach. Replacement projects will not be used simply to transfer survival improvements from one population to another, or to transfer survival improvements from one MPG to another. Rather, replacement projects could be used to evaluate overall compliance with RPA Action 35 and to evaluate risk at the MPG level. NOAA Fisheries expects the replacement project concept to be mobilized only as a last resort to meet Table 5 survival improvement commitments, and before employing it, the Action Agencies will try to identify additional projects that could be implemented to achieve population survival improvement commitments instead of using replacement projects to provide benefit at the MPG or ESU/DPS level.

3.1.2.2.5 Increased Institutional Capacity

Since the 2008 BiOp was completed, the Action Agencies have enhanced their internal organizational structure to operate more effectively to carry out the BiOp tributary habitat program. They have hired staff with expertise in geomorphology and engineering and implementation of habitat improvement actions. In addition, they have built relationships in planning, implementation, monitoring, and evaluation with regional partners. These advances have enhanced the ability of the Action Agencies and regional partners to plan, develop, prioritize, implement, monitor, and evaluate habitat improvement actions that target the most important factors limiting the growth and survival of anadromous fish in the locations where they will yield the most benefit (2013 Section 2 and Appendix A).

3.1.2.2.6 Adaptive Management

In their 2013 Draft CE and 2014–2018 Draft IP, the Action Agencies have described an adaptive management framework within which they propose to implement the tributary habitat program. The goal of the program is to leverage evolving technical tools, scientific research, and results from the RME program to identify, plan, develop, and implement actions from the menus of actions evaluated by the expert panels, the supplemental actions developed by tribal partners, and other action opportunities that arise through 2018 to provide the greatest benefits to salmon and steelhead.

The Adaptive Management framework includes the menu of actions evaluated by the expert panels and the menu of supplemental actions evaluated by the Action Agencies and to be evaluated by expert panels in 2015. It also includes a number of tools that the Action Agencies have developed and plan to utilize. These tools are summarized above in Section 3.1.1.8 and described in more detail in the 2013 Draft CE. These tools should enhance the Action Agencies' ability to refine the selection, scope, focus, and sequencing of implementation of actions within a watershed to achieve higher benefits. The tools include standardized terms and definitions for limiting factors (NOAA Fisheries developed these standard terms and they are now in use in salmon recovery planning throughout the Columbia River basin); limiting factor pie charts to illustrate limiting factor status by assessment unit; numerous tributary and reach assessments that characterize geomorphic, hydraulic, and vegetation conditions and identify opportunities for habitat improvement actions within river channels and their floodplains; the tributary habitat monitoring program; and other efforts specific to certain subbasins (for example, development of the Grande Ronde and Catherine Creek Atlas projects) (2013 Draft CE Section 2 and Appendix A; BPA and Reclamation 2013b; 2014-2018 Draft IP).

The Action Agencies note that with the foundation for the tributary habitat program now in place, it will be possible to accelerate the pace of designing and implementing actions that will yield high benefits. Moreover stakeholder support has coalesced to a greater degree around priority stream reaches and limiting factors identified through the tributary habitat program; and new tools and better understanding of limiting factors and stream reaches provide more assurance that the highest-value actions will be identified. They also note that the nature of actions being designed and implemented in the program has evolved from more straightforward actions such as those to improve access, screen diversions, or acquire water, to actions such as those to improve stream channel complexity, which may require more information on stream structure and function and more planning prior to implementation (2013 Draft CE, Section 2 and Appendix A; 2014–2018 Draft IP, Appendix C).

The Action Agencies note that they will continue to incorporate new scientific findings regarding climate change to inform tributary habitat improvement action selection, prioritization, and other aspects of adaptive management by continuing to provide expert panels with any new climate change information from NOAA Fisheries so that it can be incorporated into consideration of habitat improvement action benefits (2013 Draft CE, Section 2 and Appendix A; 2014–2018 Draft IP, Appendix C).

3.1.2.3 Effects of Tributary Habitat Program on Snake River Spring/Summer Chinook ESU

The Snake River Spring/Summer Chinook salmon ESU comprises 32 populations in 5 MPGs (see population list in Table 2.1-3). Fifteen of those populations, representing all 5 MPGs, have an HQI performance standard, and associated survival improvement, in RPA Action 35 Table 5 of the 2008 BiOp.

Effects of implementing RPA Actions 34 and 35 on the 15 populations in this ESU that have an HQI performance standard in RPA Action 35 Table 5 of the 2008 BiOp are summarized above in Table 3.1-1 and in Section 2, Table 35, of the Action Agencies' 2013 Draft CE.

Based on the Action Agencies' analysis using the CHW method, implementation of actions through 2009 was sufficient to meet or exceed HQI performance standards for 9 populations (Lostine/Wallowa, Imnaha mainstem, Secesh, South Fork Salmon Mainstem, East Fork Salmon, Lemhi, Pahsimeroi, Salmon River lower mainstem below Redfish Lake, and Valley Creek). Based on the same analysis, implementation of actions through 2011 was sufficient to achieve additional HQI gains for 7 of those 9 populations: the Lostine/Wallowa, Secesh, South Fork Salmon Mainstem, Lemhi, Pahsimeroi, Salmon River lower mainstem below Redfish Lake, and Valley Creek populations. For the Lemhi and Pahsimeroi populations and for the Valley Creek population, the estimated HQI improvements are large—28%, 62%, and 13% respectively – and would significantly exceed the performance standards.

The Action Agencies' evaluation, using the CHW method, of actions implemented through 2011, indicates progress toward achieving the HQI performance standard for five of the remaining six populations (all except the Yankee Fork). For the Catherine Creek, Grande Ronde Upper Mainstem, Tucannon, and Yankee Fork populations, however, the analysis indicates that implementation of actions through 2011 was sufficient to achieve less than 33% of the performance standard .

The Action Agencies' project that actions evaluated by the 2012 expert panel for implementation through 2018 will result in additional HQIs for the 9 populations estimated to meet or exceed their performance standard based on implementation through 2009, and that in addition, the Tucannon, a priority population, will exceed its performance standard. Some of these HQIs projected from actions to be implemented through 2018 are substantial (and substantially higher than the RPA Action 35 Table 5 HQI performance standards): for instance, 29% for the Tucannon, 32% for the Lemhi, and 70% for the Pahsimeroi.

For the Catherine Creek, Upper Grande Ronde, Yankee Fork, and Salmon River mainstem above Redfish Lake populations, projections based on the actions evaluated by the 2012 expert panel for implementation through 2018 indicate that the HQI performance standard will not be met without an increase in the pace and/or focus of action implementation. For those populations, the Action Agencies identified supplemental actions and evaluated their effects using the method described in the 2013 Draft CE, Appendix B. For all but the

Catherine Creek population, the Action Agencies' projections, based on their evaluation of supplemental actions and the results of the CHW method for actions evaluated by the 2012 expert panel for implementation through 2018, are that the HQI performance standards will be achieved. For the Catherine Creek population, the Action Agencies have outlined an adaptive management strategy consistent with achieving the HQI performance standard for that population (2013 Draft CE, Appendix A).

Actions[87] implemented through 2011 are summarized by population in the Action Agencies' CE (2013 Draft CE Section 3, Attachment 2, Table 1).[88] Actions for implementation through 2018 that contribute to meeting or exceeding the RPA 35 Table 5 2018 HQI performance standards are summarized by population in the 2014–2018 Draft IP, Appendices A and B.

For populations where projections based on expert panel results indicate the 2018 performance standards will be achieved and where the Action Agencies have made significant progress (i.e., implemented actions sufficient to achieve ≥33% of the HQI performance standard), it is reasonably certain the HQI performance standards will be met. That determination is based on NOAA Fisheries' conclusions regarding the tributary habitat analytical methods (see Section 3.1.1.8), the demonstration of significant implementation progress by the Action Agencies, and the 2012 expert panel evaluations of the potential effects of specific actions for implementation through 2018. NOAA Fisheries gave additional scrutiny to the Action Agencies' strategies for populations for which actions implemented through 2011 were sufficient to achieve < 33% of the HQI performance standard and/or for which supplemental actions were identified. Those populations are discussed in more detail below. Table 3.1-6 shows HQI performance standards, estimated HQIs from actions implemented through 2011, and projected HQIs from actions to be implemented through 2018 for these populations.

[87] BPA summarizes metrics for tributary habitat improvement actions implemented on the ground are summarized by BPA.

[88] This table contains some populations not in RPA Action 35 table 5 because the Action Agencies have commitments beyond the requirements of this BiOp under the Columbia Basin Fish Accords and the Northwest Power Act that contribute to BiOp obligations (e.g., the Table 5 HQI performance standards). The Fish Accords established the Action Agencies funding commitment to the Accord parties through 2018. The Northwest Power Act served as a catalyst for adapting processes to convene community-based and locally led organizations around a point of common interest. The delivery of funding to communities and Accord parties throughout the region has enhanced implementation.

Table 3.1-6. Snake River spring/summer Chinook salmon populations with supplemental actions and/or <33% of HQI performance standard estimated to be achieved based on actions implemented through 2011.[1]

Population	HQI Performance Standard (from RPA Action 35 Table 5)	HQI estimated from actions implemented through 2011 (based on expert panel results)	Cumulative HQI Projected from actions implemented through 2018 (based on expert panel results)	Cumulative projected HQI including Supplemental Actions implemented through 2018 (AA estimates of benefits)
Catherine Creek	23%	5%	11%	15%
Upper Grande Ronde	23%	4%	5%	23%
Tucannon	17%	2%	29%	N/A
Yankee Fork	30%	0%	21%	43%
Salmon River upper mainstem above Redfish Lake	14%	5%	13%	14%

[1] **Bold** = priority populations from RPA Action 35 Table 5.

3.1.2.3.1 Catherine Creek Population

The RPA Action 35 Table 5 2018 HQI performance standard for this population is 23%. Based on expert panel estimates and the CHW method for estimating survival improvements, implementation of tributary habitat actions through 2011 was sufficient to achieve a 5% habitat quality and corresponding survival improvement. Actions evaluated by the expert panel for implementation between 2012 and 2018 are projected to achieve an additional 6% HQI, bringing the total to 11%. With the addition of supplemental actions evaluated preliminarily by the Action Agencies and to be evaluated by the expert panel in 2015, the HQI is projected to be 15%. This is below the Table 5 HQI performance standard of 23% (2013 Draft CE Section 2, Table 35, and Appendix A). To achieve the HQI performance standard, the Action Agencies propose expanding a number of actions evaluated by the 2012 expert panel and identifying additional actions for evaluation by the expert panel in 2015 (2013 Draft CE Section 2, Appendix A, and 2014-2018 Draft IP, Appendices A, B, and C).

Actions implemented in Catherine Creek through 2011 that were estimated to achieve the 5% HQI are summarized in the Action Agencies' 2013 Draft CE, Section 3, Attachment 2, Table 1. Actions have addressed low summer flows, passage barriers, lack of habitat diversity, degraded riparian habitat, high summer water temperatures, and excess fine sediment. Habitat actions evaluated by the expert panel for implementation from 2012 to 2018 that contribute to meeting the RPA 35 Table 5 2018 HQI performance standard for this population are summarized in the 2014–2018 Draft IP, Appendix A. These actions address decreased water quantity, barriers, bed and channel form and instream complexity, riparian condition, large wood recruitment, side channel and floodplain conditions, sediment quantity, and temperature. The detailed fish and habitat studies underway in the basin generally confirm the key limiting tributary habitat factors for this population and provide a basis for prioritizing additional actions necessary to achieve the BiOp HQI performance standards.

Because the actions evaluated by the 2012 expert panel for implementation through 2018 are not projected to reach the RPA Action 35 Table 5 HQI performance standard for this population, the Action Agencies worked with the Confederated Tribes of the Umatilla Indian Reservation (CTUIR), a Fish Accord partner, to identify a menu of supplemental actions (2013 Draft CE, Appendix A). These supplemental actions are summarized in the 2014–2018 Draft IP, Appendix B, and include improving flow, addressing a passage barrier, and improving complexity in 12.45 instream miles. Based on the Action Agencies' preliminary estimates, which the expert panel will reevaluate in 2015, implementation of these actions through 2018 is projected to contribute an additional 4% HQI to the RPA Action 35 Table 5 HQI performance standard for the Catherine Creek Chinook salmon population (2013 Draft CE, Section 2, Table 35, and Appendix B).

To achieve the additional 8% HQI needed to meet the RPA Action 35 Table 5 HQI performance standard, the Action Agencies are working with their implementation partners both to expand the scale and scope of actions evaluated by the 2012 expert panel and to develop additional actions. The Action Agencies note that some actions evaluated by the expert panel in 2012 have already been increased significantly in scope as they proceed through the development phase. They will identify additional actions based on tributary and reach assessments and an additional assessment tool—the Catherine Creek Atlas—that is in development. These tools will assist the Action Agencies and their implementation partners in identifying appropriate treatment types and locations (2013 Draft CE, Section 2, Appendix A). In 2015, the expert panel will evaluate the supplemental actions identified and evaluated by the Action Agencies to date as well as additional and expanded actions identified in the interim.

The Catherine Creek population has been the focus of considerable effort by the Action Agencies and others to evaluate limiting factors and identify priority areas for restoration. These efforts have included tributary and reach assessments completed by Reclamation in 2012 and a fish tracking study by ODFW (2013 Draft CE, Appendix A). This information, which the expert panel considered in identifying and weighting limiting factors, indicates that most existing fish production is in assessment unit (AU) CCC3b, and that this AU and AU CCC3a (the next reach downstream, which had significant productive habitat historically) are limited by a lack of summer rearing habitat and flow.

Consistent with watershed restoration principles as articulated in Roni et al. (2002, 2008) and Beechie et al. (2008, 2010), and based on a review of previous limiting factors assessments for the Catherine Creek population, technical feedback from regional biologists, and initial results from the recently completed Reclamation tributary assessment, the Action Agencies' intend to focus efforts initially in AU CCC3b and then downstream in AU CCC3a. The expert panel's deliberations indicate that to create more summer rearing habitat, habitat improvement actions should improve the limiting factors of peripheral and transitional habitats, floodplains, channel structure and form, temperature, water quantity, sediment, riparian areas, and barriers (Spinazola 2013, Upper GR-Catherine Cr Chinook HABITAT FUNCTIONS 2013-18, Upper GR-Catherine Cr Chinook HABITAT ACTIONS 2013-18).

In addition, ongoing studies have highlighted relatively high juvenile mortality associated with downstream spring out-migration through the lower Catherine Creek mainstem/lower Grande Ronde Valley reach. Reducing mortality associated with emigration through this key reach would benefit production from all Catherine Creek current spawning/rearing areas. In addition, it is likely that juveniles outmigrating from the Upper Grande Ronde population would also benefit from reduced mortality in this reach. In recent years the Action Agencies have provided funding support and participated in studies aimed at gaining a better understanding of the factors driving this mortality. These efforts are key steps toward implementing actions tailored to increase outmigration survival.

The actions evaluated by the expert panel for implementation through 2018 and the supplemental actions are appropriately targeted mainly at flow and improving stream structure in AUs CCC3a and 3b (Spinazola 2013, Upper GR-Catherine Cr Chinook HABITAT FUNCTIONS 2013-18, Upper GR-Catherine Cr Chinook HABITAT ACTIONS 2013-18). For example, a proposed action in AU CCC3b would add 3 CFS to late summer flows, which would remain instream through AU CCC3a, where water quantity is limiting. Another proposed action would treat 7 of 9 miles in the AU to improve habitat complexity and help establish more summer rearing capacity . An action in AU CCC3a, completed in 2012 (the CC37 project), addressed side channel and wetland conditions and channel structure and form in .75 miles (Spinazola 2013, Upper GR-Catherine Cr Chinook HABITAT ACTIONS 2013-18). Unpublished data from the ODFW tracking study have shown fish using log-jams that were created as part of this project. ODFW will monitor the results of these activities in Catherine Creek and specifically reach CC37 and the control reaches during 2013 with a National Fish and Wildlife Foundation grant funded through Reclamation.

The Action Agencies intend to continue to use tributary and reach assessments and other best available information (e.g., the Catherine Creek Atlas and results from the ODFW fish tracking study) to identify habitat improvement actions focused in the assessment units and reaches with the greatest opportunity for change and targeted at the most significant limiting factors. They also have worked to enhance, and intend to continue working to enhance, the institutional and administrative capacity to implement actions in Catherine Creek, and will continue to engage with stakeholders to support the planning, development, and implementation of habitat improvement efforts (2013 Draft CE, Section 2, and Section 2,

Appendix A). This will include work with the Grande Ronde Model Watershed, CTUIR, Union Soil and Water Conservation District (SWCD), ODFW, and other entities to adjust the scale and scope of actions evaluated by the 2012 expert panel and the supplemental actions identified in the 2014–2018 Draft IP and to identify additional actions to achieve the greatest benefits (2013 Draft CE Section 2, Appendix A, and 2014–2018 Draft IP, Appendices A, B, and C).

This implementation and adaptive management strategy is sound. It proposes to focus implementation on the highest priority limiting factors in the most important assessment units, identified based on best available limiting factors assessments augmented by ongoing habitat analyses, and would sequence implementation in a manner consistent with sound watershed restoration principles. It is reasonably certain that the HQI performance standard and associated survival improvement for this population will be achieved using this strategy.

3.1.2.3.2 Grande Ronde Upper Mainstem Population

The RPA Action 35 Table 5 2018 HQI performance standard for this population is 23%. Based on expert panel estimates and the CHW method for estimating survival improvements, implementation of tributary habitat actions through 2011 was sufficient to achieve a 4% habitat quality and corresponding survival improvement. Actions evaluated by the expert panel for implementation between 2012 and 2018 are projected to achieve an additional 1%, bringing the total to 5%. With the addition of supplemental actions evaluated preliminarily by the Action Agencies and to be evaluated by the expert panel in 2015, the HQI is projected to be 23%, which would meet the HQI performance standard (2013 Draft CE Section 2, Table 35, and Appendix A).

Actions implemented through 2011 that were estimated to achieve the 4% HQI are summarized in the Action Agencies’ 2013 Draft CE, Section 3, Attachment 2, Tables 1 and 3. Actions have addressed passage barriers, lack of habitat diversity, degraded riparian habitat, water temperature, and excess fine sediment. Habitat actions evaluated by the expert panel for implementation from 2012 to 2018 that contribute to meeting the RPA Action 35, Table 5, 2018 HQI performance standard for this population are summarized in the 2014–2018 Draft IP, Appendix A. These actions address factors including decreased water quantity, passage barriers, bed and channel form, instream complexity, riparian condition, sediment quantity, large wood recruitment, and water temperature.

Because the actions evaluated by the 2012 expert panel for implementation through 2018 are not projected to reach the RPA Action 35 Table 5 HQI performance standard for this population, the Action Agencies worked with the CTUIR, a Fish Accord partner, to identify a menu of supplemental actions (2013 Draft CE, Appendix A). These supplemental actions are summarized in the 2014–2018 Draft IP, Appendix B, and address decreased water quantity, passage barriers, bed and channel form and instream complexity, and riparian condition, large wood recruitment, increased sediment quantity, and water temperature. Based on the Action

Agencies' preliminary estimates, which the expert panel will reevaluate in 2015, implementation of these actions through 2018, has the potential to contribute an additional 18% HQI to the RPA Action 35 Table 5 HQI performance standard for the Grande Ronde Upper mainstem spring Chinook salmon population, which would bring the total HQI to 23% and meet the RPA Action 35 Table 5 2018 HQI performance standard (2013 Draft CE, Section 2, Table 35).

The Grande Ronde Upper Mainstem population has been the focus of considerable effort by the Action Agencies to provide support and resources to improve and enhance the planning, prioritization, and implementation of habitat improvement actions and to engage and inform key landowners and constituents (2013 Draft CE, Appendix A). These efforts have included tributary and reach assessments, which Reclamation currently is developing, and the BPA's Grande Ronde "Atlas Project," a GIS-based resource that, when completed, will help guide identification of habitat improvement action opportunities to address high-priority limiting factors at a finer-scale than using tributary and reach assessments alone (2013 Draft CE, Appendix A).

Some of the supplemental actions identified for implementation in the Upper Grande Ronde mainstem involve expansion or enhancement of actions evaluated by the 2012 expert panel. The Action Agencies worked with the CTUIR to identify opportunities to expand projects in areal extent, size, or configuration, or to incorporate new features that would yield higher benefits. These actions focus on riparian improvement, floodplain reconnection and reactivation, improved instream channel complexity, flow acquisition, and changes in grazing management. Specific actions that were expanded after the 2012 expert panel review include culvert replacement, revetment removal, floodplain and side channel reconnection, and flow enhancement (2013 Draft CE, Appendix A; 2014-2018 Draft IP, Appendix B).

These CTUIR actions will complement a supplemental action that is the anchor for the Action Agencies' strategy. This anchor action would restore flow and complexity in a large stream segment that contains the majority of available Upper Grande Ronde Chinook spawning and rearing habitat. The 2007 expert panel evaluated this action and determined that, by itself, it would achieve or exceed the full 23% HQI performance standard. The Action Agencies estimated a habitat quality improvement of only 18% for this anchor action, which is conservative relative to the 2007 expert panel estimate of 23% for the same action. This anchor action, and other potential supplemental actions, when combined with actions already implemented and those evaluated by the expert panel for implementation through 2018, are projected to achieve the full 23% Table 5 HQI performance standard for this population (2013 Draft CE, Appendix A).

Actions evaluated by the expert panel and supplemental actions that will be evaluated by the expert panel in 2015 focus appropriately on increasing and improving juvenile rearing conditions throughout the Upper Grande Ronde River. The Action Agencies intend to use tributary and reach assessments for the Upper Grande Ronde and other tools to identify actions in the assessment units and reaches with the biggest opportunity for change and targeted at the most significant limiting factors (2013 Draft CE, Appendix A). A particularly important and useful tool will be the Action Agencies' "Atlas Project," which is using assessment information in a GIS format to develop a matrix of opportunities of specific project types identified at a much finer scale than in the assessments.

The Action Agencies will also continue to work with the Grande Ronde Model Watershed, CTUIR, Union SWCD, ODFW, and other entities to adjust the scale and scope of actions evaluated by the 2012 expert panel and the supplemental actions identified in the 2014–2018 Draft IP to identify opportunities for greater benefits and to continue to build stakeholder support for implementation (2013 Draft CE, Appendix A).

This implementation and adaptive management strategy is sound. It proposes to focus implementation on the highest priority limiting factors in the assessment units with the biggest opportunity for change, as identified based on best available limiting factors assessments augmented by ongoing habitat analyses, and would sequence implementation in a manner consistent with sound watershed restoration principles. It is reasonably certain that the HQI performance standard for this population will be met using this strategy.

3.1.2.3.3 Tucannon River Population

The RPA Action 35 Table 5 2018 HQI performance standard for this population is 17%. Based on expert panel estimates and the CHW method for estimating survival improvements, implementation of tributary habitat actions through 2011 was sufficient to achieve a 2% habitat quality and corresponding survival improvement for this population. Actions evaluated by the expert panel for implementation between 2012 and 2018 are projected to achieve an additional 27% HQI, bringing the total to 29% , to meet or exceed the HQI performance standard for this population (2013 Draft CE Section 2, Table 35, and CE, Appendix A).

Actions implemented in the Tucannon through 2011 that were estimated to achieve the 2% HQI are summarized in the Action Agencies' 2013 Draft CE, Section 3, Attachment 2, Table 1. Actions have addressed screening of diversions, passage barriers, stream habitat complexity and connectivity, high water temperatures, and degraded riparian conditions. Habitat actions evaluated by the expert panel for implementation from 2012 to 2018 that contribute to meeting the RPA 35 Table 5 2018 HQI performance standard for this population are summarized in the 2014–2018 Draft IP, Appendix A. These actions address decreased water quantity, bed and channel form and instream structural complexity, riparian condition, floodplain condition, sediment quantity, and high water temperature.

The Tucannon River is affected by historical land uses and river management. Past tillage, logging, and grazing practices, combined with channel straightening and diking, have degraded Chinook salmon spawning and rearing habitat. Substantial improvements over the past two decades have not yet reversed damage to the riverine ecosystem, largely because of the magnitude of the damage and the effort needed to restore this system (2013 Draft CE, Appendix A; ISRP 2013a).

Since the mid-1990s, the BPA has funded local county conservation districts and the Tucannon Model Watershed Program to implement habitat improvement actions in the Tucannon basin. (Reclamation’s work in the Tucannon involves technical assistance rather than direct funding of actions.) Since 2007, the Action Agencies have more than doubled annual budgets to implement habitat improvements in the Tucannon basin (2013 Draft CE, Appendix A). However, when the 2009 expert panel results indicated that implementation of actions through 2012 would achieve less than 50% of the HQI performance standard for this population, the Action Agencies increased their level of support for habitat improvement actions in the subbasin, and initiated the Tucannon River Programmatic Habitat Project (2013 Draft CE, Appendix A).

The goal of the Tucannon River Programmatic Habitat Project is to resolve legacy institutional constraints and to restore habitat function and channel processes in the priority reaches of the Tucannon River to improve spring Chinook salmon productivity. Specific reach-scale actions carried out under the programmatic will be identified and prioritized based on detailed assessment information and in a manner consistent with the watershed restoration framework recommended by Beechie et al. 2010. Action selection criteria include prioritization based on limiting factors identified for the Tucannon in the 2008 BiOp (2013 Draft CE, Appendix A).

As part of the NPCC’s 2013 Geographic Review, the ISRP has reviewed the Tucannon River Programmatic Habitat Project, and the NPCC has made a preliminary recommendation for continued implementation of the Tucannon Programmatic Habitat Project. The NPCC makes recommendations regarding project implementation based on consistency with the Fish and Wildlife Program, BiOp priorities, and satisfactory science review by the ISRP. Following ISRP review and NPCC recommendations, BPA makes multiyear funding decisions. In addition, there is strong local support and leadership for implementation of the programmatic habitat project through the Snake River Salmon Recovery Board (2013 Draft CE, Section 2, Appendix A; Tucannon River Programmatic Habitat Project). The reach-scale actions that have been identified under this programmatic habitat project were evaluated by the 2012 expert panel.

Supplementing the Tucannon River Programmatic Habitat Project is the Lower River Tribe Fish Accord, which will provide funding for the CTUIR to improve habitat for Tucannon Chinook salmon. The Action Agencies will use the Tucannon Programmatic Habitat Project and the CTUIR habitat project under the Accord Agreement to expand the pace, scale, and quality of habitat improvement actions in the Tucannon (2013 Draft CE, Appendix A).

The Action Agencies will continue to implement habitat improvement actions through the programmatic approach described above, working with the SRSRB, CTUIR, U.S. Forest Service (USFS), WDFW, and local SWCDs. A regional technical team composed of fish biologists and other natural resource specialists with extensive field experience and knowledge of local watershed conditions reviews actions prior to implementation, providing additional scrutiny to ensure a high likelihood of action success (2013 Draft CE, Appendix A). Based on the results of the 2012 expert panel evaluations, the approach outlined in the Tucannon River Programmatic Habitat Project to prioritize and implement habitat improvement actions, and the institutional relationships in place among implementers in the Tucannon, it appears that the mechanisms and resources to implement habitat actions in the Tucannon are in place, and it is reasonably certain that the RPA Action 35 Table 5 2018 HQI performance standard will be achieved for this population.

3.1.2.3.4 Yankee Fork Population

The RPA Action 35 Table 5 2018 HQI performance standard for the Yankee Fork population is 30%. As of the 2012 expert panel review, none of the potential actions identified for this population had been implemented. As a result, the review resulted in no projected contributions to meeting the HQI performance standard (2013 Draft CE Section 2, Table 35). The Action Agencies had anticipated a potential for delay in implementation for this population due to the complicated nature of planning for habitat improvement in the Yankee Fork. For instance, an expert panel that the Action Agencies convened in 2006 to evaluate Yankee Fork habitat improvement actions noted that no on-the-ground action should be anticipated for five years (NOAA AR Supplement S.31).

Actions evaluated by the expert panel for implementation between 2012 and 2018 are projected to achieve a 21% HQI. With the addition of supplemental actions evaluated preliminarily by the Action Agencies and to be evaluated by the expert panel in 2015, the HQI is projected to be 43%, to meet or exceed the HQI performance standard for this population (2013 Draft CE Section 2, Table 35, and CE, Appendix A).

Habitat actions evaluated by the expert panel for implementation from 2012 to 2018 that contribute to meeting the RPA Action 35 Table 5 HQI for this population are summarized in the 2014–2018 Draft IP, Appendix A. These actions address bed and channel form, instream complexity, floodplain condition, large wood recruitment, and sediment quantity.

Because actions evaluated by the expert panel for implementation through 2018 are not projected to achieve the RPA Action 35 Table 5 HQI performance standard for this population, the Action Agencies worked with the Shoshone-Bannock Tribe and with state and other local partners to identify a menu of supplemental actions that were based on tributary and reach assessments (2013 Draft CE, Section 2, Appendix A). The supplemental actions focus on increasing and improving juvenile rearing conditions in 7 miles of the Yankee Fork by improving bed and channel form and instream structural complexity. These supplemental actions are summarized in the 2014–2018 Draft IP, Appendix B.

Approximately six miles of the Yankee Fork have been drastically modified by historical dredging operations, which altered the course of the stream and caused extensive damage to riparian areas, instream structure, substrate, and hydrologic conditions, and which also limited juvenile rearing habitat. Approaches to restoring this reach of the Yankee Fork have been the subject of multiple assessments and reviews.

One review by the ISRP raised questions regarding potential toxic contamination in the area as a result of the historical dredging and mining. A second matter to be addressed in a successful restoration strategy for the Yankee Fork was cultural resource conservation related to the historical mining operations. At the present time, these issues have been resolved to a point where action implementation is now feasible. Reclamation conducted sampling and other testing and determined that the risk of toxic contamination was minimal. Reclamation also developed a Mercury Detection and Response Plan. To preserve cultural resources related to historical mining, Reclamation worked with the Idaho State Historic Preservation Office and with the landowner to archive maps and photos of the area, preserve some historical dredge piles, and provide interpretive signs explaining the historical mining.

In addition, Reclamation completed tributary and reach assessments that identify subwatersheds and reaches with the best potential habitat for Chinook salmon. Based on their assessments, Reclamation identified two habitat improvement actions that would benefit Chinook salmon and could feasibly be implemented by 2012. The actions restore side channel habitat where it had been destroyed by historical dredging. One action has been completed (but since it was completed in 2012, the expert panel did not evaluate its benefits) and the second is scheduled for completion in 2013. These actions improved complexity in 6.1 stream miles and improved 29.2 riparian acres and 4.8 wetland acres.

Reclamation has also completed the Yankee Fork Fluvial Habitat Rehabilitation Plan (Reclamation and Shoshone-Bannock Tribes, 2013), which identifies habitat improvement actions that can be implemented through 2018. There are many actions that can be implemented that will continue to address the Yankee Fork limiting factors noted above, as reflected in the Rehabilitation Plan and in the "upper bookends" that the expert panel assigned to limiting factors related to juvenile rearing habitat potential.[89] Reclamation is working with local partners to ensure implementation of actions based on the tributary and reach assessments and the Rehabilitation Plan. For example, some of the actions the 2012 expert panel reviewed would reconfigure the confluence of the Yankee Fork and West Fork to activate flow, regrade dredge tailings, open flow to the historical river channel, maintain perennial flow, reconnect historical floodplain and wetland habitat, place wood for cover and habitat diversity, replant riparian vegetation, and reduce the width of the existing river channel by creating floodplain habitat. This action should increase juvenile rearing habitat, increase high water and thermal refugia, increase adult spawning and holding habitat, and improve access to the West Fork of the Yankee Fork (2013 Draft CE 160-163). Supplemental actions, which have been identified from the Rehabilitation Plan, include the same kind of actions reviewed by the expert panel and in the same locations (Reclamation and Shoshone-

[89] For upper bookends, see Spinazola 2013, Upper Salmon Chinook 2013-18 HABITAT FUNCTIONS.

Bannock Tribes 2013; Spinazola 2013, Upper Salmon Chinook 2013-2018 HABITAT ACTIONS).

The Action Agencies plan to continue to work closely with the Idaho Office of Species Conservation, Custer County, Shoshone-Bannock Tribes, Upper Salmon Basin Watershed Project, IDFG, USFS, Yankee Fork Interdisciplinary Team, landowners, and other responsible individuals and agencies to adjust the scale and scope of the habitat improvement actions already evaluated by the 2012 expert panel and the supplemental actions (2013 Draft CE, Appendix A).

Based on the extensive assessment and planning that has been completed in the Yankee Fork, the progress that has been made to overcome obstacles to implementation, actions completed in 2012, and the identification of potential habitat improvement actions that address priority limiting factors in priority reaches that have been identified based on best available limiting factors assessments augmented by ongoing habitat analyses, the Action Agencies' implementation and adaptive management strategy is sound, and it is reasonably certain that the HQI performance standard for this populations will be achieved.

3.1.2.3.5 Upper Salmon above Redfish Lake

The RPA Action 35 Table 5 2018 HQI performance standard for this population is 14%. Based on expert panel estimates and the CHW method for estimating survival improvements, implementation of tributary habitat actions through 2011 was sufficient to achieve a 5% habitat quality and corresponding survival improvement. Actions evaluated by the expert panel for implementation between 2012 and 2018 are projected to achieve an additional 8% HQI, bringing the total to 13%. With the addition of supplemental actions evaluated preliminarily by the Action Agencies and to be evaluated by the expert panel in 2015, the HQI is projected to be 14% , to meet the HQI performance standard (2013 Draft CE Section 2, Table 35, and CE, Appendix A).

Actions implemented through 2011 that were estimated to achieve the 5% HQI are summarized in the Action Agencies' 2013 Draft CE, Section 3, Attachment 2, Table 1. Actions have addressed stream flow, screening of diversions, passage barriers, and riparian and stream improvements to decrease fine sediment and water temperature. Habitat actions evaluated by the expert panel for implementation from 2012 to 2018 that contribute to meeting the 2018 RPA Action 35 Table 5 HQI for this population are summarized in the 2014–2018 Draft IP, Appendix A. These actions address factors including water quantity, passage barriers, and additional improvements to riparian areas and roads to improve riparian condition and decrease sediment quantity and water temperature.

Because the actions evaluated by the 2012 expert panel for implementation through 2018 are not projected to reach the RPA Action 35 Table 5 HQI performance standard for this population, the Action Agencies worked with multiple partners, including the Shoshone-Bannock Tribes, Idaho Department of Fish and Game, USFS, and Custer Soil and Water

Conservation District to significantly expand the scope of a habitat improvement action that the 2012 expert panel had evaluated for Pole Creek, a major tributary to the upper Salmon River that contains important spawning and rearing habitat (2013 Draft CE, Section 2, Appendix A; Mazaika 2013).

Seven surface water diversions completely dewatered Pole Creek up through the 1980s. In 1982, the points of diversion were consolidated to a single point of diversion, and since that time Pole Creek has sustained flows through the lower reaches during all but the most severe droughts. In 2005, a minimum flow agreement for the creek was signed, and in 2007, juvenile Chinook salmon were observed occupying lower Pole Creek for the first time in decades. In 2009, an adult pair of Chinook attempted to spawn in the same reach. In 2011, an interagency technical team including the USFS, U.S. Fish and Wildlife Service, NOAA Fisheries, and the Idaho Office of Species Conservation identified key limiting factors (e.g., flow barrier culverts, fords, and riparian habitat degradation) in Pole Creek that are affected by both public and private land management. The team also identified actions to address these factors. With culvert replacement, barrier removal, riparian protection, and a key land purchase, Pole Creek will accommodate traditional agricultural use while accelerating the ability of the stream to support salmon (Mazaika 2013).

NOAA Fisheries agrees that by expanding the scope of this action, which includes improvements to habitat complexity, livestock exclusion, barrier removal, and riparian restoration, it is reasonably certain that the action would achieve an additional 1% HQI. Based on the actions evaluated by the expert panel and the expansion of the Pole Creek project, it is reasonably certain that the HQI performance standard for this population will be met.

3.1.2.3.6 RME Findings for Snake River Spring/Summer Chinook ESU

Initial RME initial findings for IMWs such as the Lemhi and Potlatch tend to support the conclusion that improvements in production have been attained.

3.1.2.3.7 Effects on Critical Habitat

As described above, implementation of RPA Actions 34 and 35 will reduce factors that have limited the functioning and conservation value of habitat that this ESU uses for spawning and rearing. Primary constituent elements expected to improve are water quality, water quantity, cover/shelter, food, riparian vegetation, space, and safe passage/access.

Tributary habitat improvement actions will have long-term beneficial effects at the project and subbasin scale. Adverse effects to PCEs during construction are expected to be minor, occur only at the project scale, and persist for a short time (no more and typically less than a few weeks). Examples of such short-term effects include sediment plumes, localized and brief chemical contamination from machinery, and the destruction or disturbance of some existing riparian vegetation. These impacts will be limited by the use of the practices described in NMFS (2013h). The positive effects of these projects on the functioning of PCEs (e.g., restored access, improved water quality and hydraulic processes, restored riparian vegetation, enhanced channel structure) will be long term.

3.1.2.4 Effects of Tributary Habitat Program on Upper Columbia River Chinook Salmon ESU

The UCR Chinook Salmon ESU comprises three populations in one MPG (see population list in Table 2.1-3). All three populations have an HQI performance standard in RPA Action 35 Table 5 of the 2008 BiOp.

Effects of implementing RPA Actions 34 and 35 on the three populations in this ESU, all of which have an HQI performance standard in RPA Action 35 Table 5 of the 2008 BiOp, are summarized above in Table 3.1-1 and in Section 2, Table 35, of the Action Agencies' 2013 Draft CE.

Based on their analysis using the CHW method, the Action Agencies have demonstrated progress toward the HQI performance standard for all three populations in this ESU. For the Methow and Wenatchee populations, the Action Agencies had made significant progress (i.e., actions implemented through 2011 were sufficient to achieve ≥33% of the HQI performance standard), although the performance standards for these populations are relatively small (6% and 3%, respectively). For the Entiat population, the Action Agencies' analysis, using the CHW method, indicates that actions implemented through 2011 were sufficient to achieve less than 33% of the HQI performance standard.

The Action Agencies project that actions evaluated by the 2012 expert panel for implementation through 2018 will result in meeting or exceeding the RPA Action 35 Table 5 HQI performance standards for the Methow and Wenatchee populations. For the Entiat spring Chinook salmon population, however, projections based on the actions evaluated by the 2012 expert panel for implementation through 2018 indicate that the HQI performance standard for that population will not be met without an increase in the pace and/or focus of action implementation. For that population, the Action Agencies identified supplemental actions and evaluated their effects using the method described in the 2013 Draft CE, Appendix B. The Action Agencies' projections, based on their evaluation of supplemental actions and the results of the CHW method for actions evaluated by the 2012 expert panel for implementation through 2018, are that the HQI performance standard for the Entiat population will be met or exceeded.

Actions implemented through 2011 are summarized by population in the Action Agencies' 2013 Draft CE, Section 3, Attachment 2, Table 1. Actions for implementation through 2018 that contribute to meeting or exceeding the RPA 35 Table 5 2018 HQI performance standards are summarized by population in the 2014–2018 Draft IP, Appendices A and B.

For populations where projections based on expert panel results indicate the performance standards will be achieved and where the Action Agencies have made significant progress (i.e., implementation of actions through 2011was sufficient to achieve ≥33% of the HQI performance standard), it is reasonably certain that the HQI performance standard will be met. That determination is based on NOAA Fisheries' conclusions regarding the tributary habitat analytical methods (see Section 3.1.1.8), the demonstration of significant implementation progress by the Action Agencies, and the 2012 expert panel evaluations of the potential effects of specific actions for implementation through 2018. NOAA Fisheries gave additional scrutiny to the Action Agencies' strategies for the Entiat population, because implementation of actions through 2011 was sufficient to achieve <33% of its HQI performance standard and because supplemental actions were identified for that population. The Entiat population is discussed in more detail below. Table 3.1-7 shows HQI performance standards, estimated HQIs from actions implemented through 2011, and projected HQIs from actions to be implemented through 2018.

Table 3.1-7. Upper Columbia River spring Chinook salmon populations with supplemental actions and/or <33% of HQI performance standard estimated to be achieved based on actions implemented through 2011.[1]

Population	HQI Performance Standard (from RAP action 35 Table 5)	HQI estimated from actions implemented through 2011 (based on expert panel results)	Cumulative HQI projected from actions implemented through 2018 (expert panel results)	Cumulative Projected HQI including Supplemental Actions implemented through 2018 (AA estimates of benefits)
Entiat River	22%	3%	9%	24%
Bold = priority populations from RPA Action 35 Table 5.				

3.1.2.4.1 Entiat River Population

The RPA Action 35 Table 5 2018 HQI performance standard for this population is 22%. Based on expert panel estimates and the CHW method for estimating survival improvements, implementation of tributary habitat actions through 2011 was sufficient to achieve a 3% habitat quality and corresponding survival improvement. Actions evaluated by the expert panel for implementation between 2012 and 2018 are projected to achieve an additional 6% HQI, bringing the total to 9%. With the addition of supplemental actions evaluated preliminarily by the Action Agencies and to be evaluated by the expert panel in 2015, the HQI is projected to be 24% , which would meet or exceed the HQI performance standard for this population (2013 Draft CE Section 2, Table 35, and Appendix A).

Actions implemented in the Entiat through 2011 that were estimated to achieve the 3% HQI are summarized in the Action Agencies' 2013 Draft CE, Section 3 Attachment 2, Tables 1 and 3. Actions have addressed low stream flow, screening of diversions, passage barriers, lack of stream habitat complexity, degraded riparian condition, and excess fine sediment. Limiting factors vary by assessment unit, but among the most significant overall are bed and channel form and instream structural complexity (see Spinazola 2013, Upper Columbia Chinook 2013-18 HABITAT FUNCTIONS). The Action Agencies and their local partners, using tributary and reach assessments to identify action opportunities, have completed multiple actions addressing those limiting factors (2013 Draft CE, Section 3, Attachment 2, Tables 1 and 3; and Spinazola 2013, Upper Columbia Chinook 2019-12 HABITAT ACTIONS).

For example, in the Middle Entiat, the assessment unit with the highest intrinsic potential in the ESU, several habitat improvement actions have been completed to place boulder clusters and large wood and work with natural processes to create hydraulic conditions that will promote the formation of instream structure. Similar actions have been completed in the Lower Entiat assessment unit (which is key for maintaining a functioning migratory corridor) (Spinazola 2013, Upper Columbia Chinook 2019-12 HABITAT ACTIONS). Preliminary monitoring has shown increased densities of juvenile Chinook salmon in pools created by the log structures (BPA and Reclamation 2013a).

Habitat actions evaluated by the 2012 expert panel for implementation from 2012 to 2018 that contribute to meeting the RPA Action 35 Table 5 2018 HQI for this population are summarized in the 2014–2018 Draft IP, Appendix A, and address screening of water diversions, passage barriers, bed and channel form and instream habitat complexity, riparian condition, floodplain and side channel condition, and sediment quantity. These include actions identified based on tributary and reach assessments and that address the limiting factors of channel form and complexity, which are among the most significant. In the Middle Entiat, for example, actions evaluated by the expert panel would:

- Treat 1 mile of stream to improve complexity by deepening backwater channels/alcoves, creating 7 large wood structures to provide cover and resting habitat as well as scour pool complexity, and 7 pools.
- Add large wood and engineered log structures in 0.5 stream miles, remove a bridge abutment to reconnect 20 acres of floodplain, reconnect 10 acres of channel migration zone, and 0.9 miles of riparian area.
- Add large wood and engineered log structures in 0.74 stream miles, remove 1000 feet of levee, open 2.7 acres of channel migration zone, reconnect 18.8 acres of floodplain, and restore 1.4 miles of riparian area (Spinazola 2013, Upper Columbia Chinook 2013-18 HABITAT ACTIONS).

Because the actions evaluated by the 2012 expert panel for implementation through 2018 are not projected to reach the RPA Action 35 Table 5 HQI performance standard for this population, the Action Agencies worked with the Yakama Nation, a Fish Accord partner, to develop a menu of supplemental actions (2013 Draft CE, Appendix A). These supplemental actions are summarized in the 2014–2018 Draft IP, Appendix B, and include additional actions to address instream structural complexity and floodplain condition. The supplemental actions identified by the Yakama Nation build upon habitat improvement approaches developed by Reclamation consistent with their reach assessments. Reclamation would design and work with local watershed partners to develop and carry out these actions, using BPA or other funding for implementation. The Yakama Nation's supplemental actions would address priority limiting factors. All the actions are being conceptualized and designed consistent with appropriate restoration techniques, such as those recommended by Beechie et al. (2010).

The actions evaluated by the expert panel for implementation in 2013 through 2018 and the supplemental actions identified by the Action Agencies and their partners are more targeted to improve conditions for Chinook salmon than previous actions have been (previous actions were developed more to benefit the Entiat steelhead population). Consistent with multiple assessments in the Entiat, the Action Agencies are targeting implementation in the Middle Entiat as the highest short-term priority because of its high potential for improvement of Chinook salmon habitat (2013 Draft CE, Appendix A).

Actions evaluated by the expert panel for implementation through 2018 address barriers and screens and stream complexity and riparian conditions. The expert panel weighted entrainment and passage relatively low as limiting factors compared to instream complexity and bed and channel form, so the expert panel results are largely driven by stream structure and complexity (Spinazola 2013, Upper Columbia Chinook 2013-18 HABITAT FUNCTIONS and HABITAT ACTIONS), as is the Action Agencies' assessment of the benefits the supplemental actions. The supplemental actions are focused heavily on the higher weighted limiting factors. While the supplemental actions cover the Upper, Middle, and Lower Entiat, the Action Agencies assessment of benefits for the supplemental actions is driven largely by actions addressing instream structure in the Middle Entiat (the assessment unit with the highest intrinsic potential), and the Action Agencies' strategy is to focus implementation in the Middle Entiat first, then in the Upper Entiat, and eventually the Lower Entiat (which has less potential for improvement).

Development and design of actions for implementation through 2018 will proceed with Reclamation technical assistance and BPA funding and in conjunction with local partners, including the Cascadia Conservation District and a regional technical team composed of fish biologists and other natural resource specialists with extensive field experience and knowledge of local watershed conditions who review habitat improvement actions prior to implementation, providing additional scrutiny to ensure a high likelihood of action success (2013 Draft CE, Appendix A; Milstein et al. 2013, Appendix A).The Action Agencies are investing considerable effort in the Upper Columbia to coalesce support of local stakeholders and implementers around the FCRPS priorities and to design an implementation strategy based on priority areas and action types that benefit spring Chinook. The implementation strategy described above and the priority areas and action types selected are sound and being implemented consistent with sound principles of watershed restoration, and based on best available limiting factors assessments augmented by ongoing habitat analyses. It is reasonably certain that the HQI performance standard for this population will be met.

3.1.2.4.2 RME Findings for Upper Columbia River Chinook Salmon ESU

Initial RME findings for IMWs including the Wenatchee, Entiat, and Methow tend to support the conclusion that that the targeted limiting factors and the planned actions that were evaluated are appropriate to meet HQI performance standards.

3.1.2.4.3 Effects on Critical Habitat

As described above, implementation of RPAs 34 and 35 will improve factors that have limited the functioning and conservation value of habitat that this ESU uses for spawning and rearing. PCEs expected to improve are water quality, water quantity, cover/shelter, food, riparian vegetation, space, and safe passage/access.

Tributary habitat improvement actions will have long-term beneficial effects at the action and subbasin scale. Adverse effects to PCEs during construction are expected to be minor, occur only at the action scale, and persist for a short time (no more and typically less than a few weeks). Examples of such short-term effects include sediment plumes, localized and brief chemical contamination from machinery, and the destruction or disturbance of some existing riparian vegetation. These impacts will be limited by the use of the practices described in NMFS (2013h). The positive effects of these actions on the functioning of PCEs (e.g., restored access, improved water quality and hydraulic processes, restored riparian vegetation, enhanced channel structure) will be long-term.

3.1.2.5. Effects of Tributary Habitat Program on Snake River Steelhead DPS

The Snake River steelhead DPS comprises 24 populations in five MPGs (see population list in Table 2.1-4). Nineteen of those populations, representing six MPGs, have an HQI performance standard in RPA Action 35 Table 5 of the 2008 BiOp.

Effects of implementing RPA Actions 34 and 35 on the 19 populations in this DPS that have an HQI performance standard in RPA Action 35 Table 5 of the 2008 BiOp are summarized above in Table 3.1-1 and in Section 2, Table 35 of the Action Agencies' 2013 Draft CE.

Based on analysis using the CHW method, actions implemented through 2011 were sufficient to meet or exceed HQI performance standards for 10 of these populations—the Selway, Grande Ronde lower mainstem tributaries, Joseph Creek (OR and WA),Wallowa River, Imnaha River, Asotin Creek, East Fork Salmon River, Lemhi River, Pahsimeroi River, and South Fork Salmon River populations. For the Lemhi and Pahsimeroi populations, the estimated HQIs are large – 23% from actions implemented through 2011 for the Lemhi River population (well over the 3% performance standard) and 27% from actions implemented through 2011 for the Pahsimeroi population (well over the 3% performance standard).

The Action Agencies' evaluation, using the CHW method, of actions implemented through 2011, indicates progress toward achieving the HQI performance standard for 8 of the remaining 9 populations. For four of these populations – the Grande Ronde upper mainstem, Tucannon River, Salmon River upper mainstem, and Secesh populations – implementation of actions through 2011 was sufficient to achieve 50% or more of the HQI performance standard. Significant progress (33% or more of the HQI performance standard estimated to be achieved by implementation of actions through 2011) has also been made for the Lochsa population. Progress on the Lolo Creek, South Fork Clearwater, and Lower Middle Fork mainstem populations has been more limited, with less than 33% of the HQI performance standard estimated to be achieved based on assessment of actions implemented through 2011.

The Action Agencies project that actions evaluated by the 2012 expert panels for implementation through 2018 will result in additional HQIs for several of the populations that had met or exceeded their performance standard by 2011, most significantly for the Lemhi and Pahsimeroi populations. The Lemhi is projected to move from 23% HQI based on actions implemented through 2011 to 27% based on additional actions to be implemented through 2018 (with an HQI performance standard of 3%), and the Pahsimeroi population is projected to move from 27% based on actions implemented through 2011 to 37% based on additional actions to be implemented through 2018 (with an HQI performance standard of 9%). In addition, the HQI performance standards for the Lolo Creek, Grande Ronde Upper Mainstem, Tucannon, Lower Middle Fork Mainstem, and East Fork Salmon populations are projected to be met or exceeded.

For the Lochsa and South Fork Clearwater populations, however, projections based on the actions evaluated by the 2012 expert panels for implementation through 2018 indicate that the HQI performance standards for those populations will not be met without an increase in the pace and/or focus of action implementation. For these populations, the Action Agencies identified supplemental actions and evaluated their effects using the method described in the 2013 Draft CE, Appendix B. The Action Agencies' projections, based on their evaluation of supplemental actions and the results of the CHW method for actions evaluated by the 2012 expert panel for implementation through 2018, are that the HQI performance standards will be met or exceeded.

Actions implemented through 2011 are summarized by population in the Action Agencies' 2013 Draft CE, Section 3, Attachment 2, Table 1. Actions for implementation through 2018 that contribute to meeting or exceeding the RPA 35 Table 5 2018 HQI performance standards are summarized by population in the 2014–2018 Draft IP, Appendices A and B.

For populations where projections based on expert panel results indicate the performance standards will be achieved and where the Action Agencies have made significant progress (i.e., implementation of actions through 2011 was sufficient to achieve ≥33% of the HQI performance standard), it is reasonably certain the HQI performance standards will be met. That determination is based on NOAA Fisheries' conclusions regarding the tributary habitat analytical methods (see Section 3.1.1.8), the demonstration of significant implementation progress by the Action Agencies, and the 2012 expert panel evaluations of the potential effects of specific actions for implementation through 2018. NOAA Fisheries gave additional scrutiny to the Action Agencies' strategies for populations for which implementation of actions through 2011 was sufficient to achieve < 33% of the HQI performance standard and/or for which supplemental actions were identified. Those populations are discussed in more detail below. Table 3.1-8 shows HQI performance standards, estimated HQIs from actions implemented through 2011, and projected HQIs from actions to be implemented through 2018 for these populations.

Table 3.1-8. Snake River steelhead populations with supplemental actions and/or <33% of HQI performance standard estimated to be achieved based on actions implemented through 2011.[1]

Population	HQI Performance Standard (from RPA Action 35 Table 5)	HQI estimated from actions implemented through 2011 (based on expert panel results)	Cumulative projected HQI projected from actions implemented through 2018 (based on expert panel results)	Cumulative projected HQI including supplemental actions implemented through 2018 (AA estimates of benefits)
Lochsa River	16%	6%	8%	17%
Lolo Creek	12%	3%	18%	N/A
South Fork Clearwater River	14%	4%	13%	17%
Lower Middle Fork Mainstem	2%	0.4%	3%	N/A
[1] **Bold** = priority populations from RPA Action 35 Table 5.				

3.1.2.5.1 Lochsa River Population

The RPA Action 35 Table 5 HQI performance standard for this population is 16%. Based on expert panel estimates and the CHW method for estimating survival improvements, implementation of habitat actions through 2011 was sufficient to achieve a 6% habitat quality improvement. Actions evaluated by the expert panel for implementation between 2012 and 2018 are projected to achieve an additional 2% HQI, bringing the total to 8%. With the addition of supplemental actions evaluated preliminarily by the Action Agencies and to be evaluated by the expert panel in 2015, the HQI is projected to be 17%, which would meet or exceed the HQI performance standard for this population (2013 Draft CE Section 2, Table 35, and Appendix A).

The Lochsa Subbasin contains 1,180 square miles of predominately undeveloped forest land and free-flowing streams. Past and present management activities, including road construction, timber harvest and subsequent infestation of noxious weed species, have degraded stream and riparian function and other processes critical to aquatic organisms. Factors limiting the abundance and productivity of the Lochsa steelhead population include sediment, temperature, loss of large wood and structural complexity, and inadequate fish. An extensive road network on national forest land and private lands is the primary reason for degradation of riparian condition, reduction of habitat complexity, and increase in water temperature passage (2013 Draft CE, Appendix A; NMFS 2011g; NPCC 2005).

The expert panel evaluations indicate that road decommissioning, barrier removal, enhanced stream complexity, and improved water quality could deliver benefits to steelhead (Spinazola 2013, Clearwater Steelhead 2013-18 HABITAT FUNCTIONS). Actions implemented in the Lochsa through 2011 that are estimated to achieve the 6% HQI are summarized in the Action Agencies 2013 Draft CE, Section 3 Attachment2, Table 1. Actions have included passage improvements and riparian area and road improvements to address limiting factors of barriers, degraded riparian conditions, poor water quality, elevated stream temperatures, and excess fine sediments. Habitat actions evaluated by the expert panel for implementation from 2012 to 2018 that contribute to meeting the RPA Action 35 Table 5 2018 HQI performance standard for this population are summarized in the 2014–2018 Draft IP, Appendix A. These actions include additional treatment of barriers, improved stream complexity in 35 stream miles, and riparian area protection and improvement and road improvements to address limiting factors of riparian condition, large wood recruitment, sediment quantity, and high water temperature.

Because the actions evaluated by the 2012 expert panel for implementation through 2018 are not projected to reach the RPA Action 35 Table 5 HQI performance standard for this population, the Action Agencies worked with the Nez Perce tribe to identify a menu of supplemental actions (2013 Draft CE, Appendix A). These supplemental actions are summarized in the 2014–2018 Draft IP, Appendix B, and include actions to address passage barriers, instream structural complexity, riparian condition, large wood recruitment, sediment quantity, and temperature. The actions would address 40 passage barriers, improve complexity in 5.25 stream miles, and improve roads and riparian areas.

The Nez Perce tribe developed these actions based on habitat assessments developed by the tribe and the USFS. Some, if not all, of the actions were proposed through the NPCC's 2013 Geographic Categorical Review. The proposal represents a cooperative effort between the Nez Perce Tribe Watershed Division and the USFS under the Nez Perce/Nez Perce-Clearwater National Forest Watershed Restoration Partnership[90] and the NPCC has recommended its implementation. The NPCC makes recommendations regarding project implementation based on consistency with the Fish and Wildlife Program, BiOp priorities, and satisfactory science review by the ISRP. Following ISRP review and NPCC recommendations, BPA makes multiyear funding decisions (2013 Draft CE, Appendix A).

Riparian treatments and some of the other supplemental actions to benefit the Lochsa steelhead population will vary in scope depending on acquisition of USFS land by the Nez Perce tribe. The Nez Perce have proposed the acquisition of 40,000 acres. The Action Agencies based their assessment of benefits of the supplemental actions on the acquisition of 10,000 acres of the 40,000 acre proposal. The Action Agencies assigned no habitat quality

[90] Nez Perce Tribe, Proposal GEOREV-2007-395-00 - Protect and Restore the Lochsa Watershed, 2013

improvement benefit for the acquisition but only for riparian and other treatments on the acquired parcels. Based on their assessment of the benefits of these actions using methods described in the 2013 Draft CE, Appendix B, the Action Agencies project that implementation of supplemental actions, in addition to those evaluated by the expert panel, would meet or exceed the HQI performance standard for this population (2013 Draft CE, Section 2, Table 35, and Appendix A).

Throughout the implementation process, the Action Agencies will continue to work closely with the Nez Perce tribe and the USFS to adjust the scale and scope of the actions evaluated by the 2012 expert panel and the supplemental actions to ensure that the HQI performance standard is met. The actions reviewed by the expert panel and the supplemental actions target highly weighted limiting factors with potential for improvement (based on the expert panel "high bookends"). The implementation and strategy and the priority areas and action types selected, in the context of the adaptive management strategy the Action Agencies propose, are sound, have been identified based on best available limiting factors assessments augmented by ongoing habitat analyses, and it is reasonably certain that the HQI performance standard for this population will be met.

3.1.2.5.2 Lolo Creek Population

The RPA Action 35 Table 5 2018 HQI performance standard for this population is 12%. Based on expert panel estimates and the CHW method for estimating survival improvements, implementation of tributary habitat actions through 2011 was sufficient to achieve a 3% habitat quality and corresponding survival improvement. Actions evaluated by the expert panel for implementation between 2012 and 2018 are projected to achieve an additional 15% HQI, bringing the total to 18%, which would meet or exceed the Table 5 HQI performance standard (2013 Draft CE Section 2, Table 35, and Appendix A).

Land use in the Lolo Creek watershed has included logging, mining, livestock grazing, and recreation. Timber harvest and road construction have had substantial impacts on stream habitat throughout the watershed, as have grazing and mining in localized areas. Extensive timber harvest and road construction began in 1957 and continued through the 1980s, by which point stream habitat conditions had become severely degraded. Sediment yield resulting from timber harvest and road construction increased from 60% to 149% over natural levels. Other impacts to stream habitat included channel impingement by roads and reduction in large woody debris recruitment to streams caused by the removal of riparian trees. Fish habitat restoration efforts to date in Lolo Creek have included revegetation of riparian areas, bank stabilization, and placement of instream structures (NMFS 2011g).

Among factors limiting the Lolo Creek population are barriers, riparian condition, sediment, and stream channel structure (NMFS 2011g; Spinazola 2013, Clearwater Steelhead 2013-18 HABITAT FUNCTIONS). Actions implemented in Lolo Creek through 2011 that were estimated to achieve the 3% HQI are summarized in the Action Agencies' 2013 Draft CE, Section 3, Attachment 2, Table 1. Actions have addressed limiting factors of passage barriers, stream complexity, water quality, stream temperature, and excess fine sediment by improving passage at 9 barriers, improving stream complexity in a small linear extent of stream, and improving riparian condition and roads in two stream miles (2013 Draft CE Section 3, Attachment 2, Table 1). Habitat actions evaluated by the expert panel for implementation from 2012 to 2018 that contribute to meeting the 2018 RPA 35 Table 5 HQI performance standard for this population are summarized in the 2014–2018 Draft IP, Appendix A. These actions address five additional barriers, instream complexity in a relatively small linear extent of stream (but several time over the extent of previous actions), riparian condition, sediment quantity, temperature, and oxygen (by improving 10 riparian acres and protecting 16 miles of riparian area, and by improving 60 road miles).

Because the projected HQI for the Lolo Creek steelhead population is based on actions evaluated by the expert panel, it is reasonably certain that these benefits will be achieved upon implementation. It is also likely that these actions will be implemented because the Lolo Creek Watershed Restoration Project, which includes some, if not all, of these actions, has gone through the NPCC's geographic review process and was recommended for implementation (ISRP 2013b). The NPCC makes recommendations regarding projects implementation based on consistency with the Fish and Wildlife Program, BiOp priorities, and satisfactory science review by the ISRP. Following ISRP review and NPCC recommendations, BPA makes multiyear funding decisions. For the reasons discussed above, it is reasonably certain that the HQI performance standard for this population will be met.

3.1.2.5.3 South Fork Clearwater River Population

The RPA Action 35 Table 5 2018 HQI performance standard for this population is 14%. Based on expert panel estimates and the CHW method for estimating survival improvements, implementation of tributary habitat actions through 2011 was sufficient to achieve a 4% habitat quality improvement and corresponding survival improvement. Actions evaluated by the expert panel for implementation between 2012 and 2018 are projected to achieve an additional 9% HQI, bringing the total to 13%. With the addition of supplemental actions evaluated preliminarily by the Action Agencies and to be evaluated by expert panels in 2015, the HQI is projected to be 17% , which would meet or exceed the performance standard for this population (2013 Draft CE Section 2, Table 35, and Appendix A) .

Primary limiting factors for the South Fork Clearwater population include reduced stream complexity, degraded riparian condition, impaired floodplain function, access to quality spawning and rearing habitat, and impaired water quality. Aquatic ecosystems in the Clearwater have been altered by past management actions including road construction, timber harvest, livestock grazing, and mining (2013 Draft CE, Appendix A).

Actions implemented in the South Fork Clearwater through 2011 that were estimated to achieve the 4% HQI are summarized in the Action Agencies' 2013 Draft CE, Section 3, Attachment 2, Table 1. These actions have addressed passage barriers, instream habitat complexity, degraded riparian conditions, and excess fine sediment. Tributary habitat actions evaluated by the expert panel for implementation from 2012 to 2018 that contribute to meeting the 2018 RPA 35 Table 5 HQI performance standard for this population are summarized in the 2014–2018 Draft IP, Appendix A. These actions address passage, instream complexity, riparian condition, large wood recruitment, side channel and wetland conditions, floodplain condition, sediment quantity, and temperature by addressing additional barriers, improving instream complexity (in 8.1 miles), and improving riparian areas (15 miles and 277 acres), wetlands (38 acres), and roads (180 miles).

Because the actions evaluated by the 2012 expert panel for implementation through 2018 are not projected to reach the RPA Action 35 Table 5 HQI performance standard for this population, the Action Agencies worked with the Nez Perce tribe to identify supplemental actions (2013 Draft CE, Appendix A). These supplemental actions are summarized in the 2014–2018 Draft IP, Appendix B, and would continue to address limiting factors of passage barriers, instream structural complexity, riparian condition, large wood recruitment, side channel and wetland conditions, floodplain condition, sediment quantity, and temperature by improving access to 150 miles, improving 63 road miles, and carrying out additional stream, riparian, and wetland improvements. Based on the Action Agencies' preliminary estimates, which the expert panel will reevaluate in 2015, implementation of these actions through 2018 has the potential to contribute an additional 4% HQI to the RPA Action 35 Table 5 performance standard for the South Fork Clearwater population (2013 Draft CE, Section 2, Table 35, and Appendix B).

The Nez Perce tribe identified these supplemental actions based on habitat assessments that they developed with the USFS (USFS 1998; NPCC 2005). Many of the supplemental actions represent expansions in scale and scope of actions evaluated by the 2012 expert panel for this population. Some, if not all, of these actions were proposed through the NPCC's 2013 Geographic Categorical Review process and address primary limiting factors.[91] Under the NPCC's Fish and Wildlife Program geographic review process, projects are reviewed by the ISRP. The NPCC then makes recommendations regarding project implementation based on consistency with the Fish and Wildlife Program, BiOp priorities, and satisfactory science review by the ISRP. Following ISRP review and NPCC recommendations, BPA makes multiyear funding decisions.

Throughout the implementation process, the Action Agencies will continue to work closely with the Nez Perce tribe and the USFS to adjust the scale and scope of the actions evaluated by the 2012 expert panel and the supplemental actions to ensure they are prioritized for implementation to address the highest-weighted limiting factors in the most important assessment units.

[91] Nez Perce Tribe 2013 Proposal GEOREV-2010-003-00 - Lower South Fork Clearwater River Watershed Restoration

The Action Agencies' analysis using the CHW method and results of the 2012 expert panel indicated that implementation of actions through 2018 would achieve 13% of the 14% HQI performance standard for the South Fork Clearwater steelhead population. The Action Agencies' review of the supplemental actions developed by the Nez Perce tribe indicates that those actions are sufficient to meet or exceed the additional 1% HQI required to meet the performance standard. NOAA Fisheries agrees that the scale and scope of these supplemental actions and the extent to which they target highly weighted limiting factors is such that it is reasonably certain that they would meet or exceed a 1% HQI, and that when combined with the HQI from actions already implemented and actions evaluated by the 2012 expert panel for implementation through 2018, it is reasonably certain that the RPA Action 35 Table 5 HQI performance standard for this population will be met.

3.1.2.5.4 Lower Middle Fork Mainstem Population

The RPA Action 35 Table 5 2018 HQI performance standard for this population is 2%. Based on expert panel estimates and the CHW method for estimating survival improvements, implementation of habitat actions through 2011 was sufficient to achieve a 0.4% survival improvement. Actions evaluated by the expert panel for implementation between 2012 and 2018 are projected to achieve an additional 2.6% HQI, bringing the total to 3%, which would meet or exceed the RPA Action 35 Table 5 2018 HQI performance standard (2013 Draft CE Section 2, Table 35, and Appendix A).

Among factors limiting the Lower Middle Fork Mainstem population are sediment conditions, barriers, and toxic water quality contaminants (Spinazola 2013, Lower Salmon Steelhead 2009-12 HABITAT FUNCTIONS and 2013-18 HABITAT FUNCTIONS). Actions implemented through 2011 that were estimated to achieve the 0.4% HQI are summarized in (2013 Draft CE Section 3 Attachment2, Table 1). Actions have included improving passage at a barrier to improve access to 2.5 stream miles and improving complexity in 0.1 instream miles. Tributary habitat actions evaluated by the expert panel for implementation from 2012 to 2018 that contribute to meeting the 2018 RPA 35 Table 5 HQI performance standard for this population are summarized in the 2014–2018 Draft IP, Appendix A. These actions address passage and riparian and road improvements to decrease sediment quantity and the mobilization and transport of toxic contaminants into water bodies used by fish.

Based on the results of the 2012 expert panel evaluations, the fact that the actions proposed for implementation through 2018 are in line with limiting factors that were weighted highly by the 2012 expert panel (i.e., sediment and barriers), and the fact that the project has gone through the NPCC's 2013 Geographic Categorical Review and been recommended for implementation (once the NPCC has recommended projects through this process, BPA makes multiyear funding decisions), it appears that the mechanisms and resources to implement habitat actions in the Lower Middle Fork Mainstem are in place and adequate, and it is reasonably certain that the 2018 HQI performance standard will be achieved for this population.

3.1.2.5.5 RME Findings for Snake River Steelhead DPS

Research, monitoring, and evaluation is underway, including IMWs in the Lemhi and Potlatch and PIT tag arrays for steelhead, but additional time and data are needed to determine whether changes in habitat and subsequent changes in production are occurring.

3.1.2.5.6 Effects on Critical Habitat

As described above, implementation of RPAs 34 and 35 will improve factors that have limited the functioning and conservation value of habitat that this ESU uses for spawning and rearing. Primary constituent elements expected to be improved are water quality, water quantity, cover/shelter, food, riparian vegetation, space, and safe passage/access.

Tributary habitat improvement actions will have long-term beneficial effects at the action and subbasin scale. Adverse effects to PCEs during construction are expected to be minor, occur only at the action scale, and persist for a short time (no more than and typically less than a few weeks). Examples of such short-term effects include sediment plumes, localized and brief chemical contamination from machinery, and the destruction or disturbance of some existing riparian vegetation. These impacts will be limited by the use of the practices described in NMFS (2013h). The positive effects of these actions on the functioning of PCEs (e.g., restored access, improved water quality and hydraulic processes, restored riparian vegetation, enhanced channel structure) will be long term.

3.1.2.6 Effects of Tributary Habitat Program on Upper Columbia River Steelhead DPS

The UCR Steelhead DPS comprises four populations in one MPG (see population list in Table 2.1-4). All four of those populations have an HQI performance standard, and associated survival improvement, in RPA Action 35 Table 5 of the 2008 BiOp, and all four are priority populations.

Effects of implementing RPA Actions 34 and 35 on the four populations in this DPS, all of which have an HQI performance standard in Table 5 of the 2008 BiOp, are summarized above in Table 3.1-1 and in Section 2, Table 35, of the Action Agencies' 2013 Draft CE.

The Action Agencies' evaluation, using the CHW method, of actions implemented through 2011 indicates progress toward achieving the HQI performance standard for all four populations in this DPS. For three of the four populations (the Methow, Okanogan, and Wenatchee populations), the analysis indicates that implementation of actions through 2011 was sufficient to achieve 50% of the HQI performance standard. For the fourth population (the Entiat River population), the analysis indicates that the Action Agencies have made significant progress (38% of the HQI performance standard estimated to be achieved).

The Action Agencies project that actions evaluated by the 2012 expert panel for implementation through 2018 will result in meeting or exceeding the HQI performance standards for all four UCR steelhead populations.

Actions implemented through 2011 are summarized by population in the Action Agencies' 2013 Draft CE, Section 3, Attachment 2, Table 1. Actions for implementation through 2018 that contribute to meeting or exceeding the 2018 RPA 35 Table 5 HQI performance standards are summarized by population in the 2014–2018 Draft IP, Appendix A.

For populations where projections based on expert panel results indicate the performance standards will be achieved and where the Action Agencies have made significant progress (i.e., implementation of actions through 2011 was sufficient to achieve ≥33% of the HQI performance standard), it is reasonably certain the HQI performance standards will be met. That determination is based on NOAA Fisheries' conclusions regarding the tributary habitat analytical methods (see Section 3.1.1.8), the demonstration of significant implementation progress by the Action Agencies, and the 2012 expert panel evaluations of the potential effects of specific actions for implementation through 2018. That is the case with all four populations in the UCR steelhead DPS.

3.1.2.6.1 RME Findings for Upper Columbia River Steelhead DPS

Initial RME findings for IMWs such as the Wenatchee, Entiat, and Methow tend to support the conclusion that improvements in steelhead production have been attained.

3.1.2.6.2 Effects on Critical Habitat

As described above, implementation of RPAs 34 and 35 will address factors that have limited the functioning and conservation value of habitat that this ESU uses for spawning and rearing. PCEs expected to improve are water quality, water quantity, cover/shelter, food, riparian vegetation, space, and safe passage/access.

Tributary habitat improvement actions will have long-term beneficial effects at the action and subbasin scale. Adverse effects to PCEs during construction are expected to be minor, occur only at the action scale, and persist for a short time (no more than and typically less than a few weeks). Examples of such short-term effects include sediment plumes, localized and brief chemical contamination from machinery, and the destruction or disturbance of some existing riparian vegetation. These impacts will be limited by the use of the practices described in NMFS (2013h). The positive effects of these actions on the functioning of PCEs (e.g., restored access, improved water quality and hydraulic processes, restored riparian vegetation, enhanced channel structure) will be long-term.

3.1.2.7 Effects of Tributary Habitat Program on Mid-Columbia River Steelhead DPS

The Mid-Columbia River steelhead DPS comprises 16 populations in four MPGs (see population list in Table 2.1-4). All 16 of those populations have an HQI performance standard in RPA Action 35 Table 5 of the 2008 BiOp.

Effects of implementing RPA Actions 34 and 35, addressing tributary habitat, on the 16 populations in this DPS, all of which have an HQI performance standard in Table 5 of the 2008 BiOp, are summarized above in Table 3.1-1 and in the 2013 Draft CE, Section 2, Table 35. Based on the Action Agencies' evaluation, using the Appendix E method (2007 CA, Appendix C, Attachment C-1), actions sufficient to meet the HQI performance standard have been implemented for all Mid-Columbia River steelhead populations. The Action Agencies continue to implement habitat improvement actions for Mid-Columbia steelhead populations under the Fish Accords associated with this BiOp and under the BPA Fish and Wildlife Program for requirements of the Northwest Power Act.

3.1.2.7.1 Effects on Critical Habitat

As described above, implementation of RPAs 34 and 35 will improve factors that have limited the functioning and conservation value of habitat that this ESU uses for spawning and rearing. PCEs expected to improve are water quality, water quantity, cover/shelter, food, riparian vegetation, space, and safe passage/access.

Tributary habitat improvement actions will have long-term beneficial effects at the action and subbasin scale. Adverse effects to PCEs during construction are expected to be minor, occur only at the action scale, and persist for a short time (no more than and typically less than a few weeks). Examples of such short-term effects include sediment plumes, localized and brief chemical contamination from machinery, and the destruction or disturbance of some existing riparian vegetation. These impacts will be limited by the use of the practices described in NMFS (2013h). The positive effects of these actions on the functioning of PCEs (e.g., restored access, improved water quality and hydraulic processes, restored riparian vegetation, enhanced channel structure) will be long-term.

3.1.2.8 Effects of Tributary Habitat Program on Snake River Sockeye Salmon ESU

Although the RPA does not require the Action Agencies to increase habitat quality or survival for SR sockeye salmon through tributary habitat improvements, water transactions implemented for SR spring/summer Chinook and steelhead in the mainstem Salmon River are likely to improve the survival of adult migrant sockeye salmon returning to the Sawtooth Valley in July and August. Examples are projects in Pole Creek, Fourth of July Creek, Alturas Lake Creek, Beaver Creek and the Salmon River.[92] The mainstem Salmon River is designated as critical habitat for SR sockeye salmon because it is part of the migration corridor that connects the spawning and rearing areas in the Sawtooth Valley with the ocean environment. Water transactions that improve flows in this area during late summer are likely to improve the PCEs of water quality, water quantity, water temperature, and water velocity in this part of the adult migration corridor.

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[92] See project information at http://www.cbwtp.org/jsp/cbwtp/projects/transactions.jsp?sub_basin_id=59

3.1.2.9 Summary: Effects of Tributary Habitat Program

The population-specific survival effects of implementing RPA Actions 34 and 35, for tributary habitat, are summarized in Table 3.1-1, above, and in Table 35 of the 2013 Draft CE. Table 3.1-1 lists the HQI performance standard for the 56 populations included in RPA Action 35, Table 5, and the projected HQIs as a result of implementation of tributary habitat improvement actions under RPA Actions 34 and 35. Projected HQIs are shown based on two time periods: for actions implemented through 2011 and for actions identified and evaluated for implementation in 2012 through 2018. Estimates based on expert panel results are shown separately from estimates that include the Action Agencies' preliminary estimates of the effects of supplemental actions.[93]

To obtain these habitat quality improvement estimates, the Action Agencies (1) identified a menu of actions for implementation through 2018; (2) convened expert panels to estimate the change in function of tributary habitat limiting factors for each population that would result from implementation of those actions, using the method developed by the CHW; (3) converted the expert panel results into an estimate of overall habitat quality improvement, corresponding to population survival improvement, expected to result from implementation of habitat improvement actions, again using the method developed by the CHW; and (4) identified supplemental actions for seven populations from RPA Action 35 Table 5 that were not projected to meet their HQI performance standard based on the suite of actions evaluated by the expert panels and made a preliminary determination of survival benefits for those actions pending evaluation by expert panels in 2015.

For populations where projections based on expert panel results indicate the performance standards will be achieved and where the Action Agencies have made significant progress (i.e., implementation of actions through 2011 was sufficient to achieve ≥33% of the HQI performance standard), it is reasonably certain the HQI performance standards will be met. That determination is based on NOAA Fisheries' conclusions regarding the tributary habitat analytical methods (see Section 3.1.1.8), the demonstration of significant implementation progress by the Action Agencies, and the 2012 expert panel evaluations of the potential effects of specific actions for implementation through 2018. NOAA Fisheries gave additional scrutiny to the Action Agencies' strategies for populations for which implementation of actions through 2011 was estimated to achieve < 33% of the HQI performance standard and/or for which supplemental actions were identified. Those populations are discussed in more detail above, in Section 3.1.2.3 through 3.1.2.7. NOAA Fisheries has also determined that it is reasonably certain that the HQI performance standards for those populations will be met.

[93] Table 1 is a simplified version of the Action Agencies' 2013 Draft CE, Table 35, which included information that NOAA Fisheries did not summarize in Table 1, because the information was not relevant to NOAA Fisheries' analysis.

Actions for implementation through 2018 have been identified in a significant level of detail, including identification of populations to benefit; type of work to be accomplished; limiting factors addressed; extent of area to be treated, volume of water protected, or other relevant metrics; and location of work (e.g., river mile, local jurisdiction, address, or road access). (This represents the same or greater level of detail with which specific actions for implementation from 2007 to 2009 were identified in the 2008 BiOp.)

Recent tributary habitat components of recovery plans for UCR Chinook and steelhead, Mid-Columbia steelhead, and the Lower Snake River populations in Washington were an important source of information in identifying potential actions and in providing technical information for the expert panel reviews.

The Action Agencies have increased their capacity to implement the tributary habitat program since 2007 through staffing additions, development of business management systems, and development of new assessment and prioritization tools. They have also helped to build local infrastructure, to coalesce stakeholder interests around FCRPS tributary habitat program priorities, and to create synergy among the range of salmon and steelhead recovery and watershed planning efforts in the interior Columbia River basin such that there is broader institutional and stakeholder support for implementation. They have laid out credible strategies for achieving HQI performance standards, and associated survival improvements, for all populations. Finally, they have developed an implementation strategy and have demonstrated the ability to implement habitat improvement actions through their record of actions implemented through 2012 (2014–2018 Draft IP, Appendix C; 2013 Draft CE).

The tributary habitat program is likely to protect and enhance Snake River spring/summer Chinook salmon, UCR Chinook salmon, Snake River steelhead, UCR steelhead, and MCR steelhead and their critical habitat to offset the adverse effects of the action sufficient to satisfy the standards of ESA § 7(a)(2). The mitigation is biologically and technologically feasible sufficient to determine that the measures are likely to be effective; the mitigation measures are sufficiently within the Action Agencies' authority and control and thus not subject to unenforceable implementation by third parties; and, although the effects of the mitigation measures may occur later in time than the mitigation measures, their effects are reasonably certain to occur.

The Action Agencies have outlined an adaptive management program within which to implement the tributary habitat mitigation program that has the potential to enhance the effectiveness of mitigation measures by incorporating the best information available at the time of implementation. This adaptive management program is designed to utilize the best science available throughout the mitigation program implementation by relying on sources such as data concerning baseline conditions, monitoring data, published studies in peer reviewed literature, expert opinion, and transparent, repeatable procedures.

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3.2 Estuary Habitat RPA Actions

In the following sections, NOAA Fisheries reviews the Action Agencies' implementation of RPA Actions 36 through 38, including the likelihood of achieving the survival improvements required by the 2008/2010 RPA: 9% relative survival benefit for ocean-type and 6% relative survival benefit for stream-type juveniles from interior Columbia basin ESUs/DPSs. "Ocean-type salmonids" are fish that enter the ocean during their first year, and therefore rear to adulthood predominantly in the ocean environment; "stream-type salmonids" rear for a year or more in freshwater before entering the ocean (Bottom et al. 2005). Of salmonids entering the estuary, many are ocean-type subyearlings; however, most juveniles from interior Columbia spawning areas are stream-type fish. Juvenile Snake River fall Chinook are primarily ocean-type fish, but some individuals overwinter in mainstem reservoirs and reach Bonneville as yearling (i.e., stream-type) fish (Connor et al. 2005).

Actions 58 through 61 in the 2008/2010 RPA require the Action Agencies to study juvenile salmonid growth; prey resources; and predator species composition, abundance, and foraging rates in the Columbia River plume, and require the Action Agencies to investigate critical uncertainties including:

- Ecological importance of the plume and nearshore ocean environments to the viability and recovery of listed salmonid populations in the Columbia River basin
- Causal mechanisms and migration/behavior characteristics affecting survival of juvenile salmon during their first weeks in the ocean

We discuss the Action Agencies' implementation of these studies and the scope of work through 2018 in Section 3.2.4.

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3.2.1 Description of the RPA Estuary Habitat Program

RPA Actions 36 and 37 require the Action Agencies to fund and implement habitat improvement projects in the lower Columbia River estuary (LCRE) to partially offset adverse effects to salmon from FCRPS operations. RPA Actions 58 through 61 further require the Action Agencies fund and carry out RME activities to support performance monitoring and adaptive management of the estuary habitat improvement actions. The purpose of this program is to improve the survival of juvenile migrants during passage through and residence in the estuary and thus increase the proportion and fitness of juvenile migrants that leave the estuary to begin their ocean life stage. As described below, the best available scientific information indicates that this can be accomplished by improving habitat quality and quantity in the LCRE where habitat important for salmon has been altered from its original state by floodplain development and flow regulation. Recent application of this science now focuses the Action Agencies' habitat improvement program on reconnecting large floodplain areas adjacent to the mainstem Columbia River as the most likely means of achieving the expected survival improvements.

The particular 9% and 6% relative survival improvement performance standards[94] for this program were set in the 2008 BiOp based on estimates of survival increases reasonably achievable through implementation of the Columbia River Estuary (CRE) management actions described in the Columbia River Estuary ESA Recovery Plan Module for Salmon and Steelhead (NMFS 2011h, *hereafter* Estuary Module). The Estuary Module is a component common to all NOAA Fisheries' recovery plans for salmon and steelhead species in the Columbia basin, which migrate through, in some cases after residing within, the estuary. The estimated survival increases were developed with input from technical experts including scientists at the NOAA Fisheries' Northwest Regional Office, NOAA's NWFSC, the Lower Columbia River Estuary Partnership (LCREP), and the Lower Columbia Fish Recovery Board. These figures, 9% relative survival increase for ocean-type fish and 6% for stream-type fish, were factored into the FCRPS BiOp's quantitative analysis for the interior Columbia Basin salmon ESUs and steelhead DPSs, as well as into the qualitative analysis for other affected listed salmonids, demonstrating how the implementation of the RPA by the FCRPS Action Agencies would likely avoid jeopardizing listed species and adversely modifying designated critical habitat.

3.2.1.1 Scientific Support for RPA Estuary Habitat Program Performance Standards

The Columbia River estuary and its freshwater plume extending into the ocean constitute one of three major stages in the life cycle of anadromous salmonids. Upriver freshwater spawning and rearing habitat and the ocean are the other major stages in the salmon life cycle. The

[94] By "performance standards," NOAA Fisheries refers to the 9% and 6% relative survival improvements that the Action Agencies refer to as "survival improvement targets" in their 2013 Draft CE.

estuary and plume constitute the environment in which these fish transition to and from the saltwater environment from freshwater habitats. The estuary and plume provide important habitat for these fish to rear, feed, avoid predators, and acclimate to salt or fresh water.

The estuary extends 146 river miles from the ocean to the upriver extent of tidal influence at the base of the Bonneville Dam, and includes tidally influenced waters of its tributary rivers including 26 miles of the Willamette River, the largest river entering the estuary. Salt water intrudes up the Columbia River as far as 28 miles, and the tides can reverse the river's flow as far as 53 miles upriver.

The Columbia River plume is that part of the Pacific Ocean that is influenced by the freshwater and sediment discharged at the river's mouth, understood to provide an important transition zone for juvenile salmon to feed and further acclimate to salt water.

Over the last 100 years the estuary and plume have undergone significant change as a result of human development in the Columbia River basin generally and in the estuary itself. These changes have altered the estuary's function as habitat for salmon and steelhead (Fresh et al. 2005). Where historically there were marshes, wetlands, and side channels along the river, providing salmon with food and refuge, currently most of these shallow water habitats have been diked and filled for agricultural, industrial, and other uses (Figure 3.2-1). The LCREP's (2012a) historical change analysis estimates losses of 68% to 70% for vegetated tidal wetlands and 55% for forested uplands. Most of this loss was due to the conversion of land for agriculture, but there also has been significant loss to urban development.

The timing and volume of river flows have changed with the construction of upstream reservoirs in the U.S. and Canada, diversion of water for agriculture, and measures to control river flooding. Reservoir storage and release operations have shifted flow from the spring to the winter, altering the salmon's migration to and use of the estuary and plume. The elimination of over-bank flows into shallow areas of the estuary has also changed the nature of food available for fish by significantly reducing the insects, crustaceans, and organic material derived from the marshes, wetlands, and shallow habitats of the estuary (Bottom et al. 2005). Where the river historically was murky with sediment washed down from above, now dams block sediment flow and thereby increase the exposure of juvenile salmon to predatory fish and birds.

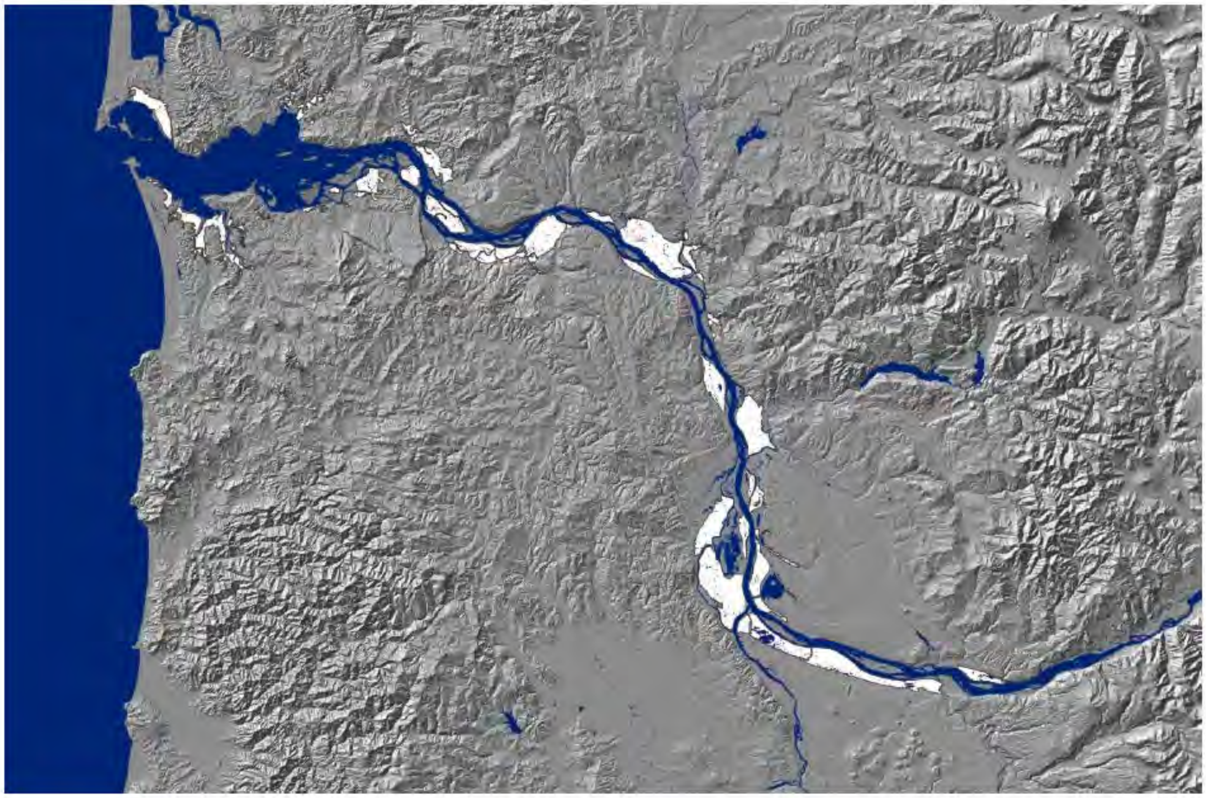

Figure 3.2-1. Diked Areas in the Columbia River Estuary (NMFS 2011h).

The factual, scientific, and policy dimensions of the estuary and plume are further discussed in Section 5.3 of the 2008 SCA, incorporated by reference into the environmental baseline chapter of the 2008 BiOp, Chapter 5, and, more recently, in the Estuary Module (NMFS 2011h).

The RPA's estuary habitat improvement program is based on the understanding that there is significant opportunity to restore some of the lost estuarine function through habitat improvement projects and that restoring such function will improve the survival of salmon and steelhead, including those from the interior Columbia basin. The available science supports this understanding. Salmon benefit from access to off-channel habitat in the estuary providing food resources for stream-type salmonids (Diefenderfer et al. 2013, Weitkamp 2013) and also for rearing and refuge for ocean-type salmonids.

Sherwood et al. (1990) summarized changes in the estuary from the historical, pre-development condition. They found large changes in morphology caused by navigational improvements and by diking and filling much of the wetland area. Tidal influence has decreased by 15% and there has been a net accumulation of sediment in the lower estuary. River flow had been significantly altered by water storage and release operations and by the diversion of water for irrigation. Flow variability has been dampened and net discharge slightly reduced. As a result of these factors, Sherwood et al. (1990) calculated an approximate reduction of 85% in wetland plant production, a 15% reduction in algal production, and a combined reduction of about 52,000 metric tons/year of organic carbon input to the estuary. The net result has been a major change in the organic matter sources supporting the estuarine food web, including the insects and crustaceans consumed by salmon.

Similarly, NOAA Fisheries (NMFS 2011h) describes habitat-related limiting factors in the LCRE today as the result of changes in flow, sediment and nutrients, water quality, food sources, and contaminants. Many potential systems are simply unavailable due to migration barriers (Thom et al. 2013). Reduced flushing due to reduced peak flows leads to high-temperature and low oxygen conditions and appears to limit the time salmon can benefit from some wetland habitats during summer months. Tide gates,[95] even those with "fish friendly" designs, improve access but are not as beneficial as more open hydraulic reconnections either for salmon movements or for maintenance of adequate water-quality parameters. Each of these problems creates an opportunity to improve the survival of juvenile salmon and steelhead through habitat improvement.

3.2.1.2 RME Support for RPA Estuary Habitat Program

Research, monitoring, and evaluation (RME) supports the RPA actions that call for habitat improvements by answering key questions:

- What estuary habitat improvement activities are most likely to improve the survival and fitness of juvenile salmon and steelhead as they enter the ocean phase of their life cycle?
- Are the actions developed and implemented pursuant to RPA Actions 36 through 38 through 2018 likely to be effective and of sufficient scope to achieve the RPA's biological performance standards for the estuary and plume?

The Action Agencies have detailed their RME effort under these RPA actions since 2008 in their 2013 Draft CE (Section 2, pp. 380–428). The Action Agencies have funded a number of major RME projects under RPA Actions 58 through 61; some of which focus on the estuary and some on the plume and near-coastal ocean environment. This work has generally confirmed that estuary habitat improvement actions developed by the Action Agencies are likely to achieve the survival benefits for juvenile salmon called for by the RPA. The RME has also been fundamental in guiding the program to the habitat improvement projects most likely to be effective. Key findings from this RME are summarized in the 2013 Draft CE, Bottom et al. (2011), Thom et al. (2013), and Diefenderfer et al. 2013. The latter work describes empirical evidence for the conclusion that habitat improvement activities in the estuary are likely having a cumulative beneficial effect on juvenile salmon directly, as they

[95] A tide gate is an adjustable gate that is used to prevent flooding in the area behind a dike or levee. Traditional tide gates prevent both fish passage and tidal exchange/flushing; the latter leads to reduced dissolved oxygen levels and elevated temperatures in the channel or area behind the dike. Modified tide gates allow fish passage and water exchange behind the dike while still preventing flooding in upland areas.

access restored shallow-water areas, and indirectly, during active transit through the mainstem:

- *Historical reconnections:* Where dikes were breached at three sites between ten and 60 years ago, plants are now wetland species. Most other environmental characteristics are similar to those at reference marshes in the Columbia River estuary.
- *Cumulative effects of the number and spatial pattern of reconnections:* Based on a hydrodynamic model that uses data from three recently restored sites, the degree of increase in floodplain wetted area was related to distance from the mainstem, and the greater the proportion of historical channels breached, the greater the proportion of floodplain area inundated. Also, particulate organic matter produced at one site can be transported into the channels of a nearby site, affecting the food web encountered by migrating salmon and steelhead.
- *Flux of particulate organic matter to the mainstem Columbia:* Approximately 52% of the mobilized particulate organic matter at a habitat improvement site located 4 to 5 miles up the Grays River was transported downstream to the mainstem Columbia River, again affecting the food web encountered by migrating salmon and steelhead.
- *Interior Columbia ESUs and DPSs have been detected in these shallow, off-channel habitats:* SR spring/summer and fall Chinook salmon, SR steelhead, and mid/upper Columbia spring Chinook salmon were identified in these restored habitat areas using a combination of PIT tag detections and genetic stock identification methods. Sockeye have been captured at shallow water sites, but in very small numbers compared to Chinook salmon (Thom et al. 2013).
- *Landscape assessment:* About 10.8 km^2 or 3.1% of the restorable area in the Columbia River estuary has been reconnected to the mainstem under the Action Agencies' estuary habitat improvement program, equivalent to a maximum potential increase in productivity of 8,529 metric tons of herbaceous plant biomass per year and 7 billion dipterans per 48 hours.
- *Offsite benefits to juvenile salmonids:* Stomachs of Chinook salmon and steelhead near the mouth of the estuary were substantially fuller than those of fish exiting the hydropower system (sampled at Bonneville and John Day dams). Although some juvenile salmon and steelhead moved through the mainstem without entering marshes, they fed on dipteran insects and amphipods that were produced in shallow water areas.

These beneficial effects will increase as existing habitat improvement projects mature and new ones are implemented.

3.2.1.3 Methods for Determining Performance Standard Compliance

During the first few years of implementation, the Action Agencies created the scientific and technical infrastructure needed for a program of this size and complexity. This included formation of the Expert Regional Technical Group (ERTG), a procedural requirement of RPA Action 37. The ERTG is a committee of regional scientists with strong research experience in estuarine ecology and habitat restoration as well as fisheries biology (Table 3.2-1).

Table 3.2-1. Membership in the ERTG, which evaluates the survival benefits of estuary habitat improvement projects as required by RPA 37.

Name	Affiliation	Position	Expertise
Dan Bottom	NMFS, Northwest Fisheries Science Center, Newport, OR	Research Fishery Biologist, Estuarine and Ocean Ecology Program	Estuarine ecology, salmon early life history, fish biology
Greg Hood	Skagit River System Cooperative, La Connor, WA	Senior Research Scientist, Research Department	Estuarine ecology, hydro-geomorphology, botany, wetland restoration
Kim Jones	ODFW, Fish Division, Corvallis, OR	Leader, Aquatic Inventories Project	Fish biology, habitat restoration, LCRE ecology
Kirk Krueger	WDFW, Habitat Program, Science Division, Olympia, WA	Senior Scientist, Salmon and Steelhead Habitat Inventory and Assessment Program	Salmon biology, stream ecology, quantitative assessment, statistics
Ron Thom	PNNL, Marine Sciences Laboratory, Sequim, WA	Technical Group Manager, Coastal Ecosystem Research	Restoration ecology, adaptive management, estuary ecosystem science

Based on their professional experience in restoration science, the ERTG developed a list of guidelines to identify and prioritize projects that would result in the highest juvenile salmonid survival benefit scores (ERTG 2010a, 2011a):

- A landscape scale perspective is better than narrow site-specific perspective
- Natural processes are preferred over engineered processes
- A larger area is better than a smaller area and close to the mainstem is better than farther away
- Restoring remnant channels is better than excavating new ones

Using the ERTG guidelines, the Action Agencies refocused their program during 2010 through 2012 on projects that (1) reconnected large sections of the historical floodplain and (2) improved wetland channels in tidally influenced areas located relatively near the mainstem. They replaced some of the projects described in their 2008 and 2009 Implementation Plans with others more in line with this updated strategy (2013 Draft CE).

Section 2 of the 2013 Draft CE describes details of the Action Agencies' modified project identification and prioritization program.

The primary purpose of the ERTG under the procedural requirements of RPA Action 37 was to ensure use of the best available scientific information in estimating survival benefits for ocean- and stream-type juvenile salmon for each estuary habitat action. The ERTG began by reviewing the benefit scoring method used in USACE et al. (2007c), which was developed by the Habitat Technical Subgroup (2006), an intergovernmental group convened pursuant to the Court ordered remand for the 2004 FCRPS BiOp (*hereafter* the Remand Workgroup method). NOAA Fisheries adopted this workgroup's recommendations for the 2008 RPA as the best available scientific information. Upon its review of the first years of employing the method, the ERTG determined that the Remand Workgroup benefit scoring method could be made more objective and further standardized for the sake of consistency, repeatability, and transparency.

The benefit scoring method the ERTG developed for assessing individual habitat improvement projects provided greater resolution of the 9% ocean-type salmonids and 6% stream-type salmonids survival performance standards. To better allocate the relative survival improvements required for the estuary at the management action scale the Action Agencies divided each percentage into five Survival Benefit Units (SBUs). Thus the performance standard for ocean-type salmonids of 9% would require 45 SBUs. Similarly, the 6% performance standard for stream-type fish would require 30 SBUs.

The ERTG then developed a formula called the "SBU calculator," based on the best available science, with which to estimate the survival benefit units of estuary habitat improvement projects (ERTG 2011; see Appendix F in this document). Projects begun in 2010 were scored using the SBU calculator with the exception of four projects that had been scored previously using the Remand Workgroup method.[96] When the ERTG compared scores across all projects rated previously, they found that the survival benefits generated using the 2008 RPA (or "BA") method were slightly lower (more conservative) than those using the SBU calculator with its weighting factor (ERTG 2010). Thus, the benefits estimated by the Action Agencies using the RPA's method for projects implemented during 2007 through 2009, before the ERTG developed its calculator, are conservative.

The ERTG added a weighting factor to address concerns that the survival scores generated by the Remand Workgroup method did not accurately reflect the potential contribution to juvenile salmon survival among the various recommended actions (ERTG 2011; see Appendix F in this document). The weighting factor standardized the potential survival benefits among all the different types of habitat improvement actions by calculating the expected density of juvenile salmon per square meter based on each target goal (acres or miles) and the ocean-type survival units (increased numbers of ocean-type fish expected when

[96] SBUs estimated using the Remand Workgroup method are identified as "BA Final" scores in the 2013 Draft CE, Section 3, Attachment 4, Table 1.

the target goal was achieved).[97] In addition, the ERTG standardized the scoring criteria for the factors used as inputs to the SBU calculator: certainty of success,[98] potential benefit for habitat access/opportunity,[99] and potential benefit for habitat capacity/quality.[100] For each, the ERTG applies a score between 1 and 5 according to very specific, documented criteria.

Finally, to ensure objectivity, transparency, and repeatability, the ERTG (2012; see Appendix F in this document) developed a template that proponents must use when providing the information needed for scoring. For example, proponents must identify the Estuary Module subaction(s) that correspond with their restoration actions and state the number of acres or miles the project addresses for each. The ERTG reviews the template to confirm that it incorporates the appropriate subactions and that the associated physical measurements such as acres and miles, based on GIS mapping data, are accurate. The ERTG then scores the project on a scale of 1 to 5 in the three areas required by the SBU calculator—certainty of success, access, and capacity—according to the criteria in ERTG (2010; see Appendix F in this document).

3.2.1.3.1 New Scientific Information and the SBU Scoring Process

The results of ongoing scientific studies have a fundamental role in the ERTG scoring process as described in BPA and USACE (2013; *Role of Science and Process for the Expert Regional Technical Group to Assign Survival Benefit units for Estuary Habitat Restoration Projects*). The ERTG developed a list of uncertainties that the Action Agencies use to prioritize future RME under their Columbia Estuary Ecosystem Restoration Program (CEERP; ERTG 2012), which guide Action Effectiveness Research as developed in the annual CEERP Strategy Report (BPA and USACE 2012), and enacted as described in the annual CEERP Action Plan (BPA and USACE 2012). Action effectiveness monitoring is designed to confirm (or refute) the mechanisms through which estuary habitat improvements benefit juvenile salmonids. The Action Agencies are increasing the amount of action effectiveness monitoring for habitat improvement projects in the 2014 through 2018 period within the framework of the new CEERP plan (Johnson et al. 2013a).

Although many of the key inputs to the SBU Calculator are quantitative (e.g., water surface elevation and weighting factors based on fish densities), professional judgment is necessarily a prominent element of the process to assign SBUs. The ERTG scores for success, habitat

[97] The ERTG used the same weighting factor for ocean- and stream-type fish. A separate adjustment for benefits to stream-type fish is made elsewhere in the calculator.
[98] “Certainty of Success” refers to an action’s expected scientific functionality and not whether it will be implemented.
[99] Habitat access/opportunity is a habitat assessment metric that "appraises the capability of juvenile salmon to access and benefit from the habitat's capacity," for example, tidal elevation and geomorphic features (ERTG 2010).
[100] Habitat capacity/quality is a habitat assessment metric involving "habitat attributes that promote juvenile salmon production through conditions that promote foraging, growth, and growth efficiency, and/or decreased mortality," for example, invertebrate prey productivity, salinity, temperature, and structural characteristics (ERTG 2010).

access, and habitat capacity in the SBU calculator use professional judgment within a scoring criteria framework. The ERTG method combines quantitative metrics with professional judgment, which is applied within a science-based process by a group of scientists who are experts in the subject matter. This method for determining the efficacy of estuary habitat actions uses the best science available.

3.2.2 Estuary Habitat Program Implementation

NOAA Fisheries divided the RPA estuary habitat program into two periods—2007 through 2009 (RPA Action 36) and 2010 through 2018 (RPA Action 37). However, the current remand is focused on the likelihood of project implementation and the reasonable certainty of project effectiveness from 2014–2018. The Court found the projects described in the Action Agencies' 2010–2013 Implementation Plan to be sufficiently developed and therefore the Court ordered that their implementation continue during the remand period (*NWF v. NMFS*, CV 01-00640-SI, D. Or., #1855 Opinion and Order, 8/2/2011). Therefore, this section will first examine the implementation of the estuary habitat improvement program for the 2008 through 2013 time period, then the proposed implementation of projects for the 2014 through 2018 time period. Details about projects implemented or currently developed for implementation are available in the Action Agencies' 2013 Draft CE. These details include project names and locations, lead Federal agency and partner/sponsor, Estuary Module management action, linear miles and acres of habitat restored, ocean- and stream-type SBUs, and status of implementation.

Overall, the estuary program has evolved since the Action Agencies proposed it in their 2007 Biological Assessment based on the method developed by the Remand Workgroup. As proposed, the Action Agencies' estuary program was designed to address factors limiting habitat function for salmonids in the estuary. When it adopted the Action Agencies' proposed estuary improvement program for the 2008 BiOp RPA, NOAA Fisheries further required that the Action Agencies' manage the program to meet the 9% and 6% quantitative biological performance standards for ocean- and stream-type salmonids. This required the Action Agencies to more specifically focus the program's projects not only on addressing limiting factors, but in a manner that would demonstrably improve salmon survival sufficient to meet the biological performance standards.

The Action Agencies' experience with this program since 2008 reflects the complexity of the Columbia River Estuary ecosystem and the need to bring the best available science to bear on the objective of improving salmon survival. As the Action Agencies explain in their 2013 Draft CE, the program's performance has steadily ramped up, reflecting the need to establish the science and implementation infrastructure necessary to identify, develop, and implement the projects most likely to result in survival benefits for salmon sufficient to satisfy the performance standards.

To develop this implementation infrastructure, the Action Agencies established relationships with a number of institutional and organizational partners already doing habitat work in the estuary to identify and carry out the restoration projects with Action Agency funding and oversight. The State of Washington is a key partner with the Action Agencies; BPA and the Corps entered into a Memorandum of Agreement with the State so that BPA could commit matching funds needed for Corps-sponsored habitat improvement projects in the estuary. The State of Washington has involved its Department of Fish and Wildlife to ensure the development and implementation of projects that will promote salmonid recovery in southwest Washington. Other restoration partners include the Columbia Land Trust Estuarine Restoration Project[101], a non-profit organization that has worked to conserve Columbia River habitats since 1990; the Columbia River Estuary Study Taskforce Estuary Habitat Restoration Project[102], a non-profit organization working on science-based project management of fish and wildlife efforts in the Columbia River Estuary since 1974; and the Cowlitz Indian Tribe's Estuary Restoration Program[103], which identifies estuary habitat improvement projects within its "Historical Area of Interest."

The Action Agencies also funded a number of tools for prioritizing habitat improvement projects likely to contribute to the survival benefit performance standards. These tools included:

- Habitat Change Analysis, which compares historical land cover conditions (from late 1800s topographical survey maps) to current land cover conditions (2010 remotely sensed imagery; LCEP 2012).
- Habitat Suitability Index Model for juvenile Chinook salmon, which uses model outputs from an Oregon Health and Science University hydrodynamic model to predict times and locations that meet suitable water temperature, depth, and velocity criteria as identified in Bottom et al. (2005) for juvenile salmon (LCEP 2012).
- Landscape Planning Framework, an application of the Columbia River Estuary Ecosystem Classification (Simenstad et al. 2011), which allows the user to evaluate different inundation scenarios and the corresponding effect on the landscape

The Habitat Change Analysis and Habitat Suitability Index Model are available to proponents for use in project development through the LCREP Web site.[104] The Landscape Planning Framework is currently under development.

[101] Project No. 2010-073-00 in www.cbfish.org
[102] Project No. 2010-004-00 in www.cbfish.org
[103] Project No. 2012-015-00 in www.cbfish.org
[104] http://estuarypartnership.org

Thus, the estuary program has matured due to the experience of implementing restoration projects since 2007 and before; the scientific advice of the ERTG; the development of site prioritization and design tools; and the implementation support of partners capable of identifying and carrying out projects necessary to achieve the survival benefits expected.

3.2.2.1 Estuary Habitat Projects 2007 through 2013

The Action Agencies completed (or are expected to complete) 45 projects during 2007 through 2013. The FCRPS 2010–2013 Implementation Plan (USACE et al. 2010) detailed these projects, and Section 3, Attachment 4, Table 1 in the 2013 Draft CE records or predicts their completion. These projects include a variety of actions to improve habitat function and capacity and include numerous projects of the following general types:

- Replace impassable or restrictive culverts with bridges to allow unrestricted fish passage to upstream shallow-water habitat.
- Modify or remove tide gates to allow fish passage to off-channel habitat.
- Plant riparian vegetation to increase macrodetrital food inputs and to reduce water temperature.
- Breach dikes and levees to allow tidal inundation of historic floodplain and to provide fish access to shallow-water habitat while increasing the production and delivery of insects, crustaceans, and detritus to the river’s mainstem.
- Acquire currently connected floodplain areas for passive restoration of habitat function through changes in land use management (e.g., discontinue agricultural practices).
- Restore circulation in degraded side-channel habitats.

Specific projects that have been implemented to date are described in Section 2 of the 2013 Draft CE:

- **Fort Columbia**: This site includes 96 acres of wetlands near the town of Chinook, Washington. Historically, the wetland drained into the Columbia estuary, but road construction during the 1950s diminished hydraulic connectivity at this site by installing a 24-inch perched culvert. The Columbia River Estuary Study Taskforce, one of the Action Agencies’ restoration partners, replaced the 24–inch culvert at the confluence of the wetland and the mainstem Columbia with a 12-feet by 12-feet box culvert and excavated a tidal channel to reconnect the wetland to the mainstem Columbia. They re-established habitat complexity by adding large wood to the excavated channel. Construction was completed in February 2011 and Chinook and coho salmon were found at the site during the first post-restoration sampling the following month (0.173 ocean-type SBUs; 0.078 stream-type SBUs).

- **Mill Road**: This BPA-funded Columbia Land Trust project, completed in 2011, removed 500 feet of an existing levee, restoring hydrologic connectivity to approximately 46 acres of historical spruce swamp habitat. The site is located approximately three miles upstream of the Grays River confluence with the Columbia River at RM 22 (0.397 ocean-type SBUs; 0.128 stream-type SBUs).
- **Columbia Stock Ranch—Phase 1**: BPA funded the acquisition of this property by the Columbia Land Trust in 2012, securing 545 acres of Columbia River floodplain plus some mixed deciduous and coniferous upland forest. The site is located in Oregon adjacent to the Columbia River at RM 75. Passive restoration includes transitioning from contemporary land uses (e.g., agriculture) to ecologically beneficial uses. This will allow natural plant communities, including tidal marsh, scrub-shrub, forested wetlands, and upland forests to return to the site. Water quality will also be improved by eliminating cattle grazing. Beaver colonization is expected to increase with the return of native plants, which will create habitat for juvenile salmonid rearing and refuge. Over time, large stands of successional mature forests will provide cooler waters and large wood inputs to the floodplain (0.711 ocean-type SBUs; 0.267 stream-type SBUs).

The projects implemented from 2007 through 2013 are expected to improve survival for ocean-type fish by 8.3 SBUs and for stream-type fish by 3.5 SBUs (Table 3.2-2). While this means that the program still must achieve the bulk of the SBUs (at least 36.7 and 26.5, respectively; Table 3.2-3) needed to satisfy the estuary performance standards (equivalent to 45 and 30 SBUs), the program has now matured sufficiently for NOAA Fisheries to conclude that the projects the Action Agencies and their partners have identified and described for implementation in 2014 through 2018 are likely to make up this sizeable difference.

Table 3.2-2. Summary of improvements (miles and acres) and Survival Benefit Units (ocean- and stream-type fish) by year, 2007–2013 (Source: 2013 Draft CE, Section 3, Attachment 4, Table 1, with some values rounded off).

Completion Year	Location	Improvements		SBUs	
		Miles	Acres	Ocean	Stream
2007	Fort Clatsop – Phase 1 Scappoose Bottomlands Ramsey Lake	2	80	0.470	0.250
2008	Walluski R. North Big Creek Mirror Lake - Phase 1 Sandy River Delta Riparian Restoration Wolf Bay - Phase 1 Willow Grove - Phase 1 Scappoose Bay	4.3	879	0.527	0.190
2009	Perkins Creek Columbia Slough Crazy Johnson - Phase 1 Elochoman Slough - Phase 1 Gray's River - Gorley Springs Vancouver Water Resources Wetland	3.0	403	0.425	0.349
2010	Haven Island Mirror Lake - Phase 2 Sandy R Delta Riparian Restoration Julia Butler Hansen NWR	5.7	612	0.291	0.115
2011	Ft. Columbia Mill Rd (Grays R) Sandy R Delta Riparian Reforestation Germany Creek - Floodplain	1.5	382	0.663	0.299
2012	Otter Point Colwort Creek (Nutel Landing) Gnat Creek - Phase 1 South Tongue Point (Liberty Lane) Abernathy Creek Wallacut River - Phase 1 Grays Bay, Deep R Confluence Elochoman Slough - Phase 2 Columbia Slough Stock Ranch - Phase 1	2.1	1,436	1.557	0.766

Completion Year	Location	Improvements		SBUs	
		Miles	Acres	Ocean	Stream
	Knappton Cove - Phase 1				
2013	Sharnelle Fee Grays Bay, Kandoll Farm - Phase 2 Gnat Creek - Phase 2 Julia Butler Hansen NWR - Steamboat Slough Skamokawa Creek - Phase 2 Louisiana Swamp Dibblee Point Honeyman Creek Sauvie Island - North Unit Phase #1 Sandy River Dam Removal Horsetail Creek	20.7	865	4.382	1.550
	Total (completed 2007-2013):	**39.3**	**4,657**	**8.3**	**3.5**

Table 3.2-3. Summary of improvements (miles and acres) and Survival Benefit Units (ocean- and stream-type fish) by year, 2014–2018. (Sources: 2013 Draft CE, Section 3, Attachment 4, Table 1; 2014–2018 Draft IP, Section 3, Appendix A: Project Lists, Action Agency 2014–2018 Estuary Habitat Projects)

Location	Improvements		SBUs	
	Miles	Acres	Ocean	Stream
Initiated by 2012 for completion by 2018: Skipanon Slough, 8th St. Dam Wallacut R. - Phase 2 Chinook River Walluski–Youngs Bay Confluence Grays Bay, Deep R. confluence - Phase 2 and 3 Karlson Island Elochoman Slough - Phase 3 Miller Sands Wallace Island Complex Julia Butler Hansen NWR-Tenasilahe Island Phase 2 Kerry Island Columbia Stock Ranch - Phase 2 Large Dike Breach - Reach E Oaks Bottom Section 536 Ridgefield NWR: Ridgeport Dairy Unit, Post Office Lake Ridgefield NWR: Ridgeport Dairy, Campbell Lake and Slough Shillapoo Wildlife Area Steigerwald NWR Thousand Acres, Sandy River Delta	28.7	11,550	51.5	18.8
To be initiated in 2013+ for completion by 2018: Youngs Bay/River Tidal Floodplain Reconnection Walluski Bottomlands Trestle Bay Jetty Breach Port of Astoria (Skipanon) Port of Astoria (Phase 2) Lewis and Clark River Upper #1 Rangila Slough South Grays Bay – Matteson Road Crooked Creek Upstream Mary's Creek Jim Crow Creek Svenson Island – Cathlamet Bay Westport Slough, USFWS	20.6	5,877	24.4	8.1

Location	Improvements		SBUs	
	Miles	Acres	Ocean	Stream
Westport Levee Setback Reach C/D – Rinearson Tidegate Upgrade Klatskanie Levee Setback RM-81 Island Lewis River East Fork – Site 43 Smith and Bybee Scappoose Landing Sauvie Island, North Unit Phase 2 Large Dike Breach – Reach F Buckmire Slough Sandy Delta – Sun Dial Island Tidal Restoration				
Total (completed 2014–2018):	49	17,426	75.9	26.8
Grand Total (incl. completed 2007–2013; Table 3.2-2):	89	22,083	84.2	30.3

3.2.2.2 Estuary Habitat Projects 2014 through 2018

Beginning in 2012, mindful of the substantial SBUs still needed and the Court's directive to describe further the offsite habitat actions after 2013, the Action Agencies redoubled their level of collaboration with their restoration partners to address the need for additional habitat improvement opportunities in the estuary. Important to this effort is making sure that the new projects are guided by the expert advice of the ERTG. This advice directs that the remaining survival benefits needed are most likely obtained from large habitat improvement projects, located close to the mainstem, that reconnect flood and tidal influences.

Working with its partners, the Action Agencies used maps showing the relevant GIS (geographic information system) layers for all possible sites for habitat restoration in the LCRE; public versus private lands (generally large tracts); and an inventory of existing projects. The Action Agencies and its partners evaluated the pros and cons of performing work on each site as well as potential habitat improvement benefits. After all project opportunities were identified, BPA and the Corps identified cost effective, high-value (SBU) projects that fit within the implementing capacities of their partners.

Once potential projects were identified and described in the ERTG template format, the restoration partners worked with the Action Agencies to develop and document preliminary SBU scores. To reduce the opportunity for bias, each partner did not score the habitat projects it was likely to implement. The Action Agencies reviewed the partners' consideration of the ERTG scoring criteria and brought corrections back to the group for discussion. The resulting SBU scores for projects the Action Agencies have pursued are identified as "Action Agency Preliminary" scores in Attachment 4, Table 1 to Section 3 of the 2013 Draft CE.

The Action Agencies have committed to implement the prioritized list of habitat improvement projects that forms the basis of the Action Agencies' out-year SBU projections in Attachment 4, Table 1 to Section 3 in the 2013 Draft CE. This list includes one project that is extremely large and technically complex ("Large Dike Breach—Reach E") and the Action Agencies state in the CE that if this project proves infeasible, they will implement others that collectively contribute an equivalent number of SBUs.

Having developed and employed these tools for project prioritization, description, and preliminary scoring, the Action Agencies expect to achieve totals of 75.9 ocean- and 26.8 stream-type SBUs. These are equivalent to relative percent survival improvements of 15.2% and 5.4% for ocean- and stream-type fish (2013 Draft CE, Section 2).[105] Added to the SBUs achieved for projects completed during 2007 through 2013, the Action Agencies have identified projects they can implement by 2018 that are likely to provide a total of 84.2 and 30.3 SBUs for ocean- and stream-type fish, respectively. This far exceeds the 45 SBUs needed to achieve the required 9% relative survival improvement for ocean-type fish, and meets the 30 SBUs needed for the 6% relative survival improvement for stream-type fish.

Some of the projects that will be completed during 2014 through 2018 have received ERTG final scores, which are based on the final project templates prepared at a construction-ready status. Four large projects have been given ERTG preliminary scores.

- **Walluski–Young's Bay Confluence:** This project will restore approximately 165 acres of isolated juvenile salmonid floodplain habitat near the confluence of the Walluski and Youngs rivers. This site is characterized by an extensive levee along its perimeter that isolates the area and prevents daily tidal interaction with historical floodplain habitat that is now drained pasture land. Restoration elements include lowering approximately 1.2 miles of levee to initiate natural breaching, fully breaching four areas to reconnect relic channels and provide salmonid access, and re-establishing a drainage channel network within the site. Additional elements include enhancing riparian/floodplain habitats and connectivity by restoring native floodplain plant communities and controlling non-native invasive species.
- **Columbia Stock Ranch Phase II:** This project will actively restore approximately 598 acres of estuary floodplain. The stock ranch was purchased in 2012 and two adjacent parcels were purchased in 2013 to make this large-scale habitat improvement project possible. Project objectives include re-establishing estuarine habitat forming processes on the site by increasing hydraulic connection to disconnected pasture and improving juvenile salmonid ingress/egress to approximately 360 acres of disconnected wetlands and channels. To accomplish these objectives, a substantial levee will be breached in several locations, interior

[105] NOAA Fisheries multiplies the assigned SBU scores by 0.2% to calculate the relative percent survival for ocean- or stream-type fish.

hydrologic constraints will be removed, a more natural channel network will be created, and passive ecosystem enhancements will be jumpstarted with exotic plant control and native plantings.

- **Large Dike Breach—Reach E:** This project is a large-scale restoration of a floodplain island. Land use at the site has been predominately agricultural. Hydrologic connectivity will be restored to the site through multiple breaches of a federally-authorized flood control levee allowing juvenile salmonid access to as many as 2,063 acres of estuarine floodplain for rearing and high river flow refugia. Due to the large and historically diverse site, restored habitats will include shallow water, intertidal, emergent, and forested wetlands. Hydrology to a primary floodplain slough will be fully restored to a flow-through system. Ecological benefits will also be restored and maintained on approximately 38 miles of riparian zone within the project through exotic plant control and native plantings.
- **Steigerwald National Wildlife Refuge:** The refuge is located near the City of Washougal, Washington at RM 123. Steigerwald Lake and surrounding river bottomland habitats are disconnected from Columbia River freshets by a large flood control levee along the site's border with the river. Gibbons Creek, which enters the site from the north, remains isolated from Steigerwald's significant floodplain wetlands under most hydrologic conditions. The proposed work includes reconnecting Gibbons Creek with the Steigerwald floodplain and breaching the flood control levee in multiple locations. Additional actions include channel enhancements, exotic plant control, and native plantings.

These projects have the potential to provide a large fraction of the total SBUs needed to meet the RPA's relative survival improvement requirements. The ERTG provided the Action Agencies with preliminary scores for each of these projects in the concept stage of development (Attachment 4, Table 1 to the 2013 Draft CE) due to the significant investment each project required. All of the projects to be completed during 2014 through 2018 will be given ERTG final scores in the final planning phase before the Action Agencies proceed with construction. NOAA Fisheries will re-evaluate the contributions of all these projects to meeting the RPA's survival requirements during the 2016 check-in. If any of these projects prove infeasible, the Action Agencies will ensure that the total sum of projects implemented, including any replacement projects, will collectively reach the BiOp estuary habitat survival benefit targets (2014–2018 Draft IP).

The Action Agencies did not obtain ERTG Preliminary scores for the other 2014 through 2018 projects referenced above. Instead the Action Agencies worked with their restoration partners to use the ERTG's scoring criteria to develop and document survival benefit scores based on project information available in the preliminary planning phase, as described above. NOAA Fisheries finds it likely that the Action Agencies' preliminary scores for the 2013 through 2018 actions, developed with the restoration partners, are consistent with preliminary scores the ERTG reached for multiple similar projects. NOAA Fisheries has compared evaluations by the Action Agencies' restoration partners with similar ERTG project scoring, considering the project scoring criteria used by ERTG, and is confident that these scores are consistent with the best available science for yielding the survival benefits required. The ERTG SBU calculator and template make it possible for the Action Agencies to produce preliminary benefit scores with objectivity, transparency, and repeatability for NOAA's review.

3.2.2.3 Summary: Effects of the Estuary Habitat Program

In Attachment 4, Table 1, in the 2013 Draft CE, the Action Agencies identify estuary habitat actions for implementation through 2018 in a significant level of detail, including the estuary module management actions to be addressed; the extent (miles or area) of treatment; the location of work (Reach A through G); and the degree to which ocean- and stream-type juveniles are expected to benefit. They have increased their capacity to implement the estuary habitat program by creating the infrastructure needed to identify, develop, and implement high quality projects that are likely to meet the biological performance standards. This includes funding the creating of GIS, database, and modeling tools for project identification and selection; establishing relationships with institutional and organizational partners that are already doing habitat work in the estuary; creating a roadmap (strategy and action plan) in the form of the CEERP; and forming the ERTG, tasked with reviewing and upgrading the survival benefit scoring process and with applying the SBU calculator to project design. The Action Agencies have laid out a credible strategy for implementing projects by 2018 that will achieve the 9% and 6% relative survival improvements for ocean- and stream-type fish, respectively. Finally, they have demonstrated the ability to implement large, complex projects (e.g., the Columbia Stock Ranch) through their record of projects implemented through 2012.

3.2.2.4 Effects of RPA Actions 36 and 37 on Critical Habitat

Implementation of RPA Actions 36 and 37 is reducing factors that have limited the functioning of PCEs in estuarine areas needed by both ocean- and stream-type salmonid juveniles: water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh- and saltwater; natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels; and juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation (see Section 3.2 in the 2008 BiOp). The PCEs of recently proposed critical in the estuary for LCR coho are identical to those for other Columbia basin salmonids and thus the effects of the RPA estuary habitat improvement program are the same—habitat improvement actions are improving the functioning of PCEs at the project scale; adverse effects during construction are minor, occur only at the project scale, and persist for a short time.

3.2.2.5 Relevance to the 2008/2010 BiOp

Based on the Action Agencies 2013 Draft CE and 2014–2018 Draft IP, as well as information from the estuary portion of the RME program and the habitat improvement projects implemented to date, NOAA Fisheries concludes that

- The projects described for implementation during 2014 through 2018 are detailed and developed to the same or better degree as projects that were presented in the Action Agencies' 2010–2013 Implementation Plan. Those prospective projects are at least as likely, if not more so, to be implemented and as certain to be as effective as the pre-2014 projects; and
- The Action Agencies are on track to implement the estuary habitat improvement program such that estuary survival performance standards of RPA Actions 36 through 37 are reasonably certain to be achieved.

3.2.3 RPA Action 38—Piling and Piling Dike Removal Program

The RPA Action 38 requires that "[t]o increase access to productive habitat and to reduce avian predation, the Action Agencies will develop and implement a piling and pile dike removal program." Specifically, the Action Agencies are to work with LCEP to develop a plan for strategic removal of these structures and to begin implementation in 2009. Changes in juvenile survival due to piling removal are expected to accrue as part of the estuary habitat improvement program (i.e., as specific actions under RPA Actions 36 and 37). That is, the Action Agencies can propose a project that corresponds with Management Action CRE-8 ("Remove or modify pilings and pile dikes when removal or modification would benefit juvenile salmonids and improve ecosystem health") in the Estuary Module (NMFS 2011h).

As described in the 2013 Draft CE, the Action Agencies set up a Pile Structure Program subcommittee under LCEP's Science Work Group in 2008 and began designing a scientific approach to guide piling and piling structure removal. The LCEP's work included the following objectives:

- Develop a plan for the removal and/or modification of select pile structures.
- Determine program benefits for juvenile salmonids and the lower Columbia River ecosystem through a series of intensively monitored pilot projects.
- Incorporate the best available science and pilot-project monitoring results into an adaptive management framework to guide future management actions.

The program team established the Pile Structure Program by implementing a number of steps toward feasibility and implementation that are described in the 2013 Draft CE. However, several issues limited program progress including ongoing uncertainties about the likely survival benefits of piling removal (or modification) and questions about ownership, liability for shoreline changes, and other costs (LCEP 2009).

As stated in the 2014–2018 Draft IP, the Action Agencies are not implementing RPA 38, the Piling and Piling Dike Removal Program. All SBUs attributed to this program in USACE et al. (2007c) will now be acquired by implementing other projects under RPA Action 37. This conforms with NOAA Fisheries' assumptions in the 2008 BiOp that the Piling and Piling Dike Removal Program was one of several management subactions that could be addressed in the Action Agencies' estuary habitat improvement program (CRE-8.2—Remove priority pilings and pile dikes; see Attachment 2 to ERTG 2012) under RPA Actions 36 and 37.

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3.2.4 RME in the Columbia River Plume

RPA Actions 58 through 61 require the Action Agencies to study juvenile salmonid growth and prey resources; predator species composition, abundance, and foraging rates in the Columbia River plume—and require that they investigate critical uncertainties. Progress on these actions to date and the scope of research through 2018 are described below.

3.2.4.1 Implementation of Plume Studies through 2013

Jacobson et al. (2012) described the results of this work from 1998 through 2011 in the "Ocean Synthesis Report," whereas highlights of findings during 2012 and 2013 are described in Jacobson et al. (2013), Section 2 of the 2013 Draft CE, and Section 2.2.3 of this supplemental opinion. The NPCC directed the Independent Science Review Panel (ISRP) to review Jacobson (2012) to determine whether, among other things, critical information gaps have been addressed. The ISRP's review (ISRP 2012) was generally favorable. In recognizing the complexity of interactions between the different factors that can influence ocean survival, they suggested a careful prioritization of future work. In particular, the ISRP recommended that researchers obtain stock-specific data wherever possible. Combining data from hatchery- and natural-origin fish, or fish from different ESUs or DPSs, can lead to misleading findings if the groups differ in their life history trajectories and likelihood of survival in response to the same environmental conditions. The ISRP also stated that more work was needed on the early ocean survival of steelhead and considered the need for a comprehensive genetic baseline for identifying stocks a high priority. NOAA Fisheries agrees with the ISRP's assessment.

In terms of practical application of the information derived from the ocean/plume studies, the AMIP, which NOAA Fisheries incorporated into the RPA in the 2010 Supplemental Opinion, directed the Action Agencies to support the development of a new Early Warning Indicator for a potential decline in a species' abundance levels (See Section 3.7 of this supplemental opinion). This new forecasting tool is to include information on ocean conditions as a predictor of future adult returns. Buhle and Zabel (2011) developed the tool using the PDO Index; the multivariate El Niño Southern Oscillation Index (ENSO); coastal upwelling indices; and sea surface temperatures off the Columbia River as indices of ocean climate. However, these authors recognized that many more indices should be considered to find the best set for predicting future adult returns for each interior Columbia ESU and DPS. For example, average sea surface temperatures off Newport during November through March were a better predictor for Snake River spring/summer Chinook salmon returns to Ice Harbor Dam than for Upper Columbia spring Chinook salmon returns to Priest Rapids Dam (see "SST.Nov.Mar" in Figure 5 in Burke et al. 2013). This type of refinement of ocean indicators will also improve the accuracy of forecasts using the enhanced life cycle model discussed in Section 3.7.1 of this supplemental opinion. The life cycle modeling project began in 2010 and an updated version of the model was provided to the ISAB in June 2013 for review. Thus far, only the PDO and an upwelling index have been used as predictors of adult returns for the ocean phase of the life cycle. Given the failure of these traditional indices to predict the size of spring Chinook adult returns to the Columbia in 2013 (Section 2.2.3.1 in this document), information from the ongoing ocean research and plume studies will be important to this management problem.

3.2.4.2 Rescoping the Plume RME Program for 2014 through 2018

Based on our own and the ISRP's evaluation of findings to date, we have determined that the following two objectives are the primary information needs, with respect to ocean research, for RPA Actions 58 and 61 during 2014 through 2018:

- **Objective 1.** Determine the suite of estuary, plume, and ocean indicators that best predict early marine survival and adult returns, supporting the use of early warning indicators for specific genetic stocks, differentiating the responses of hatchery- and natural-origin fish where practical. This work will also support the development of better data sets for the AMIP life-cycle model (see above).
- **Objective 2.** Determine the extent of coupling among estuarine, plume, and early ocean habitats and marine survival of interior Columbia juvenile salmon and steelhead. Although many juvenile salmon from interior ESUs and DPSs quickly move downstream from Bonneville Dam to the ocean (McMichael et al. 2011, Harnish et al. 2012), most feed during this portion of their migration and many of these prey come from estuarine wetlands (Diefenderfer et al. 2013, Weitkamp 2013). Information collected under this objective will improve our understanding of variation in use of estuary habitat services between and among stock groups and life history types and between and among years that affects subsequent growth and survival.

3.3 Hydropower RPA Actions

As described in the 2013 Draft CE, the Action Agencies have made substantial progress implementing hydropower-related RPA Actions 4 through 32 (and related actions to reduce predation within the hydrosystem, RPA Actions 43, 44, and 48), and the 2014–2018 Draft IP indicates that the remaining hydropower related RPA actions are likely to be completed by 2018. The following sections summarize the most important configuration and operational changes that have occurred since May 2010 (i.e., since we completed our 2010 supplemental opinion), and the effects of these actions—interacting with annual variations in environmental conditions—on key survival and productivity performance metrics for interior Columbia basin salmon and steelhead. These are the listed species that are most affected by passage through the mainstem dams and reservoirs.

3.3.1 Mainstem Project Configuration and Operations

By 2009, each of the eight mainstem lower Snake and lower Columbia river dams had been equipped with a surface passage structure (spillbay weirs, powerhouse corner collectors, or modified ice and trash sluiceways). Smolts primarily migrate in the upper 20 feet of the water column in the lower Snake and Columbia rivers. Water is drawn through these new surface passage routes from the same depths as juveniles migrate, whereas conventional spillbays or turbine unit intakes draw water from depths greater than 50 feet. Surface passage routes provide a safe and effective passage route for migrating smolts by reducing migration delay (time spent in the forebay of the dams) and increasing the proportion of smolts passing the dams via the spillway rather than via the turbines or juvenile bypass systems (spill passage efficiency). Together, these factors have improved the inriver survival of SR spring/summer Chinook salmon, SR fall Chinook salmon, SR sockeye salmon, SR steelhead, UCR spring Chinook salmon, UCR steelhead, and MCR steelhead. (Section 3.3.2.2 and 3.3.2.3).

The Corps constructed a spillway wall at The Dalles Dam in 2010. Previous studies indicated that substantial numbers of smolts passing this project via the spillway were being carried across a rocky "shelf" on the Oregon side of the Columbia River, exposing these fish to predatory birds and fish and reducing juvenile survival rates at the dam. The new spillwall directs fish towards the deep, fast moving channel closer to the Washington shore, where there are fewer predators, increasing survival of spillway passed fish through The Dalles tailrace. In addition, avian wires were installed following the 2010 performance standard testing to reduce juvenile losses to avian predators – especially on steelhead smolts. Together, these measures appear to have effectively increased the survival of spillway passed fish, especially steelhead smolts (CE, Section 2, RPA Action 19).

The Corps relocated the juvenile bypass system outfalls at Lower Monumental and McNary dams in 2012. In both cases, the old outfalls released fish into the slower-moving water close to the shoreline, again exposing these fish to concentrations of predatory fish and birds. By relocating the outfalls to areas further downstream and from shore, where higher velocities prevent predatory fishes from maintaining their positions, the new outfalls increase the survival of juvenile salmon and steelhead passing the dam via the juvenile bypass system through the tailrace at each of these projects (99-100% for yearling Chinook and steelhead, 96-100% for subyearling Chinook based on preliminary 2012 study results) (CE, Section 2, RPA Actions 21 and 23).

Spillway operations since 2008, including adjustments to accommodate performance standard testing and other research at specific projects, have been consistent with the Court Order and have been similar in most respects to the spill levels that would have been required by the BiOp (2013 Draft CE, Section 2, RPA Action 29—*Spill Operations to Improve Juvenile Passage*).

The Action Agencies' planned spring and summer spill operations for 2014–2018 are displayed in Table 2 of the 2014–2018 Draft IP. They propose to continue recent spill operations throughout the spring and summer periods but curtail spill at the Snake River projects when subyearling collection counts fall below 300 fish per day for three consecutive days as originally contemplated in the 2008 BiOp (see 2014–2018 Draft IP, Table 2 for details).

3.3.2 Flow Operations for Mainstem Chum Salmon Spawning and Incubation

Chum spawning flows were provided during the first week of November during the years 2008–2012, consistent with the measures described in RPA Action 17. However, during the month of March in the years 2010 and 2013, the water supply forecast indicated there was insufficient water to achieve both the tailwater level needed for incubation of established redds in the Ives Island area below Bonneville Dam and to achieve the upper flood control rule curve at Grand Coulee Reservoir. This resulted in removing the tailwater protection level at Ives Island in mid-March of 2010. Based on accrued temperature units, it was estimated that a substantial percentage of the redds reached a stage of development to allow fry to emerge prior to dewatering this habitat. During 2013 the chum protection level was set at an elevation of 13.5 feet late in the spawning season. However, by mid-March the water supply forecast indicated there was insufficient water to maintain that elevation and achieve the targeted elevation at Grand Coulee Dam. The decision was made to lower the protection level to 11.8 feet to provide protection for most of the established redds. These decisions were coordinated through the Technical Management Team process.

Additional spawning habitat was constructed, and recently rehabilitated 2012, near the Ives Island area in a side channel of Hamilton Creek. This off channel habitat is productive and used by hundreds of fish. The addition of this habitat (and consistent access to this and other tributary habitat resulting from maintaining minimum tailwater elevations in November and December) should decrease the risk to the population when water supply precludes protection of the Ives Island habitat through the spawning and incubation season.

In summary, the Action Agencies are coordinating through the Technical Management Team process and have implemented flow operations to maintain minimum tailwater elevations for spawning and incubating chum as anticipated given variable annual flow conditions. The additional, rehabilitated, spawning habitat provided in a side channel of Hamilton Creek is providing productive spawning and incubation habitat that substantially mitigates for impacts to the population in the mainstem Columbia River. Therefore the Action Agencies have implemented this RPA Action consistent with NOAA’s expectations in the 2008 and 2010 BiOp analyses.

3.3.3 Juvenile and Adult Survival Rates Based on RPA Implementation

The following sections summarize survival estimates used to track the performance of configuration and operational improvements described in Section 3.3.1. The Action Agencies present detailed information in the 2013 Draft CE and 2013 Progress Report with respect to specific study results—especially for Juvenile Dam Passage Performance Testing (2013 Draft CE; BioAnalysts Inc, 2013)

3.3.3.1 Adult Conversion Rate (Minimum Survival) Estimates

The RPA required the Action Agencies to meet adult survival performance standards for Snake River fall Chinook salmon, spring Chinook salmon, and steelhead from Bonneville Dam to Lower Granite Dam and for UCR spring Chinook salmon and steelhead from Bonneville Dam to McNary Dam (NOAA Fisheries 2008, RME Strategy 2 – Hydrosystem Research, Monitoring, and Evaluation, including RPA Actions 52 through 54). Adult ladder systems are operated to specific criteria to provide effective passage conditions within the ladder itself and sufficient attraction flows at the ladder entrances. Aside from passage through the ladders at each dam, other factors can also affect the survival of adults through mainstem reaches of the Columbia and Snake Rivers: recreational and tribal fisheries, environmental conditions (spillway operations, flows and temperature), "fall-back" of adults at the dams (through spillways, turbines, or juvenile bypass systems), straying (adults spawning in river basins other than their natal streams), injuries resulting from attacks by marine mammals, etc. Unlike downstream migrating juveniles, there is no indication that reservoirs substantially delay adult upstream migration (Ferguson et al. 2005).

Adult fish ladders have been operated in the same way for several decades, and, in particular, since 2002, the first year for which stock-specific adult detections were available at Bonneville, McNary, and Lower Granite dams. The 2008 BiOp therefore determined that there would be no change in adult survival through the FCRPS under the RPA, compared with adult survival during the approximately twenty year Base Period. To monitor adult survival, NOAA Fisheries based the survival standards on the new stock-specific detection method using PIT tags identifying the origin of adults passing Bonneville, McNary, and Lower Granite dams (2002 to 2006-07), The RPA survival standard accounted for reported harvest and natural straying rates (see 2008 SCA, Adult Survival Estimates Appendix A for details). However, adult survival estimates based on PIT tags could not be compared directly to Base Period adult survival estimates because the PIT tag technology was not available for most of the Base Period before 2002. The 2008 BiOp's implicit assumption was that Base Period survival was the same as that estimated from PIT tags in 2002 to 2006-2007.

Table 3.3-1 displays recently estimated average conversion rates (2008–2012 unless otherwise noted) in the lower Columbia reach (Bonneville to McNary dams), lower Snake River reach (McNary to Lower Granite dams), and the entire migration corridor (Bonneville to Lower

Granite Dam for Snake River ESUs/DPSs) compared to the 2008 BiOp's Adult Performance Standard for Chinook salmon and steelhead. Figure 3.3-1 graphically displays the average annual conversion rate estimates based on empirical PIT tag data from 2008 through 2012, compared with the Adult Performance Standards in the 2008 BiOp.

Recent conversion rates for Snake River fall Chinook salmon, based on PIT tag detections, averaged 90.5% between Bonneville and Lower Granite dams, nearly 10% higher than estimated for the 2008 BiOp RPA adult performance standard (81.0%). Average conversion rates for this species appeared to be about 5% higher in both the lower Columbia River and lower Snake River reaches compared with our 2008 BiOp (2002–2007) average estimates. In contrast, the recent average conversion rate estimate for Snake River spring/summer Chinook salmon, based on PIT tag detections between Bonneville and Lower Granite dams was 82.4%, nearly 8% lower than estimated for the 2008 BiOp adult performance standard (91.0%). Average conversion rates were more than 7% lower in the lower Columbia River reach and 2% lower in the Snake River reach than estimated in the 2008 BiOp.

No data were available to directly assess conversion rates using PIT tags for Snake River sockeye salmon in the 2008 BiOp. NOAA Fisheries used PIT tag detections from upper Columbia River sockeye stocks as surrogates to assess survival rates in the lower Columbia River reach and extrapolated these to assess likely survival rates for the entire Bonneville to Lower Granite dam migration corridor (see Table 3.1-1, footnote 2 for more detail). Although reported in the 2008 BiOp (81.1%), NOAA Fisheries thought this estimate was too uncertain to use as a performance standard. Enough known-origin adult Snake River sockeye salmon returned to the Columbia basin in 2010–2012 to make PIT tag-based direct (rather than extrapolated) conversion rate estimates for the Bonneville to Lower Granite reach. Average conversion rates for these years averaged 70.4%, which is more than 10% lower than our 2008 BiOp estimate. Recent average conversion rates in the lower Columbia River reach (75.7%) were nearly 16% lower than the 2008 BiOp estimate for this reach (91.4%), while the recent average conversion rate for the lower Snake River reach (93.0%) was over 4% higher than the 2008 BiOp estimate (88.7%).

The recent (2008–2011) average conversion rate for Snake River steelhead based on PIT tag detections from Bonneville to Lower Granite Dam (80.3%) is nearly 10% lower than the average estimate for the 2008 BiOp adult performance standard (90.1%). Average conversion rates in the lower Columbia River reach (91.0%) and lower Snake River reach are both more than 4% lower than our estimates in the 2008 BiOp (95.3% and 94.6%, respectively).

Table 3.3-1. Summary of adult salmon and steelhead survival estimates (adjusted for reported harvest and natural rates of straying) based on PIT tag conversion rate analysis of SR and UCR ESUs from Bonneville (BON) to McNary (MCN) dams, McNary to Lower Granite dams (LGR), and Bonneville to Lower Granite dams.[1] Bold text indicates Adult Performance Standards (see 2008 BiOp RPA Table of Actions, Table 7); shaded cells denote differences (+ equals exceeding and – equals not meeting performance standards). (Sources: http://www.PTAGIS.org; WDFW and ODFW 2012a, 2012b; Appendix A in the 2008 SCA).

Species	Years	BON to MCN	MCN to LGR	BON to LGR
SR Fall Chinook	2008 BiOp Standard (2002–2007 data)	88.0%	92.0%	**81.0%**
	2008–2012 Average	93.5%	96.9%	**90.5%**
	Difference	+5.5%	+4.9%	**+9.5%**
SR Spring/Summer Chinook	2008 BiOp Standard (2002–2007 data)	94.9%	95.9%	**91.0%**
	2008–2012 Average	87.6%	94.1%	**82.4%**
	Difference	–7.3%	–1.8%	**–8.6%**
SR Sockeye	2008 BiOp (2006–2007 data) [2]	91.4%	88.7%	81.1%
	2010–2012 Average[3]	75.7%	93.0%	70.4%
	Difference	–15.7%	+4.3%	**–10.7%**
SR Steelhead	2008 BiOp Standard (2002–2006 data)	95.3%	94.6%	**90.1%**
	2008–2011 Average	91.0%	88.5%	**80.3%**
	Difference	–4.3%	–6.1%	**–9.8%**
UCR Spring Chinook	2008 BiOp Standard (2002–2007 data)	**90.1%**		
	2008–2012 Average	**90.9%**		
	Difference	**+0.8%**		
UCR Steelhead	2008 BiOp Standard (2002–2006 data)	**84.5%**		
	2008–2011 Average	**88.4%**		
	Difference	**+3.9%**		

[1] See NMFS 2008 SCA, Adult Survival Estimates Appendix, pp. 887–908 for methodology.
[2] Only PIT-tagged UCR sockeye salmon in the Bonneville to McNary reach (2006 and 2007 only) were available to assess adult Snake River sockeye salmon reach survival in the 2008 BiOp. This three-dam reach was extrapolated to a 7-dam reach as surrogates for SR sockeye salmon. These estimates were considered too preliminary to use as a performance standard in the BiOp.
[3] Only known origin Snake River sockeye salmon were used to assess adult reach survival from 2010 to 2012.

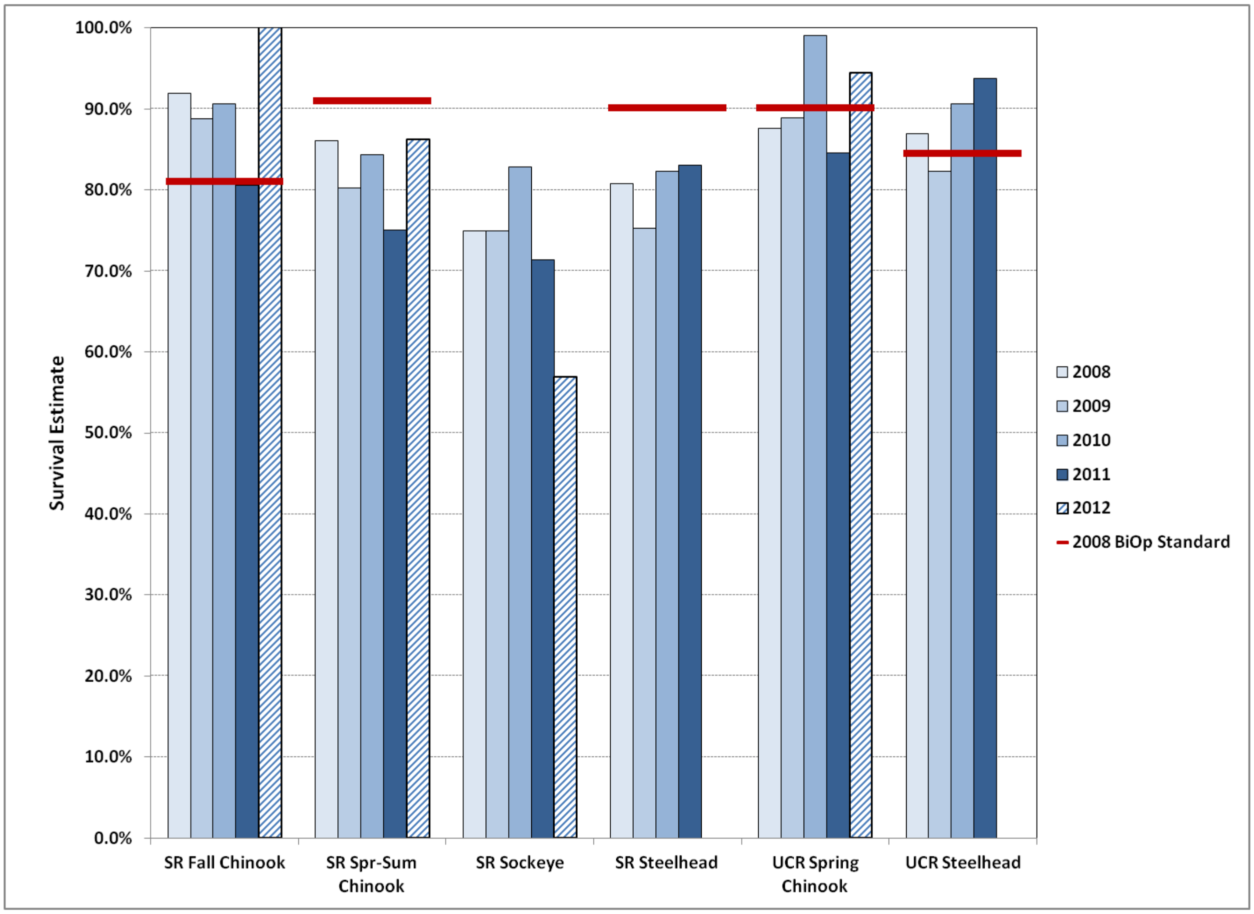

Figure 3.3-1. Recent (2008–2012) annual adult conversion rate estimates (adjusted for reported harvest and natural rates of straying) for known origin, PIT tagged salmon and steelhead that migrated inriver as juveniles compared to 2008 BiOp Adult Performance Standards (2008 SCA , Adult Survival Estimates Appendix).

The recent average conversion rate for UCR spring Chinook salmon adults in the lower Columbia Reach was 90.9%. This is slightly higher than the 90.1% estimate in the 2008 BiOp. Similarly, the average estimate for adult UCR steelhead adults migrating through this reach (88.4%) was nearly 4% higher than the average BiOp estimate (84.5%).

Conversion rate estimates for MCR steelhead migrating through the lower Columbia River were not assessed directly in the 2008 BiOp. Instead, average per dam survival estimates using SR steelhead as surrogates were used to estimate likely survival rates for populations passing through one to four of the lower Columbia River dams. It is unclear at this time if conversion rates for MCR steelhead have recently declined (as observed for SR steelhead) or not (as observed for UCR steelhead).

In summary, adult fishways have been operated consistently since 2002 and recent conversion rate estimates indicate that 2008 BiOp expectations are being met or exceeded for SR fall Chinook salmon and for UCR spring Chinook salmon and steelhead. However, conversion rates of SR spring/summer Chinook salmon and steelhead are substantially lower (by roughly 8% to 10% on average) than the 2008 BiOp Adult Performance Standards for these species.

We noted the differential survival of upper Columbia River stocks (lower) and Snake River stocks (higher) in the lower Columbia River reach as an issue of concern in the 2008 BiOp. The recent averages indicate that there is no longer a differential, but it is because the conversion rates of Snake River stocks in the lower Columbia River reach have declined. Snake River sockeye conversion rates also appear to be lower than our preliminary estimates (using unlisted sockeye stocks as surrogates) in the 2008 BiOp for the lower Columbia River reach. It is unclear if MCR steelhead conversion rates have declined (as observed for SR steelhead) or not (as observed for UCR steelhead).

Based on the initial (2008 and 2009) lower than expected conversion-rate estimates evaluated in the 2010 Supplemental BiOp, NOAA Fisheries added new RPA Action 1A (incorporation of the AMIP), including Amendment 2, which directed the Action Agencies to evaluate and construct, if feasible and effective, PIT tag detectors in the adult fishways at The Dalles Dam, John Day Dam, or both (NMFS 2010a). In 2013, the Corps of Engineers successfully installed PIT tag detectors in both ladder systems at The Dalles Dam. These detectors allow estimates of conversion rates between Bonneville and The Dalles dams and between The Dalles and McNary dams, greatly assisting regional managers to assess where within the Bonneville to McNary dam reach these discrepancies are occurring. NOAA and the Action Agencies are evaluating the information gained from The Dalles Dam adult PIT detectors and assessing the need for additional detectors at John Day Dam, as contemplated in the 2010 Supplemental BiOp.

The Corps of Engineers is also planning to install temporary (2 to 4 years) adult PIT tag detectors at Lower Monumental and Little Goose dams within the lower Snake reach (2014–2018 Draft IP). These detectors should similarly assist efforts to better isolate the sub-reaches where losses are occurring so that managers can assess the potential causes of reduced conversion rates for adult Snake River steelhead—and to a lesser extent, SR spring/summer Chinook salmon in the lower Snake River reach. Also, in order to assure that recent modifications – made primarily to enhance juvenile passage and survival – are not negatively affecting adult passage and survival, the Corps of Engineers is funding an adult radio-telemetry study in 2013 to assess adult migration and survival through the lower Columbia and Snake River dams. Adults will be trapped and tagged (with both radio tags and PIT tags) at Bonneville Dam and released about 8 km downstream of the dam and monitored as they migrate upstream through the dams and reservoirs. Tissue samples will be used to assign these fish to the proper stock ESU/DPS in order to assess straying, etc. – this information will also allow for relatively direct comparisons to survival rate estimates using known-origin PIT tagged fish used in NOAA's conversion rate estimates. Additional fish will be trapped and tagged at Ice Harbor Dam on the Snake River and released to ensure that enough Snake River fish are tagged to adequately assess passage through the lower Snake River dams. Key metrics will include passage times, passage efficiencies, fallback rates, straying rates, and estimates of unknown losses (Caudill 2013, IP RME Action Number 52).

In summary, new estimates of adult survival appear to be equal to or higher than expected for SR fall Chinook, UCR spring Chinook, and UCR steelhead. However, they are lower than expected for SR spring/summer Chinook, SR steelhead, and SR sockeye and it is unclear whether survival rates of MCR steelhead have declined or not. However, this is not yet considered a RPA implementation deficiency because:

- We are uncertain whether new estimates represent a true difference from base survival rates, or are within the Base Period's range of variation, because we do not have estimates of survival during the 2008 BiOp's Base Period prior to 2002 using PIT tags.
- There is uncertainty about the meaning of the new estimates because there is no obvious explanation (i.e., no changes in dam configuration or ladder operations, reported harvest, or river environmental conditions). At this time NOAA Fisheries cannot identify the factor that is responsible for the lower than expected conversion rates noted earlier in this section.
    - ◊ Adult ladder operations have been consistent since at least 2002. This, and the fact that PIT-tag–based conversion rate estimates for SR fall Chinook salmon and UCR spring Chinook salmon and steelhead are achieving or exceeding expectations, make it unlikely that the fishways themselves are responsible.
    - ◊ Harvest management has been implemented in accordance with the abundance-based harvest rate schedules identified in the 2008 Harvest BiOp (NMFS 2008f, WDFW and ODFW 2012a and 2012b).
- Other factors that could potentially be affecting adult passage and observed conversion rates include: environmental factors (flows, spill operations, temperature, etc.), structural modifications, errors in the harvest or stray rate estimation methods, variability in stock run timing, or some combination of these factors. NOAA plans to evaluate these factors in relation to PIT tag based conversion rate estimates (Dygert and Graves 2013) in the coming years.
- Within the 2008 BiOp's adaptive management approach, the Action Agencies and NOAA are initiating new studies to determine the explanation for lower survival estimates and, if appropriate, will develop modified actions to address contributing factors within the Action Agencies' jurisdiction and authority prior to 2018. The Action Agencies are expanding the adult PIT tag detection capabilities to additional dams (The Dalles, Little Goose, Lower Monumental, and potentially John Day dams), continuing to provide environmental data to regional databases, and are completing an active tag adult study in 2013, which can be compared directly to PIT tag estimates. Together, these actions should be sufficient for NOAA to determine where within the longer reaches unexpected losses are

occurring, and what factors are most likely responsible, so that a remedy can be fashioned and implemented.

3.3.3.2 Juvenile Dam Passage Survival

The RPA (RME Strategy 2 – Hydrosystem Research, Monitoring, and Evaluation) required the Action Agencies to achieve an average dam passage survival rate (across all eight of the lower Snake and lower Columbia River dams) of 96% for spring Chinook salmon and steelhead and 93% for subyearling Chinook salmon. We defined dam passage as survival from the upstream face of the dam to a standardized reference point in the tailrace (NMFS 2008 RPA Summary Table, RME Strategy 2 - Hydrosystem Research, Monitoring, and Evaluation, p. 72). RPA Actions 18–25 identified initial structural improvements that were likely to be implemented at each project, along with adjustments to dam operations, in order to achieve the 96% and 93% Juvenile Dam Passage Survival standards.

In 2012, the Action Agencies, after coordinating with NOAA Fisheries and receiving comments from regional co-managers, clarified how Juvenile Dam Passage Survival standard studies will be conducted, including the conditions under which results are automatically be considered valid versus those under which further discussion with regional co-managers are necessary before adopting test results as valid (2012 FCRPS Performance Testing Paper). The Action Agencies, after coordination with NOAA, have described an additional process for vetting test results with regional co-managers (2014–2018 Draft IP).

The Action Agencies summarized recent Juvenile Dam Passage Survival test results in their 2013 Draft CE (Section 1, Figures 19 and 20 and Table 2; see Table 3.3-2 below). Since 2008, at least one Juvenile Dam Passage Survival standard test has been conducted for yearling Chinook salmon, steelhead, and subyearling Chinook salmon at seven of the eight mainstem projects. These tests generally indicate that structural and operational improvements are performing well and resulting survival rates are likely very close to achieving, or are already achieving the 96% survival standard for yearling Chinook salmon and steelhead smolts, and the 93% survival standard for subyearling Chinook salmon smolts. The test results also indicate that at some projects survival rates may be substantially exceeding these performance standards and that migration delays in the forebays are being reduced. Additional testing is planned for Bonneville (2016/17), John Day (2014), McNary (2014/15), Ice Harbor (2015/16), and Lower Granite (2016/17) dams (2014–2018 Draft IP, Table 1).

In summary, project operations have been relatively stable and consistent with those ordered by the Court since 2010 and the Action Agencies have made substantial progress during the past five years to implement structural and operational improvements anticipated in the 2008 BiOp. Survival study results to date indicate that, with few exceptions, these structures (and operations) are performing as expected and are very close to achieving, or are already achieving the Juvenile Dam Passage Performance standards of 96% for yearling Chinook salmon and steelhead and 93% for subyearling Chinook salmon. Based on their record of implementing configuration and operation improvements to date, it is highly likely that the Action Agencies will implement the remaining configuration and operation improvements and complete the associated juvenile performance standard testing by 2018.

Table 3.3-2. Juvenile dam passage survival performance standard test results since 2008 (Modified from 2013 Draft CE, Table 2)

Dam	Year	Species	Survival[1] (%)	Spill Operation (Target/Actual)
Bonneville	2011	Yearling Chinook Salmon	95.69	100 kcfs / 100 kcfs
Bonneville	2011	Steelhead	97.55	100 kcfs / 100 kcfs
Bonneville	2012	Subyearling Chinook Salmon	97.39	85 kcfs day – 121 kcfs night / 149 kcfs 95 kcfs 24 hrs / 149 kcfs
The Dalles	2010	Yearling Chinook Salmon	96.41	40% / 40%
The Dalles	2011	Yearling Chinook Salmon	96.00	40% / 40%
The Dalles	2010	Steelhead	95.34	40% / 40%
The Dalles	2011	Steelhead	99.52	40% / 40%
The Dalles	2010	Subyearling Chinook Salmon	94.04	40% / 40%
The Dalles	2012	Subyearling Chinook Salmon	94.69	40% / 40%
John Day	2011	Yearling Chinook Salmon	96.66 97.84	30% / 30% 40% / 40%
John Day	2011	Steelhead	98.36 98.97	30% / 30% 40% / 40%
John Day	2012	Yearling Chinook Salmon	96.73	30% / 37.1% 40% / 37.1%
John Day	2012	Steelhead	97.44	30% / 37.1% 40% / 37.1%
John Day	2012	Subyearling Chinook Salmon	94.14	30%/37.9% 40%/37.9%
McNary	2012	Yearling Chinook Salmon	96.16	40% / 51%
McNary	2012	Steelhead	99.08	40% / 51%
McNary	2012	Subyearling Chinook Salmon	97.47	50% / 62%
Lower Monumental	2012	Yearling Chinook Salmon	98.68	Gas Cap (26 kcfs) / 29.7 kcfs
Lower Monumental	2012	Steelhead	98.26	Gas Cap (26 kcfs) / 29.7 kcfs
Lower Monumental	2012	Subyearling Chinook Salmon	97.9	17 kcfs / 25.2 kcfs
Little Goose	2012	Yearling Chinook Salmon	98.22	30% / 31.8%
Little Goose	2012	Steelhead	99.48	30% / 31.8%
Little Goose	2012	Subyearling Chinook Salmon	95.1	30% / 38.5%

[1]Grey Survival % boxes indicate tests with survival estimates that are below the appropriate performance standard. See 2012 FCRPS Performance Testing Paper for details regarding how this information will be considered (USACE 2012).

3.3.3.3 Juvenile Inriver Reach Survival Estimates

This section describes the results of empirical juvenile reach survival monitoring and compares them to expected ranges estimated in the 2008 BiOp. Unlike Juvenile Dam Passage Survival estimates, which focus on measuring the performance of structural and operational improvements at the dams, juvenile reach survival estimates can be used to assess the overall survival from a combination of environmental conditions and actions at different projects within the lower Snake and Columbia River migration corridor (and of water management operations at upstream storage projects). However, because they estimate survival over distances of hundreds of miles and days to weeks, they can be influenced by factors that the Action Agencies cannot control (e.g., fish condition and health, interactions between run timing and environmental conditions, etc.).

Juvenile reach survival estimates (Lower Granite Dam to Bonneville Dam) for wild (i.e., natural origin) yearling Snake River spring/summer Chinook salmon have ranged from about 46% to 71% since 2008 (Figure 3.3-2). The 2008 to 2010 estimates were substantially higher than the average "Base Period" estimates (33.4%) and were within the ranges of the "Current" survival rates considered in the 2008 BiOp (range of 33.9% to 60.8%, mean of 52.8%; see Appendix F, Inriver Juvenile Survival in the 2008 SCA). The 2011 and 2012 estimates were consistent with, or slightly higher than, ranges of "Prospective" survival rates (range of 46.7% to 67.8%, mean of 60.8%) expected in the 2008 BiOp (2008 BiOp; 2008 SCA).

Juvenile reach survival estimates for wild yearling Snake River steelhead ranged from about 48% to 57% (2008-2011), about double the average survival rates we estimated for the Base Period (26.5%) and higher than both the average Current survival rates (range of 3.3% to 56.9%, mean of 33.1%) and the Prospective survival rates (range of 4.0% to 64.4%, mean of 38.5%) in the 2008 BiOp (Figure 3.3-3). No survival estimate to Bonneville Dam is available for juvenile steelhead in 2012 because too few PIT tagged fish were detected at Bonneville dam and at the downstream pair-trawl detector[106].

Juvenile reach survival estimates for hatchery-origin UCR spring Chinook salmon ranged widely—from about 63% to 95% between McNary and Bonneville dams (Figure 3.3-4). The estimates from 2008, 2009, and 2012 each had relatively large standard errors (greater than 10%, implying relatively low precision). However, taken together, these estimates indicate that survival rates are likely higher than those estimated for the Base Period (66.6%) and within the range of the Current (range of 60.9% to 72.9%, mean of 66.7%) and Prospective survival estimates (range of 65.4% to 79.6%, mean of 72.6%) in the 2008 BiOp.

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[106] To estimate survival from any given point in the FCRPS to Bonneville Dam (the lowermost dam in the FCRPS) sampling of PIT-tagged fish downstream from the dam is required. PIT-tagged fish are detected by NOAA Fisheries in the lower Columbia River (rkm 61–83; RM 38–52) using a pair-trawl where the cod-end of the trawl is replaced with a large PIT tag detector through which fish pass and continue their migration (Magie et al. 2010).

Juvenile reach survival estimates for hatchery-origin UCR steelhead ranged from about 63% to 100% between McNary and Bonneville dams (Figure3.3-5). Similar to hatchery-origin UCR spring Chinook salmon, the standard errors were associated with most of the reach survival estimates (2009, 2011, and 2012) were greater than 10%. However, each juvenile reach survival estimate (2009–2012) was substantially higher than the average Base Period estimate (46.8%). These estimates are higher than the average Current survival rate (range of 16.8% to 67.4%, mean of 47.9%) and Prospective survival rate (range of 17.3% to 73.8%, mean of 52.8%) expected in the 2008 BiOp (Figure 3.3-5). Too few tagged smolts were detected at Bonneville dam and the downstream pair-trawl detector to make a survival estimate through the lower Columbia reach in 2008 for juvenile UCR steelhead.

We estimated the Current survival rates (calculated as 1-mortality) (Lower Granite to Bonneville dams) for hatchery-origin SR sockeye salmon smolts in the 2008 BiOp using 2000–2003 data from Williams et al. (2005, Table 32; see also Table 14.3 in the 2008 BiOp). These ranged from a low of about 20% to a high of about 57% in moderate- to high-flow years (greater than 65 kcfs at Lower Granite Dam), averaging about 36%. In low flow years (less than 65 kcfs at Lower Granite Dam), assuming a maximum transport operation (i.e., no spill at the three Snake River transport projects), we estimated the Current inriver survival rate to be only about 10%. Prospective survival rates in the 2008 BiOp were based on empirical data from yearling Chinook, as surrogates for juvenile sockeye (see 2008 BiOp, Incidental Take Statement Table 3). The Prospective estimate for moderate- to high-flow years ranged from about 24% to nearly 65%, averaging about 43%.

Increased smolt production from the Snake River sockeye captive broodstock program and the ability to tag and release larger groups for reach survival studies has substantially improved the accuracy of the estimates for the Lower Granite to Bonneville dam reach since 2008. Figure 3.3-6 displays recent survival information (2008–2012) compared to Current and Prospective estimates in the 2008 BiOp for the medium- to high-flow years. Survival since 2008 has ranged from 40.4% to 57.3%—all of these empirical estimates are higher than the average Current estimate in the 2008 BiOp, and three of the four are higher than the average Prospective estimate in the 2008 BiOp. A survival estimate could not be made for sockeye salmon in 2011 because too few PIT-tagged fish were detected at Bonneville dam and at the downstream pair-trawl detector.

In the 2008 BiOp, we extrapolated survival estimates for hatchery-origin subyearling SR fall Chinook smolts in the Lower Granite to McNary reach to derive Current and Prospective inriver survival rates for these fish of 19.7% to 55.4% for the reach between Lower Granite and Bonneville dams.[107] Figure 3.3-7 compares average survival rates of cohorts of fish (migrating fish grouped into consistent two week blocks of time) through this reach from 1998 to 2011 with the 2008 BiOp estimates. The Action Agencies began providing summer

[107] This equates to an average of 39.5% (low estimate) to 71.4% (high estimate) through the Lower Granite to McNary reach (per project survival estimate of 0.793 [low] to 0.919 [high] to the fourth power).

spill at the three Snake River collector projects in 2005 in response to the court order and NOAA Fisheries has since incorporated summer spill at these projects into the RPA. Figure3.3-7 shows survival rates for the years affected by summer spill prior to and including the years following installation of surface passage weirs at each of the five projects in this reach. Prior to 2005, survival estimates for subyearling Snake River fall Chinook ranged from about 25% up to nearly 80% between Lower Granite and McNary dams and survival rates trended lower as the season progressed (i.e., earlier cohorts typically had higher survival rates than later cohorts). Between 2005 and 2008 (the last year before all surface passage routes were installed), fish migrated earlier (i.e., there are no estimates for a cohort of fish passing Lower Granite Dam in the July 1 to July 14 period) and survival rates improved substantially, ranging from about 56% to 78% for individual cohorts. Beginning in 2009, years when summer spill and surface passage routes were both fully effective, survival rates have ranged from 72% to 89% for individual cohorts: all but one cohort during this period exceeded the highest average survival rate expected in the 2008 BiOp.

In summary, reach survival estimates for subyearling SR fall Chinook salmon and yearling spring/summer Chinook salmon, sockeye salmon, steelhead, and UCR spring Chinook salmon and steelhead all appear to be meeting or, in the case of fall Chinook salmon, sockeye, and steelhead, substantially exceeding both Current and Prospective 2008 BiOp expectations for migrating smolts. As noted in the 2010 Supplemental BiOp, Section 2.2.2.2, per kilometer, these survival rates are approaching those estimated in several free-flowing river systems. In general, we expect these increased average survival rates to result in increased adult returns for inriver migrating juveniles. This effect should be most pronounced for UCR spring Chinook and steelhead, which are no longer transported (i.e., all smolts migrate inriver). The overall effect on adult returns for Snake River ESUs/DPSs is unclear, as transport rates have also decreased substantially. While the effect is positive for the substantial fraction of these fish migrating inriver, the relative return rates of transported fish must also be taken into account (see transport Section 3.3.3.4 below). In addition, to the extent surface passage routes reduce forebay delays (see Section 3.3.3.2), overall migration times through the mainstem reaches will be reduced, which should further benefit migrating juveniles and potentially improve adult returns.

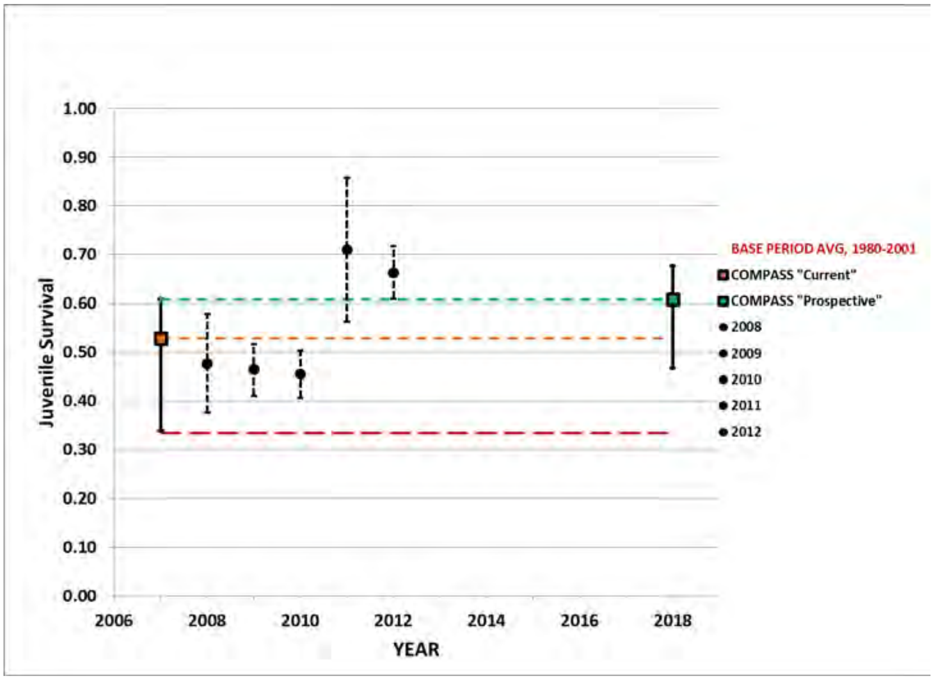

Figure 3.3-2. Lower Granite to Bonneville dam survival estimates (standard error) for wild Snake River spring/summer Chinook salmon (2008–2012) compared to Base Period (bottom horizontal dashed line), Current (middle horizontal dashed line), and Prospective (top horizontal dashed line) average estimates (ranges are indicated by vertical bars) in the 2008 BiOp.

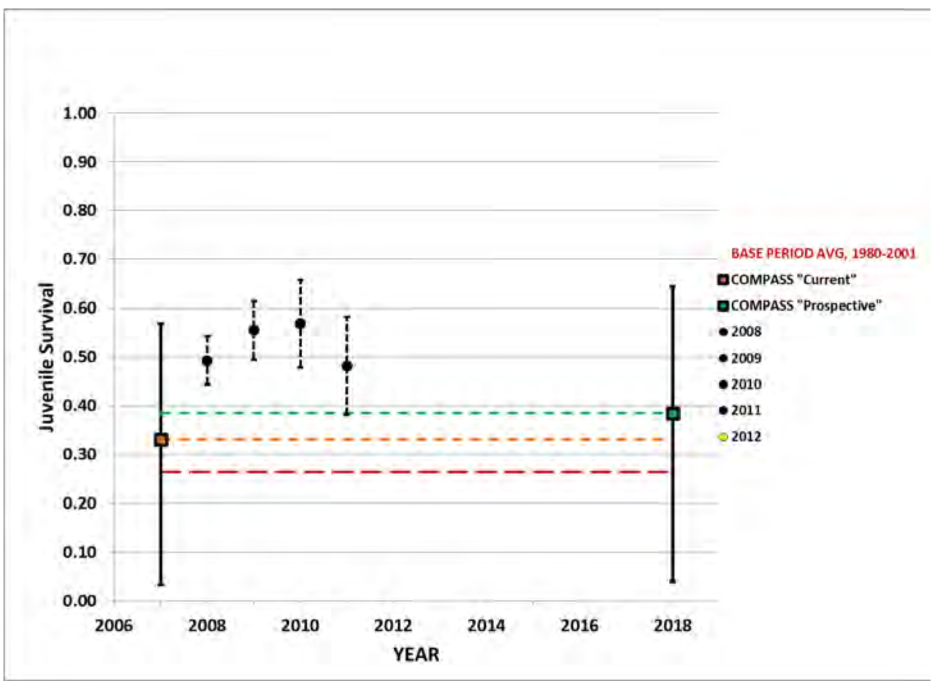

Figure 3.3-3. Lower Granite to Bonneville dam survival estimates (standard error) for wild Snake River steelhead (2008–2012) compared to Base Period (bottom horizontal dashed line), Current (middle horizontal dashed line), and Prospective (top horizontal dashed line) average estimates (ranges are indicated by vertical bars) in the 2008 BiOp.

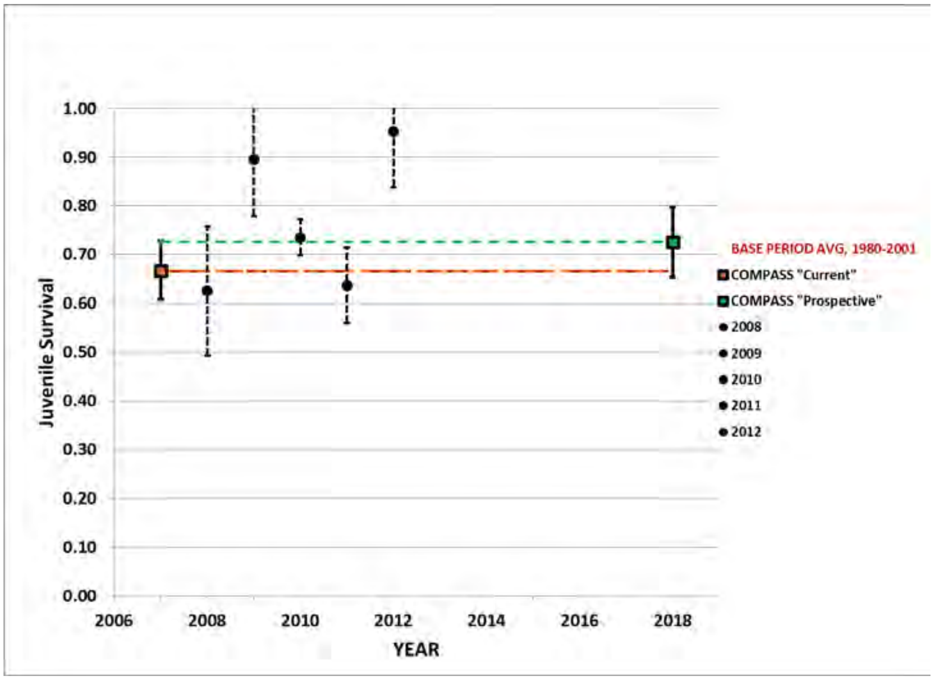

Figure 3.3-4. McNary to Bonneville dam survival estimates (standard error) for hatchery UCR spring Chinook salmon (2008–2012) compared to Base Period (bottom horizontal dashed line), Current (bottom horizontal dashed line), and Prospective (top horizontal dashed line) average estimates (ranges are indicated by vertical bars) in the 2008 BiOp.

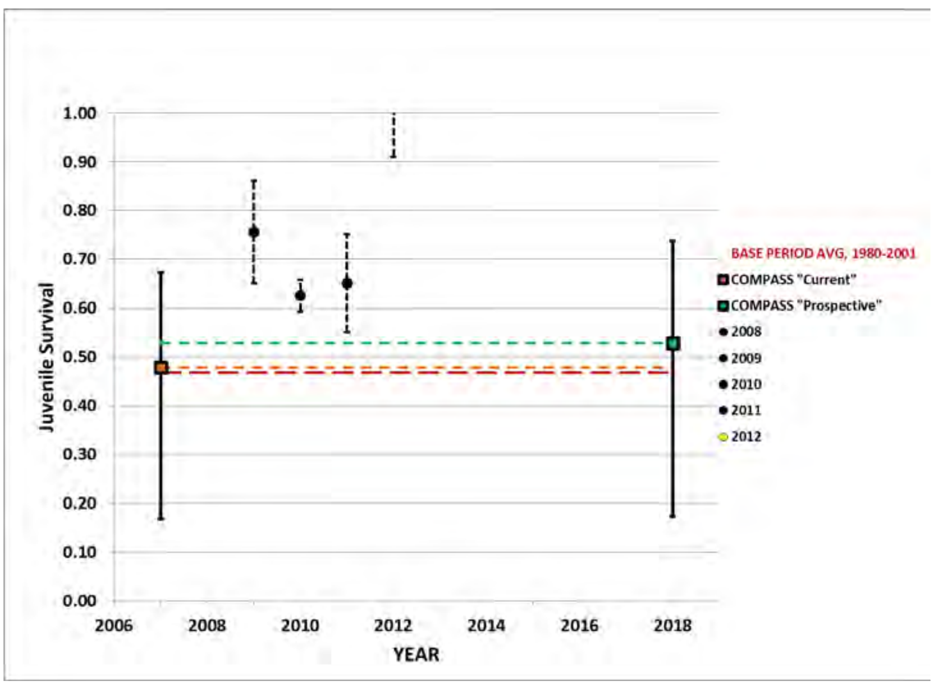

Figure 3.3-5. McNary to Bonneville dam survival estimates (standard error) for hatchery UCR steelhead (2008–2012) compared to Base Period (bottom horizontal dashed line), Current (middle horizontal dashed line), and Prospective (top horizontal dashed line) average estimates (ranges are indicated by vertical bars) in the 2008 BiOp.

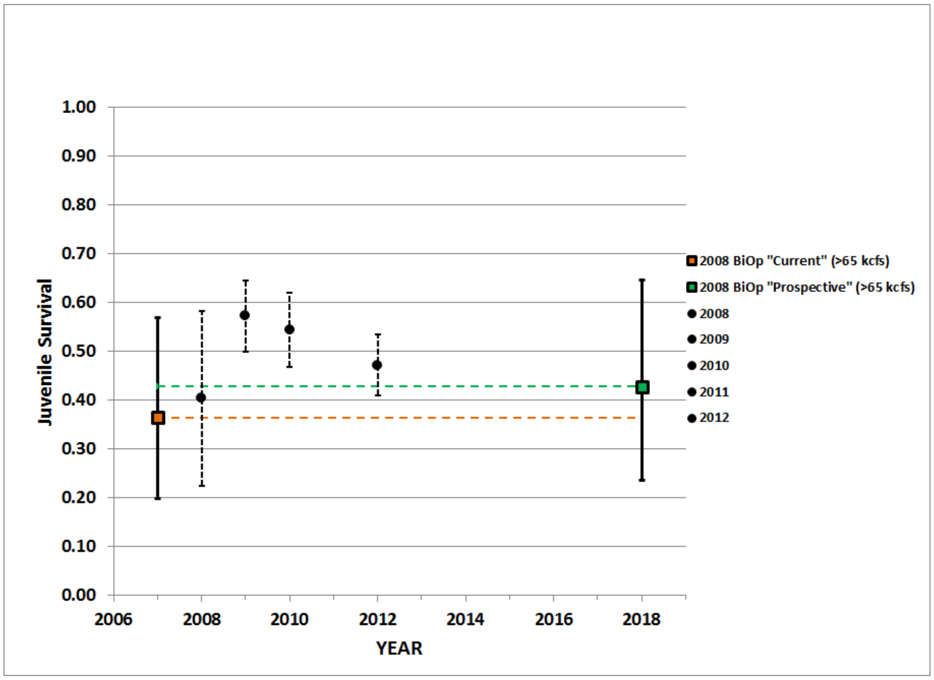

Figure 3.3-6. McNary to Bonneville dam survival estimates (standard error) for wild Snake River sockeye salmon (2008–2012) compared to Current (bottom horizontal dashed line) and Prospective (top horizontal dashed line) average estimates (ranges are indicated by vertical bars) in the 2008 BiOp.

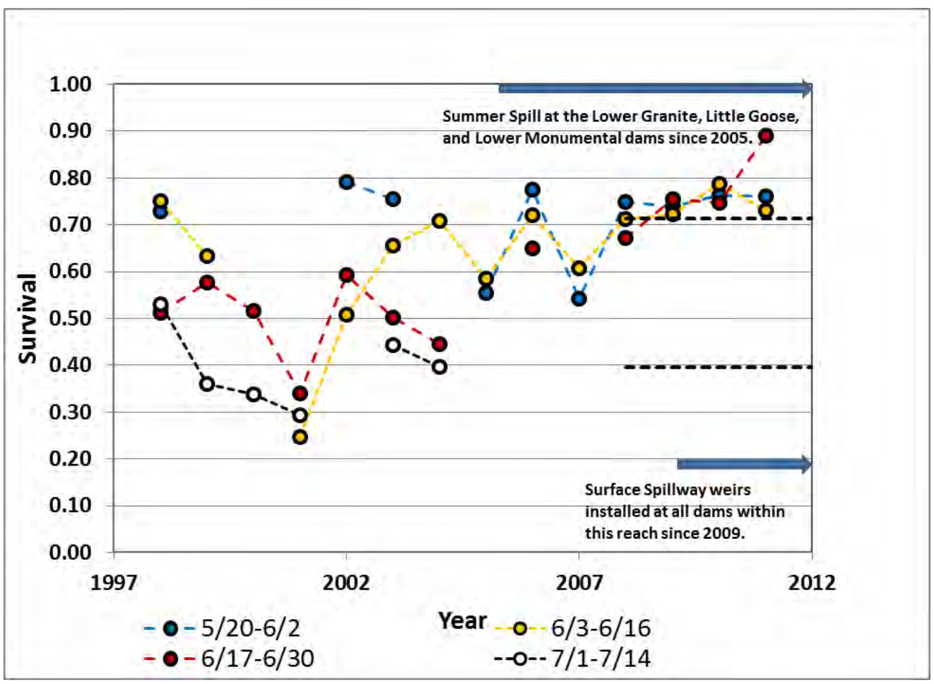

Figure 3.3-7. Estimated survival rates from two-week cohorts of juvenile subyearling Snake River fall Chinook salmon between Lower Granite and McNary Dams from 1998 to 2011. Black horizontal dashed lines denote Prospective minimum and maximum average survival rates estimated in the 2008 BiOp; blue arrows denote years in which Court Ordered summer spill occurred at the three Snake River transport projects (top) and years in which all dams in this reach were configured with surface passage routes (bottom).

3.3.3.4 Juvenile Transportation

Transport actions have been substantially different from the actions described in the 2008 BiOp, which complicates evaluation of the spring Snake River juvenile fish transportation operations conducted from 2008 to the present. The 2008 BiOp called for two different transportation operations that were dependent on the runoff volume forecast. In years when the Snake River spring flow was forecast to average less than 65 kcfs, no spill was to be provided at the three Snake River collector dams and all fish collected were to be transported beginning April 3. In years when the Snake River spring flow was forecast to exceed 65 kcfs, spill was to be provided and juvenile fish would be collected for transportation beginning April 21. The 2008 BiOp specified a spill cessation period from May 7 to May 20, with spill resuming May 21, to maximize transportation and to spread the risk between transport and inriver migration routes.

While NOAA Fisheries included a maximum transportation strategy for May 7 to May 20 in its 2008 BiOp, NOAA Fisheries also agreed to have the ISAB review this strategy prior to adopting it. The ISAB did not endorse the proposal to maximize transport even for the discreet periods proposed, citing a list of uncertainties of the effects from taking this action. These included:

- The need to evaluate the improvements made to the dams under a spill–transport operation.
- Critical uncertainties on the effects of transport on lamprey and sockeye.
- A need to reduce the uncertainties about relative amounts of adult straying and potential effects on genetic and life history diversity from transported versus inriver fish.

The ISAB recommended continuing to spread the risk (generally interpreted to mean a 50/50 transport ratio for migrating fish) between transport and inriver migration, providing spill throughout the migration season regardless of river flow and runoff forecasts. The 2010 Supplemental BiOp followed the ISAB's recommendation to provide spill through the May 7 to May 20 period and established a process to review this action annually. The Court Ordered spill operations (which eliminated the late May spill hiatus proposed in the 2008 BiOp and required summer spill at the three Snake River collector dams) have been incorporated into the Corps of Engineers' annual Fish Operations Plan. These operations are summarized in the Action Agencies' 2013 Draft CE (Section 2, Tables 31 and 32). Implementation of this recommendation and operating in accordance with the Court Ordered spill operations (foregoing the 2-week planned cessation of voluntary spill at the three transport projects in May) has resulted in the transportation of far fewer fish than forecasted in the BiOp (Table 3.3-3, Table 3.3-4, and Figure 3.3-8).

Based on the COMPASS model, the 2008 BiOp anticipated the percentage of spring Chinook transported would range between 39.3% and 96.0%; averaging 63.7% over the range of flow conditions analyzed (Table 3.3-3). The percentage of steelhead expected to be transported was somewhat higher, ranging between 49.8% and 98.3%, and averaging 74.3% (Table 3.3-4). The actual percentage of spring yearlings transported has generally been less than 50% since 2008 (roughly 23% to 40% for wild spring/summer Chinook salmon and 28 to 46% for natural-origin steelhead), significantly less than anticipated, because of the provision of spill throughout the migration season and in all flow conditions (Table 3.3-3 and Table 3.3-4). An additional factor accounting for the low transport rates has been a delay by the Action Agencies, with the advice of regional fish managers, in the initiation of collection for transportation until May 1 at Lower Granite Dam and until May 8 at Lower Monumental Dam. This is at least10 days later than the 2008 BiOp had analyzed.

The 2008 BiOp estimated that 52% of subyearling Snake River juvenile fall Chinook would be transported. The annual average percent actually transported during the years 2008 through 2011 was estimated to be 52.8% (DeHart 2012).

NOAA Fisheries' 2008 BiOp contained a provision to transport mid-Columbia and upper Columbia River spring Chinook juvenile salmon from McNary Dam during the spring season when the average seasonal flow was forecast to be less than 125 kcfs (about once every 70 years.) Flow did not approach these low levels during the years 2008–2012. NOAA Fisheries has reconsidered the value of both spring and summer transportation at McNary Dam and no longer supports planning for juvenile transportation at this project under any flow conditions (Wagner 2013).

Effect of transportation operations

Since the percentage of juvenile SR spring Chinook and steelhead juveniles transported was far less than the BiOp estimated, the potential effect of this change on adult return rates needs to be considered. The smolt-to-adult return rate of the juveniles that were transported (SAR_T), and the smolt-to-adult return rate of fish that migrated inriver (SAR_I) are needed to assess the effectiveness of transportation. A ratio of SAR_T to SAR_I is used to compare the two rates, which is referred to as the transport-to-inriver (TIR) ratio. If TIR is greater than 1, it indicates that transported fish survived to return as adults at a higher rate than inriver migrants. If TIR is less than 1, it indicates that inriver fish survived to return as adults at a higher rate than transported fish. The data used to calculate the inriver SARs are based on juveniles that were not detected at a Snake River collector project[108] (Tuomikoski 2012). The TIRs for adults returning to Lower Granite Dam under the 2008 BiOp's spill program are available for the years 2006, 2007, 2008, 2009, and 2010 for spring Chinook and 2006, 2007, 2008, and 2009

[108] Since juveniles collected at the Snake River collector project are assumed to be transported.

for steelhead (Table 3.3-5). These annual estimates are reported in the Comparative Survival Study (Tuomikoski 2012).[109]

A similar analysis of juvenile transportation effects is conducted by the NWFSC. However, the focus of the NWFSC study is to examine within season patterns of SARs relative to in-season juvenile migration timing and changing environmental conditions. To study seasonal SAR patterns, known dates of juvenile passage are required, which is obtained from juvenile fish that are bypassed at collector projects. The metric used to report the results from this analysis is the “T:B ratio”, making it clear the comparison is between transported (T) and bypassed (B) fish. The estimated T:B ratios are summarized relative to the T:I of 1.0 standard and an adjusted standard to compensate for the lower SARs of bypassed fish in a series of color-coded figures (Figures 3.3-9 and 3.3-10) The annual average T:B ratios for wild spring Chinook and wild steelhead tagged upstream from Lower Granite Dam for years 2006–2009 have ranged from 1.34 to 1.77 for spring Chinook and 1.44 to 2.89 for steelhead (Smith 2013).

The data indicates transport returned more adult steelhead and spring Chinook (TIR greater than 1) for all years with the exception of 2006. The TIR for both steelhead and spring Chinook was less than 1 in 2006, which had a transport start date of April 20 at Lower Granite Dam (Table 3.3-5). In all subsequent years, transport began May1 at Lower Granite Dam. The earlier transport start date in 2006 may explain the low TIR in that year. There is a documented seasonal benefit from transport that is most prominent for wild spring Chinook. Prior to May 1, spring Chinook often show no benefit from transport, but after May 1 transport is generally beneficial and that benefit typically increases through the month of May (Williams 2005; Smith 2013). However, steelhead have typically shown a benefit from transport during the month of April and continuing through May. A challenge to managing the transport program is to select a period when it is clearly beneficial to both species.

Given the positive TIRs for most years it is likely that more adults would have returned by transporting a greater percentage of the fish as assumed in the 2008 BiOp during the mid-May period when transport benefits are typically greatest (compared to operating under the Court Order). However, it would have been contrary to the ISAB’s advice on risk management. Also a retrospective analysis of how the BiOp operation would have performed relative to the actual operation is complicated by the fact that several important variables were changing simultaneously. These include configuration changes that were being made at the dams and uncertainty of the degree to which removing various fractions of juveniles from the river would have affected predation rates on the juvenile fish remaining in the river. Importantly,

[109] The NWFSC’s COMPASS model used seasonal, independent estimates of SARs for inriver and transported juveniles released into the river below Bonneville Dam, and did not depend upon average annual estimates of D - though a ratio of the transported SARs and inriver SARs ("D") was reported for the convenience of managers.

overall adult return rates from the operations performed have generally been within, or higher than, the range contemplated by the 2008 BiOp.[110]

NOAA Fisheries continues to provide updates of juvenile survival estimates, transport rates, and seasonal patterns of SARs for both transported and inriver migrating smolts to the Action Agencies and Regional Implementation Oversight Group (RIOG) members as part of the decision-making process for developing the annual Fish Operations Plan. At this time, NOAA Fisheries views recent transport operations as an ISAB-supported, adaptive management operation. Given annual variations in both the freshwater and marine environments, and the continual annual installation of structures to improve survival rates at the mainstem dams, NOAA Fisheries expects that additional years of data will be needed in order to better understand how, whether, and to what extent (or during which parts of the migration season) transport or inriver migration strategies are preferable given current dam configurations and relatively stable spill operations.

Starting in 2014, the Action Agencies propose to begin transport on April 21 each year to increase the proportion of juveniles transported (2014–2018 Draft IP, pp. 43–44).

Table 3.3-3. Estimated percentage of juvenile wild Spring Chinook expected to be transported in the 2008 BiOp and the actual percentage transported by year.

Year	% expected to be transported under 2008 BiOp	Actual % Transported
2008	63.7% (39.3 - 96.0%)	54.3
2009	63.7% (39.3 - 96.0%)	40.4
2010	88.7% (67.9 - 95.7%)	38.2
2011	63.7% (39.3 - 96.0%)	35.2
2012	63.7% (39.3 - 96.0%)	22.7

[110] COMPASS modeling was used in the 2008 BiOp to assess relative differences in survival and adult returns resulting from implementing alternative operations across the 70-year water record. Post-Bonneville smolt-to-adult survival relationships in COMPASS were based on empirical estimates from only 5 or 6 years of data.

Table 3.3-4. Estimated percentage of juvenile wild steelhead expected to be transported in the 2008 BiOp and the actual percentage transported by year.

Year	% expected to be transported under 2008 BiOp	Actual % Transported
2008	74.3% (49.8 - 98.3%)	50.5
2009	74.3% (49.8 - 98.3%)	46.1
2010	89.0% (71.1 - 97.9%)	36.8
2011	74.3% (49.8 - 98.3%)	36.1
2012	74.3% (49.8 - 98.3%)	28.4

Table 3.3-5. Wild spring Chinook and wild steelhead date at which transport started at Lower Granite Dam and TIR by year as reported by CSS 2012.

Year	Transport Start Date at Lower Granite Dam	Spring Chinook TIR	Steelhead TIR
2006	April 20	0.78	0.85
2007	May 1	1.27	2.89
2008	May 1	1.19	1.16
2009	May 1	1.12	1.35[1]
2010	April 25	1.03[A]	

[2]Incomplete adult return (only returning 2-salts as of July 11, 2012)
[1]Incomplete steelhead adult returns until 3-salt returns (if any) occur after July 11, 2012 at Lower Granite Dam.

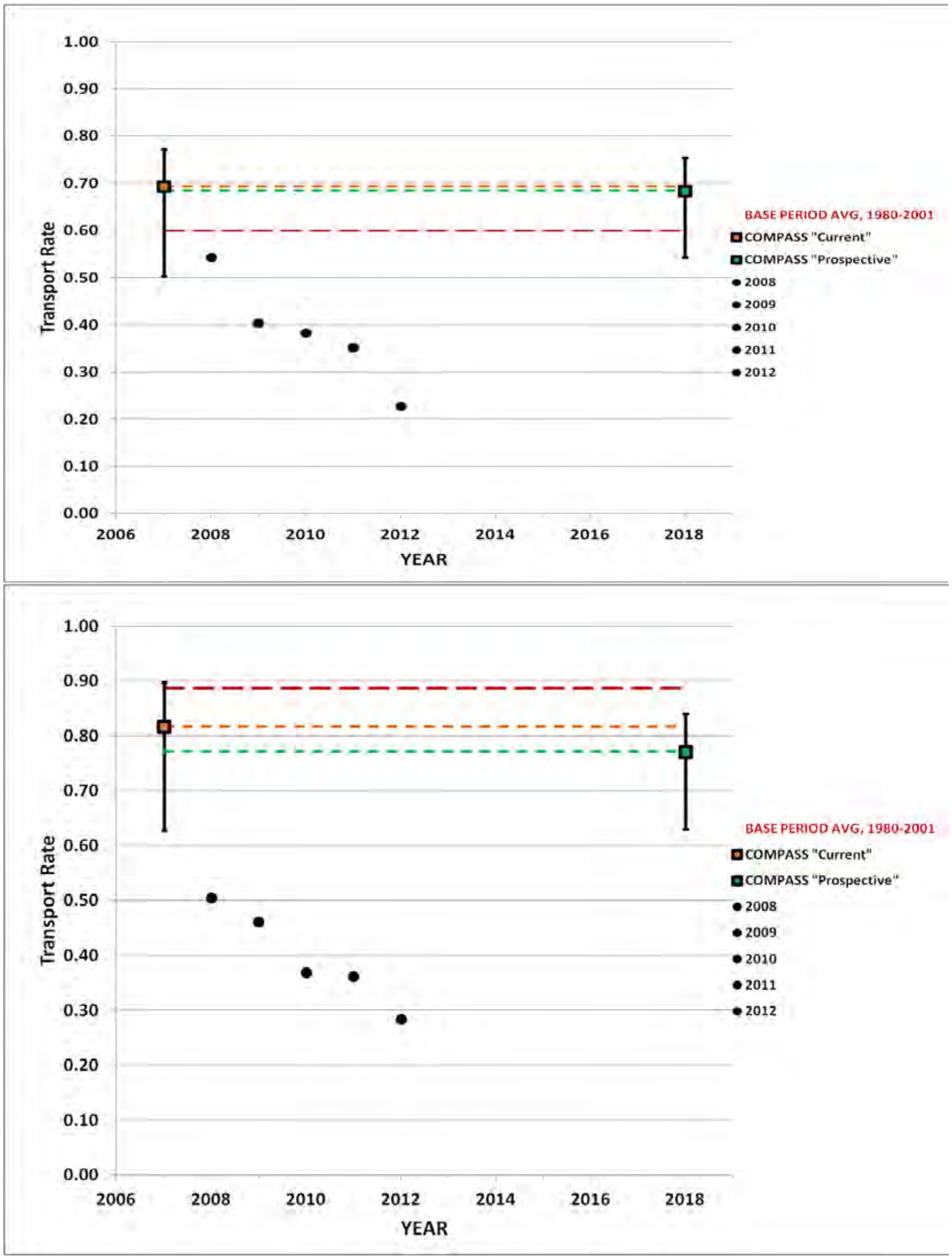

Figure 3.3-8 Estimated mean Base Period, "Current" and "Prospective" (minimum, mean, and maximum estimates of transport rates; Source: 2008 SCA, COMPASS modeling results Appendix) and recent transportation estimates for wild SR spring/summer Chinook salmon (top panel) and wild SR steelhead (bottom panel) (Faulkner et al. 2013) following review by the ISAB under Court Ordered spill operations.

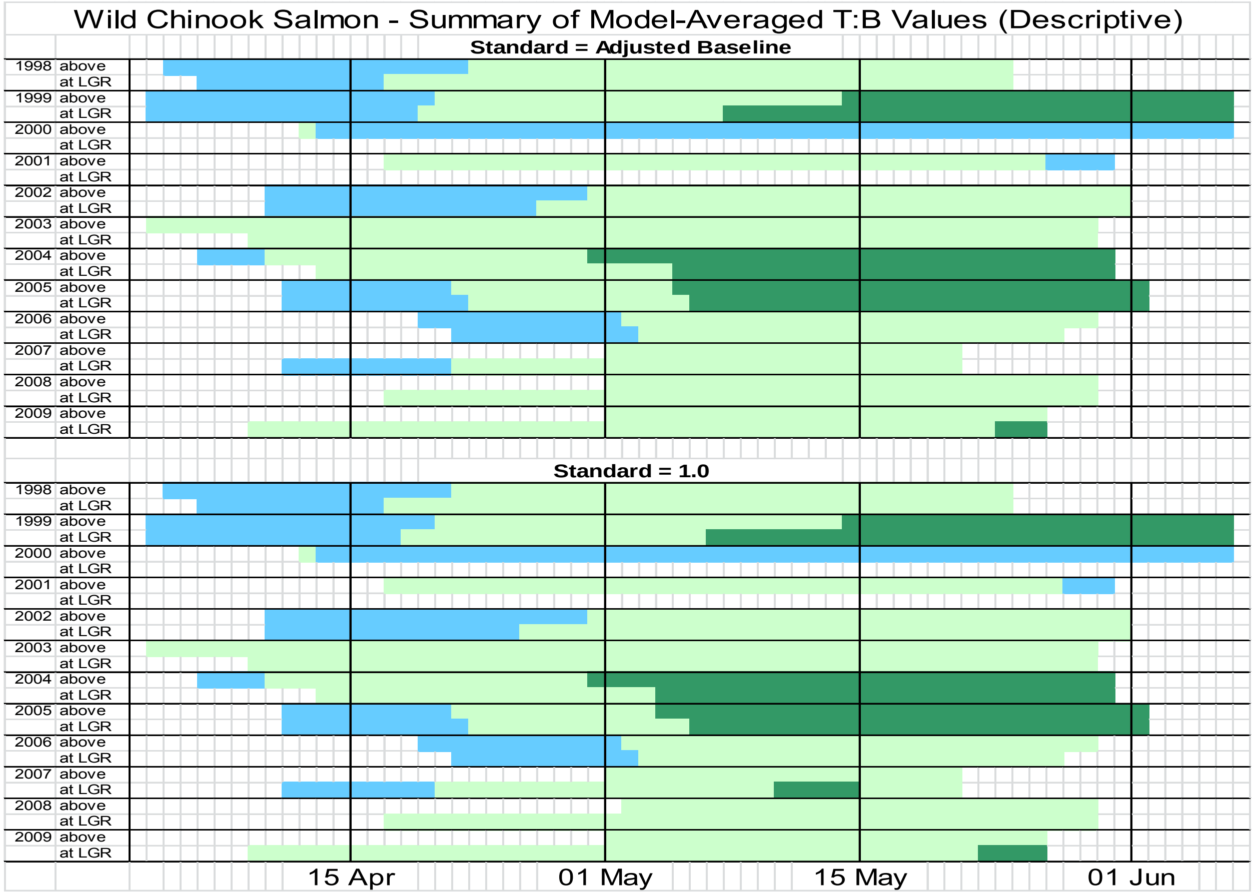

Figure 3.3-9. Color-coded summary of daily model-averaged (descriptive models) Transport:Bypass ratios (T:B) from Lower Granite Dam for Snake River wild spring/summer Chinook salmon. Fish were tagged upstream from ("above") or at Lower Granite Dam. Color coding: Dark blue cells—T:B was significantly less than the standard on that date; Light blue cells—T:B was less than the standard, but not significantly; Light green cells—T:B was greater than the standard, but not significantly; Dark green cells—T:B was significantly greater than the standard; White cells—No data. "Significance" determined from 95% confidence envelope around model-averaged curve.

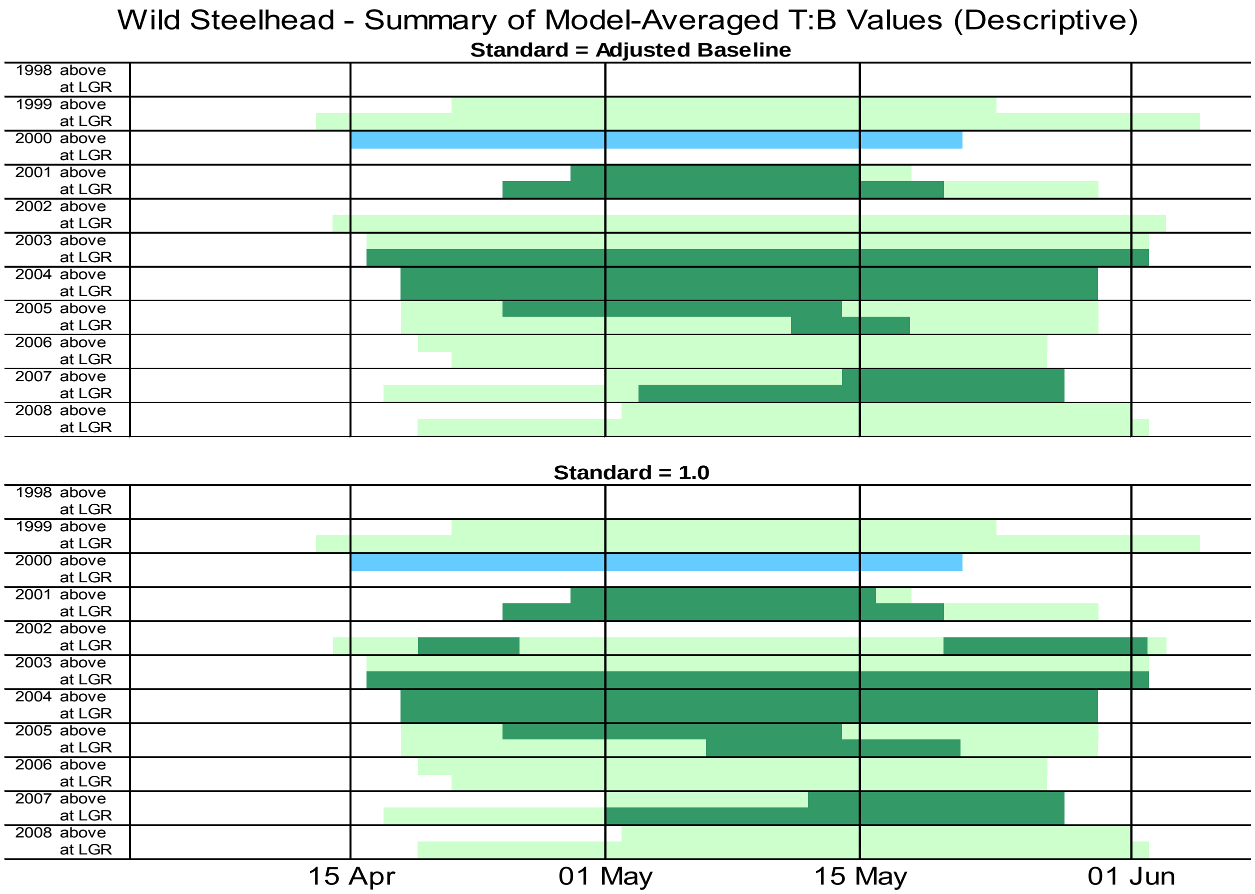

Figure 3.3-10. Color-coded summary of daily model-averaged (descriptive models) Transport:Bypass ratios (T:B) from Lower Granite Dam for Snake River wild steelhead. Fish were tagged upstream from ("above") or at Lower Granite Dam. Color coding: Dark blue cells—T:B was significantly less than the standard on that date; Light blue cells—T:B was less than the standard, but not significantly; Light green cells—T:B was greater than the standard, but not significantly; Dark green cells—T:B was significantly greater than the standard; White cells—No data. "Significance" determined from 95% confidence envelope around model-averaged curve.

3.3.3.5. System Survival

The term “system survival” is an estimate of juvenile fish survival through the FCRPS that accounts for the proportion and survival rate of juveniles that either migrated inriver, or were transported, and an adjustment factor , “D”, applied to the survival rate of transported fish. Survival through the FCRPS is approximately 98% for barged yearling Chinook salmon and approximately 50% for inriver migrants that pass through the dams (Williams et al. 2005). However, the post-hydrosystem survival (smolt-to-adult return rate) of barged fish is often lower than that of inriver migrants, and is sometimes low enough to offset the survival benefit of barging through the hydrosystem. Differential delayed mortality (D) is a convenient way to discuss differences between barged fish and inriver migrants occurring after fish pass Bonneville Dam (BON). Differential delayed mortality is a useful metric for understanding how differential survival downstream for the release point influence the effectiveness of the Juvenile Fish Transportation Program. The term D summarizes differences in mortality between transported and inriver migrants that occur after hydrosystem passage in the lower river, estuary, ocean, and during upstream migration (Anderson et al. 2011).[111]

D is an important concept for the management and recovery of listed salmon and steelhead stocks because it contrasts the impacts of barge transportation with inriver hydrosystem passage on the survival of fish as they continue their migration to complete their life histories. D is calculated using information about the survival of fish from the time they pass Lower Granite Dam as juveniles to the time they return to the hydrosystem (typically measured back to Lower Granite Dam for Snake River species) as adults. When D = 1, the post-BON survival rates for transported and inriver migrating juveniles is equivalent. When D is not equal to 1, there is a difference; whether D is greater than or less than 1 indicates which type of hydrosystem passage results in higher relative post-BON survival rates. When D is greater than 1, transported fish survive at a higher rate post-BON, and when D is less than 1 inriver migrants survive at a higher rate. Transportation is beneficial when D exceeds the inriver survival rate. Differential delayed mortality is a relative ratio and not an absolute measure of survival (Anderson et al. 2011). Numerous factors are hypothesized as affecting D. These include:

- Arrival time to the hydrosystem
- Travel time through the hydrosystem
- Fish length
- Fish physiological condition
- Fish health

[111] $D = (T: I) * S_{inriver}$ where D is differential delayed mortality, T is the SAR of transported juveniles and I is the SAR of inriver migrating juveniles (from Lower Granite Dam to the ocean and back to Lower Granite Dam for Snake River species), and $S_{inriver}$ is the estimated survival of inriver migrating juvenile from Lower Granite Dam to the Bonneville tailrace. Thus, unlike the TIR ratios discussed in Section 3.3.3.4, D takes into account the survival of inriver migrants to the tailrace of Bonneville Dam.

- Dam operations
- Barging conditions
- Lower Columbia River conditions and predation
- Estuarine conditions and bird predation
- Oceanic conditions
- Straying
- Survival estimation techniques

Differential delayed mortality values vary within and across years and are different among species (e.g. Chinook salmon and steelhead, run types (e.g., spring/summer and fall Chinook salmon) and rearing types (i.e., hatchery versus wild). The seasonal pattern is relatively consistent across years: D begins below 1 early in the season, then increases throughout the season, and sometimes rapidly decreases to below 1 at the end of the season for spring/summer Chinook salmon and steelhead (Anderson et al. 2005; NOAA 2010). Thus, estimates of D are substantially influenced by the timing of transportation.

The 2008 BiOp included estimates of expected system survival under a range of flow conditions and juvenile transport operations. These included estimates of D. Annual empirical estimates of D and transport start dates at LGR since the 2008 BiOp are provided in Table 3.3-6.

Table 3.3-6. Date at which transport started at LGR and D values reported by the CSS for wild Snake River spring Chinook and steelhead (Source: Fish Passage Center 2013).

Year	Transport Start Date at LGR	Spring Chinook D	Steelhead D
2006	April 20	0.47	0.52
2007	May 1	0.80	1.20
2008	May 1	0.82	0.60
2009[1]	May 1	0.66	0.97
2010[2]	April 25	0.62	

[1] Incomplete steelhead adult returns until 3-salt returns (if any) occur after July 11, 2012 at LGR.
[2] Incomplete adult return (only returning 2-salts as of July 11, 2012)
NOTE: "n-salt" refers to the number of years an adult has spent in the ocean prior to returning to freshwater to spawn. The great majority of Chinook salmon return to freshwater after spending 1 to 3 years in the ocean (e.g. 1 to 3-salt returns).

As previously mentioned, the transport and spill operations that began in 2006 have substantially reduced the number of juvenile Snake River fish transported to below Bonneville Dam. Considering D, this effect is probably relatively small for spring Chinook, but larger for steelhead—at least in some years (e.g. 2007 and 2009). We have too little information to make a meaningful estimate of D for naturally produced sockeye or fall Chinook salmon.

Because of the 2-5 year salmonid life cycle, only two or three years of adult return data is available since the implementation of the 2008 BiOp. SARs are presented for 2006 and 2007 because these years included the spill operations that were carried forward into the 2008 BiOp. The SARs observed for 2006 and subsequent years (Table 3.3-7) have generally been within the range of SARs anticipated in the 2008 BiOp, with the exception of 2008, which exceeded modeled expectations, especially for wild spring Chinook salmon.

Table 3.3-7. SARs of wild Snake River spring Chinook and steelhead (all detection histories through August 18, 2013) returning to Lower Granite Dam (LGR) by year for fish tagged above LGR (Source: NWFSC unpublished data).

Year	Wild spring Chinook LGR to LGR SAR	Wild steelhead LGR to LGR SAR
2006	0.82	1.08
2007	0.91	1.84
2008	2.84	3.45
2009	1.67	2.21
2010	1.16	1.75

As a way to move closer to achieving a 50:50 split between transported and inriver migrants, the Action Agencies have proposed to start transport on April 21 for future years. This is within the range of the ISAB's recommendation that transport begin in a late April to early May time frame. This action will result in a higher percentage of fish transported compared to recent estimates (see Section 3.3.2.4) and would likely benefit steelhead adult returns.

In summary, reduced transport rates—with consideration of average annual D estimates—suggests that system survival rates for SR steelhead (and to a much lesser extend SR spring/summer Chinook salmon) have likely declined, at least in some years. Too little information is available to make a meaningful estimate for naturally produced sockeye salmon or fall Chinook salmon. The Action Agencies have proposed to start transport earlier (April 21) than has been the case since 2008 (April 25 to May 1), which should somewhat reduce any negative impacts that might be occurring. However, the available SAR estimates do not indicate that substantial impacts have occurred to either SR steelhead or spring/summer Chinook salmon since 2008. The available information does not warrant an adjustment to the multipliers used in the 2008 BiOp.

As previously noted (Section 3.3.2.4), NOAA Fisheries considers the current transport operations to be consistent with both the court approved operations and the advice provided by the ISAB. NOAA Fisheries will continue to annually monitor inriver juvenile survival, percentage of juvenile fish transported, D, TIRs, and adult SAR estimates. Should this information clearly indicate that reduced transportation rates are substantially affecting system survival or the overall productivity of SR steelhead or the other Snake River species, the adaptive management process can be used to alter operations to increase the proportion of steelhead (and other species) that are transported, returning productivity to levels anticipated in the 2008 BiOp.

In recent Comparative Survival Study Annual Reports, Tuomikoski et al. (2011, 2012)[112] hypothesize that substantially increasing spill levels (which reduce exposure of juveniles to juvenile bypass systems and turbines) would substantially increase both inriver smolt survival and smolt to adult return rates (ocean survival). The reports present prospective modeling results for four scenarios, ranging from current levels of spill at the eight mainstem dams to spilling to 125% of saturated total dissolved gas levels in each tailrace.[113] The CSS participants recommend that the region design and implement a large-scale operational study to evaluate this hypothesis (CSS Workgroup 2013). NOAA Fisheries has reviewed these reports (Tuomikoski et al. 2011, 2012; Haeseker et al. 2012), attended workshops and presentations of the CSS model results, and reviewed critiques of the approach (Manly 2012; Skalski et al. 2013).

In considering this information, NOAA Fisheries finds that several substantial weaknesses in the analysis exist that would need to be resolved prior to further consideration of any operational study of this magnitude. The data used to construct the models in Haeseker et al. (2012) span a 9-year period (1998–2006). Since 2006, spill levels have increased at several of the mainstem projects and the efficiency of spill has increased as well with the addition of spillway weirs. (The last spillway weir was installed in 2009).

There is evidence that conventional and surface spill pass a greater proportion of fish for a fixed spill percentage at lower flows than at higher flows (NOAA Fisheries unpublished analyses). Thus, high spill percentages may not be needed to pass the same proportion of fish in lower flow years. The increased spill recommendation by the CSS also addresses the hypothesis that juvenile fish bypass systems are a significant source of delayed mortality based on adult returns of inriver juvenile migrants (Haeseker et al. 2012). However, an analysis of the Haeseker et al. (2012) data by Skalski et al. (2013) found that spill percentage also correlated with increased adult returns of transported fish, which conflicted with the Haeseker et al (2012) conclusions.

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[112] The 2013 Draft CSS Annual Report was released for review on August 31, 2013. NOAA Fisheries was unable to review this document prior to issuing this draft supplemental opinion but will consider any new information in the draft CSS report prior to issuing a final supplemental opinion.

[113] Current total dissolved gas variances or waivers issued by the States of Oregon and Washington generally preclude the Action Agencies from voluntarily spilling water above the 120% tailrace (and 115% forebay in Washington) limit.

The analyses in Haeseker et al. (2012) provide correlative associations only, and should not be interpreted as demonstrating causation. Spill levels are also correlated with many other inriver conditions or mortality factors, some of which are not discussed in Haeseker et al. (2012). These authors investigated only four covariates in their inriver survival models and seven covariates in their ocean survival models, and the correlations among those covariates were not provided. The Skalski et al. (2013) analysis suggests that spill levels must have correlated with other mortality factors, such as ocean conditions, that were also experienced by transported fish. If the CSS modelers had replaced spill with other correlated factors, it is likely that those factors would have also been associated with similarly increased survival. Mortality effects of this array of factors are confounded and not separately estimable with correlation studies alone. Randomized experiments would be necessary to adequately assess direct and indirect effects of spill. In the absence of randomized experiments, we suggest that a more thorough analysis that includes more potentially influential covariates, an assessment of correlation among variables, and an analysis of influential data points.

For example, an obvious variable that is missing from the CSS survival models is total dissolved gas. A model that predicts survival using a monotonic association with spill, and does not include mortality at higher levels of spill and thus total dissolved gas, will make the unrealistic prediction of increasing survival regardless of the level of total dissolved gas. Additional years of data under the current operations and configuration of the system (completed in 2010) will shed light on whether or not the CSS hypothesis is supported by the empirical data. Adult returns from the 2011 and 2012 outmigrations (high flow, high spill years) and 2010 (a lower flow, high spill year) should be especially instructive. NOAA Fisheries supports the CSS researchers' recent work to assess the proportion of spillway passed fish as an explanatory variable, which takes into account the passage efficiency of spill at each project, not just spill as a surrogate.

NOAA Fisheries is not dismissing the results of these modeling efforts and appreciates the progress made in the CSS modeling. NOAA will continue to closely monitor the effects of project operations on juvenile survival, and adult returns as reported by CSS and the Northwest Fisheries Science Center. We note the adult returns from the year 2011, a year which had high levels of spill and flow, has produced below average adult return rates. Results such as this reinforce our current management approach to hydrosystem operations. Substantial progress has been made in improving survival of juvenile anadromous fish in the hydrosystem. Models of the system effects will continue to improve through 2018 as more data from current operations is added, and NOAA Fisheries will continue to consider opportunities to make further improvements to hydrosystem operations or configurations.

3.3.4 Snake River Steelhead Kelt Management Plan

RPA Action 33 requires the Corps and BPA to "prepare a Snake River Kelt Management Plan (Plan) in coordination with NOAA Fisheries and the Regional Forum. BPA and the Corps will implement the plan to improve the productivity of interior basin B-run steelhead populations as identified in Sections 8.5." RPA Action 33 requires a Plan that will focus on the wild component of the B-run steelhead and should include:

1. Measures to increase the inriver survival of migrating kelts,
2. Potential for collection and transport (either with or without short-term reconditioning[114]) of kelts to areas below Bonneville Dam,
3. Potential for long-term reconditioning as a tool to increase the number of viable females on the spawning grounds, and
4. Research as necessary to accomplish the elements of this plan.

Between 2010 and 2012, the Action Agencies took several actions to achieve the goals of RPA Action 33—namely to increase the productivity of Snake River B-run populations by about 6%—updating the Kelt Management Plan in 2010, 2011, and 2012. Kelt-specific operations (using surface passage routes outside of the juvenile migration season) continue, which, on average, should increase adult returns by about 0.9% at The Dalles dam (Corps et al. 2013a). The water source for the kelt program at the kelt reconditioning facility at Dworshak National Fish Hatchery was improved after the Action Agencies learned that compromised water quality was affecting the survival of collected kelts. Inriver survival studies have been completed, and additional inriver survival and reconditioning research are proposed (USACE et al. 2013a, 2013b). Three main strategies (described in Sections 3.3.4.1 through 3.3.4.3 below) are available for attaining the remaining 5.1% survival improvement necessary to achieve the 6% goal.

3.3.4.1 Measures to increase the inriver survival of migrating kelts

Increasing the survival of inriver migrating kelts (e.g., by operating surface passage systems during March) appears to have the greatest long-term potential for increasing B-run steelhead population productivity by increasing kelt survival. This is because all of the other strategies rely on capturing kelts or on the use of limited resources to return kelts to the spawning population. Inriver improvements benefit the entire population of steelhead in addition to kelts by increasing the survival rate of fish passing spillways, juvenile bypass systems (either for upstream migrating adults that "fall-back" at dams, or for downstream migrating kelts).

The installation of spill weirs (or other surface passage routes) at each of the mainstem FCRPS dams to improve juvenile passage and survival has also positively affected downstream migrating kelts. A recently completed study (Coloteo et al. 2012) showed an overall average downstream

[114] Reconditioning is a term used to describe the process of treating fish with antibiotics and reestablishing feeding to enhance the likelihood that kelts will survive to return as spawners.

survival from Lower Granite Dam to rkm 156 (RM 96.9) of 40.7% with some subgroups surviving at rates as high as 52.6%. The overall survival was slightly higher than the 34.4% survival reported by Boggs and Peery (2004) in a study completed in 2003. Kelts preferred bays with spill weirs in the Snake River for passage. In the lower Columbia, kelts showed less preference for spillbays with spill weirs at McNary and John Day dams, with many passing through the adjacent bays under the spill gates. During 2012, the median travel time from Lower Granite Dam to Bonneville Dam was 9 days (BPA and USACE 2013) compared with 27 days measured in 2001, and 19 days in 2002(Wertheimer and Evans 2005). Snake River flows in 2012 (101.5 kcfs) were higher than in 2001 (47 kcfs) or 2002 (85 kcfs), which would slightly reduce travel time, but the scale of the improvement in travel time strongly suggests that improved surface passage routes have contributed to decreased travel time for kelts through the FCRPS. Reducing travel time is likely to increase kelt survival by reducing stress and the amount of energy expended migrating downstream.

3.3.4.2 Potential for collection and transport (either with or without short-term reconditioning) of kelts to areas below Bonneville Dam

In the 2011–2018 Snake River Kelt Management Plan update (USACE et al., 2011), transport from Lower Granite dam to below Bonneville dam is dismissed as not yielding a significant benefit. This is based on an average 5-year return rate of transported kelts to Bonneville of 1.17% compared with an average return rate of 0.68% for kelts migrating inriver. Although the absolute increase in survival is not large, transportation nearly doubled the rate of return of kelts to Bonneville and could contribute to achieving the overall 6% goal if needed.

3.3.4.3 Potential for long-term reconditioning as a tool to increase the number of viable females on the spawning grounds

Long-term reconditioning continues to have some potential for increasing kelt survival in the short term. Even with relatively low survival rates, the potential percentage of kelts returned to the spawning grounds from reconditioning far exceeds that of other strategies which are subject to high levels of loss during downstream migration and low rates of return from the ocean. However, success rates continue to be inconsistent ranging from nearly total loss to 50% success. There is also a high degree of variability in success between sites.

Some of the issues associated with low success rates arise from inadequacies in the facilities used for kelt reconditioning. There were issues with securing a good water supply at the kelt reconditioning facility at Dworshak Hatchery. Also, the facilities were not sufficiently sized to produce the numbers of reconditioned kelts needed to reach the desired increase in female returns. However, the 2011–2018 Kelt Management Plan (USACE et al. 2011) describes plans for improved kelt reconditioning facilities to address these issues. At present there are four 15-feet circular tanks to provide holding and rearing space to recondition over 200 B-run steelhead kelts.

Another issue is the ability to collect enough B-run female steelhead kelts in good condition to be used in long term reconditioning efforts. Recent studies indicate that the Lower Granite juvenile bypass system causes high rates of injury in steelhead kelts – probably associated with the 10-inch orifices providing egress from the gatewell slots to the juvenile collection channel. This is reflected in low survival, 85.7%, found by Coleto et al. (2012), for fish passing through the Lower Granite JBS. The same study also found that only 5.6% of the kelts passing Lower Granite Dam entered the JBS (because kelts are attracted to the spill weirs at this project). This is substantially lower than the 33% used in the calculations in the analysis of the number of reconditioned kelts that could potentially be collected that was made for the 2008 BiOp. In 2012–2013, repairs were made to the eroded upwell box that should improve both the condition and survival of kelts passing via the JBS. At present, the Corps plans to redesign the Lower Granite JBS/Juvenile Fish Facility. Construction should being in 2016, and about two-thirds of the 10 inch gatewell orifices will be replaced with 14 inch orifices (and a few overflow weirs), which should substantially improve passage conditions and survival for adult kelts and increase the number of adults available for collection and reconditioning.

In 2013, additional B-run kelts were collected directly from the Clearwater River. Though the numbers were relatively small, it could make a substantial contribution to collecting enough kelts to meet the 2008 BiOp goals.

One of the most significant remaining issues surrounding long-term reconditioning is the spawning success of reconditioned kelts. There are remaining, significant questions relating to the nutrition and proper maturation of kelts from the long- term reconditioning. Research is currently underway to assess this issue.

3.3.4.4 Conclusion

The installation of surface passage routes and kelt-specific operations at The Dalles Dam have likely increased the survival of inriver migrating kelts (and adult steelhead falling back at the dams), but the limited number of reach survival estimates are not definitive. These improvements are the result of kelt-focused efforts (The Dalles Ice and trash sluiceway operations) and are an incidental benefit from actions to improve downstream migration conditions and survival for juvenile migrants (spill weirs and other surface passage routes). Further efforts towards management for downstream passage of kelt and providing more survivable fallback routes for first time spawners is likely to provide additional benefit.

From their 2011–2018 Kelt Management Plan (USACEs et al. 2011), the Action Agencies seem ready to abandon transportation efforts. However, to reach the goal of a 6% increase in B-run female steelhead at Lower Granite Dam, no method should be abandoned, even if the benefits are relatively small. Furthermore, it is too early in the program to confidently reduce the scope of the program. The 6% survival to spawning goal has not yet been reached.

Long-term reconditioning, which once was expected to be the primary contributor to reaching the 6% survival improvement goal, has not reached the stage where it reliably produces enough reconditioned kelts to meet the requirements of the 2008 BiOp. However, in some instances the cause of failure is known (e.g., Dworshak water quality problems) and remedies are available. As improvements to facilities and husbandry continue, reconditioning could make a more significant contribution. Should future results prove the efficacy of this approach, additional kelts could be collected at Little Goose and/or Lower Monumental Dams to increase the proportion of kelts available to the reconditioning program.

Overall, substantial progress has already been made to attain the goals of RPA 33, and the Action Agencies are funding the facilities and research necessary to provide a high level of certainty that some combination of inriver improvements, transportation, or longer-term reconditioning will achieve the 6% survival improvement goal by 2018.

3.3.5 Effects on Critical Habitat

By implementing the RPA's Hydropower Strategy, the Action Agencies are reducing factors that have limited the functioning of PCEs in the juvenile and adult migration corridors. FCRPS water storage projects and run-of-river dams in the lower Snake and Columbia rivers are operated to ensure adequate water quality and water velocity in the juvenile and adult migration corridors. As described in Section 3.3.1, the Action Agencies installed surface passage structures (spillbay weirs, powerhouse corner collectors, or modified ice and trash sluiceways) at all eight of the mainstem lower Snake and Columbia River dams to improve safe passage for juvenile migrants. Construction of the spillway wall at The Dalles Dam and relocations of the juvenile bypass system outfalls at Lower Monumental and McNary dams to areas where juveniles are less vulnerable to predation are also improving the functioning of the juvenile migration corridor. The Action Agencies were able to maintain chum spawning flows in the tailrace of Bonneville Dam through emergence during 2008, 2009, 2011, and 2012, although in accordance with RPA Action 17, higher elevation redds were dewatered during March of 2010 and 2013 in favor of spring flow augmentation and other project purposes. In general, effects of implementing the RPA's Hydropower Strategy (Actions 4 through 33) on safe passage in juvenile and adult migration corridors and in spawning areas for CR chum salmon are as expected, or better than, in the 2008 BiOp. The short- and long-term beneficial effects on PCEs of recently proposed critical habitat in the juvenile and adult migration corridors for LCR coho salmon are identical to those for other Columbia basin salmonids. Adverse effects during construction of new structures and facilities have been minor, occurred only at the project scale, and persisted for a short time.

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3.4 Hatchery RPA Actions

3.4.1 Description of Hatchery RPA Actions

The overall hatchery objective of the RPA Actions was for the Action Agencies to fund FCRPS mitigation hatchery programs in a way that contributes to reversing the decline of downward-trending ESUs. Two strategies were identified to meet this objective:

- **Hatchery Strategy 1**: Ensure, guided by programmatic criteria, that hatchery programs funded by the FCRPS Action Agencies as mitigation for the FCRPS are not impeding recovery of ESUs or steelhead DPSs.
- **Hatchery Strategy 2**: Preserve and rebuild the genetic resources through safety-net and mitigation actions to reduce short-term extinction risk and promote recovery

Each strategy included specific projects under RPA Actions 39 through 42 (NMFS 2008c).

We did not consider or assume any quantitative benefits associated with the hatchery RPA Actions in the aggregate effects analysis, nor did we rely on these actions to fill survival gaps. However, we did recognize qualitative benefits that were reasonably certain to occur from implementation of the hatchery RPA Actions in the aggregate effects analysis. These benefits included:

- Conservation of genetic resources for populations propagated in hatchery programs
- Reduction in short-term extinction risk for populations propagated in hatchery programs
- Reduction in genetic risk to the natural-origin component of certain populations from improvements in broodstock development

3.4.2 Methods for Analysis

As described in Section 1.1, *Consultation Overview*, NOAA Fisheries must determine in this supplemental biological opinion (1) whether there is new information that reveals effects of the RPA on listed species or critical habitat are different than previously considered, and (2) whether the RPA has been implemented as anticipated in the 2008 BiOp and the 2010 Supplemental BiOp.

Relevant to these determinations, the Action Agencies' 2013 Draft CE reviews all implementation activities through the end of 2012 and compares them to scheduled completion dates as identified in the RPA or modified in the Implementation Plans. The 2013 Draft CE describes the status of the physical and biological factors identified in this RPA, and compares these with the expectations for survival improvements identified in the 2007 CA or the 2008 SCA. This information has been used by NOAA Fisheries in determining if the RPA has been implemented as anticipated. The analysis in the following sections applies to the hatchery portion of the RPA.

3.4.3 Best Available Science

This 2013 Supplemental BiOp considers new information since the 2010 Supplemental BiOp to determine if there is any new information that reveals effects of the action on listed species or critical habitat are different than previously considered.

The new scientific information described below reinforces conclusions regarding artificial production that were made in the 2008 BiOp and the 2010 Supplemental BiOp. In general, these papers show that hatcheries remain a viable tool in salmon and steelhead conservation, but that greater consideration must be given to the application, intensity, and longevity of hatchery interventions. Hatchery programs can reduce short-term extinction risk by conserving genetic resources, but they must be designed in a manner that minimizes effects on the genetic structure and evolutionary trajectory of the target population. Even then, there is probably a trade-off between reducing short-term extinction risk and potentially increasing long-term genetic risk. Benefits like this should be considered transitory or short-term and, while relevant for a jeopardy analysis, are not equivalent to the survival rate changes necessary to meet abundance and productivity viability criteria set forth in regional salmon and steelhead recovery plans to be considered for delisting determinations. For recovery, salmon and steelhead must become self-sustaining in the wild.

3.4.3.1 Effects on Reproductive Success and Fitness

Several new studies presented data on the reproductive success of hatchery-origin fish relative to natural-origin fish and the long-term effects of hatchery supplementation on the fitness of salmon and steelhead.

- Bowlby and Gibson (2011) modeled effects of supplementation in Atlantic salmon and concluded that while supplementation was useful in reducing extinction risk, population growth rate declines after four to six generations because of fitness loss.
- Baskett and Waples (2012) modeled the fitness consequences of isolated and integrated hatchery approaches and found that the approaches differed in fitness outcomes depending on when selection or density-dependent interactions occurred.
- Using tabulated data from a variety of sources on many populations to model productivity, Chilcote et al. (2011) found that when the proportion of hatchery-origin spawners exceeded around 30%, there was reduced productivity in a log-linear fashion in steelhead, Chinook salmon, and coho salmon in the Pacific

Northwest. Discovering some errors in their first analysis, they reanalyzed their data, and the results were the same (Chilcote et al. 2013).

- Johnson et al. (2012b) used elemental analysis of otoliths to determine the proportion of hatchery-origin fish on the spawning grounds in the Mokelumne River, illustrating that it is possible to estimate hatchery contribution rates without the use of marking or tagging.
- Christie et al. (2011) compared the fitness of Hood River hatchery-origin and natural-origin steelhead when used in the hatchery as broodstock, and they found that hatchery-origin fish were roughly twice as successful at producing returning hatchery-origin adults than the natural-origin fish. They also found that fish with greatest fitness in the hatchery were worst in the wild.
- In another paper dealing with the same population, Christie et al. (2012) concluded that although the supplementation effort had doubled the number of fish on the spawning grounds, it had reduced the effective size of the population by nearly two-thirds.
- In a steelhead supplementation program in the Imnaha basin, hatchery-origin fish were only 30% to 60% as successful as natural-origin fish at producing juvenile or adult progeny (Berntson et al. 2011).
- In an experimental spawning channel, hatchery-origin and natural-origin Chinook salmon males did not differ significantly in reproductive success (Schroder et al. 2010).
- Anderson et al. (2012) examined the reproductive success of hatchery-origin and natural-origin Chinook salmon adults colonizing new habitat above a dam on the Cedar River, and found that over three years hatchery-origin males were consistently less successful (by 70% to 90%) than natural-origin fish, but not significantly so, while the relative success of hatchery-origin females varied from 72% to 207%. Size of fish and arrival date were also important determinants of success.
- For Wenatchee spring Chinook salmon, relative reproductive success (RRS) of hatchery fish was roughly half that of wild fish for both sexes, and the differences were statistically significant (Williamson et al. 2010). Spawning location within the river had a significant effect on fitness for both sexes, accounting for a substantial portion of the reduced relative fitness of hatchery fish.
- Attempting to see if an effect such as Christie had detected in steelhead existed in Wenatchee spring Chinook salmon, Ford et al. (2012a) examined the reproductive success of progeny of broodstock fish and found that males with high reproductive success in the hatchery tended to produce offspring that had low reproductive

success in the wild. No similar correlation in reproductive success was found for females, and no correlation was found for either sex in the hatchery environment. In contrast with the Christie et al. (2011) study, origin had little effect on the reproductive success of naturally-spawning progeny.

- In a new Chinook salmon supplementation program in the Salmon River Basin, Hess et al. (2012) found that the program provided demographic benefits and that hatchery and wild fish that produced at least one adult progeny differed insignificantly in reproductive success, averaging 1.11 for females and 0.89 for males.
- In Umpqua Basin coho salmon, RRS was estimated for fish released as unfed fry and for fish released as smolts. For fish released as fry, female RRS averaged 0.84 but was statistically insignificant, while RRS of adult (3-yr old) males averaged 0.62, and was statistically significant. RRS of hatchery jacks averaged 1.75, but this was statistically insignificant. For fish released as smolts, female RRS averaged 0.75, and was statistically significant, while RRS of adult (3-yr old) males averaged 0.53, and was statistically significant. RRS of hatchery jacks averaged 0.94, but this was statistically insignificant. The similarity in performance between the two stocking strategies led the authors to conclude that absence of sexual selection is a factor in fitness decline in hatchery fish.

Additional studies were implemented as part of the RPA. These studies help assess the effects of hatchery programs on population viability, general effectiveness of hatchery programs, and the effects of hatchery reform. These studies and their results are summarized in the CE.

3.4.3.2 Genetic Effects

Several papers reported on genetic effects of hatchery programs.

- Neff et al. (2011) argue for mating strategies that consider immune-system genotypes as a means of developing more natural mating systems within the hatchery to improve the survival of hatchery fish and decrease genetic impacts of hatchery culture.
- Kalinowski et al. (2012) used simulation to determine rates of inbreeding in the Snake River sockeye salmon captive brood program and concluded that inbreeding was only 5.6% after 5.5 generations of captive breeding, indicating the program had done a good job of conserving genetic diversity.
- Suk et al. (2012) found that Green River lineage Chinook salmon introduced into Lake Huron hatcheries in the 1960s had developed statistically significant genetic effects in less than 10 generations.
- Dann et al. (2010) examined outbreeding depression by comparing survival, size, and meristics of three Alaskan coho salmon populations with their F1 and F2

hybrids. Although statistical power was low, they found no strong evidence for outbreeding depression.

- Van Doornik et al. (2010) determined that relative to pre-program conditions, a Hood Canal steelhead supplementation program had not noticeably affected genetic diversity or effective size, and that the proportion of fish with anadromous ancestry increased.
- Chittenden et al. (2010) compared hatchery-origin and natural-origin coho salmon and their offspring in natural-rearing and hatchery-rearing environments for several traits, and they found that differences observed between the naturally-reared and hatchery-reared fish were considerably greater than differences between the genetic groups.
- In spring Chinook salmon in the Klickitat Basin, hatchery practices appeared to have caused a shift in genetic composition over a 20-yr period (Hess et al. 2011).
- Heggenes et al. (2011) found no impact on genetic structure within Oncorhynchus mykiss in the upper Kitimat Basin despite extensive releases of steelhead in the lower basin over many years appeared.
- Similarly, Matala et al. (2012) found relatively large levels of genetic differentiation in the South Fork Salmon River despite substantial hatchery releases in the upper part of the basin.
- On a larger scale, an examination of steelhead genetic samples collected over nearly six decades in five B.C. rivers showed noticeable changes in effective size, genetic diversity, or genetic structure (Gow et al. 2011).
- Seamons et al. (2012) tested the efficacy of using hatchery-origin fish that spawn earlier than natural-origin fish to provide fish for harvest and at the same time not interbreed with the natural-origin (wild) fish. He found that despite the divergence in life history, interbreeding between the two stocks was common, with hatchery-wild hybrids comprising as much as 80% of the naturally-produced smolts.
- Hayes et al. (2013) volitionally released groups of spring Chinook salmon with WxW, HxW, and HxH parentage[115] from raceways, and found that WxW fish were much more likely to outmigrate in the fall (as pre-smolts) than the other groups, but that HxH fish had the highest return rates as adults.
- Westley et al. (2013) examined straying of hatchery-origin steelhead, coho salmon and Chinook salmon, by examining freshwater coded-wire tag recoveries reported to the Regional Mark Information System (RMIS) database, and concluded that although there is considerable variation among populations and some among

[115] Where W represents wild (natural-origin) and H represents hatchery-origin.

regions, coho salmon strayed less that Chinook salmon, Chinook salmon strayed more than steelhead, and ocean-type Chinook salmon strayed more than stream-type Chinook salmon.

3.4.3.3 Ecological Effects

Several noteworthy papers on ecological interactions have appeared since 2009, many of them collected in Rand et al. (2013).

- Kostow (2012) presented basic ecological risk reduction principles and illustrated them with case histories involving steelhead, coho salmon, chum salmon, and Chinook salmon populations in the Pacific Northwest.
- Tatara and Berejikian (2012) reviewed the literature on competition and concluded that competitive risk between hatchery and wild salmon depends on six factors: whether interaction is intra- or interspecific, duration of cohabitation, relative size, prior residence, developmental differences, and density.
- Similarly, Naman and Sharpe (2012) reviewed the literature on predation by hatchery yearlings on wild subyearling salmonids, and concluded that managers can effectively minimize predation by reducing temporal and spatial overlap by timing the release of hatchery fish.
- Pearsons and Busack (2012) presented a computer model to analyze hatchery/wild salmon interaction scenarios that was designed for manager use.
- New empirical work included that of Sturdevant et al. (2012), which found no evidence of density-dependent interactions between natural-origin and hatchery-origin chum salmon in Taku Inlet. They also found that release strategies had been successful at promoting spatial separation of the two groups.
- Tatara et al. (2011) evaluated the effects of stocking steelhead parr in an experimental stream channel and found that stocking larger parr at densities within the carrying capacity would have low short-term impacts on the natural parr.
- Temple and Pearsons (2012) evaluating impacts of a spring Chinook salmon supplementation program in the Yakima Basin on 15 non-target taxa of concern.

3.4.4 Implementation of Hatchery RPA Actions

The 2008 BiOp identified four hatchery RPA Actions (RPA Actions 39 through 42). The Action Agencies' 2013 Draft CE reviews all implementation activities through the end of 2012 and compares them to scheduled completion dates as identified in the RPA or modified in the Implementation Plans (2013 Draft CE). The Action Agencies also submitted an Implementation Plan for implementation of RPA Actions through 2018 (2014–2018 Draft IP). Effects of the Hatchery RPA Actions are discussed in Section 3.4.5, *Effectiveness of Hatchery RPA Actions,* and Section 3.4.6, *Additional Benefits of Hatchery RPA Actions Not Considered in the 2008 BiOp's Aggregate Effects Analysis*.

3.4.5 Effectiveness of Hatchery RPA Actions

Qualitative benefits of hatchery RPA Actions were considered in the 2008 BiOp's aggregate effects analysis for the Middle Columbia River, Upper Columbia River, and Snake River ESUs and DPSs. These benefits included (1) conservation of genetic resources, (2) reduction in short-term extinction risk, and (3) reduction in genetic risk to the natural-origin component of populations from improvements in broodstock development.

NOAA Fisheries must determine in this 2013 supplemental opinion whether each of the qualitative benefits that were considered in the aggregate effects analysis occurred after reviewing implementation progress and the best available science. As detailed in Table 3.4-1, all of the anticipated benefits have occurred.

Table 3.4-1. Summary of implementation and effectiveness of hatchery RPA Actions considered in FCRPS BiOp's aggregate analysis.

ESU/DPS	Hatchery RPA Actions considered in 2008 BiOp's Aggregate Analysis[116]	2013 Update on Implementation and Effectiveness of Hatchery RPA Actions Considered in the 2008 BiOp's Aggregate Analysis
Snake River fall Chinook salmon		
	• The RPA will ensure that the Action Agencies implement programmatic funding criteria, including those that will reform the FCRPS hatchery operations to reduce genetic and ecological effects on ESA-listed salmon. This will have a positive effect on the diversity of Snake River fall Chinook salmon	• NOAA Fisheries has completed ESA consultation on the fall Chinook salmon hatchery program, which includes substantial new monitoring and evaluation to validate assumptions on the proportion of hatchery-origin fish on the spawning grounds and the status of the natural-origin component of the population. The proportion of hatchery-origin fish on the spawning grounds is required to remain at or below the proportion in the Environmental Baseline.
Snake River spring/summer Chinook salmon		
Lower Snake River MPG	• The Tucannon River supplementation hatchery program will provide a genetic reserve for maintaining diversity, potentially accelerating recovery pending increases in natural productivity. In the longer term, proportional contributions of hatchery fish to natural spawning would have to be reduced to achieve the ICTRT diversity criteria associated with low risk. • The safety-net hatchery program for the Tucannon population will reduce short-term extinction risk for the Lower Snake River MPG.	• As expected in the FCRPS BiOp's aggregate analysis, the Action Agencies have continued to fund the Tucannon River supplementation hatchery program, which has provide a genetic reserve for maintaining diversity. NOAA Fisheries expects to complete ESA consultation on the hatchery program in 2013, and as a result of the consultation, NOAA Fisheries expects reductions in proportional contributions of hatchery fish to natural spawning . • The Action Agencies funded a one-generation safety-net program that was completed as planned in 2010.
Grande Ronde/Imnaha MPG	• There are hatchery programs, which are required to continue under the RPA, acting as a safety net for affected population in the Grande Ronde/Imnaha MPG to reduce short-term extinction risk of this MPG.	• As expected in the FCRPS BiOp's aggregate analysis, the Action Agencies have continued to fund hatchery programs that act as safety nets to reduce short-term extinction risk for affected populations in the Grande Ronde/Imnaha MPG.

[116] These are benefits that were considered in the aggregate effects analysis in the 2008 BiOp and 2010 Supplemental BiOp.

ESU/DPS	Hatchery RPA Actions considered in 2008 BiOp's Aggregate Analysis[116]	2013 Update on Implementation and Effectiveness of Hatchery RPA Actions Considered in the 2008 BiOp's Aggregate Analysis
South Fork Salmon MPG	• There is a safety-net hatchery program for the East Fork South Fork (including Johnson Creek) population in this MPG to further reduce short-term extinction risk.	• As expected in the FCRPS BiOp's aggregate analysis, the Action Agencies have continued to fund a hatchery program for the East Fork South Fork population of this MPG that acts as a safety-net to further reduce short-term extinction risk.
Middle Fork Salmon MPG	• There is not a safety-net hatchery program operating in the Middle Fork Salmon MPG to further reduce extinction risk but the hatchery Prospective Actions require the FCRPS Action Agencies to "identify and plan for additional safety-net programs. This MPG is primarily located in National Forest and wilderness areas and has been managed for wild fish production.	• After further discussions with the Action Agencies and the hatchery co-managers, NOAA Fisheries determined that the benefits of maintaining the Middle Fork Salmon as an area without hatchery production outweigh the benefits of having a safety-net program to reduce short-term extinction risk. Therefore, at this time, no safety-net programs will be operated in the Middle Fork Salmon. However, if the status of natural-origin populations in the Middle Fork Salmon decline sharply in the future, a safety-net program will be established.
Upper Salmon MPG	• There is a captive rearing program to reduce short-term extinction risk for the Yankee Fork population. A captive broodstock program for the Lemhi has existed since 1995. There are no other safety-net hatchery programs for other populations in the Upper Salmon MPG.	• As anticipated, both captive brood programs have sunset. However if the status of natural-origin populations in the Lemhi or Yankee Fork decline sharply in the future, captive rearing programs will be reinitiated.
Snake River sockeye salmon		
	• Continue to fund the safety-net program to achieve the interim goal of annual releases of 150,000 smolts while also continuing to implement other release strategies in nursery lakes, such as fry and parr releases, eyed-egg incubation boxes, and adult releases for volitional spawning • Fund further expansion of the sockeye program to increase total smolt releases to between 500,000 and 1 million fish	• The Action Agencies continued to fund the Snake River sockeye salmon safety-net program. • The Springfield Hatchery property near Pocatello, Idaho, was acquired in 2010 as the site for construction of a new Snake River sockeye hatchery to help meet production goals for the Snake River sockeye hatchery program. Construction of the Springfield Sockeye Hatchery began in the summer of 2012 and is scheduled to be completed in the summer of 2013. NOAA Fisheries expects to complete

ESU/DPS	Hatchery RPA Actions considered in 2008 BiOp's Aggregate Analysis[116]	2013 Update on Implementation and Effectiveness of Hatchery RPA Actions Considered in the 2008 BiOp's Aggregate Analysis
		ESA consultation on this program in 2013.
Snake River steelhead		
Lower Snake River MPG	• There is no safety-net hatchery program for these populations. There is a hatchery supplementation program for the Tucannon that preserves genetic resources and reduces extinction risk in the short-term.	• The Action Agencies continue to fund the Tucannon supplementation program to preserve genetic resources and reduce extinction risk in the short-term. The Tucannon program has transitioned to a locally-derived broodstock.
Clearwater MPG	• Hatchery RPA was not considered in the aggregate effects analysis.	• Hatchery RPA was not considered in the aggregate effects analysis.
Grande Ronde MPG	• Hatchery RPA was not considered in the aggregate effects analysis. There is no safety-net hatchery program for these populations.	• Hatchery RPA was not considered in the aggregate effects analysis.
Imnaha River MPG	• There is no safety-net hatchery program for this population, but a supplementation hatchery program does preserve genetic resources.	• The Action Agencies continue to fund the Imnaha River steelhead hatchery program through the Lower Snake River Compensation Plan. This hatchery program continues to preserve genetic resources.
Salmon River MPG	• There is no safety-net hatchery program for any of these populations, except the East Fork Salmon A-run population. This program increases the number of natural spawners and reduces extinction risk in the short-term.	• The Action Agencies continue to fund the East Fork Salmon hatchery program through the Lower Snake River Compensation Plan. This hatchery program increases the number of natural-origin spawners and reduces extinction risk in the short-term.
Upper Columbia River spring Chinook salmon		
Eastern Cascade MPG	• The RPA will ensure that hatchery management changes that have been implemented in recent years will continue, that safety-net hatchery programs will continue, and that further hatchery improvements will be implemented to reduce the likelihood of longer-term problems associated with	• The Action Agencies have continued to fund spring Chinook hatchery programs in the upper Columbia River. Site-specific Best Management Practices are being developed in consultation with NOAA Fisheries. • The pending ESA consultation on the

ESU/DPS	Hatchery RPA Actions considered in 2008 BiOp's Aggregate Analysis[116]	2013 Update on Implementation and Effectiveness of Hatchery RPA Actions Considered in the 2008 BiOp's Aggregate Analysis
	continuing hatchery programs although subject to future hatchery-specific consultations after which these benefits may be realized.	Methow River spring Chinook salmon hatchery program is expected to dramatically reduce genetic and ecological threats to population.
Upper Columbia River steelhead		
Eastern Cascade MPG	• The 2008 BiOp's aggregate effects analysis does not include any assumptions about future reductions in the hatchery-origin fraction of natural spawners, although such improvements are likely as a result of future changes in Federal and non-Federal hatchery practices. Since some of the changes are outside the authority of the Action Agencies, and have not yet been fully consulted upon, the potential benefits from such changes will not be evaluated at this time. • The RPA include a strong monitoring program to assess whether implementation is on track and to signal potential problems early. This includes a new steelhead study in the Methow to determine hatchery fish effectiveness compared to natural-origin fish and to determine the effects of hatchery fish on population productivity. • RPA Actions to develop local broodstocks in the Methow and Okanogan Rivers will reduce genetic risks.	• NOAA Fisheries expects to complete ESA consultations on UCR steelhead hatchery programs in 2013. As a result of these consultations, the proportion of hatchery-origin fish on the spawning grounds will be reduced for all four populations, which will increase the integrated productivity of each population. • As part of the RPA's monitoring program, an ongoing relative reproductive study in the Methow has shown that the relative reproductive effectiveness of hatchery-origin steelhead is greater relative to natural-origin steelhead than assumed in the 2008 BiOp. Consequently, the Base-to-Current adjustments in the 2008 BiOp likely underestimated the survival benefit of competed hatchery reform actions. • The Winthrop National Fish Hatchery has transitioned to a local broodstock and a rearing program (2-year smolts) that mimics the natural life history of steelhead in the upper Columbia River. • A program for steelhead in the Okanogan River basin is being implemented by the Confederated Tribes of the Colville Reservation (CTCR) and funded through the BPA.
Middle Columbia River steelhead		
Yakima MPG	• A kelt reconditioning program affects all four populations in this MPG and is expected to provide an unquantifiable survival improvement.	• BPA continues to fund a program to recondition kelts in the Yakima River basin. This program continues to provide an unquantifiable survival

ESU/DPS	Hatchery RPA Actions considered in 2008 BiOp's Aggregate Analysis[116]	2013 Update on Implementation and Effectiveness of Hatchery RPA Actions Considered in the 2008 BiOp's Aggregate Analysis
		improvement.
Cascade Eastern Slopes MPG	• Hatchery RPA Actions were not considered in the aggregate effects analysis.	• Hatchery RPA Actions were not considered in the aggregate effects analysis.
Walla Walla/Umatilla MPG	• There is a conservation hatchery program for the Umatilla population to further reduce short-term extinction risk.	• The Action Agencies continue to fund the Umatilla River summer steelhead hatchery program. This program continues to reduce short-term extinction risk of the Umatilla River summer steelhead population.
John Day MPG	• Hatchery RPA Actions were not considered in the aggregate effects analysis.	• Hatchery RPA Actions were not considered in the aggregate effects analysis.
Columbia River chum salmon		
	• Hatchery RPA Actions were not considered in the aggregate effects analysis.	• Hatchery RPA Actions were not considered in the aggregate effects analysis.
Lower Columbia River Chinook salmon		
	• Hatchery RPA Actions were not considered in the aggregate effects analysis.	• Hatchery RPA Actions were not considered in the aggregate effects analysis.
Lower Columbia River coho salmon		
	• Hatchery RPA Actions were not considered in the aggregate effects analysis.	• Hatchery RPA Actions were not considered in the aggregate effects analysis.
Lower Columbia River steelhead		
	• Hatchery RPA Actions were not considered in the aggregate effects analysis.	• Hatchery RPA Actions were not considered in the aggregate effects analysis.
Upper Willamette Chinook salmon		
	• Hatchery RPA Actions were not considered in the aggregate effects analysis.	• Hatchery RPA Actions were not considered in the aggregate effects analysis.

ESU/DPS	Hatchery RPA Actions considered in 2008 BiOp's Aggregate Analysis[117]	2013 Update on Implementation and Effectiveness of Hatchery RPA Actions Considered in the 2008 BiOp's Aggregate Analysis
Upper Willamette Steelhead		
	• Hatchery RPA Actions were not considered in the aggregate effects analysis.	• Hatchery RPA Actions were not considered in the aggregate effects analysis.

3.4.6 RPA Hatchery Program Benefits Not Considered in the 2008 BiOp's Analysis

NOAA Fisheries has completed consultation on *X*[118] of the HGMPs[119] submitted pursuant to RPA Action 39. Although the site-specific benefits of these consultations were not considered qualitatively or quantitatively in the 2008 BiOp or in the 2010 Supplemental BiOp, NOAA Fisheries will now consider these additional benefits for the purposes of this supplemental opinion.

<*Placeholder for analysis of new benefits not considered in 2008 BiOp*.>

3.4.7 Effects on Critical Habitat

Effects on critical habitat from implementing the RPA's Hatchery Strategy depend on how specific hatchery programs are operated (e.g., methods for broodstock collection). These operational details are determined during site-specific ESA consultations pursuant to RPA Action 39. NOAA Fisheries has completed consultations on *X* of the HGMPs submitted pursuant to RPA Action 39. Effects on critical habitat are as follows:

<*Placeholder for results of consultations that are completed by the end of 2013*>

[117] These are benefits that were considered in the aggregate effects analysis in the 2008 BiOp and 2010 Supplemental BiOp.
[118] *Placeholder*
[119] HGMP = Hatchery and Genetic Management Plan

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3.5 Predation RPA Actions

3.5.1 Northern Pikeminnow

<Placeholder: The Action Agencies are developing a Biological Assessment regarding the effects of the Northern Pikeminnow Removal program with the intent of adding this mitigation program to the FCRPS BiOp. To date, this program has been covered under a separate ESA consultation.

NOAA Fisheries agrees that this mitigation program can properly be considered within the context of the FCRPS consultation process. We intend to work with BPA and the other Action Agencies to assure that the effects of this program (both positive and negative) on ESA listed species are properly assessed and that take associated with this program is properly enumerated and included in the 2013 FCRPS Supplemental BiOp.>

3.5.2 Terns and Cormorants

One of the assumptions in our 2008 BiOp analysis was that specific rates of predation estimated for the Base Period would continue through the term of the RPA (i.e., through 2018). However, as noted in Section 2.2.4, this underestimated the predation rates by double-crested cormorants in the estuary, which increased substantially in numbers during 2003–2009. As a result, the productivity of interior Columbia basin steelhead populations is about 3.6% lower than assumed for the “Current” period in the 2008 BiOp analysis, and that of interior Columbia basin stream-type spring- and summer-run Chinook salmon and ocean-type Snake River fall Chinook salmon is about 1.1% lower than assumed.

Reducing the cormorant population in the Columbia River estuary back to the Base Period level is one way that a management plan might address this issue. Based on current average per capita consumption rates, maintaining the existing colony at about 5,661 pairs (range of 5,380 to 5,939)—a reduction of about 6,600 pairs, or 54%—would result in a continued steelhead consumption rate equivalent to that estimated during the Base Period (2.9%). Similarly, Base Period yearling Chinook consumption rates (1.1%) could be achieved by maintaining the existing colony at about 6,536 pairs (range of 6,221 to 6,848)—a reduction of about 5,500 pairs, or 47%. (Fredricks 2013).

Modified RPA 46 Double-crested Cormorant Predation Reduction

The FCRPS Action Agencies will develop a cormorant management plan (including necessary monitoring and research) and implement warranted actions to reduce cormorant predation in the estuary to Base Period levels (no more than 5,380 to 5,939 nesting pairs on East Sand Island).

- Implementation Plans
    - ◊ Management plan will be completed in 2014
    - ◊ Environmental Impact Statement (EIS) will be completed by late 2014.
    - ◊ Record of Decision will be issued late 2014.
    - ◊ Actions will begin to be implemented in 2015.
- Annual Progress Report
    - ◊ Progress will be documented in the Action Agencies' annual implementation reports.

The Corps is the lead agency on a draft EIS that will be using NOAA Fisheries’ survival gap and colony per capita analysis to develop objectives for double-crested cormorant management on East Sand Island. The USFWS, ODFW, WDFW, and USDA Wildlife Services are cooperating agencies to this EIS. The range of alternatives will cover lethal methods (shooting of individual birds, egg collection/nest destruction, etc.) and non-lethal methods (hazing, habitat modification, etc.) to reduce double-crested cormorant predation impacts to juvenile salmonids in the estuary. The Corps is working with the states of Oregon and Washington regarding their concerns over dispersal of double-crested cormorants. The Corps, USFWS, and USDA Wildlife Services will each be issuing a record of decision after publication of the final EIS. After the record of decision is signed by the Corps and USFWS (currently anticipated to occur in late 2014), implementation of a management plan (the EIS preferred alternative) could take place before the 2015 breeding season. Adaptive management will be used to meet the goals of the EIS.

Large numbers of double-crested cormorants have been successfully managed in other locations in the United States. A recent example of a successful cormorant damage management action includes a 2005 implementation at Leech Lake, Minnesota, by the Ojibwe Tribe, USDA Wildlife Services, and the State of Minnesota. This implementation was carried out under a Public Resource Depredation Order issued by the USFWS in 2003. According to the Minnesota Department of Natural Resources (Schultz 2010), the double-crested cormorant population at Leech Lake had grown to approximately 10,000 individual birds (fall count) in 2004. During the first five years of implementation (2005–2009), approximately 3,000 individual cormorants were removed from the lake annually. The program goal of approximately 2,000 fall count individuals was achieved in 2006 and had been maintained through 2009. Their preliminary evaluation results indicated that control actions reduced cormorant use of the lake by nearly 60%. The action was considered a success in helping to curb declining populations of walleye and contribute to record 2008–2009 walleye harvest rates.

The Action Agencies are currently implementing the Caspian Tern Management Plan, which they adopted in 2006. The plan calls for reductions in nesting habitat for Caspian terns at East Sand Island in the lower estuary, concurrent with the development of alternative nesting habitat elsewhere in the interior Northwest and along California coast (i.e., outside the Columbia River basin). To date, nine alternative nesting habitat islands totaling 8.3 acres have been constructed at interior locations, but no coastal sites have been developed. Predation (on eggs, chicks, and adults), lack of sufficient water, and limited food resources have plagued tern nesting success at several of these interior sites to the degree that a significant proportion of the alternative nesting habitat has not been available for nesting terns in any single year. These interior sites host approximately 1,500 pairs of Caspian terns at this time. Tern nesting habitat on East Sand Island has been reduced from 6 acres down to a current 1.58 acres, which has reduced the colony from a pre-management level of about 9,000 pairs to 6,000 to 6,500 pairs. However, this is short of the reduction to 3,500 to 4,000 pairs that was anticipated by the management plan and assessed in the 2008 BiOp's analysis. The reduction in tern numbers in the estuary has not translated to a similar reduction in salmonid smolt consumption, which remains similar to pre-implementation levels. Full realization of the anticipated smolt survival benefits is unlikely without additional habitat reduction on East Sand Island, an action that may be limited by the availability of adequate alternative nesting habitat.

The 2008 BiOp (RPA Action 47) also required the Action Agencies to develop an inland avian predator management plan. This plan and an associated Environmental Assessment are expected in early 2014, which will be in time for limited implementation prior to the 2014 nesting season. At this time, only Caspian terns nesting on Goose Island in Potholes Reservoir and Crescent Island in the Columbia River are slated for management action (e.g., reductions in nesting habitat). If successful, the expected survival benefits to UCR steelhead and spring Chinook (up to 11.4% and 3.0%, respectively) would be realized in 2014. Additional benefits to upper Columbia and Snake River ESUs/DPSs may follow in subsequent years once alternative tern habitat can be developed.

In summary, NOAA Fisheries has estimated that increasing numbers of double-crested cormorants in the estuary resulted in a Base-to-Current survival reduction of about 3.6% for steelhead and 1.1% for yearling Chinook (see Section 2.2.4.2 in this supplemental opinion). NOAA Fisheries has modified RPA Action 46, calling upon the Corps to reduce cormorant predation in the estuary to Base Period levels (no more than 5,380 to 5,939 nesting pairs on East Sand Island). The Corps is developing a management plan (and accompanying Environmental Impact Statement) to address this issue with implementation of management actions estimated to begin in early 2015. Similar double-crested cormorant management actions in other parts of the United States have recently been implemented in a timely manner and have proven successful.

Implementation of the Caspian Tern Management Plan has had some success. Many acres of nesting habitat has been created, some of which is being used by about 1,500 pairs of terns. About 75% of the nesting habitat is no longer usable by Caspian terns at East Sand Island, and 3,000 to 3,500 fewer nesting pairs are preying on ESA-listed salmon at this time. However, the full anticipated benefit of the management plan has not yet been realized as the remaining birds are crowding into the available habitat, and smolt consumption rates remain at pre-management levels. Additional suitable nesting habitat is being sought by the Corps and USFWS to facilitate the movement of birds from East Sand Island to areas outside the Columbia River basin. Only about one acre of suitable habitat is needed, and current likely candidate locations include Federally owned and managed areas in lower San Francisco Bay, the Salish Sea of Puget Sound, and northern Great Salt Lake. It remains likely that suitable habitat will be found, allowing for full implementation of the management plan to occur, and for the reduction of Caspian terns (and associated losses of steelhead and Chinook smolts) to levels anticipated in the 2008 BiOp.

Finally, although the 2008 BiOp required the Action Agencies to develop an Inland Avian Predator Management Plan, no reductions in avian-caused mortality rates were assumed in the analysis. Actions expected in 2014 at Goose Island in Potholes Reservoir should substantially reduce mortality rates for UCR steelhead and UCR spring Chinook salmon (up to 11.4% and 3.0%, respectively).

3.5.3 Pinnipeds

As part of the predation management strategy, RPA 49 of the 2008 BiOp required the Corps to install and improve Sea Lion Exclusion Gates (SLEDs) at all adult fish ladder entrances at Bonneville Dam. In addition, the Corps agreed to take action in support of land and water-based harassment (hazing) efforts conducted by outside agencies to exclude sea lions or reduce the time they spend in the tailrace area immediately downstream of the dam.

Since 2010, SLED and Floating Orifice Gate barriers have been installed at all entrances of the Bonneville Dam adult fishways during the spring fish passage season (Jepson et al. 2011). These barriers are completely effective at preventing sea lions from entering the fishways of Bonneville Dam (Stansell et al. 2012). Current adult count and telemetry data indicates SLEDs are not having a substantial negative impact on successful salmonid passage (Jepson et al. 2011). Ongoing research in 2013 will provide further information on any delay or other potential impacts SLEDs may have on salmon passage. Consideration for the use of exclusion devices year round may be necessary if Steller sea lions continue to be present in the fall and winter as a regular occurrence.

According to the Corps annual report, hazing in the Bonneville Dam tailrace included a combination of acoustic, visual, and non-lethal deterrents, including boat chasing, above-water pyrotechnics, rubber bullets, rubber buckshot, and beanbags fired from shotguns. Boat-based crews also used underwater percussive devices known as seal bombs outside of fish ladder entrance buffer zones. Dam-based and boat-based crews coordinated with Corps personnel to increase the effectiveness of hazing efforts. Dam-based hazing by USDA Wildlife Service agents began the first week in March and continued seven days per week through the end of May (Stansell et al. 2012).

Recent information indicates hazing is limited in its effectiveness at keeping sea lions outside of the tailrace, but hazing can be beneficial in reducing salmon consumption. While some measures appeared to be initially effective, they became less effective over time as pinnipeds learned to either tolerate or avoid the deterrence measure (Scordino 2010). Because adult salmonids tend to concentrate in tailraces in search of ladder entrances, efforts to limit the time pinnipeds spend in the tailrace is likely beneficial to salmon. Hazing at the current level of intensity slows the increase of predation (Stansell et al. 2011) and can be used to change behavior and temporarily move sea lions out of tailraces (Stansell et al. 2012). While the available information suggests intensive hazing may contribute to minor reductions in adult salmonid consumption, past research suggests hazing does not result in biologically significant reductions in salmon consumption when conducted in the absence of lethal take. Radio-telemetry studies conducted at Bonneville Dam indicate there is no substantial evidence that sea lion hazing efforts substantially delay or otherwise affect spring/summer Chinook (Jepson et al. 2011).

In summary, these actions continue to meet the goals of RPA 49 in supporting harassment efforts to reduce salmonid consumption and excluding pinnipeds from ladder entrances at Bonneville Dam. Annual reports of observations and documentation of these efforts have been timely and effective. The information available at this time indicates these actions are beneficial in reducing consumption and not negatively affecting salmon and steelhead ESUs/DPSs, or pinniped populations.

3.5.4 Effects on Critical Habitat

As described above, the RPA includes actions to reduce the numbers of northern pikeminnows, Caspian terns, double-crested cormorants, and California sea lions that reduce the functioning of safe passage in juvenile and adult migration corridors. <*Placeholder: effects of northern pikeminnow management program*>. Further reductions in tern numbers and smolt consumption rates in the estuary will depend on the availability of adequate alternative nesting habitat. The Corps is developing an Environmental Impact Statement under NEPA for actions that would reduce cormorant consumption rates to the base levels assumed in the 2008 BiOp. Exclusion gates at the adult fish ladder entrances at Bonneville Dam have successfully reduced predation by California sea lions on spring Chinook and winter steelhead. Although predation continues to reduce the functioning of safe passage in the juvenile and adult migration corridors, RPA management efforts are improving these factors.

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3.6 Harvest RME RPA Action

RPA Action 62 requires the Action Agencies to conduct RME in this category to help resolve uncertainties about trends in population productivity. Actions include:

- Evaluating the feasibility of obtaining PIT-tag recoveries between Bonneville and McNary dams to determine whether recoveries can help refine estimates of inriver harvest rates and stray rates used to assess adult survival
- Evaluating methods to develop or expand the use of selective fishing methods and gear
- Evaluating post-release mortality rates for selected fisheries
- Supporting coded-wire tagging and coded-wire tag recovery operations that inform survival, straying and harvest rates of hatchery fish by stock, rearing facility, release treatment, and location
- Investigate the feasibility of genetic stock identification monitoring techniques

The Action Agencies describe their progress to date and plans for implementation through 2018 in the 2013 Draft CE and the 2014–2018 Draft IP, respectively. In general, we have determined that RPA 62, including the projects that support coded-wire tag insertion, recovery, and data management, is being implemented as intended in the RPA.

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3.7 AMIP Contingency Planning

The 2009 AMIP required that NOAA Fisheries and the Action Agencies develop biological indicators and contingency actions in case the status of an interior Columbia basin Chinook salmon ESU or steelhead DPS reaches a pre-defined warning level during the term of the RPA. This is a precautionary approach to RPA implementation that reduces the risks associated with the scientific and technical uncertainties inherent in a 10-year mitigation program: climate change, impacts of invasive species and predators, and interactions among the listed species. NOAA Fisheries and the Action Agencies have completed the contingency planning elements of the AMIP, including the development of early warning indicators and both rapid response and long-term contingency actions (USACE et al. 2012). The expanded contingency process establishes an annual review by NOAA Fisheries and the Action Agencies to evaluate two biological indicators of species decline, the Early Warning Indicator and the Significant Decline Trigger. These two indicators are described briefly below. If the Significant Decline Trigger is tripped, the Action Agencies (in coordination with NOAA Fisheries, the RIOG, and other regional parties) will implement rapid response and, if needed, long-term contingency actions to minimize and mitigate for the decline. There are four decision points in this process: (1) tripping the Significant Decline Trigger; (2) identifying appropriate rapid response actions; (3) evaluating the sufficiency of those actions; and (4) determining appropriate long-term contingency actions if needed.

3.7.1 Early Warning Indicator and Significant Decline Trigger

The Early Warning Indicator alerts NOAA Fisheries and the Action Agencies to a decline in a species' natural adult abundance level that warrants further scrutiny. This indicator is a combination of 5-year abundance trends and rolling 4-year averages of abundance, based on the most recent 20 to 30 years of adult return data, depending on the species. The Early Warning Indicator would be tripped if the running 4-year mean of adult abundance dropped below the 20th percentile, *or* if the trend metric dropped below the 10th percentile and the abundance metric was below the 50th percentile. Tripping this indicator results in an assessment of whether a future significant decline is likely to occur in the next two years and if so which rapid response actions should be readied for possible implementation.

The Significant Decline Trigger detects notable declines in the abundance of listed species. This trigger is also a combination of 5-year abundance trends and rolling 4-year averages of abundance. The levels were set based on the same set of historical values used for the Early Warning Indicator. The Significant Decline Trigger would be tripped if the abundance metric dropped below the 10th percentile, *or* if the trend metric dropped below the 10th percentile and the abundance metric was below the 20th percentile. The Significant Decline trigger, if tripped, results in the implementation of rapid response actions (if not already implemented pursuant to an Early Warning Indicator) to minimize or mitigate for an unforeseen downturn.

The principle underlying the Significant Decline Trigger is that the conditions represented by this trigger would be significant deviations from our expectations about the status of the species in the 2008/2010 BiOps. A change in the status of the species that persisted despite implementation of the AMIP's contingency actions could result in a reinitiation of consultation.

NOAA has evaluated the listed species' status relative to these metrics each year beginning in 2009 to evaluate whether a Significant Decline Trigger has been tripped. Since that time, NOAA has annually reported updated estimates of abundance and trend to the RIOG (*<placeholder for citations>*). Four-year running averages of abundance generally increased for each species from 2010 to 2012: SR fall Chinook salmon, SR spring/summer Chinook salmon and SR steelhead at Lower Granite Dam; UCR spring Chinook salmon at Rock Island Dam; UCR steelhead at Priest Rapids Dam; and Yakima River MCR steelhead at Prosser Dam. The abundance of both SR and UCR steelhead dropped substantially in 2012, which will likely result lower four-year average abundance estimates for these species in the coming years. As noted in the 2010 Supplemental BiOp, UCR spring Chinook remains the species closest to tripping the Early Warning trigger, but the abundance of this species has increased since the recent low point observed in 2009.

In summary, at this time four-year running averages of abundance for each of the monitored species are all well above the Early Warning or Significant Decline abundance triggers identified in the AMIP and are likely to remain so for the foreseeable future.

Figure 3.7-1. Annual abundance and the 4-year running average of annual abundance in relation to the Adaptive Management and Implementation Plan's Early Warning and Significant Decline triggers for Snake River fall Chinook salmon at Lower Granite Dam.

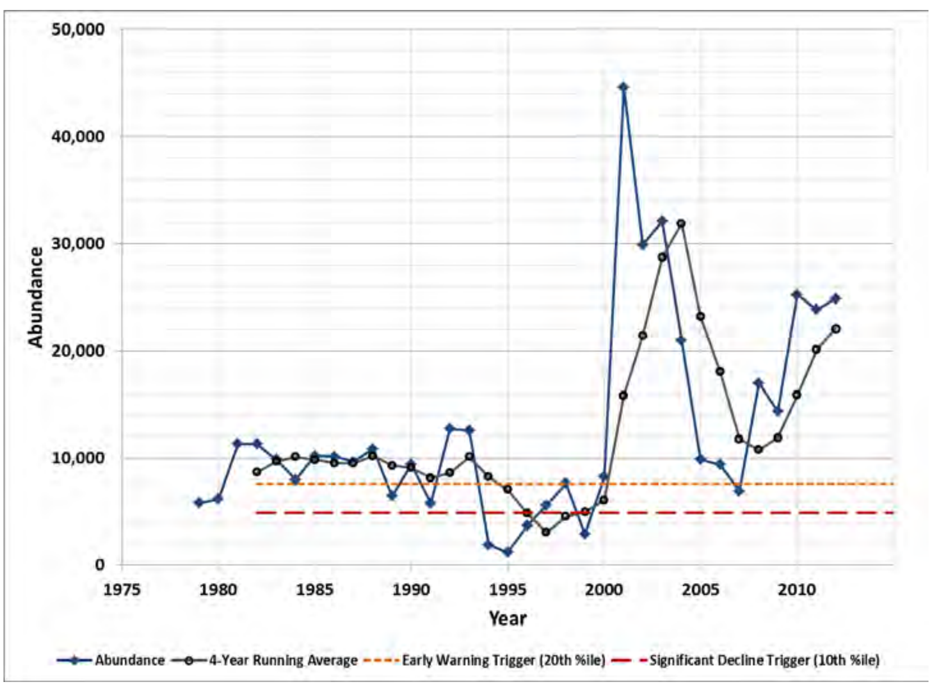

Figure 3.7-2. Annual abundance and the 4-year running average of annual abundance in relation to the Adaptive Management and Implementation Plan's Early Warning and Significant Decline triggers for Snake River spring/summer Chinook salmon at Lower Granite Dam (plus Tucannon River).

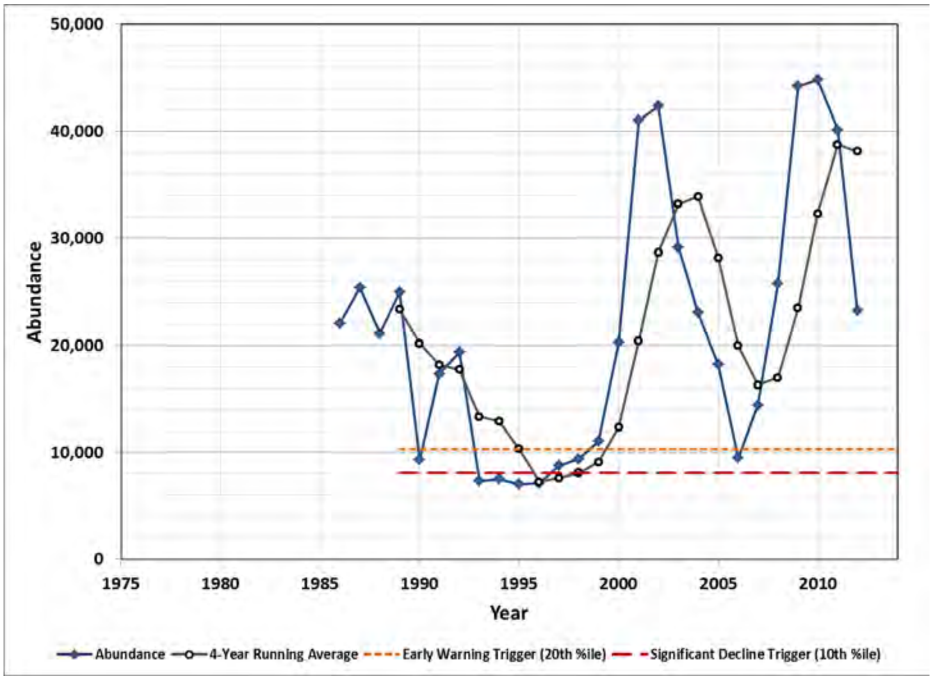

Figure 3.7-3. Annual abundance and the 4-year running average of annual abundance in relation to the Adaptive Management and Implementation Plan's Early Warning and Significant Decline triggers for Snake River steelhead at Lower Granite Dam.

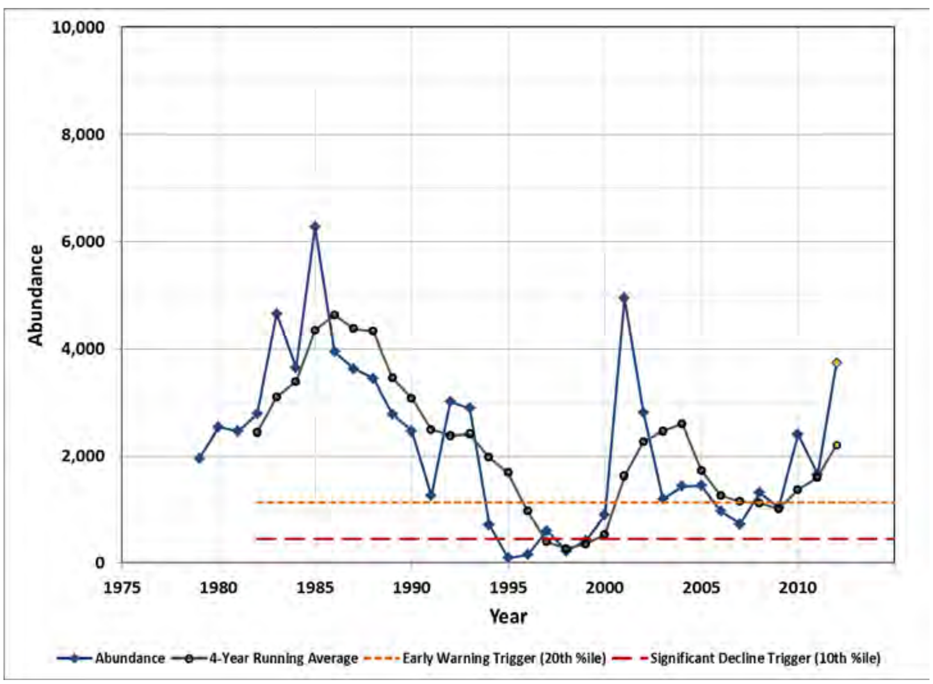

Figure 3.7-4. Annual abundance and the 4-year running average of annual abundance in relation to the Adaptive Management and Implementation Plan's Early Warning and Significant Decline triggers for UCR spring Chinook salmon at Rock Island Dam.

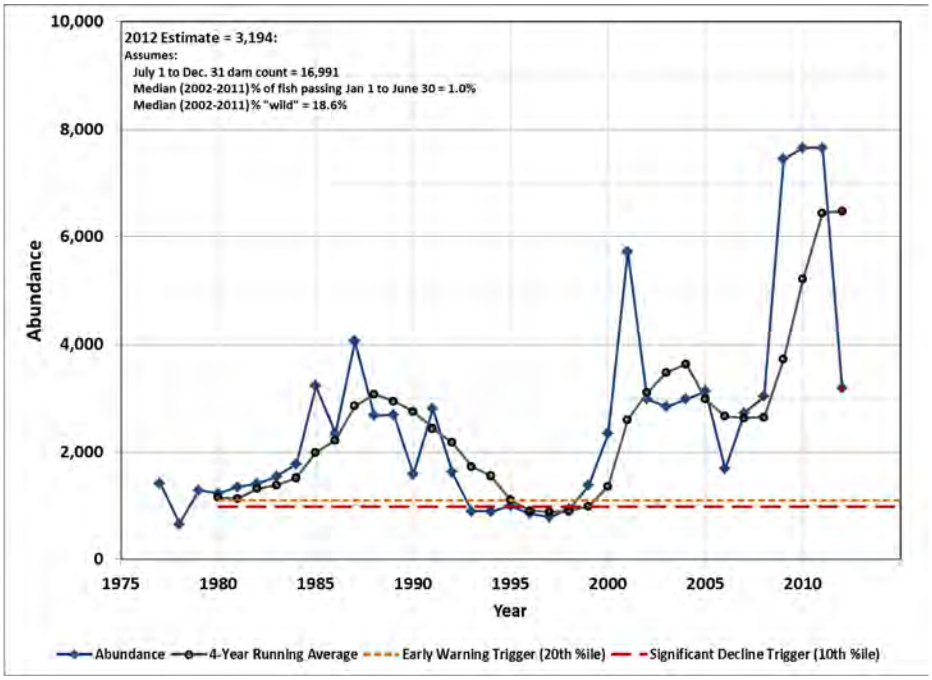

Figure 3.7-5. Annual abundance and the 4-year running average of annual abundance in relation to the Adaptive Management and Implementation Plan's Early Warning and Significant Decline triggers for UCR steelhead at Priest Rapids Dam.

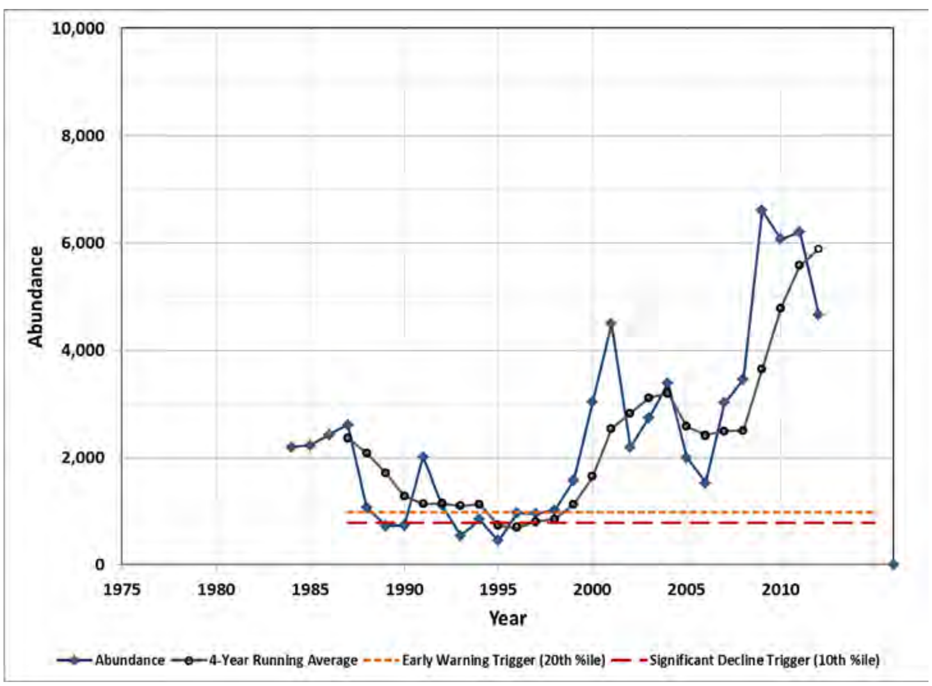

Figure 3.7-6. Annual abundance and the 4-year running average of annual abundance in relation to the Adaptive Management and Implementation Plan's Early Warning and Significant Decline triggers for MCR steelhead in the Yakima Basin at Prosser Dam.

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3.7.2 Decision Framework to Implement Rapid Response and Long-Term Contingency Actions

Within 120 days of NOAA Fisheries' determination that the Early Warning Indicator abundance levels have been observed, the Action Agencies, in coordination with NOAA Fisheries, the RIOG, and other regional parties will more closely evaluate the species' likely status and determine whether and what rapid response actions (i.e., actions that minimize or mitigate for the decline) to take. After the Early Warning Indicator has been observed and the early implementation of rapid response actions has been deemed warranted, the rapid response actions will be implemented as soon as practicable and not later than 12 months.

Once NOAA Fisheries has determined that the Significant Decline Trigger has been tripped, the agencies have up to 90 days to determine, in consultation with RIOG, what factors or conditions may have caused the trigger to trip and assess which rapid response action or actions may be effective in minimizing or mitigating for the decline. The assessment will consider all potential actions—hydro, predation, harvest, and hatchery—that may effectively address the decline.

3.7.2.1 All-H Diagnosis

The Action Agencies will conduct an initial qualitative All-H[120] analysis informed by data provided by NOAA Fisheries and any other available scientific information on the likely factors that caused the Significant Decline trigger to trip. This initial analysis will be used to inform a proposed list of rapid response actions. Concurrently, the Action Agencies (in coordination with NOAA Fisheries, the RIOG, and other regional parties) must also initiate an All-H diagnosis to: (1) evaluate whether the actions of the FCRPS are on track to meet All-H specific performance targets by 2018; (2) determine the causes of a species decline (including whether ocean and climate conditions are contributing factors); and (3) review life-cycle model results of potential long-term contingency actions and identify which "H" (hydro, predation, hatchery, habitat, and harvest) limiting factors should be addressed in the contingency actions.

The diagnosis must be completed within four to six months of a Significant Decline Trigger being tripped. The Action Agencies, in consultation with RIOG, will then use the results of the analysis to determine if the rapid response actions are likely to be sufficient, or if long-term contingency actions will need to be implemented and, if so, which long-term contingency actions will be implemented.

[120] "All-H" refers to the idea that contingency actions could be taken to improve the status of a species by reducing adverse effects of the hydrosystem, predators, hatcheries, habitat, and/or harvest.

3.7.2.2 Life Cycle Analysis and Life Cycle Model

A key component of the life cycle analysis is the life-cycle model. Information from this model will be used to determine which rapid response and, if necessary, which long-term contingency actions to take and whether or not the actions are proving effective for the ESU/DPS in decline.

The Action Agencies and NOAA Fisheries have jointly funded enhanced, data-driven life-cycle modeling for contingency planning. The life-cycle modeling project began in 2010 and continued through 2011, satisfying year 2 of the 3-year process. NOAA Fisheries' NWFSC has continued to implement and distribute the Species Life-cycle Analysis Modules developed to date, created a database that supports the models, and conducted quarterly workshops with the Oversight Committee. The modeling has made progress in the following areas (BPA et al. 2013):

- Interactions between hatchery- and natural-origin fish
- Incorporating habitat relationships into life-cycle models
- Developing hydro scenarios for rapid response and long-term contingency planning (e.g., initiating COMPASS recalibrations, developing constructs for John Day drawdown and for lower Snake River dam breaching)
- Characterizing steelhead and subyearling Chinook salmon life histories (i.e., beyond the information already developed for yearling Chinook)
- Characterizing estuary effects
- Characterizing climate change

3.7.2.3 Potential Rapid Response and Long-Term Contingency Actions

The Action Agencies and NOAA Fisheries, in collaboration with RIOG, developed a suite of potential rapid response and long-term contingency actions that could be taken if a Significant Decline Trigger is tripped. These serve as a menu of potential actions that could be used to address the needs of a specific ESU or DPS. The Action Agencies in collaboration with NOAA Fisheries, the RIOG, and other regional partners would review and select specific actions with regard to the targeted species, while considering the implications of implementation for other species and on the other authorized FCRPS project purposes. The suite of actions is described in USACE et al. (2012). For example, potential rapid response actions for Snake River spring/summer Chinook may include the following:

- **Hydro**—adjusting spill (Lower Granite, Ice Harbor, Lower Monumental, and/or McNary dams); adjusting the operation of fish passage facilities; and/or optimizing fish transportation
- **Predation**—expanding avian predator hazing and/or increasing dam angling for targeted pikeminnow removal

- **Hatcheries**—additional reprogramming of production to minimize straying of hatchery-origin adults into the natural spawning habitat; increasing the proportion of natural-origin broodstock in an integrated hatchery program; and/or reprioritizing funding so actions already in the Hatchery and Genetic Management Plans can be implemented earlier

Potential long-term contingency actions may include the following:

- **Hydro**—Phase II actions as identified in each project Configuration and Operations Plan (RPA Actions 18 through 28)
- **Predation**—short-term lethal take of targeted avian predators at a specific location; providing alternative prey for Foundation, Crescent, or East Sand Island bird colonies; and/or establishing a bass and/or walleye dam angling and/or reward program similar to that established for pikeminnow
- **Hatcheries**—initiate new conservation hatchery programs, using supplementation and/or captive breeding, as appropriate, to avert extinction of at-risk salmon or steelhead populations; and/or modify/reform existing hatchery programs to meet more conservation-oriented goals while also meeting legal harvest obligations

For harvest, if protection is needed as either a rapid response or long-term contingency measure that is beyond the abundance-based management provisions of the *U.S. v. Oregon* Agreement, NOAA Fisheries will use procedural provisions of the existing harvest agreements to seek consensus among the parties to modify the agreements.

The potential survival benefits from a given action can vary considerably depending on the specific conditions that exist for a given year and location (flows, temperatures, numbers of predators, etc.). The survival benefits from all the separate actions considered for a rapid response or long-term contingency plan will be incorporated into a life-cycle model to determine expected increases to adult returns from those actions.

3.7.3 Relevance to the 2008/2010 RPA

The 2009 AMIP established biological triggers that, if tripped, will activate a suite of short- and long-term contingency actions. The effect of these activities and contingencies will be to reduce the overall risk of unforeseen, rapid significant declines to the species posed by the uncertainty of climate change. At this time, neither the Early Warning Indicator nor the Significant Decline Trigger has been tripped for any of the interior Columbia ESUs or DPSs.

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3.8 Effects of RPA RME Program

The 2008 BiOp specified a number of research, monitoring, and evaluation (RME) actions needed to evaluate the effectiveness of system configuration and operations in protecting fish, track fish runs in real-time to inform in-season management, test hypothesis, resolve uncertainties, and track changes in species status. The 2010 Supplemental BiOp identified additional RME measures to provide greater certainty in the effectiveness of mitigation measures. These RME actions are an integral part of adaptive management and have been enhanced through that process. Progress on conducting these studies and study design are managed through the Regional Forum's System Configuration Team and Study Review Work Group, respectively. NOAA Fisheries' manages and tracks the effects of RME to ensure that the program conforms with the take authorized in the 2008 BiOp. Recent improvements in our tracking of RME handling and mortality provide a more accurate estimate of effects of the RME program than was available in 2008. This section evaluates the effects of the program through August 2013 and projects the likely effects of the program through the end of the BiOp period (2018). The projected levels of handling and mortality for RME throughout the BiOp period (2014–2018) are included in the authorization for incidental take (Section 8) in this supplemental opinion.

Based on RPA implementation to date as described in the 2013 CE, and in the Action Agencies' 2014–2018 Draft IP, NOAA Fisheries finds that all RME actions identified in the 2008 BiOp (RPA Actions 50–73) and in the 2010 Supplemental BiOp have been implemented.

NOAA Fisheries RME Authorization Process

Scientific research has the potential to affect the species' survival and recovery by killing listed salmonids, or reducing reproductive success (e.g. reduced fecundity). The 2008 BiOp authorized lethal and non-lethal sampling of listed species for the purposes of research, monitoring, and evaluation (RME). All sampling requests are reviewed by NOAA Fisheries to determine if (1) the project is sufficiently related to the requirements of the 2008 BiOp and 2010 Supplemental BiOp to allow a take letter to be issued; (2) that the importance of the information gathered justifies the level of handling and mortality requested; and (3) if there are any modifications to the project which could reduce levels of handling and mortality without compromising the project.

After review and approval, NOAA Fisheries issues a handling and mortality determination letter. The letter specifies levels of handling and incidental mortality authorized for the individual project and is valid for the calendar year in which it was issued. NOAA Fisheries maintains a database that tracks project information and authorized levels of handling and mortality to ensure that the potential levels of RME-caused mortalities, in aggregate for each ESU, do not substantially exceed levels anticipated in the 2008 BiOp. Any exceedance of permitted handling levels or episodes of high mortality are reported to NOAA Fisheries immediately. A report on the actual amount of handling and mortality is submitted to NOAA Fisheries and entered into the database at the end of the season.

Actual levels of handling and mortality associated with these activities are almost certain to be lower than the permitted levels. There are two reasons for this. First, most researchers do not handle the full number of individual fish they are allowed. (Our database indicates that researchers, on average, handle about 49% of the fish requested and incur 20% of the incidental mortality they request.) Second, we purposefully inflate our mortality estimates for each proposed study to account for the effects of accidents. Therefore, it is likely that far fewer fish—especially juveniles—would be killed during any given research project than are allotted in the permit.

3.8.1 Effects of 2014–2018 RME on ESU/DPS Abundance

The primary effects of the proposed research on the listed species would be from capturing and handling of fish. Capturing, handling, and releasing fish generally leads to stress and other sub-lethal effects, but fish sometimes die from such treatment. The mechanisms by which these activities affect fish have been well documented and are detailed in Section 8.1.4 of the 2008 BiOp. Some RME actions involve sacrificial sampling in which case the number of fish authorized to be sacrificed, as well as estimated handling effects, would be considered. All RME would be carried out by trained professionals using established protocols designed to minimize injury and mortality. Our estimates of the rates of handling and mortality associated with the proposed 2014 through 2018 RME program is provided in Table 3.8-1.

For the purposes of analyzing the effects of RME, all effects on juvenile fish are considered to be effects on outmigrating smolts of the various species. This is a conservative assumption as not all juveniles become smolts and outmigrate in a given year and would thus be subject to natural rates of mortality prior to smoltification. This means that RME effects on juveniles would often be greater than the effects on smolts. Conversion of juvenile numbers into smolt numbers facilitates our analysis of population effects because smolt survival is carefully monitored during passage through FCRPS dams and because of the conversion to adult equivalents provided by measured smolt-to-adult return ratios (SARs). For RME projects that sample or handle parr or fry, the handling and mortality rates may be adjusted by an accepted value of parr or fry to smolt survival.

Anticipated effects of RME handling and associated mortality for each ESU and DPS are presented as a percentage of 2008–2012 average smolt outmigration for juveniles, and as a percentage of estimated adult returns at the Columbia River mouth for adults. Estimates of smolt outmigration were derived from Zabel (2012; Table 3.8-1 in this document). Adult return estimates were either taken directly from annual stock status and fishery reports (e.g. WDFW and ODFW 2013) or, in locations where there was only one ESU present, estimated based on dam counts corrected by PIT-tag–derived survival estimates, to give an estimate of the number of fish at Bonneville Dam or the Columbia River Estuary (Lower Columbia and Willamette ESU). In some cases, a reliable estimate of adult returns is not available, however in these cases the number of fish handled and likely resulting incidental mortality is so low that it would only represent the loss of one to two adults from the population (e.g. lower Columbia River steelhead).

Handling and mortality of juvenile and adult salmonids is expressed both as a discrete number of fish and as a percentage of the estimated 2008–2012 run size (juvenile and adult). The total rates of mortality observed for RME activities conducted in 2008–2012 (total handled/(incidental mortality + direct mortality)) for all salmonids was 0.63% for adults and 1.11% for juveniles of fish handled. Based on rates of mortality observed in RME activities conducted in 2008–2012, the incidental mortality rate was estimated to be 1% of fish handled for adults and juveniles, and 2% for fry (rounded up). In cases where the study can demonstrate that hatchery production has actually been increased to provide them with experimental subjects (or they are using hatchery surplus fish) handling mortalities are not counted against the total allowable mortality.

As described above, actual amount of handling and mortality realized is generally much lower than that authorized. For this reason, the estimates presented below for handling and mortality are conservative; the realized levels of take are likely to be substantially lower than these estimates.

To calculate the total effects of mortality on a DPS or ESU, the number of incidental adult mortalities and the number of juvenile mortalities multiplied by an accepted value for SARs are added. This total mortality estimate is then divided by the average 2008–2012 adult returns for the particular ESU or DPS. In all cases the effects on the population were far less than 1% of the average 2008-2012 returning adult population.

As noted below, steelhead kelts are not counted towards the total allowable mortality for the DPS.

3.8.1.1 Effects of the Steelhead Kelt Reconditioning Program

The 2008 BiOp requires the development of strategies to enhance multiple spawning by steelhead. Many of these strategies include capturing, handling, and holding steelhead that have spawned (kelts). The natural mortality rate of these fish is very high, and under current conditions, natural repeat spawning rates are very low. Thus, while handling or mortality of ESA-listed kelts is still subject to NOAA Fisheries approval and review, NOAA Fisheries considers the benefits of kelt reconditioning to outweigh the negative effects of mortality and handling on the listed populations. That is, while the kelt collection for reconditioning incurs substantial mortality, kelt survival to repeat spawning absent human intervention is so low that even small levels of success would be beneficial.

3.8.1.2 Summary of Effects

A substantial research, monitoring, and evaluation program is necessary in order to assess the status of salmon and steelhead populations; the effectiveness of configurational and operational changes at the mainstem dams; smolt abundance and condition; the efficacy of habitat restoration activities; the efficacy of hatchery program changes; and other actions required by the FCRPS BiOp's RPA. Snake River species have the highest rate of handing for RME, and are therefore likely to suffer the most incidental mortalities. However, even for these species, the incidental mortality of the RME program is likely less than 1% both for adults and juveniles, and, as noted before, NOAA Fisheries has reason to believe that the assessed effects in Table 3.8-1 are conservative (higher than will likely actually occur). Impacts to other species are generally much less, especially for eulachon and green sturgeon.

The information generated by the FCRPS BiOp's required RME actions is essential for adaptively managing the hydrosystem and related mitigation activities. This information ensures that future actions to improve the survival of salmon and steelhead or the productivity or capacity of their spawning and rearing habitat are effective. NOAA Fisheries finds that the estimated levels of handling and associated incidental mortality of less than 1% of the juveniles and adults should not substantially affect the abundance or productivity of salmon or steelhead species, consistent with expectations in the 2008 BiOp, or of eulachon or green sturgeon.

The abundance effects of RME (i.e. mortalities) are part of the effects of the RPA and are considered in our jeopardy analysis and conclusions. As detailed above, these effects are small and are consistent with our estimates of the effects of RME presented in the 2008 BiOp.

Table 3.8-1. Numbers of ESA-listed species estimated to be handled and resulting incidental mortality as a percentage of estimated 2008–2012 run sizes. Adult run size estimates are derived from Joint Technical Committee Reports (WDFW and ODFW 2013) and published Dam Counts. Juvenile run size estimates are based on estimates from Zabel (2012).

***Note**: This table does not yet include RME associated with associated with the Northern Pikeminnow Removal Program or with hatchery-related RME. NOAA will include estimates of handling and associated mortalities with these RME activities in the final Biological Opinion. NOAA is also continuing to assess adult take to assure that these estimates are accurate.*

			Total Handling and Incidental Mortality							
			Adult				Juvenile			
			Hatchery		Wild		Hatchery		Wild	
	ESU/DPS		Handling	Incidental Mortality	Handling	Incidental Mortality	Handling	Incidental Mortality	Handling	Incidental Mortality
Lower Columbia	Columbia River Chum	Number	17	1	398	4	23,191	464	479,963	9,599
		% of run	3.351%	**0.202%**	4.088%	**0.041%**	8.503%	**0.170%**	8.512%	**0.170%**
		08-12 run est	495.4	495.4	9,746.5	9,746.5	272,750.0	272,750.0	5,638,950.0	5,638,950.0
	Lower Columbia Chinook	Number	868	9	47	1	99,937	999	123,668	2,041
		% of run	0.500%	**0.005%**	0.500%	**0.011%**	0.270%	**0.003%**	0.680%	**0.011%**
		08-12 run est	173,632.5	173,632.5	9,475.0	9,475.0	37,013,537.6	37,013,537.6	18,186,522.8	18,186,522.8
	Lower Columbia Coho	Number	998	10	626	6	49,026	490	17,795	265
		% of run	0.500%	**0.005%**	0.500%	**0.005%**	0.500%	**0.005%**	1.663%	**0.025%**
		08-12 run est	199,625.0	199,625.0	125,225.0	125,225.0	9,805,127.4	9,805,127.4	1,069,926.8	1,069,926.8
	Lower Columbia Steelhead	Number	200	2	128	1	4,558	46	277	3
		% of run	1.256%	**0.013%**	0.804%	**0.008%**	0.460%	**0.005%**	0.051%	**0.001%**
		08-12 run est	15,927.4	15,927.4	15,927.4	15,927.4	990,943.6	990,943.6	546,434.2	546,434.2
Mid Columbia	Middle Columbia Steelhead	Number	277	3	2,742	27	2,833	28	9,615	96
		% of run	0.051%	**0.001%**	2.745%	**0.044%**	4.590%	**0.046%**	1.248%	**0.012%**
		08-12 run est	546,434.2	546,434.2	99,894.0	61,727.6	61,727.6	61,727.6	770,380.0	770,380.0
Snake River	Snake River Fall chinook	Number	4,741	47	1,614	16	1,769,807	20,188	515,473	5,155
		% of run	16.535%	**0.165%**	19.909%	**0.198%**	26.372%	**0.301%**	73.392%	**1.146%**
		08-12 run est	28,675.7	28,675.7	8,108.5	8,108.5	6,710,874.2	6,710,874.2	702,354.5	702,354.5
	Snake River Sockeye	Number	557	5	-	1	63,701	847	9,493	191
		% of run	28.681%	**0.282%**			56.703%	**0.754%**	73.552%	**1.480%**
		08-12 run est	1,942.1	1,942.1	-	-	112,341.8	112,341.8	12,906.4	12,906.4
	Snake River Spring-Summer Chinook	Number	14,761	148	4,754	47	517,304	6,711	227,378	3,851
		% of run	16.511%	**0.165%**	16.535%	**0.165%**	12.724%	**0.165%**	17.615%	**0.298%**
		08-12 run est	89,402.6	89,402.6	28,748.8	28,748.8	4,065,512.2	4,065,512.2	1,290,830.0	1,290,830.0
	Snake River Steelhead	Number	24,900	249	11,876	119	363,895	3,880	138,609	1,960
		% of run	8.199%	**0.082%**	15.336%	**0.153%**	8.591%	**0.092%**	9.778%	**0.138%**
		08-12 run est	303,711.9	303,711.9	77,436.7	77,436.7	4,236,020.4	4,236,020.4	1,417,530.8	1,417,530.8
Upper Columbia	Upper Columbia Spring Chinook	Number	95	1	1,754	18	243,673	6,523	41,869	469
		% of run	0.500%	**0.005%**	81.619%	**0.816%**	15.785%	**0.423%**	7.422%	**0.083%**
		08-12 run est	18,993.0	18,993.0	2,149.0	2,149.0	1,543,672.2	1,543,672.2	564,158.4	564,158.4
	Upper Columbia Steelhead	Number	210	2	78	1	26,593	969	58,295	1,214
		% of run	0.905%	**0.009%**	0.896%	**0.012%**	3.160%	**0.115%**	19.533%	**0.407%**
		08-12 run est	23,234.9	23,234.9	8,679.4	8,679.4	841,696.4	841,696.4	298,446.8	298,446.8
Willamette River	Willamette River Spring Chinook	Number	174	2	149	1	29,910	299	14,213	142
		% of run	0.500%	**0.005%**	0.500%	**0.005%**	0.500%	**0.005%**	0.500%	**0.005%**
		08-12 run est	34,725.7	34,725.7	29,731.3	29,731.3	5,981,931.6	5,981,931.6	2,842,534.0	2,842,534.0
	Willamette River Steelhead	Number	73	1	62	1	923	9	1,323	13
		% of run	0.500%	**0.007%**	0.500%	**0.008%**	0.500%	**0.005%**	0.500%	**0.005%**
		08-12 run est	14,588.6	14,588.6	12,427.4	12,427.4	184,500.0	184,500.0	264,513.4	264,513.4
Non Salmonid	Eulachon	Number			6,000	60			-	1
		% of run			0.015%	**0.000%**			-	-
		08-12 run est			39,500,000.0	39,500,000.0			-	-

3.8.2 Effects of 2014–2018 RME on ESU/DPS Critical Habitat

In general, the RME activities considered in this section are capturing fish with traps, nets, hook-and-line, and electrofishing, and at fishways, diversion screens, and weirs. These techniques are minimally intrusive in their effects on habitat and thus the functioning of PCEs. They involve very little, if any, disturbance of streambeds or adjacent riparian zones and are of short duration. Therefore, the RPA's RME activities are not likely to negatively affect any designated or proposed critical habitat.

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3.9 RPA Implementation to Address Effects of Climate Change

Assumptions about climate change informed the 2008 BiOp's assessment of whether the RPA actions would be sufficient to meet indicator metric targets (R/S, lambda, BRT trend, and extinction risk) for interior Columbia species. The 2008 BiOp did not quantitatively consider effects of climate change on survival for these species during freshwater life stages, as it did for survival during ocean residence (i.e., the Recent, Warm PDO, and Historic ocean climate scenarios applied in quantitative analyses. See Section 2.1.4 in this supplemental opinion.) Reasons for not using the Crozier et al. (2008) paper to quantify freshwater effects of climate change and lack of other quantitative estimates are described on p.7-14 of the 2008 BiOp. Instead, the 2008 BiOp's approach to achieving indicator metric targets in the face of climate change affecting freshwater life stages relied on "a method of qualitative evaluation, based on ISAB recommendations for pro-active actions…" (2008 BiOp, p.7-14). That qualitative method considered effects of climate change qualitatively by determining "the degree to which the Prospective Actions implement recommendations by the ISAB (2007) to reduce impacts of climate change on anadromous salmonids" (2008 BiOp, pp.7-32 to 7-35). The 2008 BiOp listed 20 RPA actions to implement ISAB recommendations and described expectations for those RPAs relative to reducing impacts of climate change on pp.8-20 through 8-22. The 2008 BiOp concluded "that sufficient actions have been adopted to meet current and anticipated climate changes" and that we have sufficient flexibility to be sure that 2010 to 2018 habitat projects will also help to address climate change. (2008 BiOp, pp.8-22 and 8-23).

The 2013 Draft CE reviews progress implementing all RPA actions but does not specifically review the suite of actions described above in the context of climate change adaptation. The Action Agencies provided NOAA Fisheries with a separate document that explicitly reviews these RPA actions and that document is summarized in this section (Petersen 2013). NOAA Fisheries reviews these projects in the context of the ISAB (2007) recommendations, as well as more recent literature on climate change adaptation (e.g., NFWPCAP 2012; Beechie et al. 2012; see Section 2.1.4.3 *Updated Climate Change Information Since the 2010 Supplement*).

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3.9.1 Planning Processes and Climate Change

The 2008 BiOp called for the Action Agencies to provide technical assistance for the regional RPA planning process, which takes the ISAB climate change adaptation recommendations into account for implementation, research, and monitoring. Examples of these planning activities include the following:

- BPA contracted NOAA to conduct a comprehensive review of recent climate science relevant to salmon in 2011 and 2013; this review (Crozier 2011, 2012) was made available to expert panels and others involved in restoration efforts. Expert Panels considered climate information within the context of limiting factors and the degree of uncertainty or severity of effects resulting from a shift in climate.
- The AMIP requires NOAA Fisheries to establish a regional stream temperature database and requires the Action Agencies to provide NOAA with past and future water temperature data from their existing monitoring stations to contribute to regional climate change evaluations. NOAA Fisheries and the Action Agencies are satisfying this requirement by submitting data to the USFS Rocky Mountain Research stream and air temperature database.[121] This project will provide "a mapping tool to help those in the western US organize temperature monitoring efforts."
- The Action Agencies, through the River Management Joint Operating Committee, conducted an extensive climate change modeling effort by developing a common and consistent dataset describing hydrology and reservoir water supplies under scenarios of climate change generated by the Intergovernmental Panel on Climate Change. The River Management Joint Operating Committee dataset has been used for the Columbia River Treaty planning process to evaluate ecosystem impacts to fish and wildlife under a variety of scenarios of future climate and water management approaches.[122]

[121] http://www.fs.fed.us/rm/boise/AWAE/projects/stream_temperature.shtml
[122] http://www.usbr.gov/pn/programs/climatechange/reports/

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3.9.2 Tributary Habitat Mitigation and Climate Change

The ISAB (2007) details a list of actions that can directly moderate impacts of climate change in tributary streams. Among actions to improve tributary habitat in a manner that will help salmon and steelhead adapt to effects of climate change, the 2008 BiOp highlighted water rights acquisition, riparian protection, barrier removal, and restoration of habitat connectivity to wetlands and floodplains that enhance flows and improve access to thermal refugia.

The BPA Fish and Wildlife program records aggregate metrics across multiple projects of riparian stream miles protected by land purchase; stream miles improved by restoration; acres of wetland habitat improved by various means; the number of culverts removed; and the number of fish screens installed at agricultural pumps. These treatments and associated metrics are indexed by project, contract requisition, year of completion, and geographic location.[123] The comprehensive report of physical metrics at the population level for tributary habitat measures completed with funding and technical assistance from BPA and Reclamation from 2007 to 2012 is summarized in the 2013 Draft CE Section 3, Attachment 2, Table 1. A summary is included in the Citizens Guide to the Comprehensive Evaluation. Between 2007–2012, the Action Agencies opened up 2,053 stream miles of habitat to anadromous fish by removing culverts and water diversions; protected or restored 3,791 acres of estuary floodplain; restored flow of 177,277 acre-feet of water to Columbia basin streams through water transactions and irrigation improvements; and restored stream complexity to 206 miles of stream by actions such as enhancement of side channels and meanders, or by installing artificial log jams.

An example of the Action Agencies' tributary habitat improvement projects relevant to climate change adaptation is illustrated by the work of The Freshwater Trust. The Freshwater Trust develops hydrographs for the rivers it works in, and uses them to determine when flow augmentation is most crucial for anadromous fish rearing and migration. As the period of low flow shifts, timing of water transactions will shift to reflect that. The Freshwater Trust also measures temperature on numerous projects to track temperature trends during the summer and predict the relative success of restoration efforts from a temperature standpoint.

The Lolo Creek watershed provides another example of actions to mitigate for the effects of climate change through passage improvement, riparian enhancement, and restoration of floodplain connectivity. Restoration efforts proposed for Lolo Creek that can buffer the effects of climate change on this drainage include culvert and bridge replacement to specifications that will accommodate a 100-year flow event and removing barriers in areas with suitable habitat that will allow for more diversity and the potential for fish to move to higher, cooler systems. Because heat budgets in streams are typically dominated by incoming solar radiation, shading from riparian vegetation plays an important role in buffering stream temperatures on small to medium-sized streams (Isaak 2011). Riparian plantings and

[123] http://www.cbfish.org

floodplain restoration share many of the same benefits. Riparian plantings have the obvious effect of shading streams to reduce water temperatures. Floodplain restoration can help attenuate peak flows.

The North Fork John Day basin provides another example of how projects can reduce climate change impacts through protection, enhancement, and restoration of floodplain function and watershed process. Specific restoration actions address instream and riparian habitat and restoring floodplain function by eliminating passage barriers, native vegetation plantings, riparian fencing, and grazing management. The project also maintains conservation agreements that protect, enhance, and monitor floodplain and riparian habitat.

The Columbia Basin Water Transactions Program is continuing to work with its implementing partners at the state and local levels to incorporate considerations of climate change into its flow restoration program. Columbia Basin Water Transactions Program partners are taking climate change and best available science into account in working to address tributary flow issues at the subbasin and reach scales for the future. This is taking several forms, including the use of climate models to prioritize watersheds for restoration and to understand the possible long-term impacts to focal species, design flow restoration transactions to address anticipated changes in stream hydrology, and to restore ecological resiliency to streams where flow is a primary limiting factor for native fish. Lists of water transactions conducted in watersheds throughout the FCRPS are available in an online database.[124] Examples of transactions that have been identified, designed, and implemented with consideration for climate change include:

- **Lemhi River (ID)** – The Idaho Department of Water Resources is using permanent easements and annual agreements negotiated with willing water right holder to protect a base flow in the Lemhi River throughout the irrigation season. The transactions rely on senior water rights that have historically received their full diversion rate.
- **Umatilla River (OR)** – The Freshwater Trust is utilizing stored water from McKay Reservoir in the upper Umatilla Basin to restore instream flows. Working with stored water is an option for a warmer future where runoff amounts are similar but occur earlier in the year. This approach can help maintain the Umatilla River's fish runs even if the hydrograph sees a significant shift by allowing for late summer release of stored water that would otherwise have flowed out of the basin in the early summer months.
- **Chewuch River (WA)** – Trout Unlimited is using a "trigger flow" mechanism to ensure flows in the Chewuch River, a key spawning and rearing tributary for steelhead and Chinook salmon, are maintained during the late summer and fall months when flows are expected to be more severely impacted by climate change.

[124] http://www.cbwtp.org/jsp/cbwtp/projects/index.jsp

When the river drops below 100 cubic feet per second, a local irrigation district has agreed to reduce its diversion to ensure that a base flows will be maintained. As the effects of climate change worsen, this agreement can help buffer the Chewuch River from declining water supplies and the associated habitat and water quality impacts.

3.9.3 Mainstem and Estuary Habitat Mitigation and Climate Change

ISAB (2007) recommended climate change adaptation actions in the estuary and mainstem Columbia River such as removal of levees or dikes in order to restore floodplain connectivity and tidal influence, restoring side channel habitat, and replanting and restoring riparian and wetland habitat along the mainstem.

The Army Corps of Engineers sponsored a major study to identify the use and location of thermal refugia for adult steelhead and Chinook salmon in the lower Columbia and Snake rivers (USACE 2013). This study provides a comparison of existing tributary and lower Columbia and lower Snake River temperature data; a summary of the Snake and Clearwater River confluence study/modeling operations and Dworshak project releases; and a compilation of the University of Idaho studies of temperature regimes during upstream migration and the use of thermal refugia by adult salmon and steelhead in the Columbia River basin.

Through the Columbia Estuary and Ecosystem Restoration Program (CEERP), the Action Agencies fund regional partners to identify habitat actions that will benefit outmigrating juvenile salmonids. These benefits are quantified by the ERTG and assigned a Survival Benefit Unit (SBU) score that captures the projected biological improvements for juvenile salmonids. The projects that score the highest are typically large projects that reconnect fragmented portions of the historic tidally-influenced floodplain and restore natural ecological processes. This focus naturally enhances the resiliency and long-term sustainability of Action Agency habitat actions through time.

The following program components support continued efforts to minimize the impacts of climate change on AA habitat projects:

- **Action Agency estuary habitat actions target restoration of natural ecosystem processes**. Hydrologic reconnections are increasingly at the core of most Action-Agency–funded estuary habitat restoration actions because they provide the greatest estimated benefits for fish and for the estuarine environment as a whole. Restoring connections to the historic floodplain allows for the reestablishment of native vegetation communities that require tidal inundation; increased refuge and rearing habitat for juvenile salmonids; export of organic material and prey items into the mainstem; and more natural temperature regimes in off-channel habitats.

Fourteen dike breach actions in the Columbia River estuary are described in Petersen (2013).

- **U.S. Army Corps of Engineers Estuary Habitat Climate Change Pilot Study**. The Corps facilitated a series of interdisciplinary workshops (Action Agency representatives, scientists, and planners from the region) to consider climate change science relevant to Action Agency estuary habitat actions in the Columbia River estuary to evaluate if habitat action designs could incorporate additional elements to help maintain the habitat functions through time. Findings included the potential benefits of "ecotones" whereby vegetation communities may migrate to higher elevations if sea level rise becomes an issue in the lower estuary. This pilot is still ongoing.
- **Estuary modeling**. Over the past few years, BPA and others have helped fund a hydrodynamic numerical model of the Columbia River estuary and plume that can model water quality (e.g. dissolved oxygen, temperature) to help the Action Agencies project the climate change related effects of the changing ocean environment on the Columbia River estuary. These effects could include increased ocean acidification affecting the salt wedge in the estuary and more extensive hypoxic regions (seasonally) in the Columbia River estuary. This model is also being used in Columbia River Treaty evaluations of differing flow scenarios and their effects on these water quality parameters in the estuary (Columbia River Treaty evaluations also have a Climate Change Working Group).

3.9.4 Mainstem Hydropower Mitigation and Climate Change

The ISAB (2007) recommended actions in the mainstem hydropower system that could help to mitigate for impending effects of climate change, such as addressing outflow temperatures, development and implementation of fish passage strategies, transportation, and predation management. Many RPA actions address these factors, including the following examples.

In the mainstem Columbia and Snake rivers there is fairly high confidence in the prediction that increased temperatures during the juvenile outmigration will have a negative effect on survival because the principal source of mortality during this stage is predation by piscivorous fish or birds. The activity level of predatory fish such as pikeminnow and bass has been documented to rapidly increase with increasing temperatures (e.g., Petersen and Kitchell 2001). Recent dam design improvements to help smolts efficiently move through the dam forebay, such as installation of surface passage and The Dalles spillway wall, are detailed under RPA 54.1-5 of Section 2 of the 2013 Draft CE. The temporary spillway weir installed at Little Goose Dam in 2009 and the removable spillway weir installed at Lower Monumental in 2008 completed the program of installation of surface passage at all mainstem dams in the lower Snake and Columbia rivers. In order to reduce predation risk in the tailrace, the juvenile bypass outfalls were relocated at Lower Monumental dam (RPA 23) and McNary Dam (RPA 21), and spill operations targeted at reducing eddies and time delays in the tailrace have also received study, including block tests of different operations during performance tests at the Lower Monumental Dam (RPA 23).

Travel speeds of yearling and subyearling Chinook, steelhead, and sockeye through the hydrosystem are monitored annually by NOAA Fisheries (BPA project 1993-029-00). Duration of travel from Lower Granite to Bonneville Dam is substantially faster during and after installation of surface passage routes compared to earlier equivalent flow years such as 2010 versus 2004; travel speeds are currently faster than they were in the early 1970s period when only four dams were installed in the mainstem river (Muir and Williams 2011). The BPA continues to manage the Northern Pikeminnow Management Program (see program summary in 2013 Draft CE Section 2, RPA 43). It has not been possible to test whether recent dam design changes will successfully improve survival during particularly warm or low flow years. Best water management protocols for ecosystem function have been discussed as part of the Dry Year Strategy (RPA 14). Detailed in the 2013 Draft CE, Section 2, a “dry year” is defined as the lower 20th percentile of years for water supply. The FCRPS has not experienced a dry year under the technical definition since 2001,[125] and survival observations during the 2008–2012 period do not reflect dry year conditions.

A list of water management actions considered for the Dry Year Strategy are being assessed as part of the sovereign negotiations for renewal of the Columbia River Treaty. Modeling efforts for the Columbia River Treaty have considered future hydrological patterns driven by

[125] As described in the CE, 2010 met the technical definition based on the May forecast. However, because of late spring precipitation, the actual runoff exceeded the dry year trigger.

70-year scenarios of climate change developed by the River Management Joint Operating Committee (RPA 10, 11). Adult salmon are expected to be particularly sensitive to high temperatures during migration during late summer (e.g., Hague et al. 2010). Adults are less sensitive to flow volumes in the mainstem river than juvenile salmon, however minimum flows for passage are required to negotiate fish ladders and small barriers in tributary streams. Releases of water from large storage reservoirs in Canada (Arrow, Mica, etc.) and the FCRPS (Libby, Hungry Horse, Grand Coulee, Dworshak) may be managed to augment flows during the spring and summer juvenile migration seasons, and to enhance migration and spawning of fall-run Chinook and chum in fall. Under a climate future of more rapid snowmelt in spring or lower annual precipitation, the flow augmentation during these seasons can become competing needs given the maximum refill and storage capacity. The Action Agencies continue to conduct cold-water releases from Dworshak Dam, which is temperature stratified, to maintain temperatures in Lower Granite reservoir below 20°C in late summer. Recent research confirms the importance of this management practice for enhancing survival of fall-run Chinook from the Clearwater River, which may over-winter in reservoirs and then migrate the following spring as yearlings (see 2013 Draft CE, Section 2, RPA 55.4).

3.9.5 Harvest Mitigation and Climate Change

The ISAB (2007) recommended improvements in harvest and hatchery management, such as harvest reductions in years of poor climate conditions and targeting hatchery stocks or robust wild stocks. The Action Agencies have been able to coordinate several RME projects which shed light on appropriate management approaches under climate change. For example, the Action Agencies fund NOAA Fisheries' Ocean Survival of Salmonids project (see description under 2013 Draft CE Section 1 and Section 2, RPA 58.3), which produces an ocean indicators tool which has been successful in forecasting ocean survival rates of salmon useful for harvest management. The Ocean Ecosystem Indicator metrics may be a helpful tool for managers to adjust harvest during periods when poor ocean conditions will lead to low adult returns.

3.9.6 Summary of RPA Implementation for Climate Change

NOAA Fisheries continues to conclude that sufficient actions consistent with the ISAB's (2007) recommendations for responses to climate change have been included in the RPA and are being implemented by the Action Agencies as planned. Section 2.1.1.2 of this supplemental opinion previously concluded that the ISAB (2007) recommendations are consistent with new scientific literature regarding climate change adaptation for Pacific salmon and steelhead.

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3.10 Effects of RPA Implementation on Lower Columbia Basin Salmon and Steelhead

Effects of RPA implementation on lower Columbia basin salmon and steelhead, especially with respect to conditions or activities in the mainstem below The Dalles Dam and in the estuary and plume, are similar to those described above for interior ESUs and DPSs. However, there are some differential effects, which are described in the following subsections.

3.10.1 Effects of Tributary Habitat RPA Actions on Lower Columbia Basin Salmon and Steelhead

Although RPA actions in tributary habitat are principally intended to improve the survival of interior Columbia basin salmonids, RPA Action 35 recognized that the lower Columbia populations above Bonneville Dam had been significantly impacted by the FCRPS. It stated that the Action Agencies "may provide funding and/or technical assistance for habitat improvement projects consistent with basin wide criteria for prioritizing projects, including Recovery Plan priorities." Beginning in 2008, the Action Agencies provided funding to improve habitat for the Lower Gorge population of LCR coho salmon and the Hood River populations of LCR Chinook and steelhead through habitat improvements in the Hood River by installing a pipeline to conserve instream water in seven stream miles, placement of large wood structures, and adding channel complexity over 1.68 stream miles (USACE et al. 2009c). They also provided funding for the removal of Hemlock Dam on Trout Creek, a tributary to the Wind River, which restored unimpeded fish passage and improved water quality and other habitat conditions for and the Wind River population of LCR steelhead.

3.10.2 Effects of Estuary Habitat RPA Actions on Lower Columbia Basin Salmon and Steelhead

NOAA Fisheries made the qualitative assumption in the 2008/2010 BiOps that the estuary habitat improvement projects completed during the Base-to-Current Period were benefiting all stream- and ocean-type fish. This includes spring-run Chinook and coho salmon and steelhead from the Lower Columbia and Upper Willamette River ESUs/DPSs, and ocean-type juveniles from the Lower Columbia Chinook and CR chum salmon ESUs. This assumption is confirmed by the studies described in the 2013 Draft CE and in Section 3.2.1.2 (*RME Support for RPA Estuary Habitat Program*), above. For example, Weitkamp (2013) analyzed gut contents of juvenile coho salmon, steelhead, and yearling Chinook salmon captured in open water purse seines (near the navigation channel) in the lower estuary. Sample sizes to date are small, but most of these larger juvenile migrants have contained prey, dominated by chironomids insects and amphipods from local wetland areas (Diefenderfer 2013; Weitkamp

2013). Bottom et al. (2011) found that subyearling Chinook and chum salmon from lower Columbia basin ESUs reared in shallow peripheral channels throughout the lower estuary—in emergent, scrub-shrub, forested, and mixed habitat wetlands—and gradually moved offshore and toward the estuary mouth as they fed and grew. Back-calculations of residence time using otolith chemistry indicated that estuary residence averaged 2 to 3 months during 2003-2005 for the smallest fry and 4 to 6 weeks for larger subyearlings (>90 mm). Most CR chum salmon captured at beach seine sites in the lower estuary were smaller than 45 mm, indicating a rapid dispersal to the estuary soon after leaving redds, but fingerling-sized chum salmon were also observed at most sites, indicating growth during migration.

Thus, RME results under Actions 58 through 61 support the value of estuary habitat improvements to the viability of lower Columbia basin salmon and steelhead as well as those from the interior Columbia basin. NOAA Fisheries continues to assume that these projects are mitigating for the negative effects of RPA flow management operations on estuarine habitat used by these species for rearing and migration.

3.10.3 Effects of Hydropower RPA Actions on Lower Columbia Basin Salmon and Steelhead

Upper gorge populations of LCR Chinook and coho salmon, CR chum salmon, and LCR steelhead are adversely affected by passage at Bonneville Dam and by inundation of some historical spawning and rearing habitat under Bonneville Reservoir. In addition, the Lower Gorge population of CR chum salmon is affected by basin-wide flow operations that control the availability of spawning habitat in the tailrace of Bonneville Dam. The RPA therefore includes actions that limit the adverse effects of these factors. We describe progress toward their implementation in the following sections.

3.10.3.1 Bonneville Dam Configuration and Operations

As described in the 2013 Draft CE (see Table 15), the Action Agencies have implemented the following measures to reduce passage delay and increase survival of fish passing through the forebay, dam, and tailrace at Bonneville Dam (RPA Action 18):

- Powerhouse II Fish Guidance Efficiency Improvements—have increased the amount of juvenile fish guided away from turbines and into the juvenile bypass system, which has the second highest survival (after the corner collector) of all routes at the project
- New Spill Operation—setting the minimum spill gate opening to 2 feet and adjusting the pattern of gate openings to eliminate eddies and maintain shoreline velocities in the spillway tailrace has increased juvenile fish survival at the spillway through improved conveyance over the spillway chute and improved egress in the tailrace
- Conversion of the Powerhouse I Sluiceway to a Surface Flow Outlet—has provided a safer, more effective non-turbine passage route for adult and juvenile fish at Powerhouse I by increasing the hydraulic capacity, improving channel flows, and automating the entrance weirs
- New Powerhouse I Turbines—have increased juvenile fish survival at Powerhouse I through installation of Minimum Gap Runners (MGR) at all 10 turbines, designed to provide safer conveyance for juvenile fish

Per the 2014–2018 Draft IP, the Corps expects to complete Performance Standard Testing for these Phase I improvements by 2018, and if the performance standards are not met, will identify appropriate Phase II actions and implement as necessary to achieve the dam survival performance standards (96% for yearling Chinook and steelhead, 93% for subyearling Chinook; see RME Strategy 2, Reasonable and Prudent Alternative Table, 2008 BiOp). Thus, the Action Agencies are implementing configuration changes at Bonneville Dam as intended in RPA Action 18.

3.10.3.2 Flow Operations for Mainstem Chum Salmon Spawning and Incubation

As described in Section 3.3.2, the Action Agencies have provided spawning flows for the Lower Gorge population of CR chum salmon during the first week of November in the Ives Island area, consistent with the measures described in RPA Action 17. They were able to maintain these flows through emergence during 2008, 2009, 2011, and 2012, but in accordance with RPA Action 17, dewatered some redds during March of 2010 and 2013 in favor of spring flow augmentation and other project purposes.

Under a Memorandum of Agreement with the State of Washington, the Action Agencies funded the rehabilitation of spawning habitat in a side channel of Hamilton Creek, Hamilton Springs, located near Ives Island in 2012. The WDFW enhanced portions of the spawning substrate, increased groundwater flows within the refurbished channel, added large wood for channel complexity, removed exotic plant species, and planted native vegetation. This off-channel habitat is productive and used by hundreds of fish. These habitat improvements, combined with minimum tailwater elevations in November and December under RPA Action 27 for consistent access to Hardy and Hamilton creeks, decrease the risk to the Lower Gorge population when water supply precludes protection of the mainstem habitat near Ives Island through the incubation season.

In summary, the Action Agencies have implemented flow operations to maintain minimum tailwater elevations for spawning and incubating chum as anticipated given variable annual flow conditions, consistent with NOAA’s expectations in the 2008/2010 BiOps’ analyses. In addition, the rehabilitated spawning habitat in Hamilton Springs Channel provides productive spawning and incubation areas that substantially mitigate for impacts to the Lower Gorge population in the mainstem Columbia River.

3.10.4 Effects of Predation RPA Actions on Lower Columbia Basin Salmon and Steelhead

NOAA Fisheries has modified RPA Action 46, calling upon the Corps to reduce cormorant predation in the estuary to Base Period levels (no more than 5,380 to 5,939 nesting pairs on East Sand Island). The Corps is developing a management plan (and accompanying Environmental Impact Statement) to address this issue with implementation of management actions estimated to begin in early 2015.

3.10.5 Effects of the RPA RME Program on Lower Columbia Basin Salmon and Steelhead

Numbers of CR chum salmon, LCR and UWR Chinook salmon, LCR coho salmon, and LCR and UWR steelhead estimated to be handled as a result of RPA RME activities are shown in Table 38.1. In each case the incidental mortality of these fish is likely to be less than 1% of estimated 2008–2012 run sizes. These effects are small and are consistent with our estimates of the effects of RME in the 2008 BiOp.

3.10.6 Effects of RPA Actions to Address Effects of Climate Change

The ISAB recommended climate change adaptation actions in the estuary and mainstem Columbia River such as removal of levees or dikes in order to restore floodplain connectivity and tidal influence, restoring side channel habitat, and replanting and restoring riparian and wetland habitat along the mainstem (Section 3.9.3). These habitat actions will reduce impacts of climate change on lower Columbia basin species as well as those from interior Columbia ESUs and DPSs. Relevant implementation to date includes

- the Corps' study to identify the use and location of thermal refugia for adult steelhead and Chinook salmon in the lower Columbia River (USACE 2013),
- Action Agency estuary habitat actions that target the restoration of natural ecosystem processes, especially hydrologic reconnections,
- the ongoing pilot study to evaluate whether estuary habitat actions could incorporate additional elements to help maintain the habitat functions through time, and
- the hydrodynamic numerical model of the Columbia River estuary and plume that can help the Action Agencies project climate-change related effects of the changing ocean environment on the Columbia River estuary.

As described in Section 3.9.6, NOAA Fisheries continues to conclude that sufficient actions consistent with the ISAB's (2007) recommendations for responses to climate change have been included in the RPA and that these are being implemented by the Action Agencies as planned. This applies equally to the interior and lower Columbia basin species.

3.11 Relevance of RPA Implementation to the 2008/2010 BiOps' Analyses

In Sections 3.1 through 3.10, NOAA Fisheries reviewed the progress made in implementing the RPA to date, the certainty regarding the effects of remaining RPA action implementation through 2018, and new information regarding effectiveness of RPA actions, with a particular emphasis on habitat mitigation measures, as directed by the Remand Order. We compared this information with expectations in the 2008 BiOp.

In this section, we summarize this information relative to the questions posed in the introduction to Section 3 (above).

3.11.1 Relevance of RPA Implementation to Interior Columbia Basin Salmon and Steelhead

Habitat mitigation review

To address the Court's principal concern, NOAA Fisheries evaluated the habitat improvement projects the Action Agencies have now identified for implementation in 2014 through 2018. The results are presented in Sections 3.1 and 3.2 and summarized here.

Effects of the newly developed tributary and estuarine habitat improvement projects are reasonably certain to occur.

Tributary habitat improvement projects for implementation through 2018 have been identified at a significant level of detail, including identification of populations to benefit; type of work to be accomplished; limiting factors addressed; extent of area to be treated, volume of water protected, or other relevant metrics; and location of work (e.g., river mile, local jurisdiction, address, or road access). The Action Agencies have increased their capacity to implement the tributary habitat program since 2007 through staffing additions, development of business management systems, and development of new assessment and prioritization tools. They have also helped to build local infrastructure, to coalesce stakeholder interests around FCRPS tributary habitat program priorities, and to create synergy among the range of salmon and steelhead recovery and watershed planning efforts in the interior Columbia River basin such that there is broader institutional and stakeholder support for implementation. They have laid out credible strategies for achieving HQI performance standards, and associated survival improvements, for all populations. Finally, they have developed an implementation strategy, and have demonstrated the ability to implement projects through their record of projects implemented through 2012 (2014–2018 Draft IP, Appendix C; 2013 Draft CE).

Estuary habitat improvement actions identified for implementation through 2018 are described at a significant level of detail, including the estuary module management actions to be addressed; the extent (miles or area) of treatment; the location of work (reach A through

G); and the degree to which ocean- and stream-type juveniles are expected to benefit. They have increased their capacity to implement the estuary habitat program by creating the infrastructure needed to identify, develop, and implement high quality projects that are likely to meet the biological performance standards. The Action Agencies also have committed to implement the program through 2018 and have demonstrated the ability to implement large, complex projects (e.g., the Columbia Stock Ranch) through their record of projects implemented through 2012. The estuary habitat projects described for implementation during 2014 through 2018 are detailed and developed to the same or better degree as projects that were presented in the Action Agencies' 2010–2013 Implementation Plan (USACE et al. 2010). Those prospective projects are at least as certain, if not more so, to be at least as effective as the pre-2014 projects.

The projects the Action Agencies have identified for implementation after 2014, when added to projects implemented since 2007, are sufficient to achieve the RPA's Habitat Quality Improvement objectives set forth in RPA Action 35, Table 5, and the associated survival improvements for listed salmonids in tributary habitat, as well as the estuary survival improvements objectives set forth in RPA Action 36.

For populations where projections based on expert panel results indicate the performance standards will be achieved and where the Action Agencies have made significant progress (i.e., will achieve greater than 33% of the HQI performance standard by tributary habitat projects implemented through 2011), it is reasonably certain the HQI performance standards will be met. This determination is based on NOAA Fisheries' conclusions regarding the tributary habitat analytical methods (see Section 3.1.1.8) and on the demonstration of significant implementation progress. NOAA Fisheries gave additional scrutiny to the Action Agencies' strategies for populations for which less than 33% of the HQI performance standard will be achieved by projects implemented through 2011 and/or for which supplemental actions were identified. Those populations are discussed in more detail above, in Section 3.1.2.3 through 3.1.2.7. Based on this detailed review, NOAA Fisheries has also determined that it is reasonably certain that the HQI performance standards for those populations will be met.

The Action Agencies are on track to implement the estuary habitat improvement program such that achievement of estuary survival performance standards of RPA Actions 36 and 37 is reasonably certain to occur. This conclusion is based on the likelihood of implementation as described above; use of best available scientific information for analyzing effects (Section 3.2.1.3); creation of a roadmap (strategy and action plan) in the form of the CEERP; and formation of the ERTG, tasked with reviewing and upgrading the survival benefit scoring process and applying the SBU calculator to project design. A key recommendation from that group is that the most effective strategy for improving estuarine habitat for salmonids is to implement large habitat improvement projects, located close to the mainstem, that reconnect floodplain and tidal influences. This strategy is the basis of the Action Agencies' 2014–2018 estuary program. Although key 2014–2018 projects were defined subsequent to ERTG review, the ERTG's methods were applied to evaluation of the proposed projects and in Sections 3.2.2.2 and 3.2.2.3 NOAA Fisheries concludes that the estuary habitat projects are likely to achieve the 2008 BiOp's expected survival improvements.

The methodology used by the Action Agencies to determine the efficacy of the tributary and estuary habitat improvement actions uses the best science available.

The analytical approach described in Sections 3.1.1.2 through 3.1.1.7 uses the best available scientific information for assessing the effects of tributary habitat actions occurring across the Columbia River basin and affecting multiple ESUs and DPSs. Best available scientific literature on the subject of habitat restoration indicates that many habitat restoration actions can improve salmon survival over relatively short periods. Examples include increasing instream flow, improving access to blocked habitat, reducing mortality from entrainment at water diversion screens, placing of logs and other structures to improve stream structure, and restoring off-channel and floodplain habitat (see Section 3.1.1.2). Other habitat improvements, such as sediment reduction in spawning areas and the restoration of riparian vegetation, may take decades to realize their full benefit (see Section 3.1.1.2 in this document; Beechie et al. 2013; Roni et al. 2013a).

The best available scientific literature also supports the RPA approach of improving tributary habitat to increase survival of salmon and steelhead at the population scale (see Section 3.1.1.2). Preliminary results from the Action Agencies' monitoring and evaluation program (see Section 3.1.1.3) also provide evidence that the Action Agencies' habitat improvements are correctly targeting and addressing degraded conditions and that fish are responding through increased abundance, density, and survival.

The approach used to estimate changes in habitat as a result of implementing tributary habitat actions and the corresponding survival improvements is based on the best available scientific information from fish and habitat experts and on general empirical relationships between habitat quality and salmonid survival. Professional judgment by experts provided a large part of the determination of habitat function in all locations given the limited extent of readily available empirical data and information. Although empirical data and information provide the best insight for determining habitat function and corresponding salmonid survival, the extent of readily available empirical data was not adequate to make a precise determination of habitat function and salmonid response uniformly throughout the Columbia River basin. NOAA Fisheries finds that the approach developed and information gathered through the CHW, and subsequently applied here, represents the best available scientific information that can be consistently applied over the larger Columbia basin to estimate the survival response of salmonids to habitat mitigation actions.

Section 3.2.1.3.1 concludes that the Survival Benefit Unit (SBU) Calculator method for determining the efficacy of estuary habitat actions uses the best science available. Section 3.2.1.3 describes that method in detail. Although many of the key inputs to the SBU Calculator are quantitative (e.g., water surface elevation and weighting factors based on fish densities), professional judgment is necessarily a prominent element of the process to assign SBUs. The ERTG scores for success, habitat access, and habitat capacity in the SBU calculator use professional judgment within a scoring criteria framework. The ERTG method combines quantitative metrics with professional judgment, which applied within a science-based process by a group of scientists who are experts in the subject matter.

Reliability of 2008 BiOp Analysis in 2013

NOAA Fisheries evaluated implementation and effects of the RPA to inform our determination in Section 4 regarding whether the 2008 BiOp, as supplemented in 2010, and further by the additional project definition and analysis contained in this supplemental opinion, remains reliable for continued implementation of the 2008 RPA.

The RPA is being implemented in the manner considered in the 2008/2010 BiOps

Based on RPA implementation to date described in the 2013 Draft CE, the Action Agencies' 2014–2018 Draft IP, and the review of RPA action implementation in sections 3.1 through 3.9, NOAA Fisheries finds that all RPA actions are likely to be implemented by 2018 as anticipated in the 2008/2010 BiOps. As described above, NOAA Fisheries explicitly reached this conclusion in Sections 3.1 through 3.9 for all RPA actions.

New information reveals some effects of the RPA that affect listed species to an extent not previously considered in the 2008/2010 BiOps. Estimated changes result in either the same survival or greater survival than expected for all populations.

As described in sections 3.1 through 3.9, most RPA actions are expected to have effects on interior Columbia basin species that are the same as those anticipated in the 2008 BiOp. Many of these effects are qualitative (e.g., benefits of RME Actions 50–73 for increasing our ability to better manage listed species), and those effects are generally as expected. In this section, we focus on expected survival changes that were quantified in the 2008 BiOp (e.g., as summarized in the 2008 BiOp Table 8.3.5-1 for SR spring/summer Chinook and in similarly numbered tables for the other five species with quantitative survival estimates) and, in particular, those that appear to be higher or lower than estimated in the 2008 BiOp.

Tributary Habitat Improvement Actions (RPA Actions 34 and 35)

As described above and in Section 3.1, effects of the tributary habitat improvement actions are expected to achieve the estimated HQI and survival improvements anticipated in the 2008 BiOp. Additionally, Section 3.1 points out several populations that are expected to have higher than anticipated survival improvements, based on implementation of projects through 2011 and evaluation of effects by expert panels (Table 3.1-1). The relative survival improvements, beyond those anticipated in the 2008 BiOp range from +1% to +20% (i.e., additional survival multipliers of 1.01 to 1.20) and affect eight SR spring/summer Chinook populations and five SR steelhead populations.

- Upper Grande Ronde population of SR spring/summer Chinook (+1%[126])
- South Fk Salmon Mainstem population of SR spring/summer Chinook (+1%)
- Secesh River population of SR spring/summer Chinook (+4%)
- Lemhi River population of SR spring/summer Chinook (+20%)
- Valley Creek population of SR spring/summer Chinook (+12%)
- Lower Salmon River population of SR spring/summer Chinook (+2%)
- East Fork Salmon population of SR spring/summer Chinook (+1%)
- Pahsimeroi River population of SR spring/summer Chinook (+15%)
- Asotin population of SR steelhead (+1%)
- Imnaha population of SR steelhead (+ less than 1%)
- Wallowa population of SR steelhead (+1%)
- Lemhi population of SR steelhead (+19%)
- Pahsimeroi population of SR steelhead (+17%)

Hydropower Actions (RPA Actions 4 through 33)

As described in Section 3.3, most juvenile inriver performance standards are being met or exceeded, but some measures of juvenile and adult survival are lower than the 2008 BiOp estimates. However, as explained in that section, these estimates remain within the 2008 BiOp's expectations for the reasons summarized below.

Structural and operational improvements at dams are performing well and resulting survival rates are likely close to achieving or are already achieving the 96% dam passage survival standard for yearling Chinook salmon and steelhead smolts, and the 93% survival standard for

[126] These survival changes are calculated from Table 3.1-1 by: (1) converting the estimated survival changes into survival multipliers, as described in the 2008 BiOp Section 7.1.1 (i.e., +3% in Table 3.1-1 is a survival multiplier of 1.03); and (2) dividing the resulting survival multipliers in the column labeled "Habitat Quality Improvement (Survival Improvement) projected from actions implemented through 2011" by those in the column labeled "Habitat Quality Improvement (Survival Improvement) Performance Standard 2007-2018".

subyearling Chinook salmon smolts. Test results also indicate that at some projects survival rates may be substantially exceeding these performance standards.

Reach (dam and reservoir) survival estimates for subyearling SR fall Chinook salmon and yearling spring/summer Chinook salmon, sockeye salmon, steelhead, and UCR spring Chinook salmon and steelhead all appear to be meeting or, in the case of fall Chinook salmon, sockeye, and steelhead, substantially exceeding 2008 BiOp expectations for migrating smolts.

As described in Section 3.3, juvenile FCRPS system survival rates (integrating survival of both transported and in-river fish, including post-Bonneville delayed effects of FCRPS passage) for SR steelhead (and to a much lesser extend SR spring/summer Chinook salmon) have likely declined, at least in some years. Too little information is available to make a meaningful estimate for naturally produced sockeye salmon or fall Chinook salmon. The Action Agencies have proposed to start transport earlier (April 20) than has been the case since 2008 (April 25 to May 1), which should somewhat reduce any negative impacts that might be occurring. However, the available SAR estimates do not indicate that survival has declined substantially for either SR steelhead or spring/summer Chinook salmon since 2008. Therefore, at this time, the available information does not indicate that the survival estimates in the 2008 BiOp are not being met.

As described in Section 3.3, adult survival through the FCRPS was assumed to remain unchanged between the 2008 BiOp's "Base Period" and survival expected under the RPA. Estimates of expected adult survival were based on a few recent years of data using new technology based on PIT tags. New estimates of adult survival appear to be lower than expected for SR spring/summer Chinook, SR steelhead, and SR sockeye. It appears to be equal to or higher than expected for SR fall Chinook, UCR spring Chinook, and UCR steelhead. It is unclear whether survival rates of MCR steelhead have declined or not. However, this is not yet considered an RPA implementation deficiency because:

- We are uncertain whether new estimates represent a true difference from base survival rates, or are within the Base Period's range of variation, because we do not have estimates of survival during the 2008 BiOp's Base Period prior to 2002 using PIT tags.
- There is uncertainty about the meaning of the new estimates because there is no obvious explanation (i.e., no changes in dam configuration or ladder operations, reported harvest, or river environmental conditions).
- Within the 2008 BiOp's adaptive management approach, the Action Agencies and NOAA are initiating new studies to determine the explanation for lower survival estimates and, if appropriate, will develop modified actions to address the problem prior to 2018.

Overall, substantial progress has been made to attain the steelhead kelt goals of RPA Action 33, and the Action Agencies are funding the facilities and research necessary to provide a high level of certainty that some combination of inriver improvements, transportation, or longer-term reconditioning will achieve the 6% survival improvement goal by 2018.

Hatchery Improvement Actions (RPA Actions 39 to 42)

As described in Section 3.4.6, NOAA Fisheries has completed consultation on *X*[127] of the HGMPs submitted pursuant to the hatchery RPA Action 39. Although the site-specific benefits of these consultations were not considered qualitatively or quantitatively in the 2008 BiOp or in the 2010 Supplemental BiOp, NOAA Fisheries will now consider these additional benefits for the purposes of this supplemental opinion.

<*Placeholder for summary of analysis of new benefits not considered in 2008 BiOp*.>

Inland Avian Predation Management (RPA Action 47)

As described in Section 3.5.2, although the 2008 BiOp required the Action Agencies to develop an Inland Avian Predator Management Plan, no reductions in avian-caused mortality rates were assumed in the analysis. Actions expected in 2014 at Goose Island in Potholes Reservoir should substantially reduce mortality rates for all four UCR steelhead populations and all three UCR spring Chinook salmon populations (up to 11.4% and up to 3.0%, respectively).

Cormorant Predation Reduction RPA (Modified RPA Action 46)

As described in Section 3.5.2, the modified RPA Action 46 calls upon the Corps to reduce cormorant predation in the estuary to Base Period levels (no more than 5,380 to 5,939 nesting pairs on East Sand Island).

Research, Monitoring, and Evaluation (RPAs 50-73)

The 2008 BiOp evaluated effects of RME qualitatively in Section 8.1.4. Section 3.8 of this supplemental opinion quantifies the expected change in survival resulting from the RME program and finds that it is very small, well under 1% for any population, and therefore not a significant change in the 2008 BiOp's qualitative assumptions.

Climate Change Adaptation Action

While not the subject of a specific RPA action, the 2008 BiOp relied upon many of the actions called for in various RPAs to support salmon and steelhead adaptation to climate change following principles outlined in ISAB (2007) and recent literature referenced in Section 2.1. Section 3.9 concludes that the actions are occurring as expected and the qualitative effects anticipated in the 2008 BiOp are likely to be achieved.

[127] *Placeholder*

Summary of Effects

As described in Sections 3.1 through 3.9 and summarized above, the effects of all RPA actions are expected to be within expectations of the 2008 BiOp. In reaching this determination, NOAA Fisheries considered apparent reductions in juvenile system survival and adult survival through the hydropower system, but determined that these factors remain within the BiOp's expectations for reasons described above. Additionally, survival is expected to improve beyond 2008 BiOp expectations for all interior Columbia species and populations as a result of the modification to RPA Action 46 requiring a reduction in the number of cormorants on East Sand Island, and survival is expected to be further above expectations for specific species and populations as a result of tributary habitat improvement actions, hatchery improvements, and tern management in the upper Columbia area.

3.11.2 Relevance of RPA Implementation to Lower Columbia Basin Salmon and Steelhead Species

The RPA requires the Action Agencies to implement actions that address the negative effects of the FCRPS on the viability of the lower Columbia basin ESUs and DPSs, while recognizing that their generally poor status is primarily the result of other limiting factors and threats such as habitat degradation, tributary hydropower impacts, historical harvest rates, and hatchery production practices (Section 2.1.2 in this document). Section 1.2.3.2 in USACE et al. (2007) describes the historical effects of the hydrosystem on all Columbia basin species, including changes in water management since the 1990s that have restored a portion of the historical spring peak flows in the lower Columbia River. Structural changes at Bonneville Dam are improving passage conditions for juveniles from gorge populations of LCR Chinook and coho salmon, CR chum salmon, and LCR steelhead (Section 3.10.3.1). The Action Agencies are mitigating for the remaining effects of RPA operations on lower Columbia basin species, including the remaining effect on spring flows and estuary habitat due to FCRPS operations, and the inundation of some spawning and rearing habitat by Bonneville Reservoir with the specific RPA measures described in sections 3.1 through 3.10. NOAA Fisheries finds that the effects of all RPA actions on lower Columbia basin species are expected to at least be within expectations of the 2008 BiOp. Additionally, survival is expected to improve beyond 2008 BiOp expectations as a result of the amended RPA 46 cormorant management action.

3.11.3 Relevance of RPA Implementation to Designated Critical Habitat

The RPA is improving the functioning of designated critical habitat for Columbia basin salmonids by improving mainstem passage conditions, reducing limiting factors in tributary and estuary habitat, and reducing numbers of fish, bird, and sea lion predators. Actions implemented to date are improving the conservation value of critical habitat in both the short and long term. Effects on recently designated critical habitat for LCR coho salmon are identical to those described in the 2008 BiOp for other Columbia basin species. Thus, NOAA Fisheries' analysis of the effects of the RPA on the conservation value of critical habitat in the 2008 and 2010 opinions continues to be supported by the best available scientific information.

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Section 4: Conclusions for Salmon and Steelhead

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4.1 2013 Determinations for Interior Columbia Basin Salmon and Steelhead

NOAA Fisheries concludes that the §7(a)(2) analysis of the 2008 BiOp remains valid, as supplemented in 2010, and further by the additional project definition and analysis contained in this supplemental opinion. Therefore, this biological opinion supplements without replacing the 2008 and 2010 FCRPS BiOps[128].

In reaching this conclusion, NOAA Fisheries addressed the 2011 court remand order, which requires a more detailed implementation plan for habitat mitigation projects for the 2014 through 2018 period and a determination that the projects' effects are reasonably likely to occur and to achieve the survival improvements anticipated in the 2008 BiOp. As described in Section 1.1, the remand order raised three issues, which we address in Section 3.11 and recapitulate in Sections 4.1.1 through 4.1.3. Additionally, NOAA Fisheries evaluated the current validity of the ESA analysis contained in the 2008 and 2010 FCRPS BiOps. This entailed reviewing new data concerning the status of the listed species, changes to the environmental baseline, and cumulative effects. NOAA Fisheries also considers the information about effectiveness of the RPA's implementation to date. NOAA Fisheries also considers whether the Action Agencies have implemented the RPA as intended, or whether any significant discrepancies deviate from the effects expected to result from the RPA actions. These considerations are reviewed in Sections 4.1.4 and 4.1.5.

[128] The 2008 BiOp also provided an evaluation of NOAA Fisheries' issuance of an ESA Section 10(a)(1)(A) permit to the Corps of Engineers for their Juvenile Fish Transportation Program, a procedure NOAA has followed since 1992. While that analysis remains valid and informs this supplemental opinion, NOAA Fisheries no longer will issue such a permit because the effects of the Juvenile Fish Transportation Program are already considered in the ESA Section 7(a)(2) consultation as an integral component for FCRPS operations (see RPA Actions 30 and 31; Section 3.3.2.4. This change in procedure is consistent with NOAA/FWS 1998 ESA Consultation Handbook, p. 4-53. Juvenile Fish Transportation Program take is therefore exempted by the FCRPS Incidental Take Statement issued with this opinion. See Section 8.

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4.1.1 Effects of Habitat Mitigation Projects for 2014–2018 are Reasonably Certain to Occur

As required by the 2011 court remand order, the Action Agencies' 2014–2018 Draft IP identified tributary and estuary habitat actions through 2018. Those actions contain a significant level of detail, including identification of populations to benefit; type of work to be accomplished; limiting factors addressed; extent of area to be treated, volume of water or area of habitat to be protected, or other relevant metrics; and location of work (e.g., river mile, local jurisdiction, address, or road access). Action Agencies have committed to implement the program through 2018, have developed infrastructure to implement projects, and have demonstrated the ability to implement projects through their record of projects implemented through 2012. As described in Sections 3.1, 3.2, and 3.11, projects described for implementation during 2014 through 2018 are detailed and developed to the same or better degree as projects that were presented in the Action Agencies' 2010–2013 Implementation Plan (USACE et al. 2010). Those prospective projects are at least as certain, if not more so, to be as effective as the pre-2014 projects.

4.1.2 Prospective Habitat Mitigation Satisfies Performance Standards

In Section 3.11, NOAA Fisheries concluded that tributary and estuary habitat projects identified for implementation after 2014, when added to projects implemented since 2007, are sufficient to achieve the RPA's Habitat Quality Improvement (HQI) objectives set forth in RPA Action 35, Table 5, and the associated survival improvements for listed salmonids in tributary habitat, as well as the estuary survival improvement objectives set forth in RPA Actions 36 and 37.

As a first step in reaching this conclusion, in Sections 3.1, 3.2, and 3.11, NOAA Fisheries reviewed the methods of estimating the effects of tributary habitat and estuary habitat projects and determined that they represent the best available science (see Section 4.1.3, below).

In Section 3.1 and 3.11 we determined, for populations where projections based on expert panel results indicate the tributary habitat performance standards will be achieved and where the Action Agencies have already made significant implementation progress, it is reasonably certain the HQI performance standards will be met. In Sections 3.1.2.3 through 3.1.2.7, NOAA Fisheries gave additional scrutiny to the Action Agencies' strategies for populations for which less than 33% of the HQI performance standard will be achieved by projects implemented through 2011 and/or for which supplemental actions were identified subsequent to expert panel review. Following that detailed review, using the same methods applied by the tributary habitat expert panels, NOAA Fisheries has also determined that it is reasonably certain that the HQI performance standards for those populations will be met.

Section 3.11 concluded that the Action Agencies are on track to implement the estuary habitat improvement program such that estuary survival performance standards of RPA Actions 36 and 37 are reasonably certain to be satisfied. This conclusion is based on the likelihood of implementation as described above, use of best available scientific information for analyzing effects (Section 3.2.1.3), creation of a roadmap (strategy and action plan) in the form of the CEERP, and formation of the ERTG, tasked with reviewing and upgrading the survival benefit scoring process and applying the SBU calculator to project design. A key recommendation from that group is that the most effective strategy for improving estuarine habitat for salmonids is to implement large habitat improvement projects, located close to the mainstem, that reconnect flood and tidal influences. This strategy is the basis of the Action Agencies' 2014-2018 estuary program. Although key 2014-2018 projects were defined subsequent to ERTG review, the ERTG's methods were applied to evaluation of the proposed projects and in Sections 3.2.2.2 and 3.2.2.3 NOAA Fisheries concludes that the estuary habitat projects are likely to achieve the 2008 BiOp's expected survival improvements.

4.1.3 Methodology to Determine the Efficacy of Habitat Mitigation Uses Best Available Information

As described in Sections 3.1.1.8 and 3.11, NOAA Fisheries finds that the approach developed and information gathered through the Remand Collaboration Habitat Workgroup, and subsequently applied here, represents the best available scientific information that can be consistently applied over the larger Columbia basin to estimate the survival response of salmonids to tributary habitat mitigation actions. Sections 3.1.1.2 through 3.1.1.7 review the methods and evidence relevant to this determination. NOAA Fisheries first reviews scientific literature on the subject of habitat restoration, which indicates that many habitat restoration actions such as those being implemented by the Action Agencies can improve both habitat condition and salmon survival. Preliminary results from the Action Agencies' monitoring and evaluation program (see Section 3.1.1.3) also provide evidence that the Action Agencies' habitat improvements are correctly targeting and addressing degraded conditions and that fish are responding through increased abundance, density, and survival. Section 3.1.1.5 reviews analytical options and determines that the approach used to estimate changes in habitat as a result of implementing tributary habitat actions and the corresponding survival improvements is based on the best available scientific information from fish and habitat experts and on general empirical relationships between habitat quality and salmonid survival.

Sections 3.2.1.3 and 3.11 reviewed the ERTG's method of estimating SBUs to evaluate the survival changes likely from habitat improvement projects and conclude that this method for determining the efficacy of estuary habitat actions uses the best science available. Although many of the key inputs to the SBU Calculator are quantitative (e.g., water surface elevation and weighting factors based on fish densities), professional judgment is necessarily a prominent element of the process to assign SBUs. The ERTG scores for success, habitat access, and habitat capacity in the SBU calculator use professional judgment within a scoring criteria framework. The ERTG method combines quantitative metrics with professional judgment, which is applied within a science-based process by a group of scientists who are experts in the subject matter.

4.1.4 RPA Implementation is Consistent with the 2008/2010 BiOps' Expectations

Based on RPA implementation to date described in the 2013 Draft CE, the Action Agencies' 2014–2018 Draft IP, and the review of RPA action implementation in Sections 3.1 through 3.9, NOAA Fisheries determined in Section 3.11 that all RPA actions are likely to be implemented by 2018 as anticipated in the 2008/2010 BiOps.

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4.1.5 New Information Reveals No Significant Deviation from Expected Effects of the RPA

Approach

The 2008 BiOp evaluated the effects of the RPA relevant to the survival and recovery prongs of the jeopardy standard in a manner consistent with recovery planning criteria and analyses

- first at the individual population level;
- second, at the MPG level; and,
- finally, reaching ESA § 7(a)(2) conclusions at the species level.

Our determination for this supplemental opinion is that, if there are no significant changes in the effects of the action at the population level, then it follows that there are no changes from the effects considered in the 2008 BiOp at the MPG and species level. If there are changes at the population level then it would be necessary to determine if those changes are significant at the MPG or species levels. We therefore initially focus our analysis at the population level.

Population-Level Analysis

The application of the jeopardy standard (see Section 1.7 in the 2008 BiOp) required determining that the aggregate effects of the environmental baseline, cumulative effects, and effects of the action would ensure that the species would survive with an adequate potential for recovery. This determination was informed by a quantitative analysis at the population level that evaluated the following:

- **Species Status.** The likelihood of extinction and likelihood of population growth necessary to support species (ESU/DPS) recovery levels (based on productivity metrics), calculated from observed population data over a recent time period of approximately 20 years (referred to as the "Base Period")[129]
- **Environmental Baseline.** Adjustments to those Base Period productivity metrics due to effects of continuing:
    - ◊ Current (i.e. as of 2008) management practices that differed from the average practices that occurred during the 20-year Base Period (e.g., reduced harvest rates, recent hydro improvements) that have undergone Section 7 consultation; and
    - ◊ Current (i.e. as of 2008) ecological processes in the action area that differed from those that occurred during the 20-year Base Period (e.g., changes in avian and marine mammal predation rates).

[129] The 'base period' necessarily precedes the time of the consultation, i.e. 'current', by the date of the most recently observed population data—often a 5–10 year period immediately before the time of consultation for which observed data is not yet available.

- **Cumulative Effects.** If any cumulative effects had been identified in the 2008 BiOp, the metrics would have been adjusted to reflect those future effects of non-Federal actions.
- **Effects of the RPA.** The Base Period metrics were further adjusted to reflect the expected incremental effects of the RPA actions.

Because the method applied to interior Columbia basin species builds on metrics informed by the most recent status and incrementally adjusts those metrics based on other factors, changes in any of the above categories can influence the assessment of the effect of the RPA on each population. We therefore review each of these factors to determine if newly available information indicates a deviation from the fundamental expectations of the 2008 BiOp's analysis of these factors.

- If none of these factors have changed for a particular population, we can conclude that the effects of the action have not changed for that population.
- If some factors have changed for a particular population, we need to evaluate whether a change in one factor (e.g., a higher than anticipated survival improvement associated with the RPA) balances a change in another factor (e.g., lower than anticipated survival associated with environmental baseline predation rates). If the survival changes do not balance, a judgment must be made regarding the significance of the difference.
    - ◊ The primary factor informing the significance of the change is the degree to which it would affect the overall prospective analysis for that population in the 2008 BiOp. For example, if the estimate of a metric is reduced by 2%, does it affect the ability to meet the goal for that metric (i.e., would a population continue to have an expectation of R/S productivity greater than 1.0 after the RPA is fully implemented)?
- If there have been no significant changes in the effects of the action for any populations of a species, we can conclude that there have been no changes in the effects of the action for the affected MPG(s) or the species.
- If significant changes in the effects of the action are identified for some populations, we must evaluate the impact of those changes at the MPG level and, if significant, at the species level following the qualitative approach described in the 2008 BiOp sections 7.1.2.2, 7.1.2.3, and 7.3.

Review of New Information

Rangewide Status

In Section 2.1, we determined that new information regarding the status of interior Columbia and lower Columbia salmon and steelhead species and their critical habitat supports NOAA Fisheries' continued reliance on the 2008 BiOp's description of the rangewide status of these species and their critical habitat. Additionally, new information supports continued reliance on the Base Period metrics and their associated range of variability applied in the 2008 BiOp's quantitative analysis for six interior Columbia species. That new information indicates no statistically significant changes in Base Period metrics, consistent with NOAA Fisheries' GPRA Report finding that all interior Columbia species have been "stable" in recent years, except for SR sockeye, which have been "mixed." However, some populations' point estimates did change, compared to those in the 2008 BiOp, with:

- point estimates of mean abundance higher for most populations;
- point estimates of BRT abundance trend higher for most populations;
- point estimates of 24-year extinction risk either unchanged or lower (i.e., less risk of extinction) for most populations; and
- estimates associated with productivity metrics (particularly average R/S) generally lower for most populations.

The pattern of lower R/S productivity in some high abundance years was consistent with expectations of density dependence described in the 2008 BiOp and in the 2010 Supplement. The NWFSC statistically tested this interpretation and concluded that there is strong support for the hypothesis that productivity has not decreased for these populations when comparing base to recent time periods; rather, the decreased R/S resulted from density-dependent processes as a result of the increased abundance observed recently (see Section 2.1.1.4.4 and Appendix C in this document).

We also determined through a review of recent climate observations and new literature regarding future climate projections in Section 2.1 that analytical and qualitative treatment of climate variability in the 2008 BiOp remains reliable.

Environmental Baseline

In Section 2.2, we determined that new information indicates that effects of most factors influencing the environmental baseline remain similar to those considered in the 2008 BiOp and that NOAA Fisheries should continue to rely on most Base-to-Current survival estimates in the 2008 BiOp for the quantitative analysis applied to six interior Columbia basin species. These factors include tributary habitat; estuary habitat; FCRPS hydropower; fish, pinniped, and Caspian tern predation; and harvest.

However, effects of some factors influencing the environmental baseline differ in a manner that could affect the overall analysis of effects of the action for some species:

- **Cormorant Predation.** The 2008 BiOp's quantitative analysis for interior Columbia basin species implicitly assumed that cormorant predation rates were, and would remain, unchanged from average predation rates during the 2008 BiOp's Base Period. New information indicates that cormorant predation rates have been higher (and therefore salmon and steelhead survival has been lower) than that occurring in the 2008 BiOp Base Period. This affects Base-to-Current estimates with a reduction, compared to 2008 BiOp estimates:
    - ◊ for all Chinook populations (-1.1%); and
    - ◊ for all steelhead populations (-3.6%).
- **Hatcheries.** The 2008 BiOp included estimated changes in productivity expected from hatchery management actions implemented in the latter part of the 2008 BiOp's Base Period that either reduced the percentage of hatchery-origin spawners or increased the reproductive effectiveness of those spawners, or both.
    - ◊ Updated estimates based on new information <u>increase</u> the 2008 BiOp's Base-to-Current survival estimates for three populations of SR spring/summer Chinook in the Grande Ronde/Imnaha MPG and for three populations of the UCR steelhead DPS.
        - Catherine Creek population of SR spring/summer Chinook (+10%)
        - Upper Grande Ronde population of SR spring/summer Chinook (+6%)
        - Lostine River population of SR spring/summer Chinook (+8%)
        - Wenatchee population of UCR steelhead (+11%)
        - Methow population of UCR steelhead (+19-57%)
        - Okanogan population of UCR steelhead (+6%)

- ◊ Updated estimates based on new information decrease the 2008 BiOp's Base-to-Current survival estimates for two populations of SR spring/summer Chinook in the Grande Ronde/Imnaha MPG.
    - Minam River population of SR spring/summer Chinook (-5%)
    - Wenaha River population of SR spring/summer Chinook (-2%)

Cumulative Effects

In Section 2.3, we determined that the analysis of cumulative effects in the 2008 BiOp remains accurate for this supplemental opinion.

RPA Implementation

In Sections 3.1 through 3.9, we reviewed the implementation of specific RPA actions and new information regarding the effects of those actions in comparison to expected effects relied upon in the 2008 BiOp. In Section 3.11, the combined effects of implementing all RPA actions were described. Briefly, that section concluded the following:

- **Cormorant Predation Management**. The modification to RPA 46 described in Section 3.5.2 calls upon the Corps to reduce the number of cormorant nesting pairs to a level that NOAA Fisheries estimates would return predation rates to 2008 BiOp Base Period levels. This would be expected to increase salmon survival:
    - ◊ for all Chinook populations (+1.1%); and
    - ◊ for all steelhead populations (+3.6%).
- **Tributary Habitat Improvement Actions**. These are expected to achieve higher than anticipated survival improvements for a number of populations, based on implementation of projects through 2011 and evaluation of effects by expert panels. The relative survival improvements, beyond those anticipated in the 2008 BiOp range from +1% to +20% (i.e., additional survival multipliers of 1.01 to 1.20) and affect eight SR spring/summer Chinook populations and five SR steelhead populations.
    - ◊ Lostine/Wallowa population of SR spring/summer Chinook (+1%)
    - ◊ South Fk Salmon Mainstem population of SR spring/summer Chinook (+1%)
    - ◊ Secesh River population of SR spring/summer Chinook (+4%)
    - ◊ Lemhi River population of SR spring/summer Chinook (+20%)
    - ◊ Valley Creek population of SR spring/summer Chinook (+12%)

- ◊ Lower Salmon River population of SR spring/summer Chinook (+2%)
- ◊ East Fork Salmon population of SR spring/summer Chinook (+1%)
- ◊ Pahsimeroi River population of SR spring/summer Chinook (+15%)
- ◊ Asotin population of SR steelhead (+1%)
- ◊ Imnaha population of SR steelhead (+ less than 1%)
- ◊ Wallowa population of SR steelhead (+1%)
- ◊ Lemhi population of SR steelhead (+19%)
- ◊ Pahsimeroi population of SR steelhead (+17%)

- **Hatchery Improvement Actions.** As described in Section 3.4.6, NOAA Fisheries has completed consultation on *X*[130] of the HGMPs submitted pursuant to the hatchery RPA Action 39. Although the site-specific benefits of these consultations were not considered qualitatively or quantitatively in the 2008 BiOp or in the 2010 Supplemental BiOp, NOAA Fisheries will now consider these additional benefits for the purposes of this supplemental opinion.

  <Placeholder for summary for analysis of new benefits not considered in 2008 BiOp.>

- **Inland Avian Predation Management.** Although the 2008 BiOp required the Action Agencies to develop an Inland Avian Predator Management Plan, no reductions in avian-caused mortality rates were assumed in the 2008 BiOp's analysis. Actions expected in 2014 at Goose Island in Potholes Reservoir should substantially reduce mortality rates for two Upper Columbia species:
  - ◊ All populations of UCR steelhead (up to 11.4%); and
  - ◊ All populations of UCR spring Chinook salmon (up to 3.0%).

[130] *Placeholder*

Aggregate Effects of All New Information

As described above, a review of new information relevant to population status, the environmental baseline, cumulative effects, and implementation of the RPA indicates that effects of the RPA actions will be the same or, for 22 populations, more beneficial than anticipated in the 2008 BiOp. Only two populations of SR spring/summer Chinook have survival estimates that are lower than described in the 2008 BiOp. However, as discussed below, these new estimates would not change the population-specific indicator metric estimates relative to the metric goals, and therefore do not represent significant changes from the 2008 BiOp estimates. Overall, new information indicates no significant changes in 2008 BiOp expectations for effects of the RPA at the population level.

A key consideration in reaching this determination is the treatment of cormorant predation in the Columbia River estuary and implementation of a management program to reduce that predation through a modification of RPA 46. The 2008 BiOp's quantitative analysis for interior Columbia basin species implicitly assumed that cormorant predation rates were, and would remain, unchanged from average predation rates during the 2008 BiOp's Base Period. Because new information indicates that cormorant predation rates have been higher (and therefore salmon and steelhead survival has been lower) than that occurring in the 2008 BiOp Base Period, Base-to-Current survival is lower than estimated in the 2008 BiOp for all populations of interior Columbia basin species. However, in response to this new information, modification of RPA 46 calls upon the Corps to implement management actions by 2018 that will reduce cormorant nesting pairs, such that predation is reduced to a level equivalent to that during the 2008 BiOp's Base Period. The improvement in survival associated with the modified RPA 46 is expected to balance the reduced estimate of environmental baseline survival, leading to no net change in the 2008 BiOp's survival expectations related to cormorant predation.

Additionally, new information indicates that higher survival than that estimated in the 2008 BiOp for 22 populations of SR spring/summer Chinook, SR steelhead, UCR spring Chinook, and UCR steelhead (see lists of populations in discussion above) as a result of;

- higher estimates of Base-to-Current hatchery improvements,
- quantification of inland avian predation reduction from RPA 47, or
- greater survival increases than expected from RPA 34 and 35 tributary habitat improvements.

These higher estimates provide additional certainty regarding beneficial effects of RPA actions, as described in the 2008 BiOp, for the affected populations.

New information did indicate lower Base-to-Current survival than that estimated in the 2008 BiOp for two populations of SR spring/summer Chinook in the Grande Ronde MPG (Minam River and Wenaha River) as a result of new straying estimates. There do not appear to be additional RPA survival estimates that are higher than expected to offset these reductions in the hatchery environmental baseline estimates.

The next step is to determine the significance of the survival estimates that decreased for the Minam and Wenaha Chinook populations by approximately 5% and 2%, respectively. As described above, the key consideration is whether that difference in survival, if incorporated into the 2008 BiOp analysis, would have changed our assessment of each population's performance relative to the jeopardy indicator metrics (see Section 2.1.1.4.1 for metric descriptions).

Upon reviewing the 2008 BiOp's prospective survival estimates along with the new information described in this supplemental opinion, NOAA Fisheries concludes that the 2008 BiOp's characterization of the ability of these two populations to meet indicator metric criteria would not change as a result of the new survival estimates. This determination is based upon the following:

Prospective Productivity Metric Estimates in the 2008 BiOp: Table 8.3.6.1-1 of the 2008 BiOp indicates that the Minam River population was expected to achieve the goal of productivity greater than 1.0 for all productivity metrics. The range of point estimates was 1.10 to 1.36, depending upon the productivity metric and the assumption regarding effectiveness of hatchery-origin spawners. If the new information about Minam River straying reduces the hatchery Base-to-Current multiplier by 5%, the 2008 BiOp prospective productivity estimates would still remain greater than 1.0, with an excess margin of 5% or more.

Table 8.3.6.1-1 of the 2008 BiOp also indicates that the Wenaha River population was expected to achieve productivity greater than 1.0 for all productivity metrics, with a range among metrics of 1.08 to 1.28. If the new information about Wenaha River straying reduces the hatchery Base-to-Current multiplier by 2%, the 2008 BiOp prospective productivity estimates would still remain greater than 1.0, with an excess margin of 6% or more.

Extended Base Period Productivity Estimates: While we concluded in Section 2.1 that changes in observed "extended Base Period" point estimates are within the range of variability expected in the 2008 BiOp, it is relevant that the direction of change for Minam and Wenaha Chinook productivity point estimates was positive for R/S productivity, lambda HF=1, and BRT trend (Tables 2.1-9, 2.1-13, and 2.1-15). Point estimates for lambda HF=0 are either the same (Minam) or only 1% less (Wenaha) than in the 2008 BiOp (Table 2.1-11). In summary, even if the extended Base Period results are looked at in more detail, the specific estimates for these two populations would add additional support for a determination that the 2008 BiOp's prospective productivity estimates would remain greater than 1.0.

Extinction Risk Estimates in the 2008 BiOp: Table 8.3.6.1-2 of the 2008 BiOp indicates that prospective estimates of 24-year extinction risk for the Minam population were less than 5% at a quasi-extinction threshold of 50 fish. Survival estimates would have to be reduced by 39% (1.0/0.72) to 59% (1.0/0.63), depending upon assumptions regarding speed of survival rate improvements, to change the conclusion that the extinction risk goal was likely to be met. Therefore, the estimated 5% survival reduction from increased hatchery straying would not affect the 2008 BiOp's prospective extinction risk estimates.

Table 8.3.6.1-2 of the 2008 BiOp indicates that prospective estimates of 24-year extinction risk for the Wenaha population depended upon assumptions regarding the speed at which survival improvements associated with the RPA would be achieved. Under one assumption, no RPA actions would improve survival within a time frame sufficient to reduce 24-year extinction risk (i.e., only Base-to-Current survival changes from completed actions were applied). Under this assumption, prospective extinction risk was estimated to be greater than 5% and survival would have to increase an additional 2% to meet the ≤5% risk goal. For this implementation assumption, a 2% survival reduction from recent hatchery straying would not change the 2008 BiOp's determination of failing to meet the ≤5% risk goal, but it would slightly increase the level of additional improvement needed to meet the goal.

Under an alternative assumption that all RPA improvements would be implemented in time to contribute to reducing 24-year extinction risk, prospective extinction risk would be less than 5% and this would not change unless survival were reduced by at least 12% (1.0/0.89). Therefore, the estimated 2% survival reduction from increased hatchery straying would not change the 2008 BiOp's determination that prospective extinction risk estimates would be ≤5% risk under this assumption and a survival exceedance margin of approximately 10% would remain.

As described in the 2008 BiOp Chapter 7.1.1.1, these two assumptions about the rate of attaining survival improvements relevant to 24-year extinction risk bound the range of expectations and "the true extinction risk associated with prospective actions is expected to be somewhere between these two extremes."

Extended Base Period Productivity Estimates: While we concluded in Section 2.1 that changes in observed "extended Base Period" point estimates are within the range of variability expected in the 2008 BiOp, it is relevant that the direction of change for Minam and Wenaha Chinook 24-year extinction risk point estimates was positive (Table 2.1-7). In fact, extended Base Period risk estimates were considerably lower for these populations (1% versus 6% extinction risk for the Minam population and 11% versus 26% risk for the Wenaha) and, if explicitly incorporated, would reduce the effect of lower hatchery Base-to-Current estimates for these populations on prospective extinction risk and further support the conclusion that the extinction risk analysis would not change as a result of new information.

Summary

New information indicates no significant change in effects of the RPA at the population level, compared to the estimated effects relied upon in the 2008 BiOp. For most populations, new information revealed either no net survival changes or the changes indicated higher survival than anticipated in the 2008 BiOp, providing additional certainty regarding beneficial effects of RPA actions. Lower Base-to-Current estimates for the Minam and Wenaha Chinook populations would not change the population-specific indicator metric estimates relative to the metric goals, and therefore do not represent significant changes from the 2008 BiOp's estimates.

Because there are no significant changes at the population level, NOAA Fisheries finds that new information reveals no significant discrepancies that deviate from the effects expected to result from the RPA actions for interior Columbia Basin salmon and steelhead at the MPG or species (ESU/DPS) level.

Summary for SR Sockeye Salmon

In the 2008 BiOp, NOAA Fisheries concluded that the aggregate effects of the environmental baseline, the RPA, and cumulative effects would be an improvement in the viability of SR sockeye salmon. Some limiting factors are being addressed by improvements to mainstem hydrosystem passage including the installation of surface passage routes and other configuration changes and controlling summer water temperatures in the lower Snake River by regulating outflow temperatures at Dworkshak Dam. The elevated temperature conditions in the Salmon River portion of the adult migration corridor during summer, a characteristic of the environmental baseline, have not improved, but the Action Agencies continue to experiment with adult trap and haul from Lower Granite Dam to the Sawtooth Valley as a mitigation measure. Water transactions implemented for SR spring/summer Chinook and steelhead in the mainstem Salmon River are likely to improve the survival of adult migrant sockeye returning to the Sawtooth Valley in July and August. Taking into account the obstacles faced, NOAA Fisheries continues to conclude that the RPA provides for the survival of the species with an adequate potential for recovery.

4.1.6 Conclusions for Interior Columbia Basin Salmon and Steelhead

In previous sections, NOAA Fisheries determined the following:

- The Action Agencies developed a more detailed implementation plan for habitat mitigation projects for the 2014 through 2018 period and those project effects are reasonably certain to occur. (Section 4.1.1)
- Prospective habitat mitigation satisfies performance standards of RPA actions 35 through 37. (Section 4.1.2)
- The methodology used by the Action Agencies to determine the efficacy of the habitat actions uses the best science available. (Section 4.1.3)
- The RPA is being implemented in the manner considered in the 2008/2010 BiOps. (Section 4.1.4)
- New information reveals no significant discrepancies that deviate from the effects expected to result from the RPA actions at the population, MPG, or species level.

In summary, NOAA Fisheries continues to find that the RPA, as amended through this supplemental biological opinion, is not likely to jeopardize the continued existence of listed SR spring/summer Chinook, SR fall Chinook, SR steelhead, SR sockeye, MCR steelhead, UCR spring Chinook, or UCR steelhead.

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4.2 2013 Determinations for Lower Columbia Basin Salmon and Steelhead

In reaching its conclusions for lower Columbia basin salmon and steelhead (CR chum salmon, LCR Chinook salmon, LCR coho salmon, LCR steelhead, UWR Chinook salmon, and UWR steelhead), NOAA Fisheries considers information that has become available since our reviews in the 2008 and 2010 opinions. As for the interior Columbia basin stocks, the relevant areas of new information concern the rangewide status of these species (especially the information used in NMFS' recent 5-year status review for ESA-listed salmon and steelhead), scientific papers on the biological effects of climate change, recently completed consultations on actions that affect conditions in the lower Columbia River, estuary, and plume (e.g., NMFS' 2013 biological opinion on the Odessa Groundwater Replacement Project), updates to our estimates of cormorant predation in the lower Columbia River, and information on implementation of the RPA in the Action Agencies' 2013 Draft CE and 2014–2018 Draft IP.

Effects of RPA implementation on lower Columbia basin ESUs and DPSs vary between species. Four (CR chum, LCR Chinook, and LCR coho salmon and LCR steelhead) have populations in the upper gorge and thus are affected by passage conditions at Bonneville Dam and the loss of habitat that was inundated by the reservoir. The UWR Chinook ESU and steelhead DPS are not affected by Bonneville, but experience flow-mediated changes in habitat in the estuary and plume. For each of these six species, we consider whether the new information changes our evaluation of the effects of RPA implementation on the species' likelihood of survival and recovery in the 2008 and 2010 opinions.

Review of New Information

In the following sections, we summarize the information presented in Sections 2 and 3, above, and describe our rationale and conclusions regarding effects of the RPA on lower Columbia basin salmon and steelhead.

Rangewide Status of Lower Columbia Basin Salmon and Steelhead

Overall, the new information on the status of the lower Columbia basin species did not indicate a change in the biological risk category since the time of NOAA Fisheries' last status review (see Section 2.1.2). There is new information (i.e., not previously considered in NMFS's 5-year status reviews or the FCRPS biological opinion) on the Washougal population of CR chum salmon indicating there has been consistent spawning, predominantly by natural-origin fish, since at least 2002 (Section 2.1.2.1). This implies the presence of a third functioning population, in the Cascade stratum, which could reduce the species' extinction risk to some degree. In addition, a total of 177 chum fry have recorded at Bonneville Dam by the Smolt Monitoring Program since spring 2010, indicating that there has been some successful chum salmon spawning in the reservoir reach (Upper Gorge population) in recent years.

Several dams that were previously licensed by the Federal Energy Regulatory Commission and had limited the spatial structure of Chinook, coho, and steelhead populations in lower Columbia tributaries are now removed as anticipated in the 2008 BiOp. These watersheds are expected to produce natural-origin populations of LCR spring- and fall-run Chinook salmon, LCR coho salmon, and LCR steelhead in the coming years (Section 2.2.2.1). With respect to UWR Chinook salmon and steelhead, the Willamette Project action agencies have implemented a number of measures since 2008 to address factors limiting the viability of these species (Section 2.1.2.5).

Environmental Baseline

Effects of the new environmental baseline information on lower Columbia basin salmon and steelhead were similar to those described for interior ESUs and DPSs. However, the Odessa Subarea Groundwater Replacement Project (Section 2.2.1.1) is expected to reduce, very slightly, the availability of suitable spawning habitat for early spawning chum salmon in the Lower Gorge and Washougal populations. Lower Columbia and upper Willamette populations produce small subyearling fish that spend weeks to months rearing in the lower Columbia River. Their period of exposure to predation by terns and cormorants are higher than for smolts from the interior (Section 2.2.4.2). NOAA Fisheries' recent biological opinion on the harvest of LCR Chinook salmon approved an abundance based framework that allows the total annual exploitation rate to vary between 30% and 41% (Section 2.2.6), reducing risks to tule fall populations of LCR Chinook salmon under the environmental baseline compared to our assumptions in the 2008 and 2010 BiOps.

Cumulative Effects

In Section 2.3, we determined that the analysis of cumulative effects in the 2008 BiOp remains accurate for this supplemental opinion.

RPA Implementation

In Section 3.10 we reviewed the implementation of specific RPA actions and new information regarding the effects of those actions compared with effects relied upon in the 2008 BiOp. Briefly, that section concluded the following:

- **Cormorant Predation**. The modification to RPA Action 46 calls upon the Corps to reduce the number of cormorant nesting pairs to a level that NOAA Fisheries estimates would return predation rates to 2008 BiOp Base Period levels (Section 3.5.2). This action is expected to increase the survival of all lower Columbia basin Chinook and steelhead populations.
- **Tributary Habitat Improvement Actions**. The Action Agencies have provided funding to improve habitat for the Lower Gorge population of LCR coho salmon, the Hood River populations of LCR Chinook and steelhead, and the Wind River population of LCR steelhead (Section 3.10.1). For these specific populations, these

habitat improvements help to mitigate the negative effects of passage at Bonneville Dam and any loss of historical habitat under the reservoir.

- **Estuary Habitat Improvement Actions**. RME results support the value of RPA estuary habitat improvements to the viability of lower Columbia basin salmon and steelhead (Section 3.10.2). NOAA Fisheries continues to assume that these habitat improvement projects are mitigating for the negative effects of RPA flow management operations on estuarine habitat used by these species for rearing and migration.
- **Hydropower RPA Actions**.
    - ◊ The Action Agencies have implemented the measures to reduce passage delay and increase the survival of fish passing Bonneville Dam as intended in RPA Action 18. Performance standard testing (96% survival for all yearling Chinook and steelhead and 93% for all subyearling Chinook, including those from upper gorge populations) will be completed by 2018 (Section 3.10.3.1).
    - ◊ Flow operations to maintain minimum tailwater elevations for spawning and incubating chum have been implemented as anticipated given variation in annual flows conditions (Section 3.10.3.2). Rehabilitated spawning habitat in Hamilton Springs Channel substantially mitigates for impacts to the mainstem portion of the Lower Gorge population of CR chum salmon.
- **RME Program.** The incidental mortality of CR chum salmon, LCR and UWR Chinook salmon, LCR coho salmon and LCR and UWR steelhead due to handling during RPA research, monitoring, and evaluation activities is likely to be less than 1% of estimated 2008–2012 run sizes (Section 3.8.1). These effects are consistent with our estimates of the effects of RME in the 2008 BiOp.
- **RME to Address Climate Change.** NOAA Fisheries continues to conclude that sufficient actions consistent with the ISAB's recommendations for responses to climate change have been included in the RPA and that these are being implemented by the Action Agencies as planned (Section 3.9.6). This includes actions in the estuary, which benefit both interior and lower Columbia basin species.

Aggregate Effects of All New Information

As described above, a review of new information relevant to rangewide status, the environmental baseline, cumulative effects, and implementation of the RPA indicates that effects of the RPA actions on lower Columbia basin salmon and steelhead will be as anticipated in the 2008 BiOp.

Conclusions for Lower Columbia Basin Salmon and Steelhead

NOAA Fisheries continues to find that the RPA, as amended through this supplemental biological opinion, is not likely to jeopardize the continued existence of listed CR chum salmon, LCR Chinook salmon, UWR Chinook salmon, LCR coho salmon, LCR steelhead, or UWR steelhead.

4.3 2013 Determinations for Effects of the 2008/2010 RPA on Critical Habitat

NOAA Fisheries reviewed the rangewide status of designated critical habitat for Columbia basin salmonids, effects of climate change and human activities within the action area under the environmental baseline, and effects of RPA implementation in the preceding sections of this supplemental opinion. The only change to rangewide status is the recent proposal to designate critical habitat for LCR coho salmon (Section 2.1). The proposed areas overlap with existing designations for other Columbia basin salmon and steelhead and the PCEs of critical habitat within these areas are identical.

The conditions that limit the functioning of designated critical habitat under the environmental baseline, as described in the 2008 BiOp, have not significantly changed for the purpose of this consultation. The environmental baseline within parts of the action area has improved over the last decade, but as a whole does not yet fully support the conservation value of designated critical habitat for each species. Although some current and historical effects of the existence and operation of the hydrosystem and tributary and estuary land use will continue into the future, critical habitat will retain at least its current ability for PCEs to become functionally established and to serve its conservation role for each species in the near- and long-term. Implementation of the RPA (the implementation of surface passage routes at mainstem hydrosystem dams, efforts to reduce predation by birds, fish, and pinnipeds, and tributary and estuary habitat improvements) is substantially improving the functioning of many PCEs. A number of actions in the mainstem migration corridor and in tributary and estuarine areas are addressing the effects of climate change (Section 3.9). There have been short-term, negative effects on PCEs at the project scale during construction, but the positive effects will be long-term. The listed species are expected to survive until the RPA is fully implemented, as described in the 2008 BiOp and in Section 2.1, *Rangewide Status of the Species*, of this supplemental opinion. These conclusions also apply to recently proposed critical habitat for LCR coho salmon. Therefore, NOAA Fisheries concludes that the implementation of the 2008 RPA for the FCRPS, as amended in 2010 and by this consultation, is not likely to destroy or adversely affect the critical habitat designated for salmonid species and affected by the FCRPS. NOAA Fisheries further concludes that the 2008 RPA as amended is not likely to destroy or adversely modify proposed critical habitat for Lower Columbia Coho, subject to confirmation when that designation is final.

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Section 5: Southern Resident Killer Whale DPS

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5.1 New Information Relevant to the 2008/2010 BiOps

5.1.1 Updates to Abundance and Productivity

As of July 1, 2012, the Southern Resident killer whale population totals 85 individuals: J Pod = 25, K Pod = 20, and L Pod = 40 (Center for Whale Research 2012). Since the 1970s, the population has increased slowly at a realized growth rate of 0.71% per year with alternating periods of increase and decline (Hilborn et al. 2012). The low population size and low rate of population increase are two issues of concern about the Southern Residents' status (Hilborn et al. 2012).

The recent five-year species status review (NMFS 2011i) concludes that while some of the biological down-listing and delisting criteria have been met (i.e., representation in all three pods, multiple mature males in each pod) the overall status of the population is not consistent with a healthy, recovered population. Therefore, Southern Resident killer whales remain in danger of extinction and maintain the classification of Endangered. NOAA Fisheries accepted a petition to delist the Southern Resident DPS on November 26, 2012. Based on our review of the petition, public comments, and the best available scientific information, we found that delisting the Southern Resident killer whale DPS was not warranted (NMFS 2013i).

5.1.2 Updates to Spatial Distribution and Diversity

The Southern Resident killer whale DPS is composed of a single population that ranges from central California to Southeast Alaska. During the period from July to September, Southern Residents primarily inhabit the Salish Sea and the coastal waters near the entrance to the Strait of Juan de Fuca (Ford et al. 2012b). Their winter habitat use remains a key data gap. Based on the available data, Southern Residents are sometimes distributed off of central California during the winter months, though more frequently they are found off the Washington coast (Hilborn et al. 2012).

Research is currently underway to improve our understanding of the Southern Residents' winter habitat use by using satellite-linked tags. An independent science panel that assessed the impact of salmon fisheries on Southern Resident killer whales recently identified satellite-tagging as an important approach for addressing winter habitat use (Hilborn et al. 2012). For more information about the satellite-tagging project, please visit: http://www.nwfsc.noaa.gov/research/divisions/cbd/marine_mammal/satellite_tagging.cfm.

The estimated population effective size[131] is very small: less than 30 whales, or about one-third of the current population size (Ford et. al. 2011). The small effective population size,

[131] Effective population size is the number of individuals in a population who contribute offspring to the next generation.

absence of gene flow from other populations, and documented breeding within pods may elevate the risk of genetic deterioration (Ford et al. 2011). In addition, the small effective population size may contribute to the lower growth rate of the Southern Resident population in contrast to the Northern Resident population (Ward et al. 2009; Ford et al. 2011).

5.1.3 Updates to Limiting Factors

Statistical analyses link Chinook salmon abundance with killer whale fecundity and survival (Ward et al. 2009; Ford et al. 2010), suggesting a linear relationship. NOAA Fisheries recently conducted a scientific review of the effects of salmon fisheries on Southern Resident killer whales. Based on the statistical analyses they reviewed, the independent science panel identified low confidence that the predicted changes in prey availability due to salmon fisheries would affect the population growth rate of Southern Residents (Hilborn et al. 2012).

5.1.4 Relevance to the 2008 BiOp's Analysis and RPA

Since the 2007 census (87 whales, reported in the 2008 BiOp) the population size of Southern Resident killer whales has decreased by two whales, from 87 (reported in the 2008 BiOp) to 85; however, the slight change does not modify the assessment of the status and trends of this small population as reported in the 2008 BiOp. Research in progress, highlighted above, will improve our understanding of the health status of the population and its prey requirements. In the meantime NOAA Fisheries makes conservative assumptions about Southern Resident prey requirements, discussed in Section 5.2.1.4.

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5.2 Updates to Habitat Conditions and Ecological Interactions Affecting the Southern Resident Killer Whale

The following paragraphs describe new scientific information on Southern Resident killer whale prey requirements, quality, and quantity since the 2008/2010 BiOps analyses. Past and current data continue to show Southern Residents' preference for Chinook salmon in inland waters, and support the assumption that Southern Residents prefer Chinook salmon in coastal waters. The updated information does not affect the conclusion that Columbia basin hatchery production offsets losses to the killer whale prey base due to the existence and operation of the hydrosystem.

5.2.1 New Scientific Information to Update the 2008/2010 BiOps' Analysis

5.2.1.1 Prey requirements

Prey preferences in inland waters

The prey preferences of Southern Residents are the subject of ongoing research including direct observation of predation events, scale and tissue sampling of prey remains, and fecal sampling. Data from ongoing research supports Southern Residents' preference for, and heavy reliance on, Chinook salmon, particularly during the summer, but show that they also select other species such as chum salmon, smaller salmonids, or other non-salmonid prey (herring, rockfish), at times or locations of low Chinook abundance. Based on genetic analysis of feces and scale samples, Chinook from Fraser River stocks dominate the diet of Southern Residents in the summer (Hanson 2011) when Southern Residents are primarily in the Puget Sound and the Strait of Juan de Fuca.

Size selectivity

Review and summary of recent data by an independent science review panel (Hilborn et al. 2012) supports previous determinations in the 2008 BiOp and Ward et al. (2008, 2010) and Ford and Ellis (2006) that Southern Residents consumed older (larger) fish in far greater proportion than their presence in the available prey base.

Table 5.2-1. Mean abundance of prey by age class (percentage) and kills by age class

Age class of prey	NWFSC (n = 75)		Ford and Ellis (2006) (n = 127)	
	% Abundance	% Kills	% Abundance	% Kills
Age 2	59.0	-	9.6	0.7
Age 3	25.8	10.4	35.7	11.3
Age 4	13.4	45.5	48.0	55.9
Age 5	1.7	41.6	6.5	31.5

Prey preferences in coastal waters

Southern Residents' prey preference in coastal waters is a subject of ongoing research. The lack of winter diet data outside of Puget Sound limits the ability to assess the degree to which Southern Resident killer whales rely on chum salmon, smaller Chinook salmon, or other fish species in coastal waters.

Samples obtained in Puget Sound from October to December suggest a greater reliance on chum salmon and demersal species during winter months, although 16 samples collected in coastal waters indicate that Chinook and chum have similar contributions to their diet (Hanson 2011). There were also direct observations of two predation events in coastal waters of Washington State in which the prey were identified by genetic analyses as Columbia River spring Chinook stocks (Hanson et al. 2010).

Stable isotope ratios and contaminant fingerprints

A recent evaluation of Southern Resident biopsy samples provides some new information about their diet. This information was presented to an Independent Science Review Panel (ISRP), who concluded that limited data on stable isotope ratios of skin biopsies suggest that L pod's dietary trophic level may have changed over the last decade and that the dietary trophic level of K pod varies seasonally (O'Neill et al. 2012a as cited in Hilborn et al. 2012). In addition, ratios of lipophilic contaminants in blubber biopsies found that the blubber of K and L pod match with similar ratios of prey species in California, which was indicated by the relatively high concentrations of dichlorodiphenyltrichloroethane (DDT). The ISRP concluded that these DDT fingerprints suggest fish from California form a significant component of their diets (Krahn et al. 2007, 2009; O'Neill et al. 2012b as cited in Hilborn et al. 2012).

Metabolic needs

Since 2010, the NWFSC has continued to refine its model to estimate the potential range of daily energy expenditure for Southern Resident killer whales for all ages and both sexes (Noren 2011a, 2011b). The model provides a range in daily energy expenditure to represent uncertainty in the calculations. In a recent review, the ISRP concluded that the modeling approach produces reasonable estimates of energy needs (Hilborn et al. 2012). Noren (2011b) cautions that until additional information on Southern Resident killer whale body size and the energetic costs of growth in young animals and adolescent males, and lactation in females are better known, it is probably best to estimate population energetic needs and prey consumption rates based on the upper bound equation, which is the high end of the range in daily energy expenditure estimates.

Prey ratios

An ISRP critiqued NOAA Fisheries' use of forage ratios to evaluate the potential for Southern Residents' prey deficiency. The ISRP concluded that ratios of energy needed by Southern Residents to the energy available to them from Chinook salmon are not useful for understanding whether reductions in Chinook salmon affect the population dynamics of Southern Residents. The identified a lack of objective means to evaluate the biological significance of the ratios on the status of Southern Residents. Therefore, NOAA Fisheries no longer uses prey ratios in this context.

5.2.1.2 Prey Quantity

While previous research correlated coastwide reductions in Chinook abundance (Alaska, British Columbia, and Washington) with decreased survival of resident whales from the Northern and Southern Resident DPSs (Ford et al. 2009), changes in killer whale abundance have not been definitively linked to prey changes in specific areas or to changes in numbers of specific Chinook stocks. Recent review (Ward et al. 2009; Ford et al. 2010) of current work on the correlation of Chinook abundance to survival of killer whales notes that, "…considerable caution is warranted in interpreting results as confirming a linear causative relationship between Chinook salmon abundance and Southern Resident survival (Hilborn et al. 2012)."

5.2.1.3 Prey Quality and Origin

Southern Resident killer whales likely consume both natural- and hatchery-origin salmon (Hanson et al. 2010). The best available information does not indicate that natural- and hatchery-origin fish generally differ in size, run timing, or ocean distribution (Weitkamp and Neely 2002; Nickum et al. 2004; and the 2008 BiOp (NMFS 2008a)), which are differences that could affect Southern Residents. Based on genetic analysis of feces and scale samples, Chinook from Fraser River stocks dominate the diet of Southern Residents in the summer (Hanson 2011).

A comparison of the geographic distribution of Southern Residents with the distribution of Chinook salmon originating from different geographic areas (e.g., California, Columbia basin), using CWT-based assessment of Chinook salmon distribution patterns (Weitkamp 2010; Ford et al. 2012), concluded that Southern Resident Killer Whale distribution overlaps with "all major stocks from south of central BC" during the period from April to December.

The degree of overlap was less for California Chinook salmon than for Chinook from Washington coastal streams. Due to fishery closures during the period from January to March, available data concerning winter distribution of Chinook salmon are inadequate for assessment of winter distribution patterns. Data on winter distribution of Southern Residents are also limited, so it is not possible to reliably assess the possible degree of overlap of Southern Residents and Chinook salmon during this period (Hilborn et al. 2012).

5.2.2 Relevance to the 2008/2010 BiOps' Analysis and RPA

The newest scientific information available on Southern Resident killer whale prey requirements, quality, and quantity supports the assumptions from the 2008 BiOp and the 2010 Supplemental BiOp. Recent data indicate a predominance of Chinook salmon in the Southern Residents' diet in both inland and coastal waters, and demonstrate a link between Chinook abundance and whale survival and fecundity. The analyses in the 2008 BiOp and 2010 Supplemental BiOp focus on Chinook to provide a conservative estimate of potential effects on Southern Residents. The best available information detailed in the previous sections supports the analyses and estimate of potential effects from the 2008 BiOp and the 2010 Supplemental BiOp.

Since 2010 there has been no significant change in the whales' population size, their habitat use, metabolic needs, or prey selectivity. Additionally, an ISRP identified a lack of objective means to evaluate the biological significance of prey ratios on the status of Southern Residents. Therefore, a new analysis of the prey available to the whales compared with their prey needs is not warranted. As discussed in the 2008 BiOp and the 2010 Supplemental BiOp, the operation and configuration of the FCRPS causes mortality of migrating juvenile Chinook, which in turn results in fewer adult Chinook in the ocean and reduced prey availability for killer whales. However, NOAA Fisheries determined that the hatchery production contained in the 2008 RPA more than offsets losses to the killer whale prey base. The updated information provided in 2010 improved the context for considering changes in prey availability; however, it did not affect the conclusion that the hatchery production offsets losses to the killer whale prey base and the action does not reduce the quantity of prey available to the whales.

New science confirms and supports the analyses and conclusions from the 2008 BiOp and the 2010 Supplemental BiOp; thus, our analysis of prey effects remains valid. In addition, there is no new science to indicate that hatchery-origin Chinook are not sufficient to offset the losses of natural-origin and hatchery-origin fish in the short-term.

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5.3 Conclusions for Southern Resident Killer Whale DPS

The new information available does not change NOAA Fisheries' conclusions for Southern Resident killer whales. NOAA Fisheries continues to find that the operation and configuration of the FCRPS causes mortality of migrating juvenile Chinook, which in turn results in fewer adult Chinook in the ocean and reduced prey availability for killer whales. However, hatchery production contained in the 2008/2010 RPA more than offsets losses to the killer whale prey base. There is no new scientific information available to indicate that hatchery-origin Chinook are not sufficient to offset the losses of natural-origin fish in the short-term. NOAA Fisheries confirms that past evaluation of effects on Southern Resident killer whales remains valid. Additionally, NOAA Fisheries' separate ESA consultations on the effects of hatchery reform in the Columbia River are underway (see RPA Action 39). The RPA will continue to positively affect the survival and recovery of listed salmon and steelhead and bolsters protection for salmon and steelhead on the Columbia and Snake rivers in the Pacific Northwest by adding contingency measures that provide extra insurance that the fish will survive with an adequate potential for recovery. Therefore, NOAA Fisheries concurs with the Action Agencies' determination that the RPA may affect but is not likely to adversely affect this listed DPS of killer whales.

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Section 6: Southern DPS North American Green Sturgeon

6.1 New Information and Conclusions for Southern DPS Green Sturgeon

6.2 Designated Critical Habitat for Southern DPS Green Sturgeon

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6.1 New Information and Conclusions for Southern DPS Green Sturgeon

NOAA Fisheries listed the Southern DPS as threatened in 2006 (NMFS 2006b) and consulted on the Southern DPS of North American green sturgeon ("green sturgeon") in the 2008 BiOp. At that time, we concurred with the Action Agencies' determination that the RPA actions may affect, but are not likely to adversely affect green sturgeon. We reviewed new scientific information relevant to green sturgeon in the 2010 Supplemental BiOp and concluded that it did not change our determination regarding the nature and significance of effects of the RPA actions on this species. We update our review of new scientific information on the likelihood of survival and recovery of the Southern DPS of green sturgeon in the following sections and once again consider whether our determination should change. Based on the following analysis, NOAA Fisheries reaffirms its concurrence with the Action Agencies' determination that implementation of the RPA is not likely to adversely affect Southern DPS green sturgeon.

6.1.1 Background

Based on genetics and spawning site fidelity, Southern DPS green sturgeon spawn only in the Sacramento River system whereas unlisted Northern DPS green sturgeon spawn in the Klamath and Rogue rivers (Israel et al. 2004, Israel and May 2007, NMFS 2003). As summarized in Lindley et al. (2013), after one to a few years of rearing in freshwater, juvenile green sturgeon move into the estuary of their natal river and then to the ocean, where they spend ten to 15 years before maturing. Mature green sturgeon spawn every 2 to 4 years, at least in the northern DPS. In summer months, subadult and adult green sturgeon that are not spawning remain in the ocean or aggregate in the estuaries of some nonnatal rivers between central California and the Fraser River, British Columbia, as well as in the larger bays on the West Coast, including Grays Harbor, Willapa Bay, Humboldt Bay, and San Francisco–San Pablo Bay. The Columbia River estuary is one of the areas with large numbers of adult and subadult green sturgeon from both the Northern and Southern DPSs in the summer months. Lindley et al. (2011) tagged 355 green sturgeon with acoustic transmitters and examined their movement among West Coast sites. Green sturgeon from the Southern DPS made frequent use of Willapa Bay, Grays Harbor, and the Columbia River estuary during summer and early autumn months, confirming the importance of these areas as aggregation sites.

6.1.2 Update to Rangewide Status of Southern DPS Green Sturgeon

At the time of the 2008 and the 2010 Supplemental FCRPS BiOps, there were no empirical data on population size and trends for this DPS. Israel and May (2010) estimated at least five to 14 families (i.e., ten to 28 adults) spawning in the Sacramento River upstream of the Red Bluff Diversion Dam each year from 2002 and 2006 using genetic data from out-migrating juveniles.

However, empirical data from sonar surveys during 2010 and 2011 indicate that there were 175 to 250 (±50) green sturgeon in the mainstem Sacramento River during the spawning season (Mora 2012; cited in NMFS 2012d). And green sturgeon spawning was recently confirmed in the lower Feather River (a tributary to the Sacramento River), which would add to the Southern DPS spawner count (Seesholtz 2011).

In NOAA Fisheries' biological opinion on the continuing operation of the Pacific Coast groundfish fishery (NMFS 2012d), we used this new information to generate a rough minimum population estimate for the DPS. We assumed the observation of 175 to 250 (±50) sturgeon in the mainstem Sacramento River during the spawning seasons of 2010 and 2011 were representative of the total spawning run size for those years, although recognizing the uncertainty associated with these estimates and also that they did not include any fish spawning in the lower Feather River. Because an adult only returns from the ocean to spawn every 2 to 4 years (Erickson and Webb 2007), the yearly freshwater spawning run represents only a portion of the total adult population. To estimate the total population size, we assumed that the proportion of juveniles, subadults, and adults in the population is similar to that expected in an equilibrium population (25% juveniles, 63% subadults, and 12% adults; Beamesderfer et al. 2007). Under these conditions, the Southern DPS green sturgeon population is made up of about 350 to 1,000 adults; 1,838 to 5,250 subadults; and 2,917 to 8,333 individuals. Recent observations indicate that the total number of adults may be at the higher end of the range; that is, there may be about 800 to 1,000 adults in the Southern DPS **(**Israel 2012; Woodbury 2012**)**. NOAA Fisheries is currently undertaking a 5-year status review to ensure the accuracy of the listing classification for the Southern DPS (currently "threatened") and that the Northern DPS is appropriately a "NMFS Species of Concern"[132] (NMFS 2012e).

[132] Species of Concern are those species about which NOAA Fisheries has some concerns regarding status and threats, but for which insufficient information is available to indicate a need to list the species under the ESA. "Species of concern" status does not carry any procedural or substantive protections under the ESA.

6.1.3 Management Changes Affecting Southern DPS Green Sturgeon

Recent management changes (an interim recovery strategy, hydrosystem operations in the Sacramento River, changes in harvest management) directed at improving the viability of Southern DPS green sturgeon are discussed in the following sections.

6.1.3.1 Interim Recovery Strategy for Southern DPS Green Sturgeon

NOAA Fisheries (NMFS 2010b) issued a recovery outline, which serves as interim guidance for green sturgeon recovery efforts, in December 2010. The foremost threat, range wide, is the restriction of spawning habitat in the Sacramento River. Another major threat is the alteration of freshwater and estuarine habitats from human activities, including agriculture and urban development. Restoration of freshwater and estuarine habitats with optimal physical conditions (e.g., dissolved oxygen, temperature, and salinity) and adaptive water management practices will need to be addressed to resolve the long-term needs of this species. NMFS is currently developing a draft recovery plan for the Southern DPS.

6.1.3.2 Access to Spawning Habitat in the Sacramento River

Recent decisions have resulted in improvements to the quality of the habitat in the Sacramento River. In 2012, measures were implemented to keep the Red Bluff Diversion Dam gates open all year, allowing green sturgeon to access spawning habitat in the mainstem Sacramento River upstream to Keswick Dam throughout the spawning season (NMFS 2011j; Poytress 2012). Additional measures are being developed to improve fish passage at the Fremont Weir in the Yolo Bypass (where green sturgeon have been stranded in the past) and to manage the storage and release of cold water from the Shasta Reservoir to provide suitable water temperatures for green sturgeon in the Sacramento River (McInnis 2011). Despite these improvements, spawning habitat remains restricted to a limited portion of the lower reaches of the Sacramento and Feather rivers, much reduced from the species' likely historical spawning habitat.

6.1.3.3 Changes in Harvest Management

Levels of green sturgeon catch and mortality in commercial and recreational fisheries for white sturgeon and salmon are lower since the ESA listing and the bans on commercial sales and retention by recreational anglers throughout California, Oregon, Washington, and Canada that were implemented in various areas beginning in 2006 through 2010 (described in NMFS 2010c). However, these fisheries continue to encounter and incidentally catch up to an estimated 1,133 to 1,223 Southern DPS green sturgeon per year (subadults and adults), of which an estimated 61 to 66 green sturgeon die (see Table 11 in NMFS 2012e). In addition, green sturgeon are caught in the limited entry groundfish bottom trawl sector and the at-sea Pacific hake/whiting sector of the Pacific Coast Groundfish Fishery and the California halibut bottom trawl fishery (Al-Humaidhi et al. 2012). NOAA Fisheries (NMFS 2012d) estimated that the groundfish bottom trawl sector encountered an estimated 0 to 39 southern DPS green sturgeon per year from 2002 through 2010, although almost all were released alive. In the at-sea hake sector, only three green sturgeon were encountered and observed in the period from 1991 through 2011; all died because of the encounter (Al-Humaidhi et al. 2012; Tuttle 2012a,2012b). Encounters in this fishery kill an estimated 5 to 15 Southern DPS green sturgeon per year.

6.1.4 Status of Southern DPS Green Sturgeon in the Action Area

Table 4.3.3-1 shows the locations and catches of commercial gillnet harvest of sturgeon from the mainstem Columbia River from 1981 to 2006 (Langness 2013). Although the size of the catch in a particular month or harvest zone was affected by level of fishing effort, some green sturgeon were present in all reaches of the lower Columbia River, virtually throughout the year. The proportion of listed Southern versus Northern DPS fish in these numbers is unknown.

Table 6.1-1. Location of green sturgeon harvest in commercial gillnets from the mainstem Columbia River during 1981 through 2006 as reported by WDFW (Langness 2013), at which time the sale of this species became unlawful in Washington State.

	Columbia River Mile (grouped by river reach/management zones 1-5)					
Month	**1-20**	**20-52**	**52-87**	**87-129**	**129-141**	**Total**
Jan	0	1	0	0	0	1
Feb	29	10	2	0	0	41
Mar	27	1	6	0	0	34
Apr	0	0	0	0	0	0
May	10	9	0	0	1	20
Jun	212	21	0	0	0	233
Jul	2,698	5	1	0	0	2,704
Aug	9,830	1,709	0	5	19	11,563
Sept	14,535	5,458	149	18	17	20,177
Oct	1,818	878	41	9	10	2,756
Nov	46	22	12	0	5	85
Dec	0	0	0	0	0	0
Total	**29,205**	**8,114**	**211**	**32**	**52**	**37,614**

6.1.4.1 Evidence of Green Sturgeon Spawning in the Columbia River

Until 2011, only adult and subadults had been reported from the Columbia River, but a 0-age green sturgeon was found dead in a research gillnet near Rooster Rock State Park, Oregon (RM 130), on November 10, 2011 (WDFW and ODFW 2012c). This is the first evidence that green sturgeon spawn in the Columbia River. A genetic analysis performed at the University of California, Davis confirmed that the female parent was a green sturgeon, but the male parent was not identified and the juvenile was not assigned to the Northern versus the listed Southern DPS.

6.1.5 New Information on Effects of the 2008/2010 RPA on Green Sturgeon

There is no new information on effects of the 2008/2010 RPA on this species.

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6.1.6 Relevance to the 2008/2010 RPA

In the 2008 BiOp, NOAA Fisheries determined that "[b]y changing flow, sediment transport (turbidity), and the characteristics of the Columbia River estuary, the FCRPS RPA may affect green sturgeon." However, "[b]ecause these effects are slight to negligible and because adult green sturgeon, the only life stage known to use the lower Columbia River habitats, prefer deep water habitats that are generally unaffected by the FCRPS," NOAA Fisheries concurred with the Action Agencies' determination that the RPA actions "may affect, but are not likely to adversely affect green sturgeon." The new scientific information reviewed for the 2010 remand indicated that some of the assumptions made in the 2008 are being re-evaluated: subadults are present in the lower Columbia as well as adults, this species is in the estuary earlier than thought (i.e., beginning in May rather than "late summer"), and NOAA Fisheries no longer assumed that green sturgeon use the deep channel in preference to shallow margin areas. As of this 2013 analysis, a single juvenile green sturgeon of either the unlisted Northern or listed Southern DPS has been captured in the lower Columbia River, indicating that some green sturgeon have spawned within the action area. However, there is still no evidence that changes in the spring hydrograph and/or in sediment delivery to the estuary, both effects of implementing the RPA, are adversely affecting the biological requirements of this species. Thus, NOAA Fisheries reaffirms its concurrence with the Action Agencies' determination that implementation of the RPA is not likely to adversely affect Southern DPS green sturgeon.

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6.2 Designated Critical Habitat for Southern DPS of Green Sturgeon

NOAA Fisheries designated critical habitat for the threatened Southern DPS green sturgeon, *Acipenser medirostris* (*hereafter* "green sturgeon"), on October 9, 2009 (NMFS 2009c). The Action Agencies have stated their determination that the operation of the FCRPS in accordance with the 2010 BiOp's RPA may effect, but is not likely to adversely affect designated critical habitat for green sturgeon (Anderson 2010; USBR et al. 2010). In the following section, we describe the likely effects of the action on the functioning of physical or biological habitat features (or primary constituent elements, PCEs) in the designated areas and concur with the Action Agencies' determination that the RPA is likely to affect, but not likely to adversely affect designated critical habitat for green sturgeon. Effects of the RPA on the species are updated in Section 4.3 of this supplemental opinion.

6.2.1 Status of Designated Critical Habitat

The designated areas are:

- Freshwater systems in the Central Valley, California (Sacramento River, lower Feather River, lower Yuba River, Yolo and Sutter bypasses) and the Sacramento-San Joaquin delta (Delta) (*Note: spawning has been confirmed only in the mainstem Sacramento River and lower Feather River*);
- Coastal estuaries in California (San Francisco Bay, San Pablo Bay, Suisun Bay, Humboldt Bay), Oregon (Coos Bay, Winchester Bay, Yaquina Bay, Nehalem Bay), the lower Columbia River estuary, and Washington (Willapa Bay, Grays Harbor); and
- Coastal marine waters shallower than 60 fathoms (about 360 feet) from Monterey Bay, California to the Canadian border, including Monterey Bay and the Strait of Juan de Fuca.

NOAA Fisheries identified the PCEs of the designated areas that are essential for conservation of the species (Table6.2.1-1).

Table 6.2-1. Primary constituent elements of designated critical habitat for Southern DPS green sturgeon (NMFS 2009c).

Primary Constituent Element		
Site Type	Attribute	Description
Freshwater Riverine	Food resources	Abundant prey items for larval, juvenile, subadult, and adult life stages
	Substrate type or size (i.e., structural features of substrates)	Substrates suitable for egg deposition and development
	Water flow	A flow regime (i.e., the magnitude, frequency, duration, seasonality, and rate-of-change of fresh water discharge over time) necessary for normal behavior, growth, and survival of all life stages
	Water quality	Water quality, including temperature, salinity, oxygen content, and other chemical characteristics, necessary for normal behavior, growth, and viability of all life stages
	Migratory corridor	A migratory pathway necessary for the safe and timely passage of Southern DPS fish within riverine habitats and between riverine and estuarine habitats (e.g., an unobstructed river or dammed river that still allows for safe and timely passage)
	Water depth	Deep (≥5 m) holding pools for both upstream and downstream holding of adult or subadult fish, with adequate water quality and flow to maintain the physiological needs of the holding adult or subadult fish
	Sediment quality	Sediment quality (i.e., chemical characteristics) necessary for normal behavior, growth, and viability of all life stages
Estuarine areas	Food resources	Abundant prey items within estuarine habitats and substrates for juvenile, subadult, and adult life stages
	Water flow	Within bays and estuaries adjacent to the Sacramento River (i.e., the Sacramento-San Joaquin Delta and the Suisun, San Pablo, and San Francisco bays), sufficient flow into the bay and estuary to allow adults to successfully orient to the incoming flow and migrate upstream to spawning grounds
	Water quality	Water quality, including temperature, salinity, oxygen content, and other chemical characteristics, necessary for normal behavior, growth, and viability of all life stages
	Migratory corridor	A migratory pathway necessary for the safe and timely passage of Southern DPS fish within

Primary Constituent Element		
Site Type	Attribute	Description
		estuarine habitats and between estuarine and riverine or marine habitats
	Water depth	A diversity of depths necessary for shelter, foraging, and migration of juvenile, subadult, and adult life stages
	Sediment quality	Sediment quality (i.e., chemical characteristics) necessary for normal behavior, growth, and viability of all life stages
Coastal marine areas	Migratory corridor	A migratory pathway necessary for the safe and timely passage of Southern DPS fish within marine and between estuarine and marine habitats
	Water quality	Coastal marine waters with adequate dissolved oxygen levels and acceptably low levels of contaminants (e.g., pesticides, PAHs, heavy metals that may disrupt the normal behavior, growth, and viability of subadult and adult green sturgeon)
	Food resources	Abundant prey items for subadults and adults, which may include benthic invertebrates and fish

Conditions in the Sacramento River watershed are generally substantially impaired although some conditions have likely improved since 2009 because of the implementation of measures to remove seasonal passage barriers, improve passage in the Yolo Bypass, and maintain water temperatures suitable for green sturgeon and salmonids. Coastal estuaries, including the Columbia's, continue to be affected by industrial and agricultural runoff and discharges; the introduction and spread of invasive species; and activities that affect water quality, sediment quality, and food resources (e.g., dredging and dredge disposal activities, shellfish aquaculture). Less information is available on the status of and potential impacts of activities on critical habitat in coastal marine waters. Non-point source and point source discharges into coastal waters affect water quality, particularly close to shore. These discharges, along with other activities like fishing may also affect prey resources in marine waters. Oil spills and low oxygen "dead zones" along the coast may constrict migratory corridors for green sturgeon, particularly between estuaries along the Oregon and Washington coasts. However, because little information is known about how green sturgeon use coastal marine habitats and how changes in water quality or levels of available prey resources affect their use of these habitats, it is difficult to assess the effects of these activities on the status of green sturgeon critical habitat.

The lower Columbia River below Bonneville Dam, an estuarine area, and the plume, a coastal marine area, are within the action area for this consultation. The designated critical habitat in the lower Columbia River estuary contains important summer habitats that support aggregations of green sturgeon, including those from both the unlisted Northern DPS and the listed Southern DPS. As described in Section 4.3, there are large aggregations of subadult and adult green sturgeon from both the Northern and Southern DPSs in the Columbia River estuary during summer. Recently, a small juvenile, identified as the progeny of a female green sturgeon, was captured in the lower Columbia, indicating that the species has spawned in the action area (see Section 4.3.3.1). The male parent has not been identified and the juvenile has not been assigned to the unlisted Northern versus the listed Southern DPS.

6.2.2 Effects of the RPA on Designated Critical Habitat for Green Sturgeon

The following section examines the effects of the 2008/2010 RPA on green sturgeon designated critical habitat in estuarine and coastal marine sites within the action area.

6.2.2.1 Food Resources

The PCEs of critical habitat in estuarine areas include abundant prey items within estuarine habitats and substrates for various life stages.[133] Prey species for green sturgeon within bays and estuaries primarily consist of benthic invertebrates and fishes, including crangonid shrimp, burrowing thallassinidean shrimp (particularly the burrowing ghost shrimp), amphipods, isopods, clams, annelid worms, crabs, sand lances, and anchovies" (NMFS 2009c). Two green sturgeon were landed in 2004 and 2005 in the Columbia River with identifiable items in their guts, mostly crangonid shrimp. In Willapa Bay, the guts of eight individuals taken in 2000 and nine taken in 2003 contained ghost shrimp (*Neotrypaea californiensis*), fish (including lingcod, *Ophiodon elongatus*), Dungeness crab (*C. magister*), crangonid shrimp, and small amounts of polychaetes, clams, and amphipods (Dumbauld et al. 2008). Sand flats are extensive in the lower estuary and the prey items listed above are found at various locations. In surveys conducted for the Columbia River Data Development Program in 1981, the sand shrimp (*Crangon franciscorum*) dominated the motile macroinvertebrate assemblage in the estuary in terms of density and standing crop (Jones et al. 1990). Dungeness crab were also prominent at the entrance of the estuary and in the channel bottom in the seaward region of the estuarine mixing zone. There is no known causal connection between the availability of these species and implementation of the RPA.

No studies to date have reported gut contents from green sturgeon in the Columbia River plume (coastal marine areas) so that even less is known about food resources for green sturgeon in this portion of the action area. NOAA Fisheries' Biological Review Team, which developed much of the information used in designating critical habitat for green sturgeon (NMFS 2009c), stated that prey in coastal waters likely include species similar to those fed upon by green sturgeon in bays and estuaries (e.g., shrimp, clams, crabs, anchovies, sand lances). The Northern anchovy (*Engraulis mordax*) is one of four forage fishes abundant in the Columbia River plume (the others are Pacific herring, whitebait smelt, and Pacific sardines). Large changes in the abundances of pelagic forage fishes off Oregon and Washington during the 1980–1990s co-occurred with a shift in oceanographic conditions in the California Current ecosystem (Emmett et al. 2006). Forage fish were not abundant during 1998 or 1999, but were very abundant from 2000 to 2003. Northern anchovy and whitebait smelt densities were generally highest during late April and May, and then decreased as the summer progressed. These changes co-occurred with the shift in oceanic conditions between the 1998 El Niño and the 1999 La Niña.

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[133] Although a single juvenile green sturgeon has been captured in the action area (Section 6.1.4.1), we assume that these PCEs apply to subadult and adult individuals from the Southern DPS.

In another study, Brodeur et al. (2005) compared the distributions of pelagic nekton (northern anchovy, Pacific sardine, and Pacific herring) caught in surface trawls off Oregon and Washington with the presence other organisms and factors such as bottom depth, distance from shore, sea-surface temperature, latitude, and surface salinity. They found some indication that the Columbia River plume may affect the distributions of some species of nekton, but the results were uncertain.

Based on the best available scientific and commercial information, any adverse effects of implementing the RPA on the PCE of food resources are likely to be insignificant. This conclusion is based on the following considerations: (1) the availability of invertebrate and fish prey favored by green sturgeon in other estuaries appears to be high in the lower Columbia River and there is no information to indicate that flow or sediment changes due to the FCRPS decrease the availability of these species in any measurable way; and (2) the abundances of marine forage fishes in the Columbia River plume increases and decreases based on a number of variables including oceanic and climate conditions. There is no information to indicate that implementation of the RPA is a controlling factor.

6.2.2.2 Water Quality

The PCEs of critical habitat in estuarine areas include water quality including temperature, salinity, oxygen content, and other chemical characteristics necessary for normal behavior, growth, and viability of all life stages (NMFS 2009c). Water temperature is affected by operation of the FCRPS hydroelectric dams and storage reservoirs under the RPA. In general, summer maximum temperatures are reduced, late summer and fall temperatures are increased, winter minimum temperatures are increased, and spring temperatures are reduced in the impounded Columbia River compared to a free-flowing system (NMFS 2008b). These patterns are caused by the increased thermal inertia of the large volumes of stored water, increased solar radiation and interactions with ambient air temperature over the increased surface areas of the reservoirs, and altered seasonal flow regimes (i.e., reduced spring flows for flood control and increased summer and winter flows for power generation). However, effects of the FCRPS on temperatures in the reach below RM 46 (rkm 74) are also affected by tidal exchange with the ocean and by tributaries to the estuary (e.g., the Cowlitz, Elochoman, and Grays rivers in Washington and the Clatskanie River and several smaller streams in Oregon). Water temperature monitoring in marine sites near the mouth of the estuary, in zones where marine and freshwater mix with the tides, and at tidal freshwater sites in the lower Columbia River did not show temperatures exceeding 24°C during 2003 through 2006 (Bottom et al. 2008), the maximum suitable water temperature for juvenile green sturgeon and the only life stage for which preferred temperatures are stated in NOAA Fisheries' critical habitat designation (NMFS 2009c). Therefore, any negative effects of the RPA on the functioning of this aspect of the water quality PCE are likely to be insignificant.

Suitable salinities for green sturgeon range from brackish water (10 parts per thousand) to salt water (33 parts per thousand) (NMFS 2009c) with subadults and adults tolerating a wide range (Kelly et al. 2007). Estuarine salinity intrusion in the lower Columbia River is controlled by channel geometry, river flow, and tides (Fain et al. 2001). The FCRPS has reduced spring flows, which combined with channel deepening for navigation, has pushed the extent of salinity intrusion further upstream. Since green sturgeon can tolerate a wide range of salinities, implementation of the RPA is unlikely to have a negative effect on this PCE.

In coastal marine areas such as the Columbia River plume the water quality PCE requires "adequate dissolved oxygen levels" and "acceptably low levels of contaminants" (NMFS 2009c). As described above, the USEPA (2007a) has reported that 99% of the estuarine area of the lower Columbia rated "good" for dissolved oxygen conditions. An exception is the intrusion of low DO water along the bottom of the estuary with saline water during neap tides (Section 2.2.3.1). However, this is a case of ocean conditions, which are not controlled by implementation of the RPA, affecting conditions in the estuary rather than vice versa. Similarly, implementation of the RPA is not likely to contribute chemical contaminants to the plume.

Suitable water quality requires low levels of contaminants (e.g., pesticides, PAHs, heavy metals) that otherwise may disrupt growth and survival of subadult and adult life stages (NMFS 2009c). Water quality sampling using semipermeable membrane devices, which mimic the accumulation of contaminants in fatty tissues of fish, in the reach from above Bonneville Dam to below Longview (RM 54—above the boundary of green sturgeon critical habitat) during 2003 and 2004 (Johnson and Norton 2005). During each of three deployment periods, total concentrations of the banned pesticide DDT decreased going downstream from Bonneville Dam. These results suggested that there are important sources of DDT and dieldrin upstream of Bonneville Dam. A winter/spring peak for these compounds was consistent with runoff from agricultural lands in Eastern Washington. In contrast, spring measurements of polychlorinated biphenyls (PCB) increased by almost a factor of two going downstream from Bonneville Dam to below Longview. In the fall, PCBs were only detectable below Longview, also suggesting a trend toward increasing concentrations in the lower river and local rather than upstream sources. With reference to the cleanup of PCB contaminated sediments at Bradford Island, [134] the URS (2010) reported that contaminated sediments were limited to the Bonneville forebay. Johnson and Norton (2005) found no evidence of an increase in water column PCB concentrations between Bonneville Dam and below Longview, implying that Bonneville Dam/Bradford Island is not a source of PCBs in the water column downstream. Thus, implementation of the RPA is expected

[134] The Corps completed its draft final Remedial Investigation and Risk Assessment for the removal of PCB contaminated sediments at Bradford Island (part of the Bonneville Dam complex) in November 2010 (URS 2010). The Corps removed PCE-contaminated electrical equipment from the river bottom adjacent to the island in 2000 and 2002 and contaminated sediment in 2007. The Remedial investigation found that PCBs were present in sediment and sculpin and smallmouth bass tissues at concentrations that may pose a risk to predatory fish and piscivorous mammals. PCBs were identified as a contaminant of concern in sediment at two locations: the north shore of Bradford Island and the mouth of Eagle Creek, both above Bonneville Dam. Downstream sampling "appear[ed] to confirm that contaminated sediments are limited to the Bonneville Dam forebay."

to have an insignificant adverse effect on this PCE of critical habitat for green sturgeon; chemical contaminants in the estuary below RM 46 are likely to be due to local factors rather than the FCRPS. In addition, implementation of the RPA is not likely to concentrate or mobilize these contaminants or otherwise affect this aspect of the water quality PCE.

The voluntary spill operations for ESA-listed salmon and steelhead described in the RPA can result in total dissolved gas levels in the tailrace of Bonneville Dam that exceed the water quality standard of 110% of saturation set by the Oregon and Washington's water quality authorities. However, the effects of total dissolved gas on aquatic organisms are moderated by hydrostatic pressure with depth in the water column—each meter of depth compensates for 10% of gas supersaturation as measured at the water surface. When the level of dissolved gas is 120% of saturation at the surface, it is reduced to 100% at two meters. The tissues of a green sturgeon at two meters or more will be in equilibrium with the surrounding water. Any effect of dissolved gases generated by implementation of the RPA on the water quality PCE is insignificant because bottom-oriented organisms such as sturgeon are likely to avoid the effects of supersaturation through depth compensation. There are no reports of dissolved gas effects on adult or subadult green or white sturgeon in the lower Columbia River or elsewhere.[135] In summary, as long as the water column is deeper than a few meters, green sturgeon are able to avoid gas bubble disease.

The RPA includes actions to improve estuarine habitat for salmonids within the area designated as critical habitat for green sturgeon. Some of these actions will involve in-water construction, which often causes temporary increases in turbidity or sedimentation. The methods for implementing these projects are not part of the RPA, but will be the subject of site-specific ESA consultations that will consider potential adverse effects of construction on green sturgeon critical habitat.

6.2.2.3 Migratory Corridor

Migratory pathways that allow safe and timely passage among and between areas designated as critical habitat in the estuary (below RM 46) and in coastal marine areas are a PCE of the designated critical habitat. Implementation of the RPA will have no effect on this PCE in either the estuary or the plume.

6.2.2.4 Water Depth

Subadult and adult green sturgeon require a diversity of depths in estuarine areas for shelter, foraging, and migration. Although little is known of habitat use in the lower Columbia, Kelly et al. (2007) tagged and tracked five subadults (larger than 100 cm total length) and one adult in San Francisco Bay. Their sample size was too small to "clearly parse out preferred habitats (shallow or deep, high or low relief, etc.)," but the subadults typically remained in water

[135] Counihan et al. (1998) report gas bubble trauma in larval [white] sturgeon in the Columbia River, but larval green sturgeon are present only in the Sacramento River.

shallower than 10 m. The authors differentiated non-directional movements (moving slowly while making frequent changes in direction and speed, or not moving at all), which were close to the bottom and accounted for 64% of all observations, from directional movements. The latter consisted of continuous swimming in the top 20% of the water column, holding a steady course for extended periods.

These patterns of habitat use by subadult green sturgeon in San Francisco Bay—where virtually all juveniles in the Southern DPS are thought to remain for a number of years, feeding and growing before beginning their oceanic phase—may be different than those of subadults and adults in the Columbia River estuary. In either case, there is no evidence that implementation of the RPA negatively affects access to either shallow bottom or near surface waters that might be used by subadults or adults.

6.2.2.5 Sediment Quality

The PCE of sediment quality for green sturgeon in estuarine areas could be affected by chemical contaminants from local or upstream sources (e.g., the FCRPS). Sediment quality (i.e., chemical characteristics) necessary for normal behavior, growth, and viability of all green sturgeon life stages includes sediments free of elevated levels of contaminants such as polyaromatic hydrocarbons and pesticides (NMFS 2009c). The USEPA (2007b) rated the estuary (including stations between RM 46 and Bonneville Dam) “good” for sediment contaminant concentrations, with less than 1% of the estuarine area rated “poor” for this condition. Evidence that chemical contaminants are not likely to be affecting green sturgeon in the estuary can also be inferred from Feist et al. (2005), who compared levels of endocrine-disrupting chemicals in white sturgeon caught near Astoria, Oregon with those caught in reservoirs behind Bonneville, The Dalles, and John Day dams. Contaminant levels were low in tissue samples from the estuary. Based on these observations, and because there is no likely pathway for implementation of the RPA to affect sediment quality in the estuary, it is not likely to negatively affect this PCE.

Columbia River mainstem reservoirs trap sediments and nutrients, as well as reduce sediment bedload movement, thereby reducing sediment and nutrient supply to the estuary. The volume (i.e., quantity) and type (quality) of fine sediment transported downstream have the potential to affect the food web within the estuary. For example, the organic matter associated with fine sediments supports a detritus-based food web that provides much of the secondary productivity in the estuary (Simenstad et al. 1990, 1994). The available information indicates that there are abundant food resources for green sturgeon in the lower Columbia River. Implementation of the RPA is unlikely to change this.

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6.2.3 Summary and Not Likely to Adversely Affect Determination

Based on the preceding analysis of effects on the functioning of PCEs, NOAA Fisheries concurs with the Action Agencies' determination that implementing the RPA is not likely to adversely affect designated critical habitat for Southern DPS green sturgeon.

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Section 7: Southern DPS Eulachon

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7 Southern DPS Eulachon

<Placeholder: NOAA Fisheries is in consultation with the Action Agencies on effects of the FCRPS RPA on the Southern DPS of eulachon. Our biological opinion on effects on the species and its designated critical habitat is under development.>

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Section 8: Incidental Take Statement for Salmon and Steelhead

8.1 Amount or Extent of Take

8.2 Effect of the Take

8.3 Reasonable and Prudent Measures

8.4 Terms and Conditions

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8 Incidental Take Statement for Salmon and Steelhead

Section 9 of the ESA and Federal regulations pursuant to section 4(d) of the ESA prohibit the take of endangered and threatened species, respectively, without a special exemption. Take is defined as to harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or to attempt to engage in any such conduct. Harm is further defined by regulation to include significant habitat modification or degradation that results in death or injury to listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. For this consultation, we interpret "harass" to mean an intentional or negligent action that has the potential to injure an animal or disrupt its normal behaviors to a point where such behaviors are abandoned or significantly altered.[136] Section 7(b)(4) and section 7(o)(2) provide that taking that is incidental to an otherwise lawful agency action is not considered to be prohibited taking under the ESA if that action is performed in compliance with the terms and conditions of this incidental take statement.

8.1 Amount or Extent of Take

The levels of take considered and authorized in Tables 14.1, 14.2, and 14.3 in the 2008 BiOp (and reconsidered in this supplemental opinion) for adults and juveniles migrating through the mainstem FCRPS dams and for the Juvenile Fish Transportation Program[137] will continue unchanged.

Take associated with research, monitoring, and evaluation programs is being redefined in this supplemental opinion. NOAA Fisheries can better estimate take associated with specific research activities because (1) our tracking of actual take occurring during the past five years of implementation, and (2) these programs have more fully matured (as described and considered in Section 3.8.1 *Effects of 2014–2018 RME on ESU/DPS Abundance*) since 2008 and 2010. Tables 8-1 to 8-4 specify take of adult and juvenile salmon and steelhead authorized, by category, in this supplemental opinion. The effect of this take and its combined effect on the species was considered in Section 3.8.

[136] NOAA Fisheries has not adopted a regulatory definition of harassment under the ESA. The World English Dictionary defines harass as "to trouble, torment, or confuse by continual persistent attacks, questions, etc." The U.S. Fish and Wildlife Service defines "harass" in its regulations as "an intentional or negligent act or omission which creates the likelihood of injury to wildlife by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering (50 CFR 17.3). The interpretation we adopt in this consultation is consistent with our understanding of the dictionary definition of harass and is consistent with the Service's interpretation of the term.

[137] As previously noted, NOAA Fisheries is no longer issuing an ESA Section 10(a)(1)(A) permit to the Corps of Engineers for their Juvenile Fish Transportation Program, a procedure NOAA has followed since 1993, because the effects of the JFTP are already considered in the ESA Section 7(a)(2) consultation, as a necessary component of FCRPS operations.

***Note**: NOAA Fisheries is still reviewing and revising estimates for Hatchery RME – these will be appropriately considered and included in the final Supplemental BiOp. Similarly, take associated with the Northern Pikeminnow Removal Program is being reviewed and revised.*

Table 8-1. Average estimates of non-lethal take and incidental mortality associated with implementation of the Smolt Monitoring Program (including Corps monitoring at Ice Harbor Dam) and the Comparative Survival Study as a percent of recent run size estimates.

			Smolt Monitoring and Comparative Survival Study							
			Adult				Juvenile			
			Hatchery		Wild		Hatchery		Wild	
	ESU/DPS		Take	Incidental Mortality	Take	Incidental Mortality	Take	Incidental Mortality	Take	Incidental Mortality
Lower Columbia	Columbia River Chum	Number	-	-	-	-	-	-	500	10
		% of run	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.01%	0.00%
	Lower Columbia Chinook	Number	-	-	-	-	-	-	9,093	896
		% of run	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Lower Columbia Coho	Number	-	-	-	-	-	-	2,000	107
		% of run	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.19%	0.01%
	Lower Columbia Steelhead	Number	-	-	-	-	-	-	-	-
		% of run	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Mid Columbia	Middle Columbia Steelhead	Number	-	-	-	-	-	-	23,495	266
		% of run	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	3.53%	0.04%
Snake River	Snake River Fall chinook	Number	5	-	5	-	356,087	6,051	125,167	4,147
		% of run	0.02%	0.00%	0.06%	0.00%	5.31%	0.09%	17.82%	0.59%
	Snake River Sockeye	Number	5	-	-	-	8,381	293	3,768	133
		% of run	0.26%	0.00%	#DIV/0!	#DIV/0!	7.46%	0.26%	29.19%	1.03%
	Snake River Spring-Summer Chinook	Number	5	-	5	-	91,187	2,447	52,039	2,090
		% of run	0.01%	0.00%	0.02%	0.00%	2.24%	0.06%	4.03%	0.16%
	Snake River Steelhead	Number	5	-	5	-	37,883	611	28,279	855
		% of run	0.00%	0.00%	0.01%	0.00%	0.89%	0.01%	1.99%	0.06%
Upper Columbia	Upper Columbia Spring Chinook	Number	-	-	-	-	177,985	5,866	11,904	169
		% of run	0.00%	0.00%	0.00%	0.00%	11.53%	0.38%	2.11%	0.03%
	Upper Columbia Steelhead	Number	-	-	-	-	13,888	842	35,396	985
		% of run	0.00%	0.00%	0.00%	0.00%	1.65%	0.10%	11.86%	0.33%

Table 8-2. Average estimates of non-lethal take and incidental mortality associated with implementation of research, monitoring, and evaluation activities as a percent of recent run size estimates.

			Research							
			Adult				Juvenile			
			Hatchery		Wild		Hatchery		Wild	
	ESU/DPS		Take	Incidental Mortality	Take	Incidental Mortality	Take	Incidental Mortality	Take	Incidental Mortality
Lower Columbia	Columbia River Chum	Number	17	1	398	4	23,191	464	479,463	9,589
		% of run	3.35%	0.20%	4.09%	0.04%	8.50%	0.17%	8.50%	0.17%
	Lower Columbia Chinook	Number	868	9	47	1	99,937	999	114,575	1,146
		% of run	0.50%	0.01%	0.50%	0.01%	0.27%	0.00%	0.63%	0.01%
	Lower Columbia Coho	Number	998	10	626	6	49,026	490	15,795	158
		% of run	0.50%	0.01%	0.50%	0.01%	0.50%	0.01%	1.48%	0.01%
	Lower Columbia Steelhead	Number	200	2	128	1	4,558	46	277	3
		% of run	1.26%	0.01%	0.80%	0.01%	0.46%	0.00%	0.05%	0.00%
Mid Columbia	Middle Columbia Steelhead	Number	2,642	26	1,633	16	1,001	10	15,308	153
		% of run	2.64%	0.04%	2.65%	0.03%	0.13%	0.00%	2.30%	0.02%
Snake River	Snake River Fall chinook	Number	143	1	307	3	1,412,639	14,126	389,947	3,899
		% of run	0.50%	0.01%	3.79%	0.04%	21.05%	0.21%	55.52%	0.56%
	Snake River Sockeye	Number	337	3	-	1	55,294	553	5,698	57
		% of run	17.35%	0.17%	#DIV/0!	#DIV/0!	49.22%	0.49%	44.15%	0.44%
	Snake River Spring-Summer Chinook	Number	447	4	144	1	361,831	3,618	124,801	1,248
		% of run	0.50%	0.01%	0.50%	0.01%	8.90%	0.09%	9.67%	0.10%
	Snake River Steelhead	Number	1,519	15	387	4	303,326	3,033	64,356	644
		% of run	0.50%	0.01%	0.50%	0.01%	7.16%	0.07%	4.54%	0.05%
Upper Columbia	Upper Columbia Spring Chinook	Number	95	1	1,754	18	38,901	389	13,822	138
		% of run	0.50%	0.01%	81.62%	0.82%	2.52%	0.03%	2.45%	0.02%
	Upper Columbia Steelhead	Number	210	2	78	1	3,703	37	10,207	102
		% of run	0.90%	0.01%	0.90%	0.01%	0.44%	0.00%	3.42%	0.03%
Willamette River	Willamette River Spring Chinook	Number	174	2	149	1	29,910	299	14,213	142
		% of run	0.50%	0.01%	0.50%	0.01%	0.50%	0.01%	0.50%	0.01%
	Willamette River Steelhead	Number	73	1	62	1	923	9	1,323	13
		% of run	0.50%	0.01%	0.50%	0.01%	0.50%	0.01%	0.50%	0.01%
Non Salmonid Species	Eulachon	Number			6,000	60			-	1
		% of run			0.02%	0.00%			#DIV/0!	#DIV/0!

Table 8-3. Average estimates of non-lethal take and incidental mortality associated with implementation of the ISEMP and other Status Monitoring programs as a percent of recent run size estimates.

Note: adult numbers especially are preliminary; work is ongoing to ensure these estimates are correct.

			ISEMP and Status Monitoring							
			Adult				**Juvenile**			
			Hatchery		**Wild**		**Hatchery**		**Wild**	
	ESU/DPS		**Take**	**Incidental Mortality**	**Take**	**Incidental Mortality**	**Take**	**Incidental Mortality**	**Take**	**Incidental Mortality**
Lower Columbia	**Columbia River Chum**	Number	-	-	-	-	-	-	-	-
		% of run	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Lower Columbia Chinook	Number	-	-	-	-	-	-	-	-
		% of run	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Lower Columbia Coho	Number	-	-	-	-	-	-	-	-
		% of run	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
	Lower Columbia Steelhead	Number	-	-	-	-	-	-	-	-
		% of run	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Mid Columbia	**Middle Columbia Steelhead**	Number	100	1	1,200	12	8,613	86	43,642	436
		% of run	0.10%	0.00%	1.94%	0.02%	1.12%	0.01%	6.56%	0.07%
Snake River	**Snake River Fall chinook**	Number	4,588	46	1,297	13	-	-	-	-
		% of run	16.00%	0.16%	16.00%	0.16%	0.00%	0.00%	0.00%	0.00%
	Snake River Sockeye	Number	210	2	-	-	-	-	-	-
		% of run	10.81%	0.11%	#DIV/0!	#DIV/0!	0.00%	0.00%	0.00%	0.00%
	Snake River Spring-Summer Chinook	Number	14,304	143	4,600	46	63,761	638	50,319	503
		% of run	16.00%	0.16%	16.00%	0.16%	1.57%	0.02%	3.90%	0.04%
	Snake River Steelhead	Number	23,371	234	11,479	115	22,103	221	45,762	458
		% of run	7.70%	0.08%	14.82%	0.15%	0.52%	0.01%	3.23%	0.03%
Upper Columbia	**Upper Columbia Spring Chinook**	Number	-	-	-	-	26,787	268	16,144	161
		% of run	0.00%	0.00%	0.00%	0.00%	1.74%	0.02%	2.86%	0.03%
	Upper Columbia Steelhead	Number	-	-	-	-	9,002	90	12,692	127
		% of run	0.00%	0.00%	0.00%	0.00%	1.07%	0.01%	4.25%	0.04%

<Placeholder for Table 8-4 – Summary of Hatchery related RME>

8.2 Effect of the Take

In Section 4, *Conclusions for Salmon and Steelhead*, NOAA Fisheries determined that the level of anticipated take, coupled with other effects of the proposed action, is not likely to result in jeopardy to the species or destruction or adverse modification of critical habitat when the reasonable and prudent alternative is implemented.

8.3 Reasonable and Prudent Measures

"Reasonable and prudent measures" are nondiscretionary measures to minimize the amount or extent of incidental take (50 CFR 402.02). The Reasonable and Prudent Measures set forth in Section 14.4 of the 2008 BiOp remain in effect.

8.4 Terms and Conditions

The terms and conditions described below are non-discretionary, and the Action Agencies (or their contractors) must comply with them in order to implement the reasonable and prudent measures (50 CFR 402.14). The Action Agencies (or their contractors) have a continuing duty to monitor the impacts of incidental take and must report the progress of the action and its impact on the species as specified in this incidental take statement (50 CFR 402.14). If the following terms and conditions are not complied with, the protective coverage of section 7(o)(2) will likely lapse. The Terms and Conditions set forth in Section 14.5 of the 2008 FCRPS BiOp remain in effect.

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Appendices

Appendix A: Extended Base Period Metrics for 1990–Present Time Period

Appendix B: Hinrichsen (2013) Extinction Risk Analysis—Detailed Results

Appendix C: Recruits-per-Spawner in base versus current time periods—do they differ?

Appendix D: Impacts of climate change on Columbia River Salmon: Review of the scientific literature published in 2012

Appendix E: 2013 Update to Hatchery Effects in the Environmental Baseline

Appendix F: Estimating Survival Benefits of Estuary Habitat Improvement Projects

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Appendix A
Extended Base Period Metrics for 1990–Present Time Period

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Extended Base Period Metrics for 1990-Present Time Period

NOAA Fisheries evaluated "Base Period" estimates by focusing on the time period used by the ICTRT for recovery planning, which encompasses approximately the 1980 through 1999 brood years (which include spawner returns at age through about 2004 or 2005). Updated estimates that include recent return years are presented in Section 2.1.1.4.2 of this supplemental opinion.

NOAA Fisheries also evaluated an alternative historical time period for "base" estimates, which began in 1990, rather than 1980. Prospective estimates based on this alternative time period were included in Tables 1 through 12 of Appendix B of the 2008 BiOp under the headers "Average R/S: 10-yr non-SAR adj.; non-delimited," "12-yr Lambda HF=0," "12-yr Lambda HF=1," and "1990-Current [BRT] Trend." As described in Appendix B of the 2008 BiOp, productivity estimates were derived from this alternative Base Period of approximately 1990 to the present because this time period is described in the Metrics Memo (NMFS 2006b). It also represents one of the time periods used to calculate trend in the Biological Review Team analysis available at the time (Good et al. 2007). Appendix C of the 2010 Supplement included updated 1990-present extended Base Period estimates based on new information available at the time.

This appendix updates the 1990–present extended Base Period productivity metrics to reflect the most recent observations. Methods used to generate these tables are identical to methods used to produce the tables in Section 2.1.1.4.2 of this supplemental opinion. The only difference is the starting year (1990). Some populations with relatively short time series of spawner estimates, which made them unsuitable for the longer Base Period estimates in Section 2.1.1.4.2, are included in these 1990–present tables.

Table A-1. 1990-present Chinook median population growth rate (lambda) under the assumption that hatchery-origin spawners are not reproductively effective (HF=0) and under the assumption that hatchery-origin spawners are as reproductively effective as natural-origin spawners (HF=1). These extended Base Period estimates are based on new information in the NWFSC SPS database that has become available since the 2008 BiOp. The 2008 BiOp's goal for prospective actions for this metric is lambda greater than 1.0.

ESU	MPG	Population	Lambda HF=0				Lambda HF=1			
			Base Period Lambda HF=0	Probability Lambda >1.0	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Extended Base Period Lambda HF=1	Probability Lambda >1.0	Lower 95% Confidence Limit	Upper 95% Confidence Limit
Snake River Spring/ Summer Chinook Salmon	Lower Snake	Tucannon	1.06	0.62	0.63	1.76	0.90	0.28	0.56	1.46
		Asotin - Functionally Extirpated								
	Grande Ronde / Imnaha	Catherine Creek	1.12	0.81	0.78	1.61	0.96	0.38	0.61	1.50
		Upper Grande Ronde	1.02	0.60	0.82	1.27	0.80	0.09	0.54	1.19
		Minam River	1.07	0.86	0.91	1.26	1.02	0.63	0.85	1.24
		Wenaha River	1.09	0.86	0.88	1.36	1.02	0.63	0.85	1.22
		Lostine/Wallowa Rivers	1.11	0.86	0.86	1.45	0.95	0.35	0.68	1.35
		Imnaha River	1.05	0.63	0.71	1.54	0.83	0.14	0.54	1.28
		Big Sheep Creek - Functionally Extirpated								
		Lookingglass- Functionally Extirpated								
	South Fork Salmon	South Fork Salmon Mainstem	1.01	0.56	0.80	1.28	0.90	0.11	0.71	1.12
		Secesh River	1.06	0.67	0.75	1.49	1.04	0.64	0.74	1.47
		East Fork S. Fork Salmon (including Johnson)	1.02	0.54	0.69	1.49	0.94	0.31	0.63	1.38
		Little Salmon River (including Rapid R.)								
	Middle Fork Salmon	Big Creek	1.05	0.62	0.67	1.64	1.05	0.62	0.67	1.64
		Bear Valley/Elk Creek	1.04	0.63	0.72	1.52	1.04	0.63	0.72	1.52
		Marsh Creek	1.05	0.63	0.69	1.60	1.05	0.63	0.69	1.60
		Sulphur Creek	1.01	0.52	0.74	1.37	1.01	0.52	0.74	1.37
		Camas Creek	1.01	0.52	0.58	1.76	1.01	0.52	0.58	1.76
		Loon Creek	1.02	0.53	0.56	1.84	1.02	0.53	0.56	1.84
		Chamberlain Creek[1]	0.94				0.94			
		Lower Middle Fork Salmon (below Ind. Cr.)								
		Upper Middle Fork Salmon (above Ind. Cr.)								
	Upper Salmon	Lemhi River	1.03	0.57	0.66	1.62	1.03	0.57	0.66	1.62
		Valley Creek	1.07	0.72	0.77	1.49	1.07	0.72	0.77	1.49
		Yankee Fork	0.97	0.45	0.51	1.87	0.88	0.30	0.42	1.81
		Upper Salmon River (above Redfish L.)	1.05	0.64	0.71	1.57	0.99	0.47	0.65	1.50
		North Fork Salmon River								
		Lower Salmon River (below Redfish L.)	1.03	0.59	0.74	1.44	1.03	0.59	0.74	1.44
		East Fork Salmon River	1.09	0.71	0.68	1.75	1.07	0.65	0.66	1.73
		Pahsimeroi River	1.22	0.96	0.95	1.57	1.01	0.55	0.82	1.24
		Panther - Extirpated								
Upper Columbia Spring Chinook Salmon	Eastern Cascades	Wenatchee R.	0.99	0.47	0.65	1.51	0.83	0.11	0.55	1.23
		Methow R.	0.97	0.44	0.56	1.70	0.76	0.09	0.46	1.25
		Entiat R.	1.01	0.54	0.70	1.47	0.92	0.24	0.65	1.29
		Okanogan R. (extirpated)								
Snake River Fall Chinook Salmon	Main Stem and Lower Tributaries	Lower Mainstem Fall Chinook 1990-Most Recent BY	1.16	0.95	0.94	1.44	0.94	0.26	0.72	1.23

[1] Valid lambda confidence limit estimates could not be obtained for this population.

Table A-2. 1990-present steelhead median population growth rate (lambda) under the assumption that hatchery-origin spawners are not reproductively effective (HF=0) and under the assumption that hatchery-origin spawners are as reproductively effective as natural-origin spawners (HF=1). These extended Base Period estimates are based on new information in the NWFSC SPS database that has become available since the 2008 BiOp. The 2008 BiOp's goal for prospective actions for this metric is lambda greater than 1.0.

ESU	MPG	Population	Lambda HF=0				Lambda HF=1			
			Base Period Lambda HF=0	Probability Lambda >1.0	Lower 95% Confidence Limit	Upper 95% Confidence Limit	Extended Base Period Lambda HF=1	Probability Lambda >1.0	Lower 95% Confidence Limit	Upper 95% Confidence Limit
Upper Columbia River Steelhead	Eastern Cascades	Wenatchee	1.05	0.67	0.77	1.42	0.82	0.09	0.56	1.18
		Methow	1.05	0.66	0.75	1.48	0.67	0.01	0.52	0.86
		Entiat	1.05	0.69	0.79	1.39	0.78	0.02	0.62	0.98
		Okanogan	1.06	0.68	0.73	1.55	0.58	0.01	0.42	0.80
Snake River Steelhead[1]	Lower Snake	Tucannon								
		Asotin								
	Imnaha River	Imnaha R. (Camp Cr)	1.02	0.61	0.82	1.26	1.02	0.61	0.82	1.26
	Grande Ronde	Upper Mainstem	1.02	0.79	0.95	1.11	0.99	0.33	0.90	1.08
		Lower Mainstem								
		Joseph Cr.	1.00	0.52	0.84	1.20	1.00	0.52	0.84	1.20
		Wallowa R.								
	Clearwater River	Lower Mainstem								
		Lolo Creek								
		Lochsa River								
		Selway River								
		South Fork								
		North Fork - (Extirpated)								
	Salmon River	Upper Middle Fork Tribs								
		Chamberlain Cr.								
		South Fork Salmon								
		Panther Creek								
		Secesh River								
		North Fork								
		Lower Middle Fork Tribs								
		Little Salmon/Rapid								
		Lemhi River								
		Pahsimeroi River								
		East Fork Salmon								
		Upper Mainstem								
Mid Columbia Steelhead	Yakima	Upper Yakima	1.09	0.86	0.89	1.33	1.08	0.85	0.88	1.33
		Naches	1.09	0.85	0.88	1.36	1.08	0.82	0.87	1.34
		Toppenish	1.09	0.80	0.82	1.45	1.08	0.77	0.82	1.42
		Satus	1.08	0.82	0.86	1.35	1.06	0.78	0.85	1.34
	Eastern Cascades	Deschutes W.	1.05	0.72	0.82	1.35	0.99	0.42	0.79	1.23
		Deschutes East	1.04	0.61	0.68	1.60	0.96	0.38	0.66	1.40
		Klickitat								
		Fifteenmile Cr.	1.01	0.56	0.75	1.37	1.01	0.56	0.75	1.37
		Rock Cr.								
		White Salmon - Extirpated								
	Umatilla/Walla Walla	Umatilla	1.05	0.77	0.87	1.27	0.97	0.30	0.81	1.15
		Walla-Walla	1.03	0.63	0.77	1.37	1.02	0.60	0.76	1.37
		Touchet	1.01	0.62	0.94	1.08	0.97	0.10	0.91	1.03
	John Day	Lower Mainstem)	1.01	0.53	0.63	1.63	0.99	0.46	0.61	1.60
		North Fork	1.06	0.77	0.85	1.32	1.04	0.71	0.84	1.30
		Upper Mainstem	0.98	0.42	0.75	1.28	0.97	0.36	0.74	1.26
		Middle Fork	0.98	0.42	0.69	1.39	0.96	0.38	0.67	1.38
		South Fork	1.03	0.59	0.73	1.46	1.01	0.54	0.72	1.43

[1] Only the populations with empirical estimates are shown, as in the 2008 BiOp. In the 2008 BiOp, other populations were analyzed using "average A- and B-run" estimates, as understood at the time.

Table A-3. 1990-present Chinook BRT abundance trend (trend of ln[abundance+1]). These extended Base Period estimates are based on new information in the NWFSC SPS database that has become available since the 2008 BiOp. The 2008 BiOp's goal for prospective actions for this metric is BRT trend greater than 1.0.

ESU	MPG	Population	New Information			
			Extended Base Period BRT Trend	Probability BRT Trend >1.0	Lower 95% Confidence Limit	Upper 95% Confidence Limit
Snake River Spring/ Summer Chinook Salmon	Lower Snake	Tucannon	1.10	0.95	0.98	1.23
		Asotin - Functionally Extirpated				
	Grande Ronde / Imnaha	Catherine Creek	1.11	1.00	1.04	1.19
		Upper Grande Ronde	1.02	0.72	0.95	1.09
		Minam River	1.10	1.00	1.05	1.14
		Wenaha River	1.11	1.00	1.06	1.16
		Lostine/Wallowa Rivers	1.12	1.00	1.07	1.17
		Imnaha River	1.05	0.98	1.00	1.10
		Big Sheep Creek - Functionally Extirpated				
		Lookingglass- Functionally Extirpated				
	South Fork Salmon	South Fork Salmon Mainstem	1.03	0.96	1.00	1.07
		Secesh River	1.06	0.99	1.02	1.11
		East Fork S. Fork Salmon (including Johnson)	1.02	0.77	0.97	1.08
		Little Salmon River (including Rapid R.)				
	Middle Fork Salmon	Big Creek	1.09	0.99	1.01	1.18
		Bear Valley/Elk Creek	1.09	1.00	1.02	1.16
		Marsh Creek	1.10	0.96	0.99	1.23
		Sulphur Creek	1.07	0.91	0.97	1.18
		Camas Creek	1.07	0.95	0.99	1.17
		Loon Creek	1.09	0.94	0.98	1.21
		Chamberlain Creek	1.09	0.99	1.02	1.17
		Lower Middle Fork Salmon (below Ind. Cr.)				
		Upper Middle Fork Salmon (above Ind. Cr.)				
	Upper Salmon	Lemhi River	1.04	0.92	0.98	1.10
		Valley Creek	1.12	1.00	1.04	1.20
		Yankee Fork	1.00	0.52	0.91	1.10
		Upper Salmon River (above Redfish L.)	1.09	1.00	1.04	1.15
		North Fork Salmon River				
		Lower Salmon River (below Redfish L.)	1.06	0.99	1.01	1.11
		East Fork Salmon River	1.15	1.00	1.07	1.23
		Pahsimeroi River	1.22	1.00	1.17	1.27
		Panther - Extirpated				
Upper Columbia Spring Chinook Salmon	Eastern Cascades	Wenatchee R.	1.03	0.80	0.96	1.10
		Methow R.	1.02	0.67	0.93	1.12
		Entiat R.	1.05	0.95	0.99	1.11
		Okanogan R. (extirpated)				
Snake River Fall Chinook Salmon	Main Stem and Lower Tributaries	Lower Mainstem Fall Chinook 1990-Most Recent BY	1.19	1.00	1.15	1.23

Table A-4. 1990-present steelhead BRT abundance trend (trend of ln[abundance+1]). These extended Base Period estimates are based on new information in the NWFSC SPS database that has become available since the 2008 BiOp. The 2008 BiOp's goal for prospective actions for this metric is BRT trend greater than 1.0.

ESU	MPG	Population	New Information			
			Extended Base Period BRT Trend	Probability BRT Trend >1.0	Lower 95% Confidence Limit	Upper 95% Confidence Limit
Upper Columbia River Steelhead	Eastern Cascades	Wenatchee	1.06	0.99	1.01	1.10
		Methow	1.08	1.00	1.03	1.13
		Entiat	1.06	1.00	1.02	1.11
		Okanogan	1.10	1.00	1.04	1.16
Snake River Steelhead[1]	Lower Snake	Tucannon				
		Asotin				
	Imnaha River	Imnaha R. (Camp Cr)	1.05	0.98	1.00	1.09
	Grande Ronde	Upper Mainstem	1.02	0.88	0.99	1.06
		Lower Mainstem				
		Joseph Cr.	1.02	0.86	0.98	1.06
		Wallowa R.				
	Clearwater River	Lower Mainstem				
		Lolo Creek				
		Lochsa River				
		Selway River				
		South Fork				
		North Fork - (Extirpated)				
	Salmon River	Upper Middle Fork Tribs				
		Chamberlain Cr.				
		South Fork Salmon				
		Panther Creek				
		Secesh River				
		North Fork				
		Lower Middle Fork Tribs				
		Little Salmon/Rapid				
		Lemhi River				
		Pahsimeroi River				
		East Fork Salmon				
		Upper Mainstem				
Mid Columbia Steelhead	Yakima	Upper Yakima	1.10	1.00	1.07	1.13
		Naches	1.10	1.00	1.07	1.13
		Toppenish	1.12	1.00	1.07	1.16
		Satus	1.10	1.00	1.06	1.13
	Eastern Cascades	Deschutes W.	1.07	1.00	1.03	1.11
		Deschutes East	1.08	1.00	1.02	1.13
		Klickitat				
		Fifteenmile Cr.	1.02	0.83	0.98	1.07
		Rock Cr.				
		White Salmon - Extirpated				
	Umatilla/Walla Walla	Umatilla	1.06	1.00	1.03	1.09
		Walla-Walla	1.03	0.92	0.99	1.07
		Touchet	1.00	0.48	0.98	1.02
	John Day	Lower Mainstem)	1.01	0.66	0.96	1.07
		North Fork	1.06	1.00	1.02	1.10
		Upper Mainstem	0.99	0.31	0.94	1.04
		Middle Fork	0.98	0.20	0.94	1.03
		South Fork	1.04	0.96	0.99	1.08

[1] Only the populations with empirical estimates are shown, as in the 2008 BiOp. In the 2008 BiOp, other populations were analyzed using "average A- and B-run" estimates, as understood at the time.

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Appendix B
Hinrichsen (2013) Extinction Risk Analysis—Detailed Results

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Hinrichsen (2013) Extinction Risk Analysis—Detailed Results

<Placeholder: A final report will be available after final population data are available for all species. For example, Snake River fall Chinook estimates in draft tables are likely to change. This appendix includes extinction risk estimates based on four quasi-extinction thresholds (QET), as included in the 2008 BiOp. Section 2.1.1.4.3 [Extended Base Period Productivity and Extinction Risk Indicator Metrics Calculated From Updated Population Information] presented in tables with QET 50 results.>

Table A. Probability of extinction for Interior Columbia River Spring/Summer Chinook populations using data from 1978-most currently available year. The data set used was contained in the file **R_S_Chin_SPS_from Mari_062813_072913ct.xlsx** . Extinction probabilites were calculated for a 24-year time horizon. The reproductive failure threshold value was 2 when quasi-extinction threshold (QET)=1, and 10 otherwise. Confidence intervals were calculated by drawing 1,000 random samples from the joint sampling distribution of the maximum likelihood estimates of the Beverton-Holt model parameters, where the error term followed an auto-regressive process of order 1 to account for autocorrelation in the residuals. Extinction probabilities were calculated by generating 10,000 random spawner trajectories and calculating the fraction of these that fell below QET four years running. Prob=probability of quasi-extinction; LOWER95=lower 95% confidence limit; UPPER95=upper 95% confidence limit;NA = no maximum likelihood estimates of the Beverton-Holt parameters could be found.

	QET=1			QET=10			QET=30			QET=50		
	Prob	LOWER95	UPPER95	Prob	LOWER95	UPPER95	Prob	LOWER95	UPPER95	Prob	LOWER95	UPPER95
Bear Valley Creek Chinook	0.00	0.00	0.03	0.00	0.00	0.17	0.00	0.00	0.33	0.02	0.00	0.45
Big Creek Chinook	0.00	0.00	0.24	0.01	0.00	0.40	0.10	0.00	0.70	0.29	0.01	0.86
Camas Creek Chinook	0.05	0.00	0.57	0.42	0.01	0.92	0.78	0.12	0.99	0.92	0.43	1.00
Catherine Creek Chinook	0.01	0.00	0.47	0.09	0.00	0.80	0.24	0.00	0.91	0.37	0.05	0.95
Chamberlain Creek Chinook	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Entiat River Spring Chinook	0.00	0.00	0.05	0.00	0.00	0.28	0.01	0.00	0.56	0.05	0.00	0.79
Grande Ronde Upper Mainstem Chinook	0.00	0.00	0.09	0.01	0.00	0.46	0.19	0.01	0.76	0.48	0.07	0.94
Imnaha River Chinook	0.00	0.00	0.45	0.00	0.00	0.96	0.00	0.00	0.98	0.00	0.00	0.94
Lemhi River Chinook	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Loon Creek Chinook	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lostine River Chinook	0.00	0.00	0.15	0.00	0.00	0.31	0.01	0.00	0.40	0.04	0.00	0.51
Lower Mainstem Salmon River Chinook	0.00	0.00	0.18	0.00	0.00	0.34	0.05	0.00	0.53	0.23	0.00	0.78
Marsh Creek Chinook	0.01	0.00	0.43	0.06	0.00	0.63	0.24	0.00	0.86	0.39	0.01	0.92
Methow River Spring Chinook	0.00	0.00	0.32	0.02	0.00	0.52	0.06	0.00	0.59	0.10	0.00	0.74
Minam River Chinook	0.00	0.00	0.06	0.00	0.00	0.20	0.00	0.00	0.37	0.01	0.00	0.47
Pahsimeroi River Chinook	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Secesh River Chinook	0.00	0.00	0.03	0.00	0.00	0.12	0.00	0.00	0.20	0.00	0.00	0.37
South Fork Salmon East Fork/Johnson Cre	0.00	0.00	0.01	0.00	0.00	0.07	0.00	0.00	0.22	0.00	0.00	0.37
South Fork Salmon Mainstem Chinook	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.06	0.00	0.00	0.19
Sulphur Creek Chinook	0.00	0.00	0.73	0.04	0.00	0.99	0.37	0.02	1.00	0.67	0.21	1.00
Tucannon Spring Chinook	0.00	0.00	0.20	0.00	0.00	0.34	0.01	0.00	0.46	0.03	0.00	0.56
Upper Mainstem Salmon River Chinook	0.00	0.00	0.03	0.00	0.00	0.09	0.00	0.00	0.29	0.00	0.00	0.44
Upper Salmon East Fork Chinook	0.00	0.00	0.23	0.01	0.00	0.45	0.09	0.00	0.66	0.23	0.01	0.73
Valley Creek Chinook	0.00	0.00	0.17	0.02	0.00	0.56	0.40	0.02	0.92	0.76	0.17	0.99
Wenaha River Chinook	0.00	0.00	0.19	0.01	0.00	0.43	0.05	0.00	0.56	0.10	0.00	0.64
Wenatchee River Spring Chinook	0.00	0.00	0.21	0.00	0.00	0.43	0.02	0.00	0.50	0.04	0.00	0.64
Yankee Fork Salmon River Chinook	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table B.Probability of extinction for Interior Columbia River steelhead populations using data from 1978-most currently available year. The data set used was contained in the file **R_S_Sthd_SPS_from Mari_062813_071813ct.xlsx**. Extinction probabilites were calculated for a 24-year time horizon. The reproductive failure threshold value was 2 when quasi-extinction threshold (QET)=1, and 10 otherwise. Confidence intervals were calculated by drawing 1,000 random samples from the joint sampling distribution of the maximum likelihood estimates of the Ricker model parameters, where the error term followed an auto-regressive process of order 1 to account for autocorrelation in the residuals. Extinction probabilities were calculated by generating 10,000 random spawner trajectories and calculating the fraction of these that fell below QET four years running. Prob=probability of quasi-extinction; LOWER95=lower 95% confidence limit; UPPER95=upper 95% confidence limit.

	QET=1			QET=10			QET=30			QET=50		
	Prob	LOWER95	UPPER95	Prob	LOWER95	UPPER95	Prob	LOWER95	UPPER95	Prob	LOWER95	UPPER95
Deschutes River Eastside Steelhead	0.25	0.01	0.56	0.43	0.05	0.79	0.52	0.16	0.88	0.57	0.21	0.90
Deschutes River Westside Steelhead	0.00	0.00	0.12	0.00	0.00	0.28	0.00	0.00	0.29	0.00	0.00	0.37
Entiat River Steelhead	0.03	0.00	0.45	0.41	0.01	0.92	0.74	0.12	1.00	0.89	0.25	1.00
Fifteenmile Creek Steelhead	0.00	0.00	0.07	0.00	0.00	0.12	0.00	0.00	0.18	0.00	0.00	0.26
Grande Ronde Upper Mainstem Steelhead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Imnaha Camp Creek	0.00	0.00	0.03	0.00	0.00	0.14	0.04	0.00	0.48	0.33	0.01	0.78
John Day Lower Mainstem Steelhead	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.04	0.00	0.00	0.06
John Day Middle Fork River Steelhead	0.00	0.00	0.15	0.00	0.00	0.20	0.00	0.00	0.36	0.00	0.00	0.33
John Day North Fork River Steelhead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.02
John Day South Fork River Steelhead	0.00	0.00	0.13	0.00	0.00	0.24	0.00	0.00	0.33	0.01	0.00	0.34
John Day Upper Mainstem	0.00	0.00	0.14	0.00	0.00	0.24	0.00	0.00	0.32	0.00	0.00	0.35
Joseph Creek Steelhead	0.00	0.00	0.01	0.00	0.00	0.09	0.00	0.00	0.12	0.00	0.00	0.08
Methow River Steelhead	0.00	0.00	0.23	0.34	0.01	0.95	0.75	0.10	1.00	0.88	0.31	1.00
Naches River Steelhead	0.20	0.01	0.56	0.34	0.04	0.61	0.40	0.11	0.68	0.46	0.17	0.74
Okanogan River Steelhead	0.92	0.39	1.00	1.00	0.70	1.00	1.00	0.77	1.00	1.00	0.78	1.00
Satus Creek Steelhead	0.09	0.00	0.75	0.18	0.00	0.75	0.26	0.00	0.80	0.31	0.00	0.79
Toppenish Creek Steelhead	0.44	0.15	0.73	0.58	0.30	0.87	0.67	0.38	0.94	0.72	0.49	0.97
Touchet River Steelhead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Umatilla River Steelhead	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.02
Upper Yakima River Steelhead	0.30	0.02	0.66	0.47	0.15	0.76	0.64	0.36	0.93	0.78	0.54	0.99
Walla Walla River Steelhead	0.00	0.00	0.40	0.00	0.00	0.46	0.00	0.00	0.49	0.00	0.00	0.56
Wenatchee River Steelhead	0.00	0.00	0.31	0.03	0.00	0.52	0.12	0.00	0.70	0.20	0.00	0.82

Appendix C
Recruits-per-Spawner in base versus current time periods—do they differ?

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Recruits-per-Spawner in base versus current time periods—do they differ?

DRAFT – August 29, 2013

Rich Zabel and Tom Cooney

NOAA Fisheries

Northwest Fisheries Science Center

Background

The 2008 Supplemental Comprehensive Analysis[138] (SCA) included a quantitative evaluation of the effects of 2008-2018 harvest and hydropower activities[139] on populations of six species of interior Columbia River salmon and steelhead (Appendix Table 1) listed under the Endangered Species Act. The SCA estimated the following measures of population performance during a "Base Period" for which empirical data were available (approximately 1980-2004, corresponding to the ~1980-2000 completed brood cycles [BY]):

- 24-year extinction risk
- Geometric mean of recruits-per-spawner (R/S)
- Median population growth rate (lambda) under two assumptions regarding effectiveness of hatchery-origin spawners
- Trend of ln(abundance+1), referred to as "BRT Trend"

The ~1980-2000 BY Base Period metrics were the starting point for all subsequent calculations and projections in the SCA for the six interior Columbia basin species. There are now 5-7 new years of population data and NOAA Fisheries' Northwest Regional Office has requested assistance in determining whether the new observations represent a change in the original Base Period estimates or if they are within the expected range of variability.

[138] Supplemental Comprehensive Analysis of the Federal Columbia River Power System and Mainstem Effects of the Upper Snake and Other Tributary Actions. May 5, 2008. NOAA Fisheries, Northwest Regional Office, Portland, Oregon. Available at: http://www.nwr.noaa.gov/publications/hydropower/fcrps/final-sca.pdf .
[139] Activities were: Columbia River harvest under *US v Oregon*, operation of the Federal Columbia River Power System (FCRPS), and operation of Bureau of Reclamation water storage projects in the Upper Snake River.

In general, incorporating the new observations into "extended Base Period" (~1980 to most recent year) estimates[140] indicates:

- either unchanged or reduced extinction risk for most populations;
- higher abundance trends for nearly all populations;
- variable lambda estimates, depending in part on hatchery assumptions, but including reductions for a number of populations; and
- reduced mean R/S estimates for most populations.

Looking at the new observations independently, rather than combined with the original Base Period estimates, the contrast between improved abundance and reduced mean R/S productivity is even more apparent. Twenty-six out of 26 populations of spring and summer Chinook increased in abundance, measured as geometric mean abundance during the previous 10 years, when comparing the recent period to the Base Period, and 14 out 18 steelhead populations increased in abundance over the same period (Tables 1 and 2). However, mean R/S decreased in 22 out of 26 spring and summer Chinook populations and 14 out of 18 steelhead populations (Tables 1 and 2).

Although the decrease in productivity might suggest that overall population performance has declined, it is also consistent with expectations that recruits-per-spawner will decline as abundance increases due to density-dependent processes (Ricker 1954, Zabel et al. 2006). This is commonly observed in fish populations, and in fact forms the basis of most fisheries management models (e.g., Hilborn and Walters 1992). Here we test the density-dependent hypothesis by first testing whether the spawner and recruit data during the Base Period are consistent with a density-dependent model. Then we examine whether the current data fall within 95% prediction intervals for new observations.

[140] Personal communication, C. Toole, NOAA Fisheries Northwest Regional Office, March 22, 2013.

Table 1. Geometric mean abundance and recruits-per-spawner during base (brood years from approximately 1980-2000) and recent (approximately 2001 and later) time periods for interior Columbia basin spring and summer Chinook populations. To calculate the geometric means, we first added 1 to all spawner counts (because some counts were 0), and then subtracted 1 from the calculated mean.

Population	Mean Abundance		Mean Recruits–Per-Spawner	
	Base	Recent	Base	Recent
LS-Tucannon	246	534	0.74	0.60
GR-Wenaha	249	561	0.71	0.72
GR-Lostine	213	661	0.81	0.47
GR-Minam	290	487	0.87	1.03
GR-Upper Mainstem	86	146	0.46	0.30
GR-Catherine Cr	159	276	0.42	0.30
GR-Imnaha	526	1592	0.82	0.17
SF-Mainstem	592	1208	0.89	0.51
SF-Secesh	292	868	1.22	0.46
SF-East Fork	190	325	1.06	0.53
MF-Big Creek	80	182	1.42	0.99
MF-Camas Cr	32	89	0.94	0.54
MF-Loon	39	146	1.32	0.52
MF-Sulfur Cr	38	50	1.1	1.18
MF-Bear Valley/Elk	163	429	1.46	0.72
MF-Marsh Cr	127	203	1.08	1.18
SR-Lemhi	95	116	1.2	0.61

SR-Pahsimeroi	58	376	1.29	0.64
SR-Lower Mainstem	79	177	1.31	0.64
SR-East Fork	106	306	1.32	1.08
SR-Yankee Fork	16	24	1.17	0.54
SR-Valley Cr	42	74	1.36	1.23
SR-Upper Mainstem	164	647	1.71	0.56
UC-Wenatchee	844	915	0.75	0.40
UC-Methow	541	1277	0.92	0.26
UC-Entiat	152	206	0.79	0.51

Table 2. Geometric mean abundance and recruits-per-spawner during base and recent time periods for interior Columbia basin steelhead populations. To calculate the geometric means, we first added 1 to all spawner counts (because some counts were 0), and then subtracted 1 from the calculated mean.

Population	Mean Abundance		Mean Recruits–Per-Spawner	
	Base	Recent	Base	Recent
UC-Wenatchee	1645	2965	0.29	0.33
UC-Entiat	166	656	0.37	0.20
UC-Methow	1297	4942	0.15	0.11
UC-Okanogan	988	2504	0.07	0.06
MC-Fifteenmile Cr	455	828	1.32	0.59
Deschutes-W	483	951	1.03	0.58
JD-Lower Mainstem	1626	2886	1.64	0.40
JD-North Fork	1412	2273	1.37	0.70
JD-Upper Mainstem	939	662	1.24	0.69
JD-Middle Fork	1063	1032	1.37	0.49
JD-South Fork	459	385	1.15	1.06
MC-Umatilla	1632	3211	1.07	0.70
YR-Satus	451	673	1.01	1.73
YR-Toppenish	154	562	1.57	1.06
YR-Naches	392	806	1.14	1.47
YR-Upper Yakma	72	143	1.14	1.57
GR-Upper Mainstem	1538	1333	0.93	1.08
GR-Joseph Cr	1959	2484	1.26	0.80

Data

The spawning time series data for interior Columbia basin Chinook salmon and steelhead populations include estimates for the most recent annual returns obtained from state, tribal and federal managers. The data series are generated using protocols agreed upon through the Interior Columbia Technical Recovery Team and are updated versions of the data series available through the Salmonid Population Summary (SPS) data base maintained by the NWFSC (https://www.webapps.nwfsc.noaa.gov/apex/f?p=261:home:0#). The SPS includes documentation and is designed to accommodate annual updates. The additional years included in the analysis described below will be available in the SPS later this year.

Spawning abundance, hatchery/wild proportions and age composition follow the follow the protocols used in previous Biological Review Team and Technical Recovery Team reports (e.g., Good et al. 2005). Annual spawning abundance represents the estimated number of hatchery and wild origin fish contributing to spawning in natural production reaches for each population. Spawning abundance does not include 3-year olds (jacks). Brood year recruits are calculated assigning natural origin returns to age at return and then using this information to assign adult recruits to brood year. Because these recruits were estimated after any harvest occurred, we adjusted recruits to account for harvest:

$$R_t = \frac{A_t}{1 - h_t}$$

where R_t are estimated recruits from brood year t, A_t are post-harvest returning adults, and h_t is the harvest rate for adults from brood year t. R_t represent the number of naturally produced fish that would have appeared on the spawning grounds had there not been a harvest. We adjusted recruits to account for harvest because our goal here is to examine whether the inherent productivity of populations, measured as recruits-per-spawner, has changed between the baseline and recent time periods. Harvest removes recruits, and if harvest occurred differentially across time, it could alter the underlying relationships. In Appendix 2, we examined the impacts on results of adjusting for harvest versus not.

Annual estimates of mainstem harvest rates were obtained from the most recent U.S. v Oregon Technical Advisory Team report. Tributary harvest-rate estimates were provided by regional state and tribal fisheries managers.

Analysis

The first step in the analysis was to test whether the spawner and recruit data, by population, are consistent with a density-dependent recruitment model. We used a Ricker model because it is a simple linear model and therefore does not have the potential model-fitting issues that exist with nonlinear models, such as the Beverton-Holt model, when sample sizes are small.

The Ricker model relates recruits (R_t), referenced to brood year t, to spawners (S_t) as

$$R_t = S_t \cdot \exp(a - b \cdot S_t) \quad (1)$$

where a and b are density-independent and density-dependent model parameters, respectively. After rearranging terms and taking the natural log of both sides, the Ricker model can be expressed as

$$\ln(R_t / S_t) = a - b \cdot S_t \quad (2)$$

which is a linear model and easily fit to data using standard linear regression. We can express this in linear regression form as

$$\ln(R_t / S_t) = a + b \cdot S_t + \varepsilon_t \quad (3)$$

where ε_t is the error term which is distributed normally with mean 0 and variance σ^2. The data support the hypothesis of density-dependence if the b parameter is significantly different from 0 and negative. When this occurs, recruits-per-spawner decreases as spawners increase.

We note that in several populations, there were years where the estimate of spawners was 0. Because this would produce undefined terms in equation 3, we added 1 to every spawner and recruit estimate. This is a standard approach, but we acknowledge that other approaches, such as removing years in which spawner estimates were 0, are also justifiable. In Appendix 3, we assessed the implications of the various approaches.

We fit equation (3) to 44 populations of interior Columbia basin spring and summer Chinook and steelhead populations. To perform these fits, we only used data from the Base Period. For each population, we estimated model parameters, and we also calculated an R^2 and *P*-value. If the model was deemed significant ($P < 0.1$), we plotted the predicted relationship along with the data points. In addition, we also estimated 95% prediction intervals (Zar 2009) about the predicted relationships. This interval covers the envelope in which 95% of new data points would fall if they follow the modeled relationship and variability. If the model was not deemed significant ($P > 0.1$), we only plotted the data points. We chose this significance level because of the relatively low sample sizes in some of the populations.

For the populations that demonstrated significant relationships, we plotted the current data points and determined whether they fell within the 95% prediction interval, below the interval (indicating the R/S was lower than expected), or above the interval (indicating the R/S was greater than expected). Note that we expect 5% of the points to fall outside the interval by chance alone.

Results

For spring and summer Chinook populations, 20 out of 26 demonstrated significant relationships (Table 3). In all cases where the model was significant, the *b* (slope) parameter was negative, providing evidence for density dependence. When we plotted the "recent" data points onto the plots with the 95% prediction intervals, the vast majority of points fell within the 95% prediction intervals. In addition, only 1 point fell below the interval and 4 points fell above, providing no support for the hypothesis that recent conditions are less productive than those experienced during the Base Period (Figures 1-2).

For steelhead populations, 18 out of 18 demonstrated significant relationships (Table 4). In all cases, the *b* parameter was negative, providing strong evidence for density dependence. When we plotted the "recent" data points onto the plots with the 95% prediction intervals, the vast majority of points fell within the 95% prediction interval. In addition, 3 points fell below the interval and 14 points fell above, providing little support for the hypothesis that recent conditions are less productive than those experienced during the Base Period (Figures 3-4).

Discussion

These analyses provide strong support for the hypothesis that density-dependent recruitment is occurring in these populations. Further, when we plotted "recent" data points onto relationships derived from the "base" period data, the vast majority of these points fell with the 95% prediction intervals, providing strong support for the hypothesis that productivity has not decreased for these populations when comparing base to recent time periods but that the decreased R/S resulted from density-dependent processes as a result of the increased abundance observed recently (Tables 1 and 2, Figures 5-8).

One issue with this analysis was that the basic density-dependence model did not significantly fit the data for some of the populations. This was particularly the case for spring and summer Chinook populations, where 6 out 26 populations did not exhibit a significant density-dependent relationship. We believe that this was partially due to the fact the base time period encompassed a period where population abundance was generally low and thus did not cover a broad range of abundance levels. In contrast, abundance levels during the recent time period were generally higher. We thus combined the base and recent time periods together and re-fit Ricker model to the combined datasets. When we did this, 24 out of 26 spring and summer Chinook populations had significant fits (Figures 9-12).

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Table 3. Results from the regression analysis for interior Columbia basin spring and summer Chinook populations. a and b are model parameters. “above” refers to the number of recent points that fell above the 95% prediction interval, and “below” refers to the number of points that fell below the 95% prediction interval.

Population	a	b	R^2	P	above	below
LS-Tucannon	0.68	-0.0028	0.257	0.023	0	0
GR-Wenaha	0.365	-0.0023	0.124	0.128	NA	NA
GR-Lostine	0.893	-0.0036	0.433	0.002	0	0
GR-Minam	1.03	-0.003	0.420	0.002	0	0
GR-Upper Mainstem	0.0697	-0.0045	0.351	0.006	0	0
GR-Catherine Cr	0.109	-0.0036	0.294	0.014	0	0
GR-Imnaha	0.69	-0.0015	0.215	0.040	0	0
SF-Mainstem	0.726	-0.0011	0.395	0.003	0	0
SF-Secesh	0.566	-0.0011	0.033	0.441	NA	NA
SF-East Fork	0.335	-0.0012	0.031	0.459	NA	NA
MF-Big Creek	1.11	-0.0054	0.211	0.042	0	0
MF-Camas Cr	0.892	-0.016	0.237	0.035	0	0
MF-Loon	0.0679	0.0016	0.001	0.893	NA	NA
MF-Sulfur Cr	1.06	-0.0098	0.204	0.045	0	0
MF-Bear Valley/Elk	0.787	-0.0016	0.110	0.152	NA	NA
MF-Marsh Cr	1.03	-0.0045	0.147	0.095	0	0
SR-Lemhi	1.39	-0.0085	0.489	0.001	0	0
SR-Pahsimeroi	2.12	-0.021	0.451	0.006	4	0

SR-Lower Mainstem	1.28	-0.0095	0.412	0.002	0	0
SR-East Fork	1.52	-0.0077	0.331	0.008	0	0
SR-Yankee Fork	1.65	-0.055	0.465	0.001	0	0
SR-Valley Cr	1.49	-0.017	0.438	0.001	0	0
SR-Upper Mainstem	1.51	-0.0039	0.277	0.017	0	0
UC-Wenatchee	0.162	-0.00037	0.060	0.298	NA	NA
UC-Methow	1.13	-0.0014	0.234	0.031	0	1
UC-Entiat	0.658	-0.0045	0.254	0.024	0	0

Table 4. Results from the regression analysis for interior Columbia basin steelhead populations. a and b are model parameters. "above" refers to the number of recent points that fell above the 95% prediction interval, and "below" refers to the number of recent points that fell below the 95% prediction interval.

Population	a	b	R^2	P	above	below
UC-Wenatchee	-0.799	-0.00019	0.445	0.001	1	0
UC-Entiat	-0.447	-0.0027	0.270	0.019	0	0
UC-Methow	-0.868	-0.00066	0.537	0.000	4	0
UC-Okanogan	-2.18	-0.00037	0.385	0.004	0	0
MC-Fifteenmile Cr	1.11	-0.0016	0.449	0.006	0	0
Deschutes-W	0.977	-0.0017	0.372	0.004	0	0
JD-Lower Mainstem	1.43	-0.00038	0.514	0.000	0	0
JD-North Fork	1.45	-0.0006	0.785	0.000	0	0
JD-Upper Mainstem	1.01	-0.0006	0.434	0.002	0	1

JD-Middle Fork	1.24	-0.00068	0.547	0.000	0	2
JD-South Fork	0.98	-0.0013	0.404	0.003	0	0
MC-Umatilla	1.19	-0.00064	0.369	0.005	0	0
YR-Satus	1	-0.0018	0.627	0.000	3	0
YR-Toppenish	1.45	-0.0057	0.223	0.076	0	0
YR-Naches	1.28	-0.0026	0.505	0.003	3	0
YR-Upper Yakma	1.16	-0.012	0.536	0.002	3	0
GR-Upper Mainstem	0.968	-0.00056	0.640	0.000	0	0
GR-Joseph Cr	1.33	-0.00042	0.619	0.000	0	0

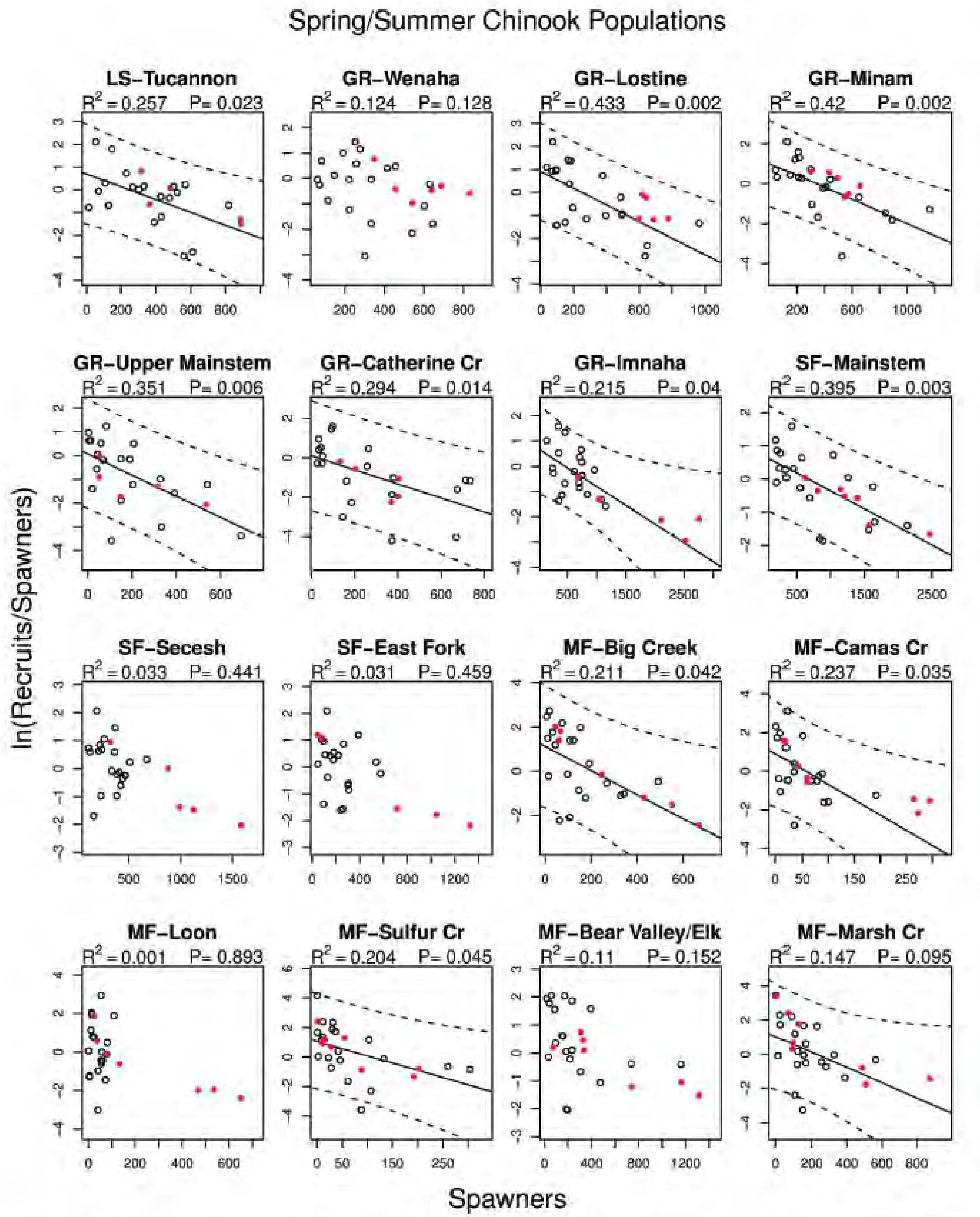

Figure 1. Ln(recruits/spawner) versus spawners for Interior Columbia River spring and summer Chinook populations. Open black points represent base period (1980-2000), and red points represent recent period. Based on linear regression, if P < 0.1, the dark line is the best fit, and the dashed lines are the 95% prediction interval for the data.

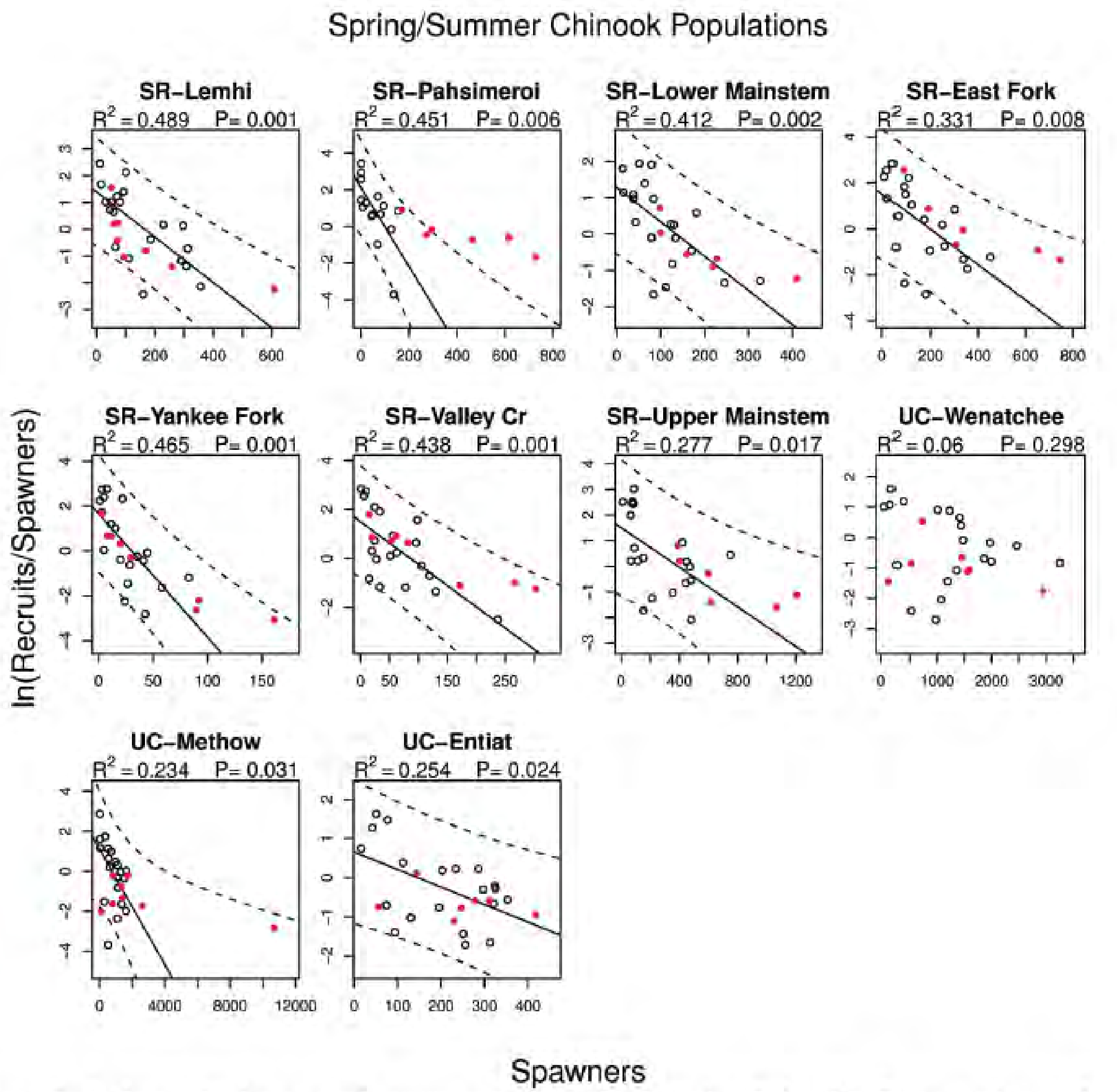

Figure 2. Ln(recruits/spawner) versus spawners for Interior Columbia River spring and summer Chinook populations. Open black points represent base period (1980-2000), and red points represent recent period. Based on linear regression, if $P < 0.1$, the dark line is the best fit, and the dashed lines are the 95% prediction interval for the data.

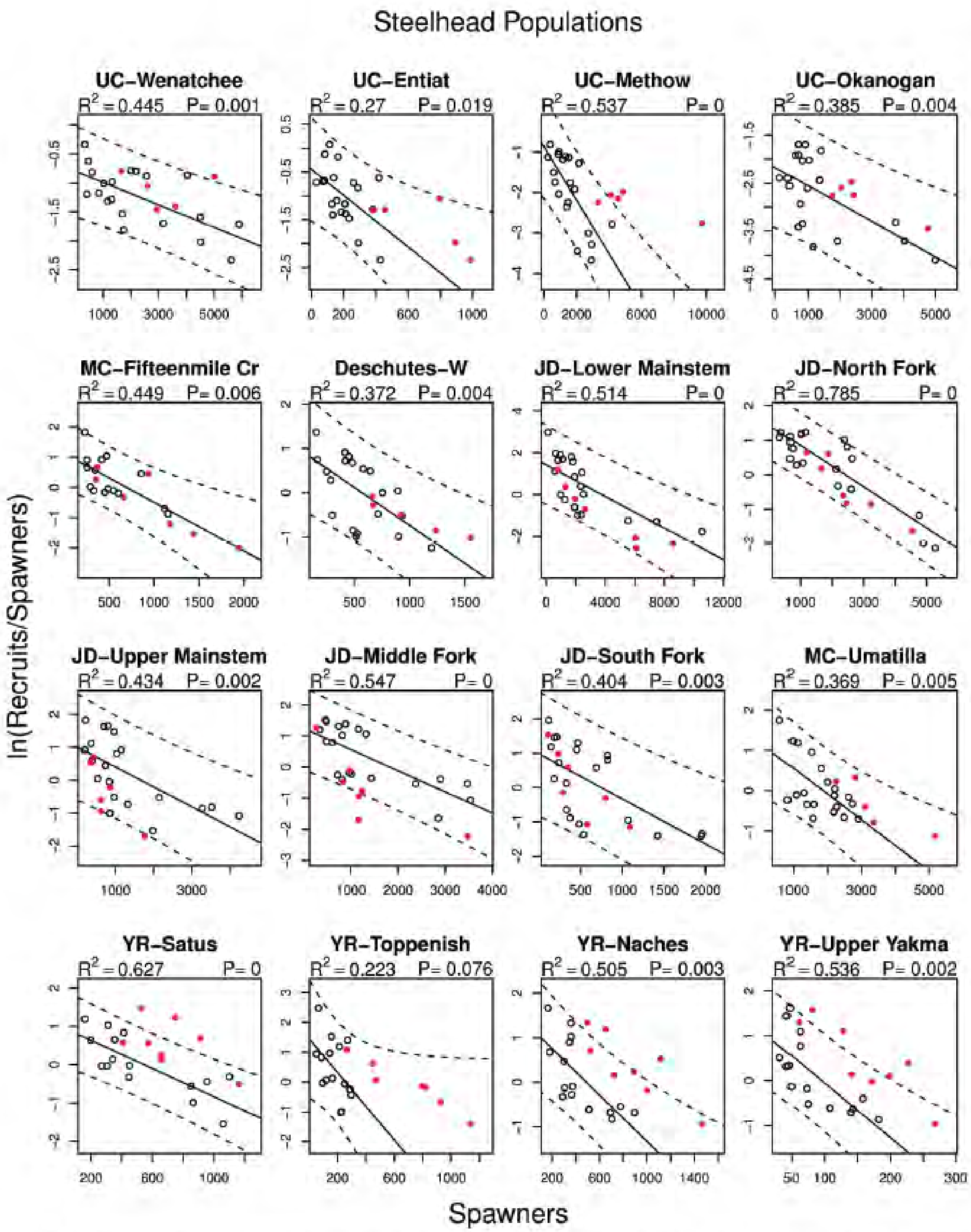

Figure 3. Ln(recruits/spawner) versus spawners for Interior Columbia River steelhead populations. Open black points represent base period (1980-2000), and red points represent recent period. Based on linear regression, if $P < 0.1$, the dark line is the best fit, and the dashed lines are the 95% prediction interval for the data.

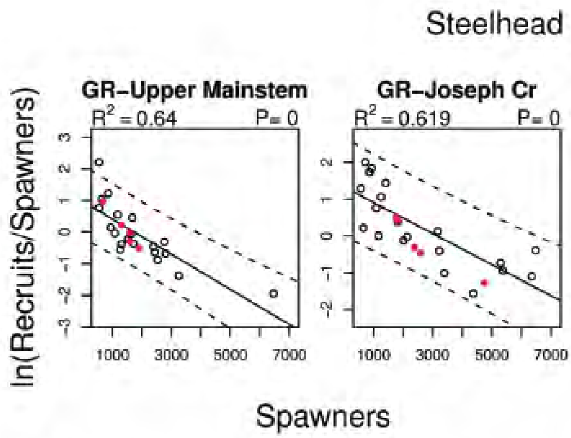

Figure 4. Ln(recruits/spawner) versus spawners for Interior Columbia River steelhead populations. Open black points represent base period (1980-2000), and red points represent recent period. Based on linear regression, if P < 0.1, the dark line is the best fit, and the dashed lines are the 95% prediction interval for the data. Note that these 2 populations did not have any harvest data.

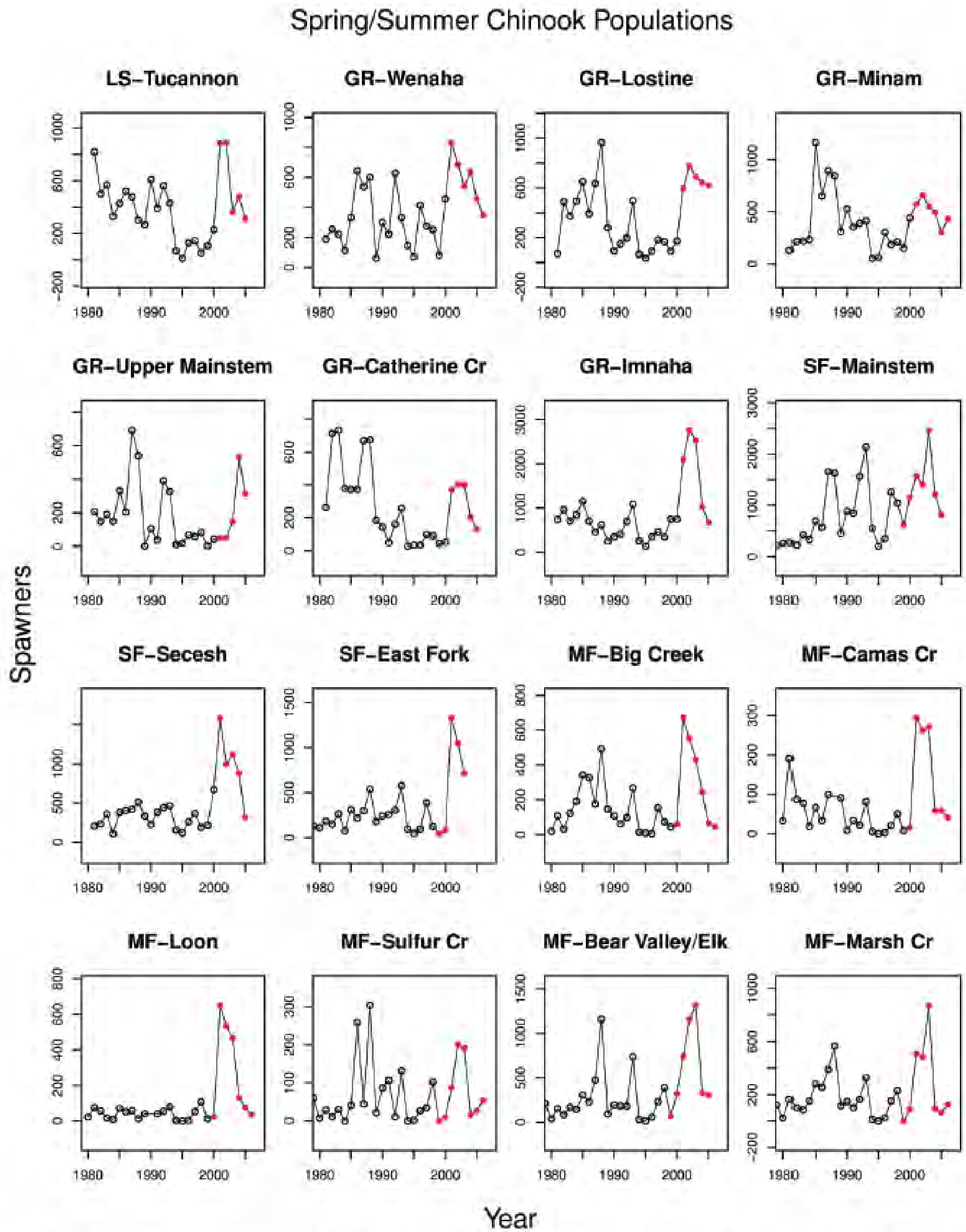

Figure 5. Spawners versus year for Interior Columbia River spring and summer Chinook populations. Open black points represent base period (1980-2000), and red points represent recent period.

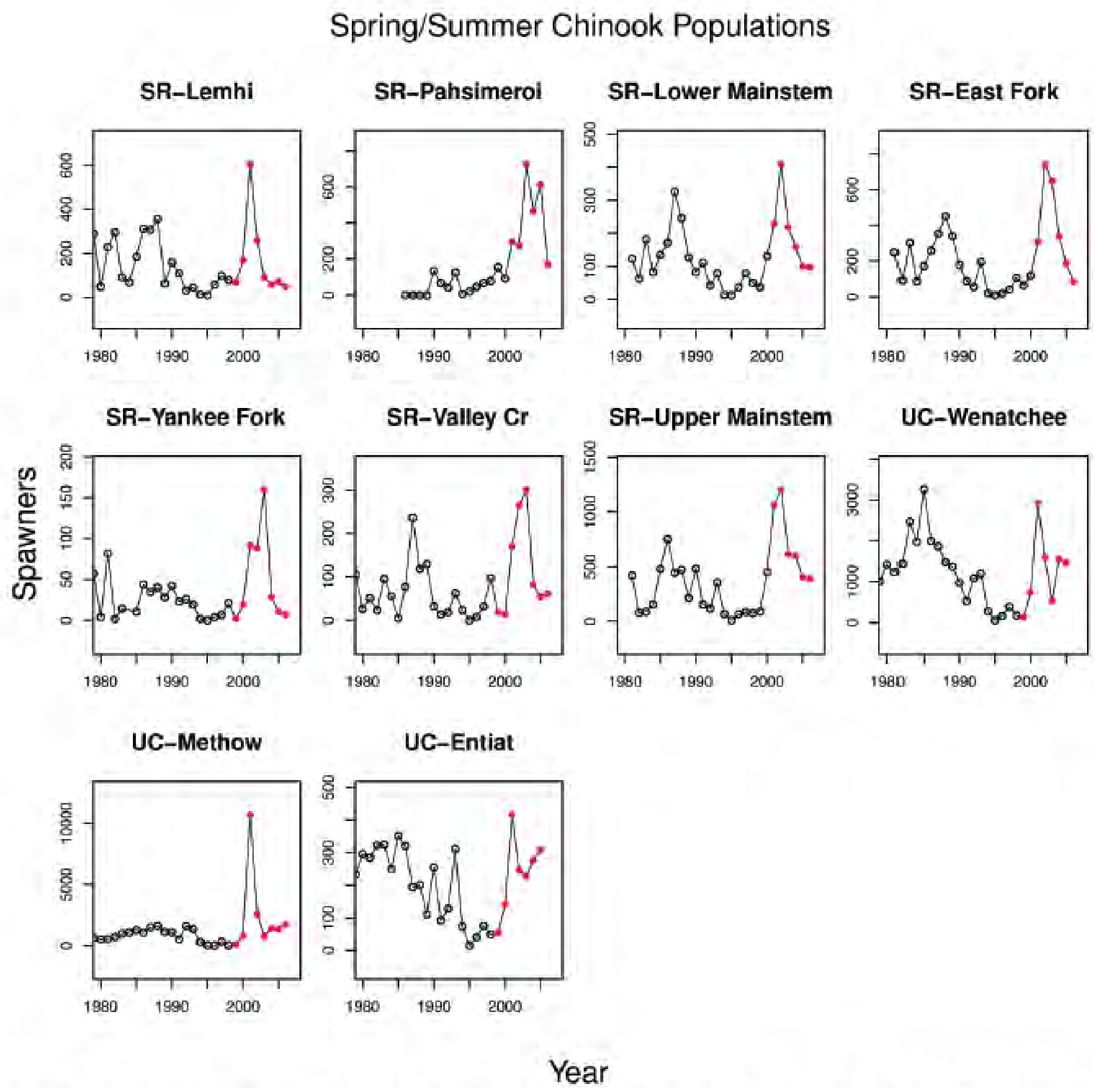

Figure 6. Spawners versus year for Interior Columbia River spring and summer Chinook populations. Open black points represent base period (1980-2000), and red points represent recent period.

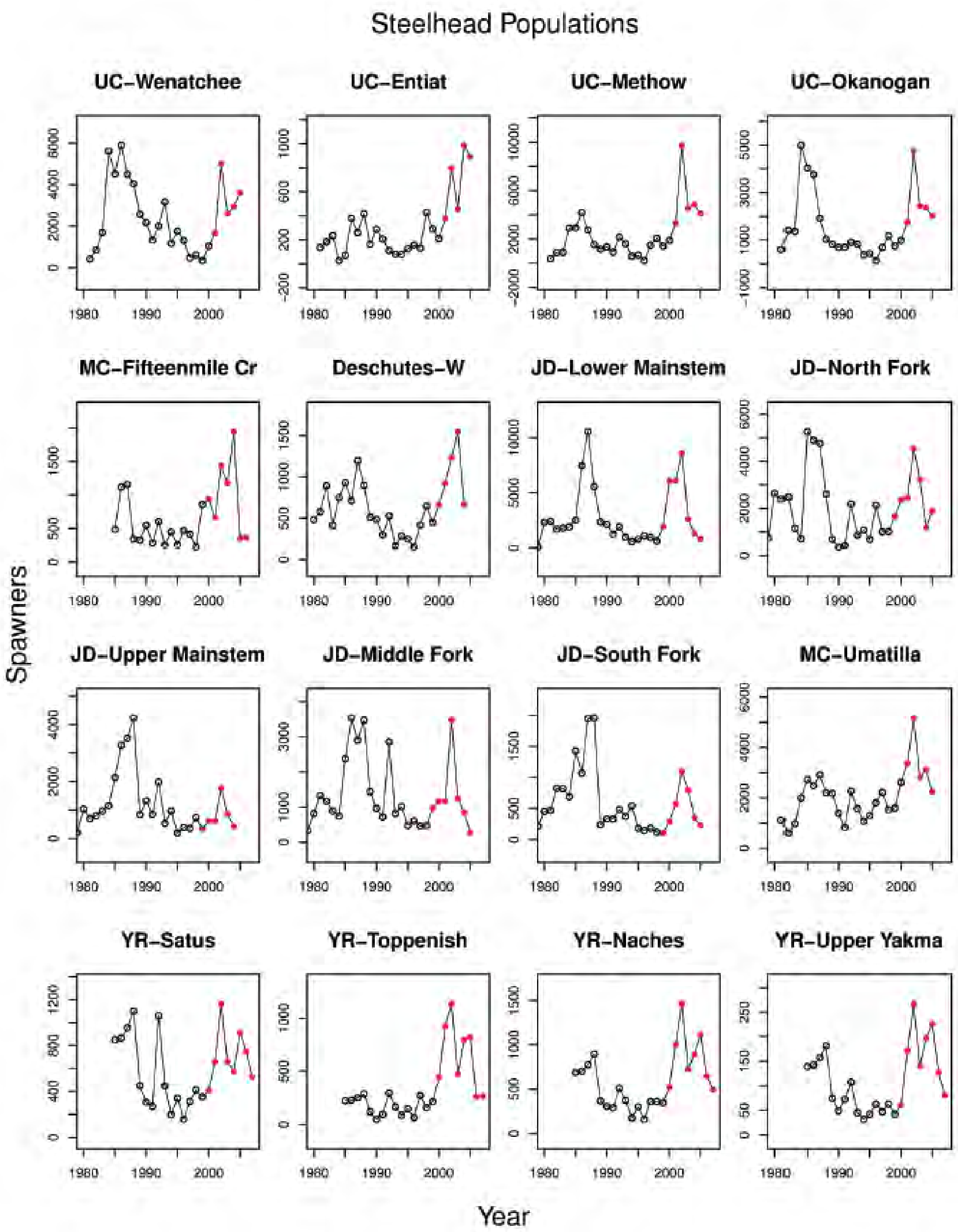

Figure 7. Spawners versus year for Interior Columbia River steelhead populations. Open black points represent base period (1980-2000), and red points represent recent period.

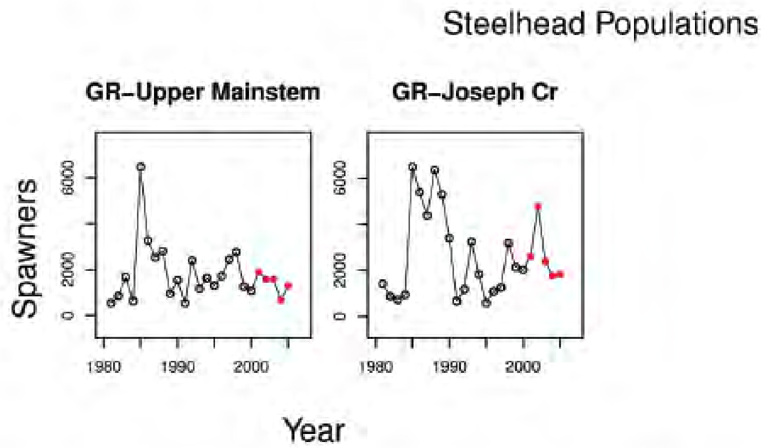

Figure 8. Spawners versus year for Interior Columbia River steelhead populations. Open black points represent base period (1980-2000), and red points represent recent period. Note that these 2 populations did not have any harvest data.

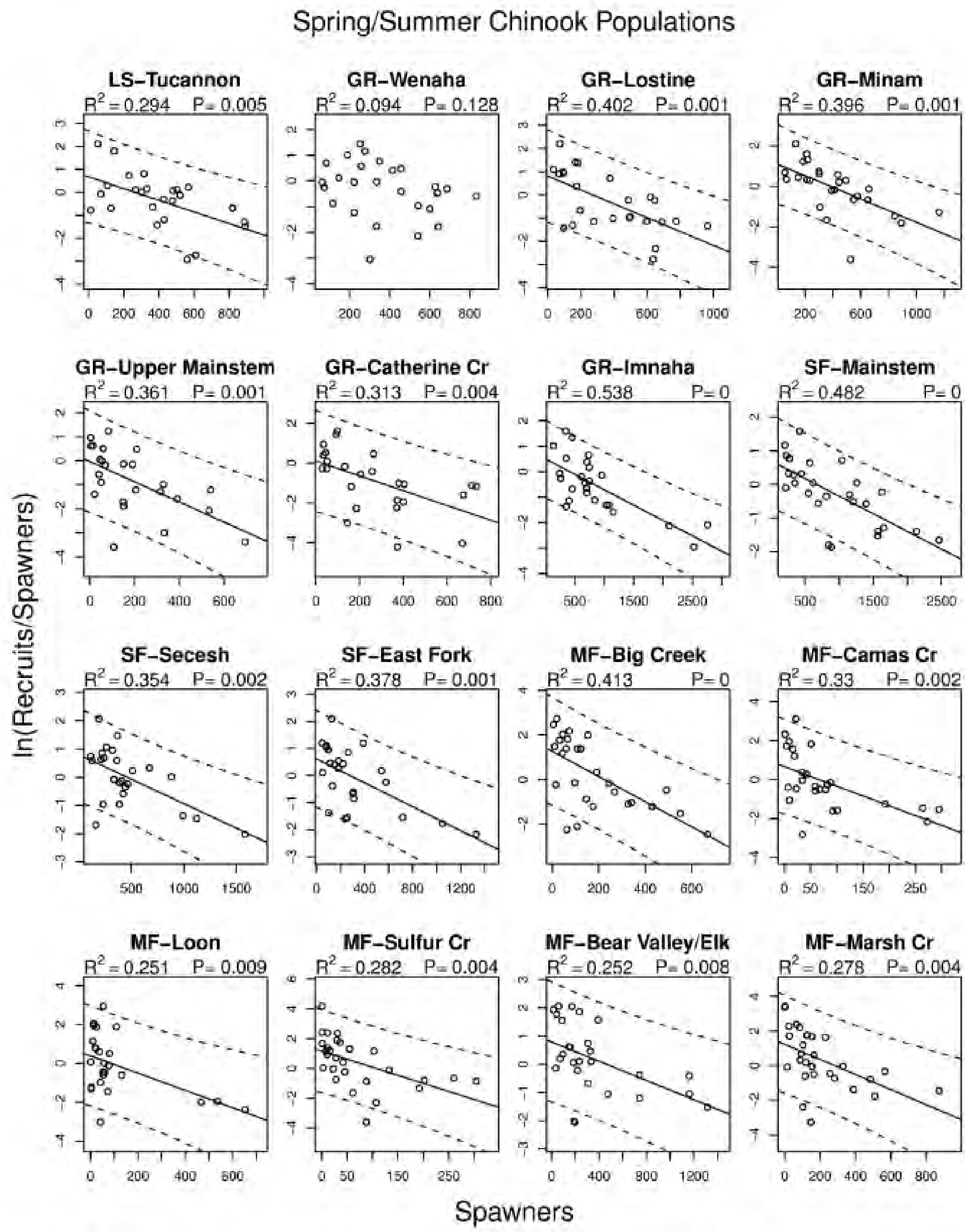

Figure 9. Ln(recruits/spawner) versus spawners for Interior Columbia River spring and summer Chinook populations. Open black points represent base period (1980-2000), and red points represent recent period. **The regression model was fit to all data (base and recent)**. Based on linear regression, if P < 0.1, the dark line is the best fit, and the dashed lines are the 95% prediction interval for the data.

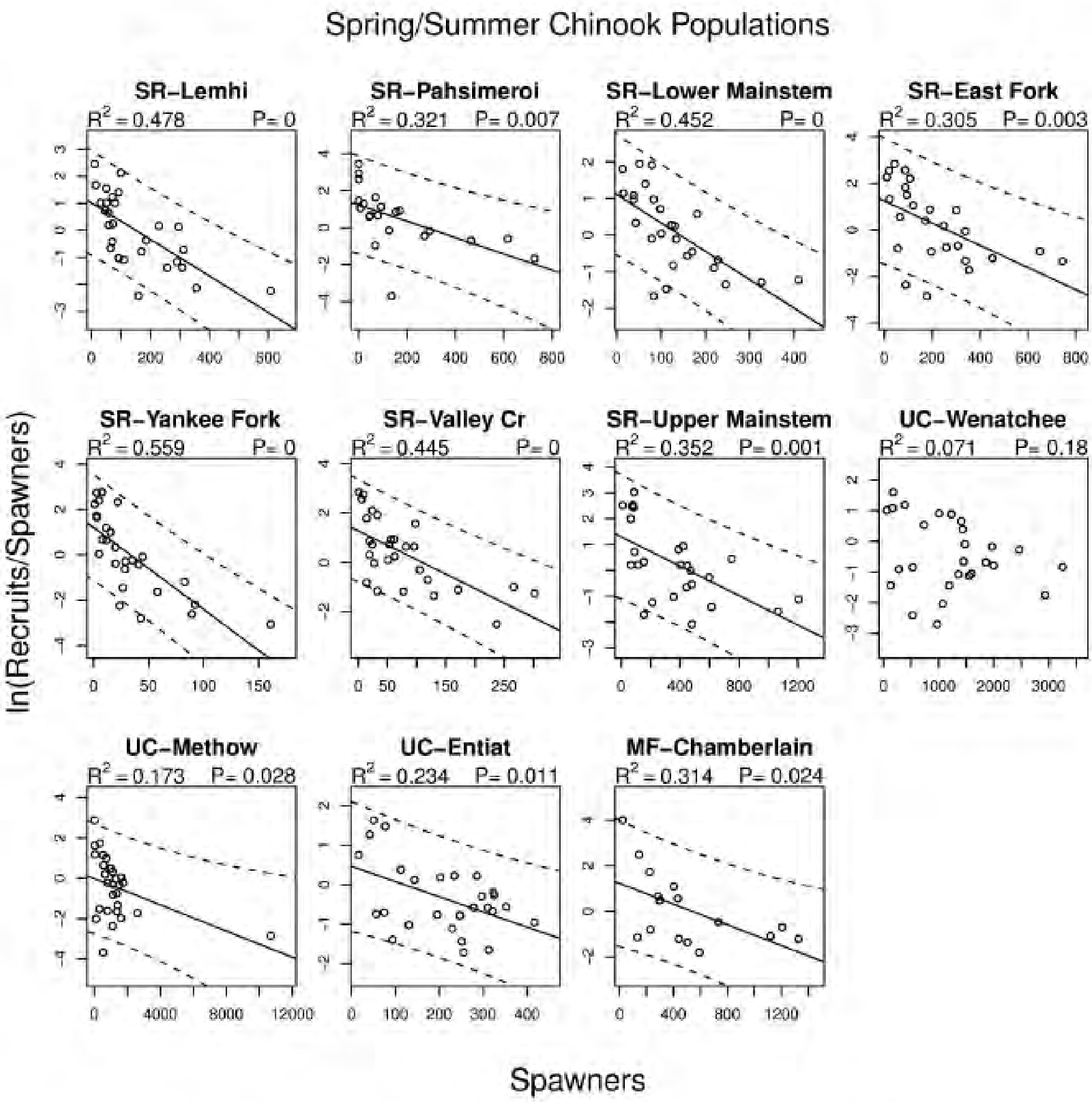

Figure 10. Ln(recruits/spawner) versus spawners for Interior Columbia River spring and summer Chinook populations. Open black points represent base period (1980-2000), and red points represent recent period. **The regression model was fit to all data (base and recent).** Based on linear regression, if $P < 0.1$, the dark line is the best fit, and the dashed lines are the 95% prediction interval for the data. The MF-Chamberlain population did not have any "base period" data, and was not included in the previous analyses.

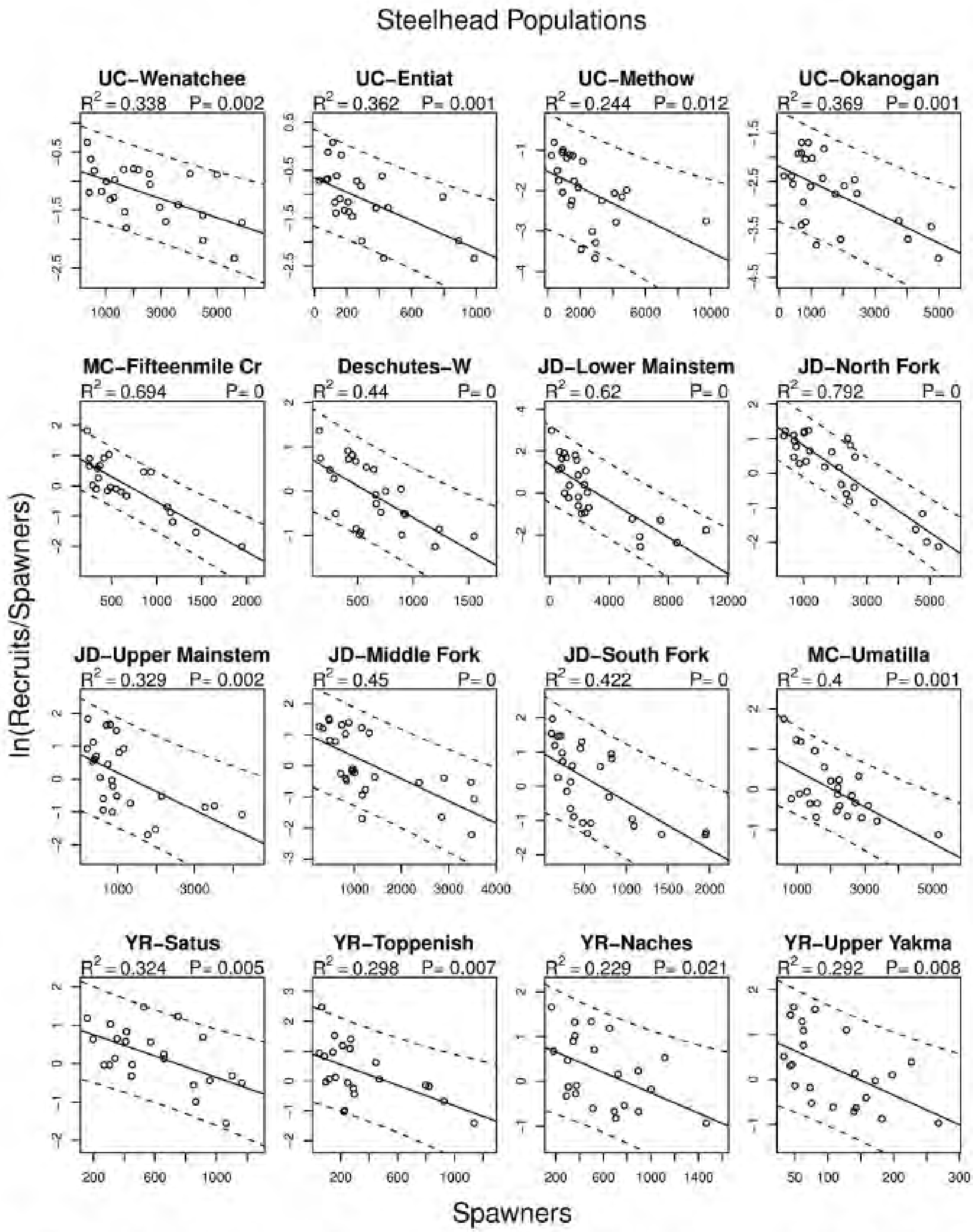

Figure 11. Ln(recruits/spawner) versus spawners for Interior Columbia River steelhead populations. Open black points represent base period (1980-2000), and red points represent recent period. **The regression model was fit to all data (base and recent).** Based on linear regression, if P < 0.1, the dark line is the best fit, and the dashed lines are the 95% prediction interval for the data.

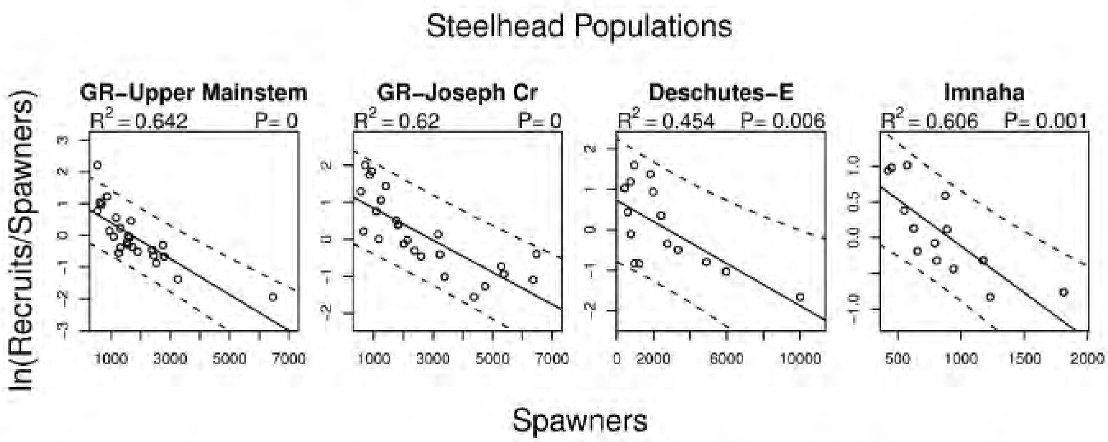

Figure 12. Ln(recruits/spawner) versus spawners for Interior Columbia River steelhead populations. Open black points represent base period (1980-2000), and red points represent recent period. **The regression model was fit to all data (base and recent).** Based on linear regression, if P < 0.1, the dark line is the best fit, and the dashed lines are the 95% prediction interval for the data. Note that the GR-Upper Mainstem and GR-Joseph Cr populations did not have harvest data. Also, the Deschutes-E and Imnaha populations did not have any "base period" data, and were not included in the previous analyses.

Appendix Table 1. Populations, major population groups (MPG), evolutionarily significant units (ESU), and distinct population segments (DPS) of salmon and steelhead addressed in this report. Shading indicates populations for which data were lacking or insufficient for the analysis and populations that are functionally extirpated.

ESU	MPG	Population	Codes for Populations Addressed in This Report
Snake River Spring/ Summer Chinook Salmon	Lower Snake	Tucannon River	LS-Tucannon
		Asotin Cr - Functionally Extirpated	
	Grande Ronde / Imnaha	Catherine Creek	GR-Catherine Cr
		Upper Grande Ronde	GR-Upper Mainstem
		Minam River	GR-Minam
		Wenaha River	GR-Wenaha
		Lostine/Wallowa Rivers	GR-Lostine
		Imnaha Mainstem	GR-Imnaha
		Big Sheep Creek - Functionally Extirpated	
		Lookingglass- Functionally Extirpated	
	South Fork Salmon	South Fork Salmon Mainstem	SF-Mainstem
		Secesh River	SF-Secesh
		East Fork S. Fork Salmon (including Johnson Cr)	SF-East Fork
		Little Salmon River (including Rapid R.)	
	Middle Fork Salmon	Big Creek	MF-Big Creek
		Bear Valley/Elk Creek	MF-Bear Valley/Elk
		Marsh Creek	MF-Marsh Cr
		Sulphur Creek	MF-Sulphur Cr
		Camas Creek	MF-Camas Cr
		Loon Creek	MF-Loon
		Chamberlain Creek	MF-Chamberlain
		Lower Middle Fork Salmon (below Ind. Cr.)	

		Upper Middle Fork Salmon (above Ind. Cr.)	
	Upper Salmon	Lemhi River	SR-Lemhi
		Valley Creek	SR-Valley Cr
		Yankee Fork	SR-Yankee Fork
		Upper Salmon River (above Redfish L.)	SR-Upper Mainstem
		North Fork Salmon River	
		Lower Salmon River (below Redfish L.)	SR-Lower Mainstem
		East Fork Salmon River	SR-East Fork
		Pahsimeroi River	SR-Pahsimeroi
		Panther - Extirpated	

Upper Columbia Spring Chinook Salmon	**Eastern Cascades**	Wenatchee R.	UC-Wenatchee
		Methow R.	UC-Methow
		Entiat R.	UC-Entiat
		Okanogan R. (extirpated)	
Snake River Fall Chinook Salmon	**Main Stem and Lower Tributaries**	Lower Mainstem Fall Chinook	

DPS	MPG	Population	Codes for Populations Addressed in This Report
Upper Columbia River Steelhead	**Eastern Cascades**	Wenatchee River	UC-Wenatchee
		Methow River	UC-Methow
		Entiat River	UC-Entiat
		Okanogan River	UC-Okanogan
Snake River Steelhead	**Lower Snake**	Tucannon River	

		Asotin Creek	
	Imnaha River	Imnaha River	Imnaha
	Grande Ronde	Upper Mainstem	GR-Upper Mainstem
		Lower Mainstem	
		Joseph Cr.	GR-Joseph Cr
		Wallowa R.	
	Clearwater River	Lower Mainstem	
		Lolo Creek	
		Lochsa River	
		Selway River	
		South Fork	
		North Fork - (Extirpated)	
	Salmon River	Upper Middle Fork Tribs	
		Chamberlain Cr.	
		South Fork Salmon	
		Panther Creek	
		Secesh River	
		North Fork	
		Lower Middle Fork Tribs	
		Little Salmon/Rapid	
		Lemhi River	
		Pahsimeroi River	

		East Fork Salmon	
		Upper Mainstem	
Mid Columbia Steelhead	Yakima	Upper Yakima R.	YR-Upper Yakima
		Naches R.	YR-Naches
		Toppenish Cr	YR-Toppenish
		Satus Cr	YR-Satus
	Eastern Cascades	Deschutes West	Deschutes-W
		Deschutes East	Deschutes-E
		Klickitat R.	
		Fifteenmile Cr.	
		Rock Cr.	
		White Salmon - Extirpated	
	Umatilla/ Walla Walla	Umatilla R.	MC-Umatilla
		Walla-Walla R.	
		Touchet R.	
	John Day	Lower Mainstem	JD-Lower Mainstem
		North Fork	JD-North Fork
		Upper Mainstem	JD-Upper Mainstem
		Middle Fork	JD-Middle Fork
		South Fork	JD-South Fork

Appendix 2: Comparisons of alternative approaches

When we compiled the spawner and recruit data for interior Columbia River salmonid populations, we needed to make the following choices: 1) how to treat harvested fish in the estimation of recruits, and 2) how to treat years when few or no spawners returned. In this appendix, we made comparisons of alternative approaches to determine how influential these approaches were to final results.

When we calculated brood year recruits, R_t, we had to choose how to treat fish that were harvested during upstream migration. Harvest removes potential recruits, and if harvest occurred differentially across time, it could alter the underlying relationships that characterize population dynamics. Therefore we chose to add harvested fish to fish that returned to spawning sites in the following manner:

$$R_t = \frac{A_t}{1 - h_t}$$

where R_t are estimated recruits from brood year t, A_t are post-harvest returning adults, and h_t is the harvest rate for adults from brood year t. R_t represent the number of naturally produced fish that would have appeared on the spawning grounds had there not been a harvest. For comparison purposes, we performed an analysis where we did not add harvested to fish to estimate recruits. In this case, we just set $R_t = A_t$.

In some populations for a few years, few or no adults returned to the spawning area. Because the analysis required dividing recruits by spawners, dividing by zero spawners would result in an undefined term. Further, dividing by 5 or fewer spawners could produce biased results (ICTRT analysis). Accordingly, we examined the following three approaches: 1) deleting all years in a population where zero spawners returned; 2) deleting all years in a population where 5 or fewer spawners returned; 3) adding 1 to spawners and recruits for all years.

In this appendix, we made the following 3 comparisons:

1) Calculating recruits by adjusting for harvest rate *versus* calculating recruits without adjusting for harvest rate.

2) Deleting years with 0 spawners *versus* deleting years with 5 or fewer spawners.

3) Deleting years with 0 spawners *versus* adding 1 to spawners and recruits and using all data.

For all comparisons, we made pairwise comparisons by population of the following 4 outputs: 1) *a* parameter in Ricker model; 2) *b* parameter in Ricker model; 3) P-values from Ricker model fit; 4) Variance of residuals from Ricker model fit.

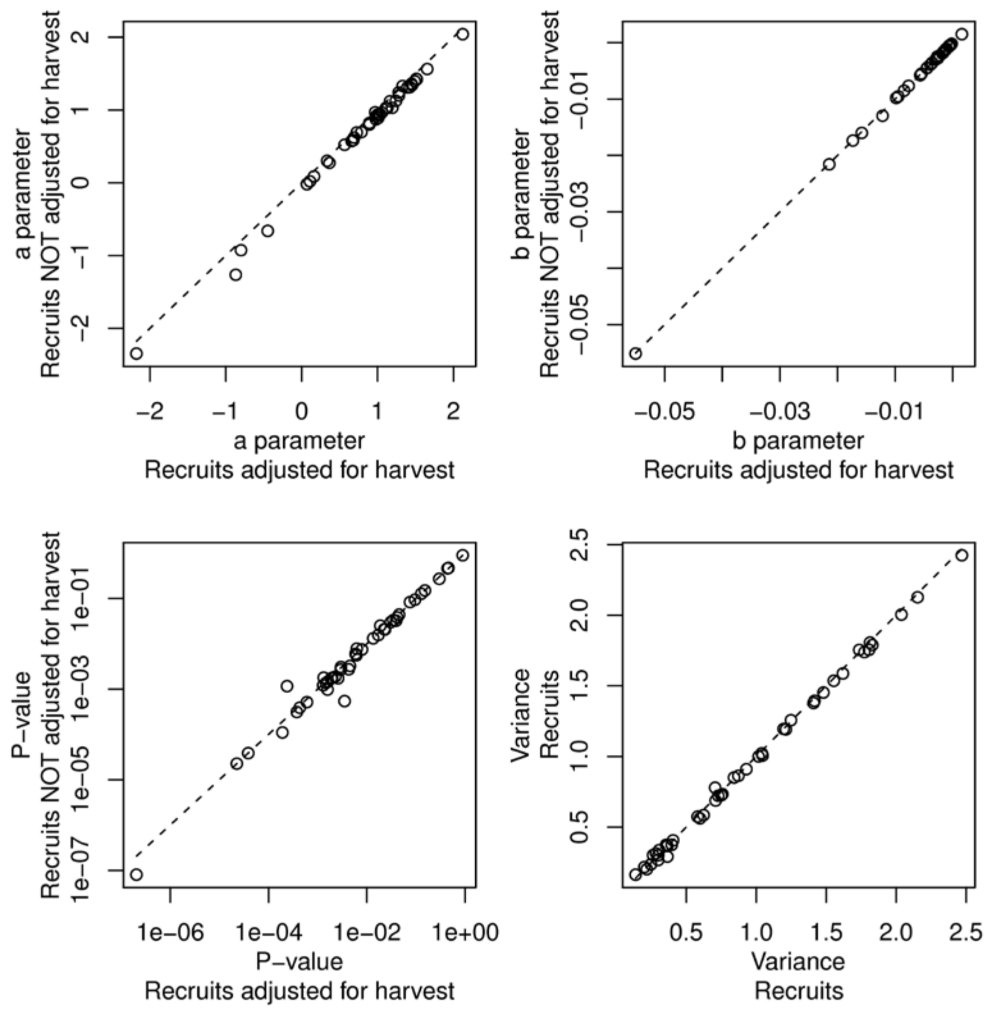

Figure 1. Comparison of calculating recruits by adjusting for harvest rate *versus* calculating recruits without adjusting for harvest rate. In each comparison, each point represents a population. Note that the axes for the comparison of P-values are on a log scale to spread out the points. The dashed line is the one-to-one line.

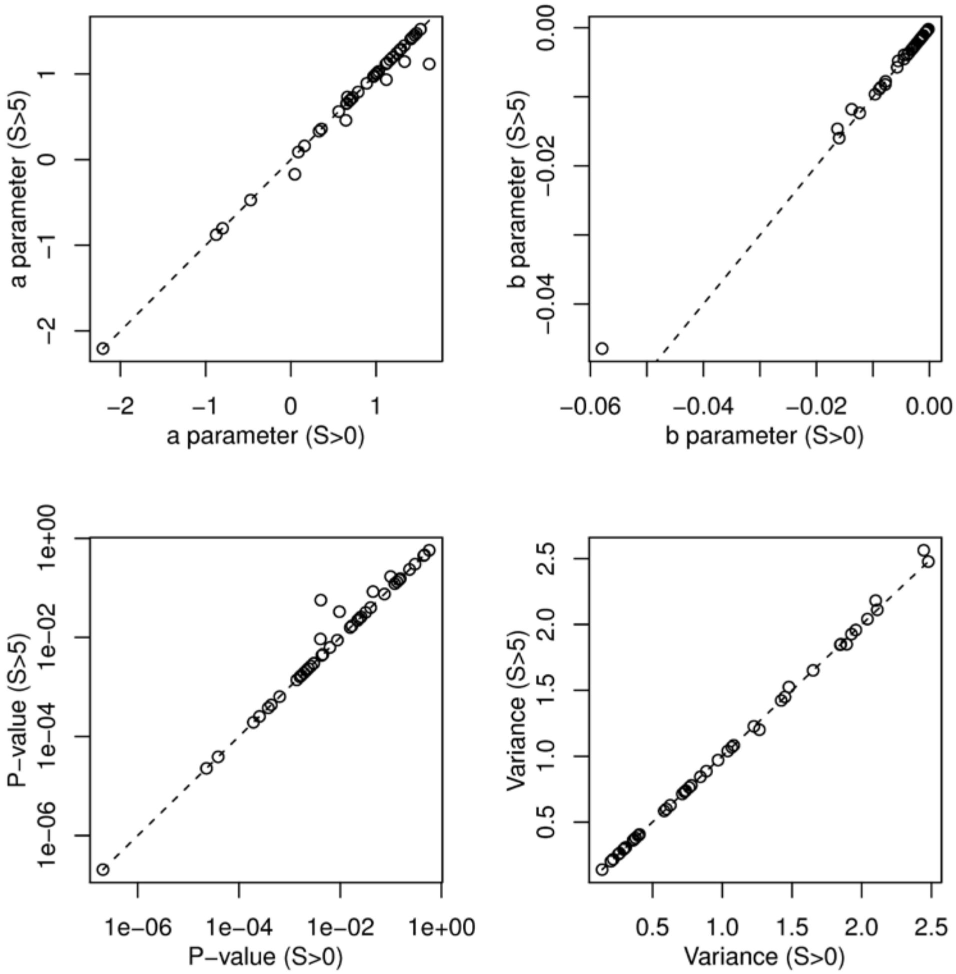

Figure 2. Comparison of deleting years with 0 spawners *versus* deleting years with 5 or fewer spawners. In each comparison, each point represents a population. Note that the axes for the comparison of P-values are on a log scale to spread out the points. The dashed line is the one-to-one line.

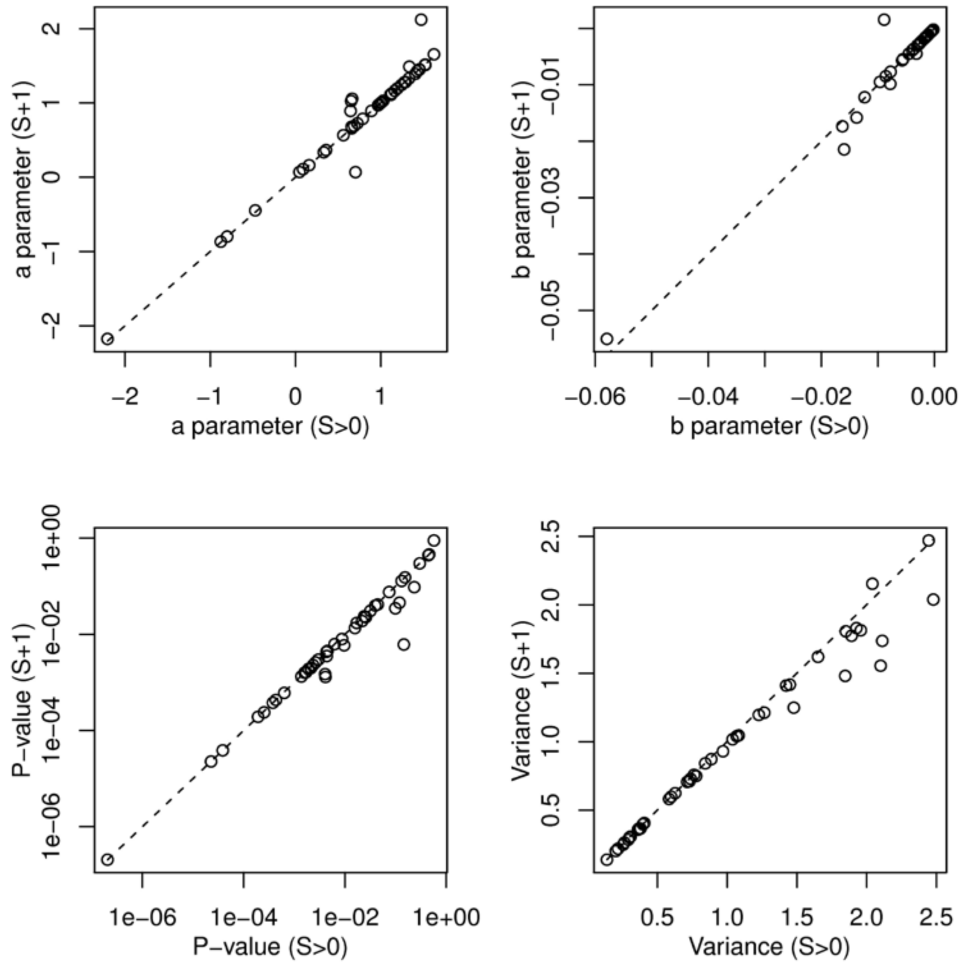

Figure 3. Comparison of deleting years with 0 spawners versus adding 1 to spawners and recruits and using all data. In each comparison, each point represents a population. Note that the axes for the comparison of P-values are on a log scale to spread out the points. The dashed line is the one-to-one line.

Results and Discussion

The comparison between adding harvested fish to recruits versus not adding harvested fish demonstrated little difference in the approaches (Figure 1). The Ricker *a* parameter (productivity) was slightly greater when harvested fish were added to recruits, but this is expected. Importantly, the Ricker *b* parameter (density dependence) was nearly identical between the two approaches. Because our analysis in the main document is focused on whether population dynamics have changed across time periods, we chose to add harvested fish to estimate recruits. However, we note that analyses with other goals might choose to ignore harvested fish when estimating recruits.

The comparison between deleting years with 0 spawners versus deleting years with 5 or fewer spawners demonstrated that these two approaches produced very similar results (Figure 2). For one population (Yankee Fork Chinook), deleting years with 0 spawners resulted in a greater *b* parameter than did the approach of deleting years with 5 or fewer spawners. This was not concerning because this population had the strongest density dependence regardless of approach.

The comparison between deleting years with 0 spawners and adding 1 to spawners and recruits in all years produced slightly more scatter in the Ricker *a* and *b* parameters (Figure 3). But there were no apparent biases between approaches because the points fell above and below the 1-to-1 line. However, the variance and P-values were smaller when we added 1 to spawners and recruits. This is expected because removing years from the dataset results in smaller sample sizes. Because of this reduced variance, we adopted the approach of adding 1 to spawners and recruits for all years.

Appendix D
Literature Reviews for Impacts of Climate Change on Columbia River Salmon

D.1 Impacts of climate change on Columbia River Salmon: Review of the scientific literature published in 2012

D.2 Literature review for 2010: Biological effects of climate change

D.3 Literature review for 2011: Biological effects of climate change

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Appendix D.1
Impacts of climate change on Columbia River Salmon: Review of the scientific literature published in 2012

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Impacts of climate change on Columbia River Salmon

Review of the scientific literature published in 2012

Prepared by Lisa Crozier with help from Delaney Dechant
Northwest Fisheries Science Center, NOAA-Fisheries
[September], 2013

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Appendix D.2
Literature review for 2010: Biological effects of climate change

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Literature review for 2010 citations for BIOP: Biological effects of climate change

Prepared by Lisa Crozier
Northwest Fisheries Science Center, NOAA-Fisheries
August, 2011

Table of Contents

1 Executive summary

Nationally and globally, the climate of 2010 continued trends of global warming, being one of the two warmest years on record. New analyses of observational data were generally consistent with previously reported historical trends of climate change. Climate, oceanographic, hydrologic, and stream-temperature models continue to be developed, tested, improved, and applied. Most of their assessments and projections indicated worsening physical conditions for salmon in mid-latitude regions, consistent with previous analyses: rising air temperature, moderately rising precipitation, declining snowpack, declining stream flow (partly due to water withdrawals), and rising sea surface temperature (although at reduced rates in upwelling regions). However, a few of the results could have either beneficial or negative implications for salmon. Historical analyses and predictions of net changes in primary productivity are spatially variable, and increases in the intensity of coastal upwelling (see below) could have positive or negative impacts. New studies on the biological effects of most of these processes were consistent with previous analyses, and showed that where salmon are limited by cool temperatures, warming is beneficial, at least over the short term, but in areas that are already relatively warm or where floods or low flows have negative impacts, climate change scenarios consistently project declines in salmon. In the ocean, several new studies pointed to the importance of sea surface temperature for early marine survival (as opposed to the Pacific Decadal Oscillation or smolt condition), but there were large differences among populations included in the study, and the single Columbia River population included did not show a strong ocean effect in this analysis (Sharma et al. 2009). The most geographically relevant papers include stream temperature analyses of the Boise River Basin (Isaak et al. 2010), the Wenatchee River Basin (Cristea and Burges 2010), and the Touchet Basin (Wiseman et al. 2010); and numerous climatological analyses of the Columbia Basin (see sections 4 and 5).

Several new papers documented historical and projected increases in upwelling intensity in the California Current (Bakun et al. 2010; Garcia-Reyes and Largier 2010; Wang et al. 2010). Although stronger upwelling has been positively associated with Columbia River salmon survival in the 20th century, Bakun et al. (2010) presented some possible scenarios (exacerbated by bad fisheries management) in which anoxia, toxic gas eruptions and jellyfish take over. Furthermore, although increased primary productivity predicted by some models would be expected to benefit salmon, most ecosystem models predict declines in salmon productivity south of the Arctic. Arctic conditions were expected to improve for salmon based on increased nitrate concentration (Rykaczewski and Dunne 2010), primary productivity (Kahru et al. 2010; Steinacher et al. 2010), and fisheries catches generally (Cheung et al. 2010; MacNeil et al. 2010).

A few emerging potential threats were documented for Fraser River salmon, with unknown potential for affecting Columbia River salmon. Algal blooms lowered survival of Chilko sockeye smolts (Rensel et al. 2010), and apparently increasing aggregations of sharks might be increasing predation on returning adults (Williams et al. 2010).

One other highly novel study found that gene flow increased during unfavorable river conditions, suggesting that straying might increase in response to rising temperatures (Valiente et al. 2010).

Three studies documented strong trends in salmonid phenology (one smolt-timing and two spawn-timing studies). Two of these studies also involved declining populations, and the authors suggested that part of the problem was a mismatch between rates of temperature change either in fresh- or saltwater (Kennedy and Crozier 2010) or between spring and summer (Wedekind and Kung 2010). In the 2010 BIOP we mentioned a trend toward earlier smolting in Snake River spring Chinook (Achord et al. 2007), so attention to potential phenological mismatches seem warranted. Several other studies attributed population decline more directly to environmental deterioration (Clews et al. 2010; Wiseman et al. 2010).

A large number of recent studies on Fraser River sockeye found negative impacts of high temperatures on adult migration survival and throughout the life cycle, and warned that a majority of populations within the Fraser River Basin are highly vulnerable to extinction due to climate change, based on both quantitative (Hague et al. 2011; Martins et al. 2011) and qualitative analyses (Jacob et al. 2010; McDaniels et al. 2010). McDaniels et al. (2010) considered possible management actions, but found they were limited. One study found individual variation in the use of thermal refugia during migration that depend on individual condition (Donaldson et al. 2010), while another study found that thermal refuge use corresponded to higher survival (Mathes et al. 2010). Disease morbidity and mortality is being exacerbated by warmer temperatures (Braden et al. 2010; Bradford et al. 2010; Marcos-Lopez et al. 2010) and artificial propagation (especially fish farms, Krkosek 2010; Pulkkinen et al. 2010).

Several theoretical papers described new mathematical methods of detecting impending extinction due to environmental deterioration (Drake and Griffen 2010; Ovaskainen and Meerson 2010) and elevated risks from environmental impacts at particular time scales and life stages (Worden et al. 2010).

Several studies demonstrated strong maternal effects on larval survival, compared with stronger genetic effects on juvenile growth and survival. These studies could possibly imply that negative effects of the hydrosystem could persist into the next generation, whereas evolution might modify juvenile growth and survival.

New studies provided additional details on adaptation strategies, such as those previously described in ISAB (2007), for Pacific salmon. For example, Cristea and Burges (2010) found that the cooling potential of riparian vegetation restoration is likely to postpone stressful temperatures for salmonids in Wenatchee River tributaries through the end of the century. However, vegetation restoration did not significantly reduce temperature in the mainstem Wenatchee. Such studies need to be site specific, because, for example, Null et al (2010) found that restoring and protecting cool springs was more beneficial than increasing riparian shading in the Shasta River. Several papers provided more information on adaptation strategies in general and the practical social and technical considerations for implementing them (e.g., Binder et al. 2010; Brekke et al. 2010).

In conclusion, new information from 2010 publications was generally consistent with previous analyses in reporting ongoing trends in climate consistent with climate change projections and negative implications for salmon at mid-latitudes. Modeling techniques continue to improve. A few studies focused on areas that did not receive much attention in our previous report, and thus provide new information. These areas include predicted and observed intensification of upwelling (compared with various similar and contradictory reports published previously), reduced salmon survival due to algal blooms, climate-induced straying, and climate change-induced mismatches in phenology associated with population declines. Numerous new studies of Fraser River sockeye warn of very severe risk from climate change. Finally, several theoretical papers augment our toolbox for anticipating extinction due to environmental deterioration.

2 Table of acronyms

AO	Arctic Oscillation
BPA	Bonneville Power Administration
CCS	California Current System
ENSO	El Niño-Southern Oscillation
ESU	Evolutionarily Significant Unit
GCM	General Circulation Model
IPCC	Intergovernmental Panel on Climate Change
NPI	North Pacific Index
NPGO	North Pacific Gyre Oscillation
NO	Northern Oscillation
OA	Ocean Acidification
PDO	Pacific Decadal Oscillation
SO	Southern Oscillation or Southern Annual Mode
SST	Sea surface temperature
VIC	Variable Infiltration Capacity model
WACCA	Washington State Climate Change Assessment
WRF	Weather Research and Forecasting

3 Goals and methods of this review

The goal of this review was to identify the literature published in 2010 that is most relevant to predicting impacts of climate change on Columbia River salmon listed under the Endangered Species Act. A large amount of literature related to this topic is not included, because almost anything that affects salmon at all relates to or is altered in some way by changes in temperature, stream flow or marine conditions. We have tried to identify the most directly related papers by combining climatic and salmonid terms in my search criteria. Thus many general principles demonstrated in other taxa or with more general contexts in mind have been omitted. This review also does not include potentially relevant gray literature, because the search engine used only includes the major peer-reviewed scientific journals. Additional references were solicited from NOAA staff and independent scientists who specialize in freshwater habitat, estuary behavior, marine ecosystems, ocean acidification, and climate-fish dynamics in other species. In total, the methods employed involved review of over 800 papers. Of these, 223 are included in this summary.

This search was conducted in ISI Web of Science in June, 2011. Each set of search criteria involved a new search, and results were compared with previous searches to identify missing topics. The specific search criteria all included PY=2010, plus:

1) TS=(climat* OR temperature OR streamflow OR flow OR snowpack OR precipitation OR PDO) AND TS=(salmon OR Oncorhynchus OR steelhead);

2) TS=(climat* OR Temperature OR Precipitation OR streamflow OR flow) AND TS="Pacific Northwest";

3) TS=(marine OR sea level OR hyporheic OR groundwater) AND TS=climat* AND TS=(salmon OR Oncorhynchus OR steelhead);

4) TS=(upwelling OR estuary) AND TS=climat* AND TS=Pacific;

5) FT=("ocean acidification" OR "California current" OR "Columbia River")

6) TS="prespawn mortality"

The review is organized by first considering physical environmental conditions (historical trends and relationships) and then predictions of future climate, snowpack, stream flow, temperature, ocean conditions, etc. A summary follows of the literature on salmonid responses to these environmental conditions, progressing through the life cycle.

4 National Climate Summary of 2010

Nationally and globally, 2010 was at or near record-breaking levels in many respects, based on NOAA's Annual State of the Climate Report (Blunden et al. 2011) Strong El Niño-Southern Oscillation (ENSO), Arctic Oscillation (AO), and Southern Annular Mode (SO) conditions drove very dramatic weather events in many parts of the world, while we emitted greenhouse gases at very high levels (above the average over the past 30 years). Trends consistent with global climate change reported in the 2010 Supplemental Biological Opinion (NMFS 2010) continued: 1) 2010 was one of the two warmest years on record; 2) average global sea surface temperature was the third warmest on record and sea level continued to rise; 3) ocean salinity variations at a global scale showed intensification of the water cycle; and 4) Arctic sea ice shrank to the third smallest area on record, the Greeland ice sheet melted at the highest rate and over the largest area since at least 1958, and alpine glaciers continued to melt.

5 Historical analysis of terrestrial climate, stream flow and stream temperature in the western US and British Columbia

A number of new papers have conducted historical analyses of trends over the past half century or so in air temperature (rising), precipitation (rising), snowpack (declining) and stream flow (declining). Trends in ocean conditions and El Niño events are discussed in the ocean section. These results are generally consistent with trends described in the 2010 Biological Opinion (NMFS 2010). Further, several papers have analyzed how broad-scale climatic conditions such as the Pacific Decadal Oscillation (PDO) and ENSO drive variation in processes with significant biological implications, such as drought, forest fire, landslides, and coastal fog.

Specifically, Fu et al. (2010) showed that in Washington State from 1952 to 2002, annual mean air temperature increased 0.61ºC (daily mean), 0.24ºC (daily maximum), and 0.93ºC (daily minimum), on average (or at a rate of 0.122, 0.048, and 0.185ºC, respectively, per 10 years). Despite increasing annual precipitation, stream flow decreased at a rate of -4.88 cms/yr, with the largest effects in May and June on the west side of the Cascade Mountains. Temperature increased throughout the year (except October and December) across the state, with a small area of maximum temperature cooling in the central-eastern portion of the state. Minimum temperatures rose more than maximum temperatures. To explain the declines in streamflow, the authors suggested that human water use and increased evaporation rates due to rising temperature and more surface area exposure (e.g., from reservoirs) play important roles. Ryu et al. (2010) showed a positive relationship between a drought index based on streamflow and El Niño in the Pacific Northwest. Bumbaco and Mote (2010) studied the role of winter and summer precipitation and temperature in causing three droughts in Washington and Oregon (2001, 2003, and 2005), and found a different driver in each case (low winter precipitation in 2001, low summer precipitation in 2003, and warm winter temperatures during key precipitation events in 2005).

Corresponding to the lower availability of water for biological processes, Meyn et al. (2010) showed that summer drought correlates strongly with the forest area burned in British Columbia. The PDO index the previous winter was related to summer drought in some areas of British Columbia, but is not a very strong driver over most of the province. Johnstone and Dawson (2010) tracked a new index of climate not mentioned in our previous report, which is the frequency of coastal fog along the California coast. They showed that fog levels are correlated with the strength of upwelling and have declined 33% from 1951 to 2008, increasing drought stress for plants.

Intense precipitation events, predicted to increase in winter with climate change, exacerbated by rain on snow events and high wind also increase the risk of landslides (Guthrie et al. 2010).

Average snow depth decreased widely across the western United States, especially at lower-elevation stations (<1000 m, Grundstein and Mote 2010). The vast majority of lower-elevation stations (80%) and a majority of mid-elevation stations (2000-3000m, 62%) showed significantly negative trends. Snow depth was strongly related to the PDO and the North Pacific Index (NPI).

Streamflow reflects both climatic factors and local habitat. For example, recent papers discussed the impact of glacier runoff and projected changes (quantified on Mt Hood by Nolin et al. 2010), and combinations of snow fall and forest integrity, whether due to harvest or fire. Specifically, Jones and Perkins (2010) studied how rain-on-snow events and harvest differentially affected different sized basins, while Eaton et al. (2010) examined changes in peak flows and the timing of the freshet, in addition to channel morphology following fire.

Wetlands are highly dynamic environments. Large scale variability in climate such as oscillations of the PDO can dramatically change local environmental conditions. After the regime shift of 1976, a wetland in southern California experienced a dramatic increase the frequency of extreme storms and floods due to a shift in the storm track across the Pacific. Zedler (2010) classified the types of events and their ecological consequences (mostly for plants) in terms of their relationships, for example, whether the ordering of events matters (e.g., river-mouth closure followed by a drought, that killed many more plants than additive effects would predict. They suggested focusing restoration actions on preparing ecosystems for likely future climates rather than restoring past communities necessarily.

6 Projected changes in terrestrial climate for the 21st century

Some of the most relevant projections of climate change conditions within the Columbia Basin were summarized in the 2010 BIOP based on reports produced for the Washington State Climate Change Assessment (WACCA), but were published in formal climate journals in 2010. In this category, Mote and Salathé (2010) described climate changes in the Pacific Northwest predicted by general circulation models produced for the Intergovernmental Panel on Climate Change (IPCC) fourth assessment report. Salathé et al. (2010) described changes predicted by the regional dynamical climate model Weather Research and Forecasting (WRF) Model. Elsner et al. (2010) summarized the regional hydrological implications of the global model predictions, and Mantua et al. (2010) described projected increases in peak winter flows, lower late summer flows, and high summer stream temperatures that will threaten salmon. A few other sections of the WACCA report were not mentioned in the BIOP, and are summarized in this report.

Predictions of how rising greenhouse gases will affect climate depend on how functional relationships are modeled. A large body of work describes tests and improvements of the climate models, and are mostly beyond the scope of this review. It is worth noting here that work is ongoing on many aspects with especially large levels of uncertainty at the moment, such as the extent of intra-model variability compared with inter-model variability (over half of the variation between models can be explained by variation within models, Deser et al. 2010), how the global circulation models drive ENSO variability (An et al. 2010) and regional downscaling -- i.e., how to convert the large-scale global model output (~200km^2 resolution) to the regional scale (~8 km^2 resolution, Ainslie and Jackson 2010). There are important differences in predictions made by different downscaling approaches. Qian et al. (2010) compare predictions from two dynamical downscaling methods, a subgrid parameterization and a regional climate model. They found that both methods greatly improved the modeled snowpack compared with observations over simpler downscaling methods, but the regional model captured precipitation and snowpack along the coastal mountains much better because of the importance of mountain orientation for wind direction. This model predicted a greater change in snowpack under climate change scenarios than the subgrid approach.

Predictions of changes in snowpack are very sensitive to how temperature changes with elevation. Minder et al. (2010) clarified spatial and temporal variation in the lapse rate in the Cascades, and Minder (2010) studied the effect of different determinants of the snow melting level in physical models. Minder (2010) predicted a loss of 14.8%-18.1% of Cascade snowfall per degree of warming, assuming precipitation increases, and 19.4%-22.6% loss per degree without precipitation increases, with profound impact on accumulated snowpack.

6.1 Stream flow

Many hydrological projections are based on the Variable Infiltration Capacity model (VIC). Wenger et al. (2010) conducted a test of this model in the Pacific Northwest. They found that model predictions were relatively accurate for center of flow timing and mean annual and summer flows, and the frequency of winter floods. However, modeled frequencies of low flows and groundwater-impacted streams did not match observations closely.

Chang and Jung (2010) projected the hydrology of the Willamette River Basin. They considered predictions from 8 general circulation models (GCMs), and downscale to 1/16th degree resolution for their hydrological model. Like previous projections, the models predicted increased winter flow, decreased summer flow, reduced snowpack, and earlier runoff. The different GCMs varied significantly in their predictions, especially later in the century. There was also substantial variation at the subbasin scale, indicating important local controls in hydrology. A new analysis by the Climate Impacts Groups for the Bonneville Power Administration (BPA) showed similar spatial variation, uncertainty, and general trends. This was a comprehensive study in draft form in 2010 (Brekke et al. 2010). It will be summarized more thoroughly in the 2011 report.

Three papers focused on changes in precipitation or hydrologic extremes. Tohver and Hamlet (2010) analyzed shifts in extreme streamflow statistics at 297 sites in the Columbia Basin, based on the Columbia Basin Climate Change Scenarios Project. First they described the same results previously reported: there was a general shift from weakly snow-dominant basins to transient basins, and from transient basins to rain-dominant basins, such that no snow-dominant sources remained in the US portion of the Columbia Basin by 2080, under the A1B scenario, and extremely few even in the highly optimistic B1 scenario. However, they found significant differences between the two downscaling methods employed in flood projections. The "hybrid delta" method predicted flooding increases throughout the Columbia Basin, whereas in Mantua et al. (2010) and the "composite delta" method, increased flooding is more spatially variable. The hydrid delta method is thought to be more accurate in this regard, reflecting the spatial distribution of warming and precipitation increases better than the composite method. Higher winter temperatures and precipitation regimes increase flooding most in transient and rain-dominant basins, but also in snow-dominant basins, despite the reduced accumulation of snowpack. Even greater increases in flooding could be caused by increasing spring storm intensity and more precipitation falling as rain rather than snow. Increased flooding in transitional and rain-dominated basins followed from increased winter precipitation. Low flow risk increased most in rain-dominant and transient basins due to rising summer temperatures and evapotranspiration rates. Snow-dominant basins, so important in the Columbia and Snake tributaries, were relatively resilient to this effect in this analysis possibly because the lowest flows tend to occur in winter, and they did not separate out summer low flows.

Rosenberg et al. (2010) examined precipitation extremes for stormwater infrastructure. They found that uncertainty in projections is too large to make engineering preparations, but that some potential outcomes could be very serious. Towler et al. (2010) similarly examined extreme precipitation events and secondary effects, in this case, turbidity, important for Portland's water supply. They developed a technique for applying climate change scenarios to detect the impacts of predicted shifts in extreme events.

A study in California (Meyers et al. 2010) found that +2ºC and +4ºC climate warming and altered precipitation are likely to shift floods from spring to winter, and increase the frequency and intensity of floods. Such a change would negatively affect brook trout more than rainbow trout, which would then experience less competition from brook trout.

Another study (Moradkhani et al. 2010) explored climate change scenarios in the Tualatin River in Oregon using a different hydrological model and found that the 50-year floods and the riparian ecotone decreased in low emissions scenarios, but increased in high emissions scenarios. Thus well-established trees along the riparian corridor were flooded in the high-emission scenarios.

Some streams are currently fed by significant amounts of glacier meltwater. Nolin et al. (2010) studied a stream on Mt Hood that currently derives 41-73% of its late summer flow from glaciers. Under climate change scenarios, glaciers retreated, ultimately reducing summer flow.

7 Historical analyses and projections of ocean conditions

A number of studies published in 2010 provided insight into areas of profound importance for salmon that have been especially uncertain in prior climate change analyses. Two papers indicated that over the 20th century, upwelling in the California Current System (CCS) and the Humboldt Current System have become more intense, which is consistent with a new analysis of GCM projections that predicted it will continue to intensify with global warming. Papers focusing on historical sea surface temperatures (SST) addressed previous criticisms that observed trends are due to instrument bias, re-established the global pattern of decadal oscillations overlaid upon a background of rising SST, and documented the shifting character of El Niño events and their impact on long-term SST trends.

7.1 Upwelling

Upwelling dynamics along the Washington and Oregon coasts are a key element in Columbia River salmon marine survival and growth. The impacts of climate change on upwelling dynamics are among the most uncertain of all the predictions of climate change models. Conflicting predictions stem from 1) changes in the various driving processes that affect upwelling are expected to act in opposite directions, necessitating quantitative comparisons for determining net effects (i.e., rising SST should reduce upwelling, while increasing alongshore winds should increase upwelling) and 2) the spatial resolution of both climate models and empirical datasets have generally been too coarse to accurately capture upwelling dynamics.

Two papers published in 2010 basically supported the intensification prediction by documenting empirical trends over the 20th century, and a 3rd paper analyzed GCM reconstruction and projections of upwelling dynamics over the next century. Garcia-Reyes and Largier (2010) analyzed hourly buoy data off the California coast to describe the historical trend at an appropriate spatial and temporal scale. They found strong evidence for intensification of upwelling from 1982 to 2008, especially in central California (35ºN-39ºN). Specifically, they documented trends in the upwelling index (based on pressure fields), the strength of upwelling winds (based on alongshore wind speed), SST directly within the upwelling region (hence a negative trend in absolute temperature during the upwelling season), the number of days of upwelling within the season, a lengthening of the upwelling season (more days in March and October, hence earlier spring and later fall transition), and increased variability in upwelling winds (an increase in the 90th percentile and a decrease in 10% percentile), indicating stronger upwelling alternated with more relaxation in winds. They also found correlations of magnitude 0.6 or 0.7 between upwelling winds and the Northern Oscillation and the North Pacific Gyre Oscillation (NPGO), and between SST and the PDO and ENSO.

The second paper (Bakun et al. 2010) reviewed the basic argument that increasing land temperatures will intensify the pressure gradient between ocean and land, and hence intensify the alongshore wind stress, which initiates upwelling. Bakun et al. (2010) then reviewed previous tests of the hypothesis, and described a new test focusing on the relationship between water vapor and upwelling off Peru. This test showed significant correlations most of the time. Because water vapor acts as a greenhouse gas, they concluded this was consistent with a prediction of intensifying upwelling with rising greenhouse gas concentrations. One very important point they made in this paper, however, is that intensification of upwelling is not necessarily good for fish. They described scenarios in which excessive upwelling advects zooplankton offshore too quickly for effective phytoplankton control. If omnivorous fish such as sardines are overfished or not present for some reason, there could be an ecosystem regime shift toward that currently found off Namibia, in which unconsumed phytoplankton sink and generate hypoxic zones and toxic gas eruptions, which kill fish and leave an ecosystem dominated by jellyfish.

In the third paper, Wang et al. (2010) analyzed the performance of all the major GCMs produced for the 4th IPCC assessment using a number of criteria, including PDO variation across the Pacific and upwelling near the mouth of the Columbia River. Twelve of the 23 GCMs had a reasonable representation of the PDO over the 20th century (i.e., had a spatial correlation coefficient of the first Empirical Orthogonal Function of winter SST of at least 0.7). Half of these models predicted that SST would exceed the variability of the PDO within 50 years under the A1B emissions scenario (the reminder predicted it would happen within 90 years). Averaged over 10 models, SST in the CCS was expected to increase 0.26ºC per decade in the 21st century. Although the GCMs were not designed to characterize dynamics at the spatial scale of coastal upwelling, these models did remarkably well at capturing the seasonality of upwelling, even if they overestimated seasonal variation somewhat. Representation of the California Current was better than the Humboldt Current. In the CCS, 17 models predicted increases in July upwelling while only two models predicted decreases.

7.2 Ocean temperatures

Three studies analyzed historical trends in ocean temperatures. Carson and Harrison (2010) examined the impact of instrument bias in previously reported interdecadal trends at the ocean surface, 50m, 100m, and 300m temperatures. They found coherent signals of interdecadal variability at multiple depths, even with bias correction and comparisons of different datasets. This contrasts with recent work on the global average temperature, which showed reduced decadal variability after bias correction. Schwing et al. (2010) describe global atmospheric and oceanic teleconnections (e.g., the PDO, AO, NO, SO, and major current systems) and the major factors driving large marine ecosystems. Atmospheric teleconnections synchronize much of the decadal variability in the California and Humboldt Current Systems, as well as the Gulf of Alaska. Schwing et al. (2010) showed a persistent warming trend of 1-2ºC over 100 years in SST in all large marine ecosystems, although the rate of warming was weaker in the upwelling (or downwelling) dominated coastal region. The general patterns (overall trend and decadal fluctuations) were similar to global mean surface temperature, despite some regional differences. The western Pacific showed roughly similar trends, but lags behind the eastern Pacific by about 10 years, and was driven by quite different physical processes. Thus they predicted similarities among the eastern Pacific large marine ecosystems in responses to climate change, but less so between eastern and western Pacific large marine ecosystems. Another paper (Moore et al. 2010), made a very interesting point, which is that ENSO warm water events usually only affect winter temperature in Pacific Northwest waters, while the PDO warm phase often persists through summer and fall. This has important implications for the salmonid life stage that is affected by these events, which then has implications for impacts on population dynamics (Worden et al. 2010), as described below in the Population Dynamics Modelling Section.

Finally, Lee and McPhaden (2010) paper parsed out sea surface temperature increases in the central Pacific during El Niño events, and found that the increasing frequency and intensity of these events in this region drove most of the overall trend in sea surface temperature (SST). SST during El Niño events warmed by 0.24ºC/decade, whereas SST warming in neutral and La Niña years was positive, but much smaller (0.05-0.07ºC/decade) and not statistically significant over the 1982-2008 time frame. The reason for this shift in the position of the maximum warm anomaly is not known, but increasing intensity and frequency of El Niño events has been predicted to follow from rising greenhouse gases (Yeh et al. 2009), as cited in the 2010 Biological Opinion.

7.3 Ocean acidification

Two papers found that measured declines in pH near urban areas are faster than expected from CO_2 uptake alone and partially reflect nutrient loading (in the Hood Canal of Puget Sound, Washington, Feely et al. 2010; along the Dutch coast, Provoost et al. 2010). Wong et al. (2010) studied trends in pCO_2 in seawater along line P out from Vancounver Island, and found that it has risen in the oceanic zone at a rate of 1.36 μatm per year, tracking the atmospheric growth rate. The coastal zone pCO_2 rose at a similar rate in winter, but spring levels showed no trend.

8 Impact of stream temperature and flow on juvenile salmon

8.1 Effects of temperature on embryo development

There has been much concern that warmer winter temperatures will increase embryo mortality, cause ealier fry emergence, smaller fry size, and a mismatch between larval needs and food supply. In an experiment on coho survival, Lohmus et al. (2010b) found the optimal temperature for hatching and alevin survival was a relatively high 12ºC; they found substantial survival (40%) still at 16ºC, but very low survival at 18ºC (2.5%). In a review article, Teletchea and Fontaine (2010) found a strong positive relationship between egg size and larval energy reserves, and a strong negative relationship between temperature and time to first mixed feeding (i.e., requiring external food supply) among Pacific salmon. Thus although Pacific salmon have relatively large eggs and hence more flexibility in temporally matching food availability than other fish, higher temperatures are likely to produce smaller, less flexible fry. Janhunen et al. (2010) found that alevins hatched at the higher temperature were developmentally less advanced.

If either egg or larval survival is reduced under future climatic conditions, it is theoretically possible that they might evolve in response to selection. Several studies showed that populations from different climates have locally adapted development rates and thermal tolerances. Narum et al. (2010) found evidence of selection for differing climates by comparing genetic markers in redband trout: temperature was strongly correlated with allele frequencies. And Kavanagh et al. (2010) found evidence of local adapation to cool temperatures and reduced critical maximum temperatures in European grayling within 22 generations. However, Evans et al. (2010) and Janhunen et al. (2010) found similar results in Chinook salmon and Arctic charr, respectively, that genetic variation was relatively weak for embryo survival, but was slightly greater for larval length. Maternal effects were strong in both studies especially at the earlier developmental stages, indicating that adult migration and prespawn condition could have long-lasting effects through the next generation.

The effect of temperature during development might have more complicated effects beyond body size and emergence time. In sticklebacks, developmental temperatures and consequent compensatory growth affected skeletal and muscle morphology, with potential effects on locomotor performance (Lee et al. 2010). In zebra fish, brief exposures to cool developmental temperatures affected dorsal, anal, caudal, and pelvic fin positions, as well as gill cover and the position of the lower jaw (Georga and Koumoundouros 2010). It is not clear whether these shape changes have functional implications, but they were preserved through adulthood. Zabel et al. (2010) showed that different Chinook salmon ESU (fall vs spring/summer life history types) had different otolith/fish length relationships, demonstrating differences in morphology that are not simply explained by different growth rates. The populations do rear in very different environments, but the role of environmental temperature requires further study.

Other effects of high temperature during development include sex reversal. Magerhans and Horstgen-Schwark (2010) reported an experiment that showed that sensitivity to temperature in sex determination in rainbow trout is substantial and heritable. The initial population had a sex ratio of 51.9% female when eggs were reared at 18ºC, and 49.3% female when reared at 12ºC. After one generation of selection, they produced a sex ratio of either 57.6% or 44.5% female at 18ºC, indicating a heritability of 0.63 for this trait. Stelkens and Wedekind (2010) reviewed the various mechanisms of sex determination and sex reversal in teleost fish.

8.2 Effects of temperature and flow on juvenile growth and survival

Many papers have continued to demonstrate strong effects of temperature and flow on juvenile salmon growth and survival. Most papers are consistent in showeding improved growth when relatively cool habitat warms up: spring in Massachusetts, (Xu et al. 2010a), fall in Idaho (Jenkins and Keeley 2010); and a long-term trend of larger smolts in the Baltic (Vainikka et al. 2010). However, negative effects of warming were typical during summer (Xu et al. 2010b) and winter (Xu et al. 2010a), when consumption cannot compensate for increased metabolic demands. In northern Europe, the net effects are expected to still be positive except under the warmest climate change scenario examined (+4ºC). This prediction was consistent with observations of increased size at age over 23 years in Baltic Sea Altantic salmon, although hatchery practices and size-selective fishing also affect these populations. In more southerly locations, the negative effects were predicted to outweigh positive effects even in moderate warming scenarios (Xu et al. 2010a). Changes in growth rates might affect the timing of vulnerability to predators such as bass, which are very size selective (Christensen and Moore 2010).

Similarly, several papers showed that higher flow has positive effects when it is relatively low to start with (e.g., in spring in the heavily water-withdrawn Lemhi Creek, in fall in the more natural Marsh Creek, and higher spring flows in the Columbia for both populations of Chinook salmon (Arthaud et al. 2010), and throughout the brook trout growing season in Massachusetts, (Xu et al. 2010a), and in bringing in more insect drift to cutthroat trout in Jenkins and Keeley (2010), and increasing Atlantic salmon habitat volume (Teichert et al. 2010). However, the highest flows (floods) had negative effects (Hayes et al. 2010; Xu et al. 2010a). Hayes et al. (2010) found that relaxed density-dependent mortality over the following season compensated for the immediate negative effects on brown trout, thus there was no net effect in this case.

The rest of this section provides more detail on the papers mentioned in the previous two paragraphs. Xu et al. (2010a) tracked individual brook trout growth over an 8 year study. They found strongly interacting effects of temperature, flow, season, and density. Highest growth rates occurred in spring, and were positively correlated with temperature and flow. In the warmest season, summer, temperature was negatively correlated with growth. Flow was generally positively correlated with growth, except in winter. Furthermore, density had greater negative effects at high temperatures. Because current climate predictions indicated the greatest increases in temperature and flow are in the winter, and that flow decreases in the summer, the net prediction based on their data was a decrease in mean fish spawner size and fecundity under a moderate (1.5ºC) warming scenario.

Davidson et al. (2010) studied the same study system as Xu et al. (2010a), but analyzed Atlantic salmon growth instead of brook trout growth, and included the impacts of the density of both Atlantic salmon and brook trout. Using a linear mixed model, they found that environmental effects (both temperature and discharge) were much more important than density in driving variation in growth. Warmer temperatures within a season generally had a very small negative effect, while high discharge had a strong positive effect. Interestingly, they found that more variability in temperature (the second principle component in temperature) had a negative impact at low discharge, but a positive impact at high discharge.

Habitat quality depends in part on food availability and the cost of aquiring it, which in turn depend on flow and temperature. Jenkins and Keeley (2010) found that cutthroat trout foraging location matched that predicted by the amount of energy gained (net energy intake NEI), with habitat type (pool versus riffle) and temperature explaining most of the variation among sites. Using an energetic model, they concluded that warmer temperatures will have negative effects on smaller fish, but will lengthen the growing season for larger fish.

Hayes et al. (2010) used changes in the relationship between weight and density in a New Zealand brown trout population over time to assess the impact of unusually low flows and one flood on population dynamics. They argued that although the flood caused substantial emigration or mortality, survival after the flood was higher than in other years (i.e., reduced density-dependent mortality), such that the population recovered quickly. The low-flow events had no effect on survival or biomass.

Arthaud et al. (2010) examined how well variation in flow during freshwater stages affected egg-smolt and egg-adult rates in a pristine stream (Marsh Creek, Idaho) and a stream subject to very high rates of water withdrawal (Lemhi Creek, Idaho). In

Lemhi Creek, water withdrawals are so severe that spring flows during the parr year strongly limited production and drove variation in both egg-smolt and egg-adult survival. In Marsh Creek, egg-smolt survival was correlated with parr-year August flow, but the cumulative impact on egg-adult survival was much weaker. In both populations, smolt-adult return rates were best predicted by Columbia River spring flow and ENSO.

Rising temperatures increase not only the metabolic rate of salmonids, but that of their predators, and potentially the risk from warm-adapted invasives such as bass. Christensen and Moore (2010) documented levels of bass predation on stocked rainbow trout in Twin Lakes, Washington.They found that trout sizes in fall (100-160mm) made them vulnerable to predation by large largemouth bass, but larger trout (>210mm) escaped predation. This suggests that changing growth rates due to temperature might affect not just total predation, but also the temporal period salmon are vulnerable to bass predation.

Westley et al. (2010) considered the affects of dispersal of anadromous fish through lake systems and discover a consequent lag in the community response to environmental forcing, in addition to habitat change and fishing mortality. By examining fish composition over 46 years, they found an immediate response and a 1-year time lagged response to the PDO in an upper lake where sockeye rear their first year, but just a 1-year time-lagged response in a lower lake. They emphasized these processes are important for anticipating the impact of environmental variability on community composition.

Lohmus et al. (2010a) studied variation in juvenile growth among wild-type and growth-enhanced coho salmon at 3 temperatures. They saw little evidence of compensatory growth, perhaps because fish were fed to satiation, so rank order in size was relatively consistent throughout the experiment. The fish grew more at 16ºC than at 12ºC, which is consistent with previous studies that found 15ºC to be the optimal temperature for growth.

8.2.1 Local adaptation/genetic control in growth rates

Growth rate in general and the growth response to temperature in particular is a heritable trait, and several papers showed differences between populations consistent with a history of different selection pressures. Latitudinal gradients are especially useful for demonstrating evolutionary effects of different thermal regimes. In general, colder temperatures slow growth rate within populations, producing a latitudinal gradient of smaller size at age in cooler locations (Chavarie et al. 2010; Morita and Nagasawa 2010). However, over evolutionary time populations in cooler environments have compensated for this effect by evolving faster growth rates and better tolerance of adverse conditions at northern latitudes. Chavarie et al. (2010) demonstrated these higher growth rates in northern populations across 66 populations of lacustrine Arctic charr in eastern North America, although their anadromous forms did not showed the same strong effect. Finstad et al. (2010) showed that compared to southern Norwegian populations, northern populations of Atlantic salmon have adapted higher feeding activity and reduced metabolic expenditures to sustain them over a longer winter.

Although these patterns prove that fish evolve to different thermal regimes over long time periods, potential evolutionary responses to rapid climate change are a very different matter. Understanding the roles of phenotypic plasticity, genetic variability, and maternal effects controlling larval survival and fry growth is key to predicting plastic and evolutionary responses to climate change. In a carefully controlled breeding design plus translocation experiment, Evans et al. (2010) quantify the strengths of these various effects in Chinook salmon from Quinsam and Big Qualicum rivers. They found that all processes were important for explaining their results, but that maternal effects were the most important process for larval survival, while additive genetic effects dominated fry survival and fry growth. These results suggest that maternal condition is very important for cross-generational effects, and that there is substantial genetic variation available for an evolutionary response to environmental change.

Van Doorslaer et al. (2010) explored rapid evolution in Daphnia, which are a major prey item of lake-dwelling salmonids, to increased temperature through artificial selection. They compared these newly evolved populations to Daphnia from a historically warmer climate. After only six months of exposure to unusually warm conditions, size at maturity had evolved. In this semi-natural experiment, the intrinsic population growth rate did not evolve. However, in a previous study (Van Doorslaer et al. 2009a) they showed the reverse effect, where population growth rate evolved but not size at maturity, demonstrating that either response is feasible, depending on ecological conditions. Furthermore, another previous study (Van Doorslaer et al. 2009b) showed that *in situ* evolution might reduce the competitive advantage and hence likelihood of invasion of more southerly, warm-adapted genotypes.Thus rapid evolution is possible, at least in Daphnia and perhaps other planktonic prey of salmonids, but it remains to be seen how this will pan out in natural communities and longer-lived species like salmon.

8.2.2 The timing of growth

In addition to total growth in a season being important, the rate of growth early in the season can have complex repercussions for smolting decisions, negative consequences of compensatory growth, and the ability to capitalize on ephemeral resources with large potential benefits. By manipulating the timing of food supply for California steelhead, Beakes et al. (2010) confirmed previous work indicating that the decision whether to smolt in a given year is based on growth rates the previous year, and that early size advantages are maintained over the year. Lee et al. (2010) showed that in three-spined sticklebacks, compensatory growth after cool temperature-induced slow growth negatively impacted swimming endurance, especially when it occurred near to the breeding season. Armstrong et al. (2010) found that juvenile coho salmon in the Wood River system in Alaska can only benefit from eating sockeye eggs if they are large enough to swallow them. Because growth rates are very temperature-dependent, coho juveniles in warmer streams were able to exceed the 70mm size limit necessary for eating the highly nutritious eggs. This enormous nutrient gain led to a highly non-linear response of growth rate to temperature.

8.2.3 Assessment of survival and growth risks from climate change in European salmonids

Elliott and Elliott (2010) reviewed the temperature limits for European salmonids in regard to survival, feeding and growth. They did not found evidence of local adaptation (within species) in temperature tolerance, although there were marked differences in the upper thermal limits among species. They described the relationship between the North Atlantic Oscillation and emergence dates and adult return ages and rates. Using a growth model under climate change conditions, they predicted improved growth and earlier smolting in brown trout (age 1 instead of 2) except under the most extreme conditions (>4ºC), but suggested eggs of Arctic charr in some streams in southern Britain and Ireland might be at risk from high temperatures and low oxygen content. They noted several examples in which fish preferred cooler temperatures despite low oxygen levels over warmer temperatures with more oxygen, and emphasized the importance of maintaining deep pool refugia.

8.3 Behavioral and survival responses to winter conditions

Several papers described *in situ* behavioral responses to environmental conditions, especially concealment behavior and nocturnality. Winter (cold) temperatures tend to induce concealment behavior in both Grande Ronde River Chinook salmon (Van Dyke et al. 2010) and Oregon steelhead (Reeves et al. 2010), but Reeves et al. (2010) found that the response was stronger in a montane population than a coastal population. Reeves et al. (2010) also found an increase in nocturnality was more pronounced in winter in the montane population. Orpwood et al. (2010) found that riparian cover increased concealment and nocturnality in both summer and winter, regardless of food supply.

Linnansaari and Cunjak (2010) found that juvenile Atlantic salmon mortality or emigration over winter in New Brunswick, Canada was highest in early winter, before ice formation, and mortality was low during ice cover. They noted that this suggests that warmer winters that have shorter ice cover will not necessarily improve survival. Furthermore, they found that high discharge events and early maturation lowered apparent survival, although the latter might have been related to spawning-related dispersal.

One additional study (Pettersson et al. 2010) compared the suitability of different diets for aquaculture, but found that swimming ability at low temperature can be greatly impaired by an inadequate composition of fatty acids. This could have implications for wild fish if prey availability changes.

8.4 Juvenile residency, migration timing and straying responses to growth and environmental conditions

Life history diversity is a profoundly important issue in relation to environmental variability, both in facilitating a rapid response to directional environmental change and in maintaining bet-hedging strategies in case of unpredictable environmental conditions. One key trait in salmonids that is very sensitive to environmental conditions is the decision of whether to migrate to sea or not, and if they do migrate, when do they do it, and do they return to the natal rearing grounds to spawn or do they stray to a new location. Papers published in 2010 addressed all of these issues.

Johnson et al. (2010) showed that resident and migratory life-history forms of cutthroat trout were not genetically differentiated in two lower Columbia River tributaries (Abernathy Creek and the Chinook River). This study showed that resident and migratory families were not reproductively isolated, but not whether there is genetic basis to the behavior (a genetic basis has been found with brook and rainbow trout). Thus it is still not completely resolved whether the long-term trend in these populations toward residency is an evolutionary or plastic response.

Steelhead/rainbow trout also have significant variation among populations in the probability of migrating to sea. Satterthwaite et al. (2010) built on previous models to argued that reduced smolt survival is the most important vital rate that could drive anadromous populations toward residency. The next most important rate was freshwater survival and growth.

Reed et al. (2010a) also found a strong relationship between smolt size and timing and growth opportunities. They found that sockeye salmon outplants from the same hatchery smolted earlier and at a larger size when they reared in a more productive lake, despite negative density dependence. They also had higher marine survival.

Morita and Nagasawa (2010) focused on the rate of maturation of age 0+ males and females in relation to temperature and latitude within Japan. Masu salmon matured as parr at higher rates in warmer streams, and May stream temperature was the best predictor of maturation rates across 12 populations. Furthermore, masu matured at smaller sizes in warmer streams.

8.5 Freshwater ecosystem processes

A variety of studies explored the effects of changes in temperature and flow on freshwater plankton communities. For example, raising the temperature reduced mean body size and prevalence of smaller phytoplankton, and total phytoplankton biomass (but not zooplankton, Yvon-Durocher et al. 2010), affected trophic dynamics (predator impact) and carrying capacities in bacteria-protist mesocosms (Beveridge et al. 2010) and increaseed overall productivity (Stich and Brinker 2010). Variation in the seasonality of flow (increased winter and decrease summer flow) increased phytoplankton abundance (Jones et al. 2010).

Moore and Schindler (2010) showed that insects in Alaskan streams with large salmon populations have adapted to salmon phenology by developing faster than insects in non-salmon streams so that they emerge prior to spawning, and the enormous habitat disturbance salmon create by digging redds.

McDermott et al. (2010) studied the development of hyporheic communities in recently de-glaciated streams in Alaska. These communities were negatively affected by redd-digging.

9 Environmental impacts on salmon marine stages and marine ecosystems

9.1 Smolt timing and early ocean survival

When salmon migrate from fresh to saltwater, they must balance the opportunities and constraints in both habitats. As discussed above, growth rates strongly influence whether and when to smolt from a freshwater perspective, and better growth might lead to earlier smolting or larger smolts (or both, e.g., Reed et al. 2010a). Similarly, some interference with the natural growth or behavioral pattern by stocking at an inappropriate time can lead to delayed smolting (Skilbrei et al. 2010). Kennedy and Crozier (2010) showed a trend from 1978 to 2008 toward earlier smolting in wild Atlantic salmon in the River Bush, Northern Ireland. The emigration has shifted 10-14 days (depending on whether one tracks the start of the emigration or the peak emigration date), which correlates with the 5th day of river temperatures over 10ºC. Nonetheless, marine survival has declined dramatically (from 30-35% early in the time series to 5-10% more recently), which the authors attributed to increasing disparity between river and ocean temperatures. Thus despite apparent tracking of some thermal cue for smolting, river temperatures still increased too fast to avoid a potentially dangerous differential (2.5ºC) between river and ocean temperatures. It is not clear whether other aspects of marine conditions could be driving the population decline.

Smolt timing is well-known to be population-specific, presumably reflecting adaptation to the particular balance of trade-offs between freshwater and marine growth and survival at a given location. Spence and Hall (2010) analyzed the large scale geographic patterns in smolt timing across 53 coho populations from Alaska to central California, and found very strong geographic clustering of smolt timing, duration and variability with oceanographic zones. They suggested links to the predictability of ocean conditions. Because climate change might directly alter the timing of maximal ocean productivity and predictability, meaning specifically interannual variation in the optimal arrival time for smolts, these observations have important implications. Spence and Hall (2010) found that high latitude (mostly Alaskan) populations smolt relatively late, over a short temporal window, and with very little variability from year to year. They argued this is adaptive given the high predictability of the photoperiod-driven increases in productivity characteristic of the Arctic ocean. Southern populations (mostly Oregonian and Californian) that migrate into an ocean dominated by upwelling dynamics tend to enter earlier, but over a much larger temporal window. They argued that this is a bet-hedging strategy given the high interannual variability and unpredictability (from freshwater locations) of the spring transition. They also identified a third cluster in a transitional area mostly from British Columbia and Washington that were intermediate in smolt characteristics, and mostly migrated into buffered areas of Puget Sound and the Strait of Georgia. Although they also discussed alternative explanations and additional important factors, such as natal site elevation, migration distance, and watershed and stream size, these other factors are less likely to change with climate change.

What determines optimal ocean arrival timing is not well understood. Nonetheless, juvenile salmon survival is correlated with forage fish abundance, possibly because they provide alternative prey for predators. Zooplankton or food supply has also been identified as important. Kaltenberg et al. (2010) described the phenology and patterns of variability of forage fish and mesozooplankton populations near the Columbia River plume in 2008 and 2009. Kaltenberg et al. (2010) found a very sudden appearance in mid-May both years of large schools of forage fish which corresponded with similar sea surface temperature, salinity, and river flow (from the Columbia) each year. Zooplankton peaks occurred throughout the spring and summer as fronts passed over the sampling stations, and thus did not showed strong seasonality compared with the forage fish. Litz et al. (2010) found that forage fish switched from eating mainly dinoflagellates early in 2005, during the very delayed upwelling season, to a mostly diatom-based food source after the more normal upwelling season of 2006. They based this conclusion on lipid and fatty acid composition of the forage fish.

Chittenden et al. (2010) analyzed the survival of coho from Seymour and Quinsam Rivers, British Columbia 2007-2009, as a function of release date and marine plankton productivity. They found that coho stayed in the estuary during low marine productivity. Fish that arrived during zooplankton blooms passed quickly through the estuary and had the highest marine detection rates and smolt-adult survival (1.5-3x higher). The optimal time in both years was intermediate among the release groups.

MacFarlane (2010) measured growth in the San Fransisco Bay estuary and coastal ocean over 11 cohorts. They found that the first month following ocean entry was critical for subyearling Chinook. They found very little growth accrued in the estuary, but far better growth upon arrival in the ocean. Higher salinity and lower freshwater outflow produced better growth in the estuary, while cooler temperatures, lower sea level, and greater upwelling improved growth in the ocean. They concluded that climate change conditions would yield reduced growth.

Juvenile salmon presumably do not always encounter adequate food resources. To develop a reference point for interpreting the amount of deprivation that marine fish experience, Fergusson et al. (2010) conducted a laboratory starvation experiment and compared various indices of condition with that usually observed in wild-caught Southeast Alaskan chum salmon in 2003. They found that whole body energy content, percent moisture content, and condition residuals were better indicators of starvation than weight or length, and that after 10-15 days of starvation, laboratory fish fell outside the range normally observed in wild fish.

Two studies found that sea surface temperatures during the first year in the ocean best explained adult returns. Focusing on 24 stocks of northwest Pacific Chinook salmon, Sharma and Liermann (2010) found that the PDO and ENSO indices explained much less variation in recruitment than local sea surface temperatures, which were strongly affected by the strength of upwelling and hence reflected more information about ocean productivity than basin-wide average temperatures. They simulated the effect of a 1ºC change in SST, and found a 13% decline in productivity on average across populations. However, the only one population from the Columbia River was included in this analysis, Deschutes River fall Chinook, and this population showed a minimal effect of ocean predictors (SST, PDO and ENSO). Saito et al. (2010) studied the factors that best predicted smolt-adult return rates of chum salmon in Nemuro Strait in Hokkaido, Japan, 1999-2002. They found that somatic condition and growth rates during the coastal residency period (first 2-3 months in the ocean) did not predicted adult returns. Instead, sea surface temperatures during the first year (especially winter) in the ocean and the size of smolts at release best explained variation in smolt-adult returns.

Petrosky and Schaller (2010) found that warm ocean conditions in March, reduced upwelling in April, and slower river velocity (or additional trips through powerhouses at dams) during the spring migration period were the best predictors of poor ocean survival for both Chinook and steelhead. They recommended increasing spill to help compensate for lower flows and poorer ocean conditions due to climate change.

9.1.1 Algal bloom lowers survival

Although most studies of early marine survival focused on food availability and predation, algal blooms can cause high mortality in Fraser River sockeye salmon. Rensel et al. (2010) found that earlier and larger spring and early summer Fraser River flows were linked to major blooms of harmful raphidophyte flagellate *Heterosigma akashiwo* in the Strait of Georgia. Chilko sockeye salmon survival declined from 10.9% in non-bloom years to 2.7% in bloom years.

9.2 Marine habitat usage

Several studies have focused on ocean habitat usage, especially thermal preference. NOAA scientists have documented a strong aversion to temperatures over 19ºC in the Columbia estuary. This is a strong limitation on habitat usage in the late summer, when juvenile salmon were once abundant (Dan Bottom, personal comm., technical reports). Peterson et al. (2010) synthesized 15 years of survey data to describe the distribution of yearling coho and Chinook salmon distribution and abundance in June and September (after leaving the estuary). The species differed in depth preference and distance offshore. Higher catches correlated positively with chlorophyll and copepod biomass in both species, and with temperature in Chinook salmon. Duffy et al. (2010) described Chinook salmon diet and habitat usage in Puget Sound. "At nearshore sites, insects (all months) and gammarid amphipods (July) were dominant prey sources, whereas in offshore diets decapods (primarily crab larvae; July) and fish (September) were most important." They emphasized that the terrestrial sources of many of the prey items demonstrates an important link between waterfront landuse and salmon survival.

Based on trawl data, Morita et al. (2010a) found that larger and older adult sockeye, chum, and pink salmon inhabited cooler areas than smaller and younger salmon. Using this information, Morita et al. (2010b) developed a bioenergetic model explaining this pattern as a function of the optimal temperature for growth decreasing with body size, which was validated with a laboratory experiment. They concluded that the negative effects of climate warming on growth will be more severe for larger fish. Radchenko et al. (2010) described the results from surveys in the eastern Pacific, documenting the location of salmon and many other ecosystem components in 2009.

Using a combined bioenergetic-ecosystem model, Kishi et al. (2010) explained trends of declining body size in chum from 1970 to 2000 in terms of reduced densities of zooplankton and rising sea surface temperatures. They then characterized suitable potential ocean habitat for Hokkaido chum as 8-12ºC in the summer and 4-6ºC in the winter, based on survival studies and relationships between CPUE and SST. Using global circulation models to simulate global warming conditions, they predicted future distribution shifts: loss of habitat in the eastern North Pacific (Gulf of Alaska), and a northward shift in the Arctic Ocean. Furthermore, they predicted a lower carrying capacity in several areas. Finally, they predicted the current migration route to the Sea of Okhotsk will become unsuitable by 2050. Somewhat along similar lines, Genner et al. (2010) analyzed trends in size and abundance in the English Channel from 1911 to 2007, and found that smaller-sized fish fluctuated in abundance with temperature, showeding quick responses to environmental change. Larger-sized fish, however, showed persistent declines in the larger size classes and overall abundance, perhaps due to size-selective overharvesting.

9.3 Biological Implications of ocean acidification

Literature on how ocean acidification (OA) will affect marine species and communities is exploding, making a complete review beyond of the scope of this report. A recent meta-analysis of the impacts of OA on marine species indicated that there is significant variation in how sensitive marine species are to OA, and, if sensitive, what aspect of organismal biology changes in the face of low pH (Kroeker et al. 2010). However, in general, when all taxa are pooled, OA had negative impacts on survival, calcification, growth and reproduction (Kroeker et al. 2010). Here, we focused on laboratory experiments that explored the sensitivity of fish and salmon prey to OA.

Given the paucity of research, it is impossible to concluded whether the direct and indirect impacts of OA on salmon prey, as a whole, will be positive, negative, or neutral. Development timing of amphipods increased in response to low pH conditions, which may negatively impact population dynamics of this important food source (Egilsdottir et al. 2009; Hauton et al. 2009). Pteropod calcification rate declined with ocean pH, although pteropods can calcify below an aragonite saturation state of 1 (Comeau et al. 2010a; Comeau et al. 2009a; Comeau et al. 2009b; Comeau et al. 2010b). Pteropods in the laboratory survived without shells (Comeau et al. 2010a), though their ability to do this in the field is unknown. How OA affects pteropod population dynamics is also unknown, but energetic challenges (e.g., respiration rates) increase (Comeau et al. 2010b). A study on Antarctic krill indicated that OA is unlikely to affect the progression of early development until CO_2 levels exceed 1000ppm (effect observed at 2000ppm; Kawaguchi et al. 2011). Surface oceans may reach this level by 2100, though deep, cold water may exceed it sooner. The impact of OA on copepods varied with species and life stage, but includes evidence for increased nauplius mortality and decreased egg hatching rate (Kurihara and Ishimatsu 2008; Kurihara et al. 2004a; Kurihara et al. 2004b; Mayor et al. 2007; Pascal et al. 2010). In addition, high CO_2 levels countered some toxic effects of cadmium and copper ions on benthic copepods (Pascal et al. 2010). However, mercury and silver accumulation in *Loligo* squid paralarvae increased with CO_2 levels, which has implications for transfer of metals through food webs (Lacoue-Labarthe et al. 2011).

The role of gelatinous zooplankton in North Pacific ecosystems is steadily increasing. Analysis of time series data from the North Sea showed a negative correlation between gelatinous zooplankton and pH (Attrill and Edwards 2008; Richardson et al. 2009; Richardson and Gibbons 2008), although asexual reproduction and polyp survival in *Aurelia labiata* were not affected by OA in the laboratory (Winans and Purcell 2010).

The direct impacts of OA on salmonids are uncertain, especially because the species group spends its early life stages in fresh, not marine, waters. In the last BiOp, we reported no effect of pH 7.0 on *Salmo salar* mortality, growth, condition, metabolism, or plasma pH, hematocrit, sodium, or chloride (Fivelstad et al. 1998) and impairment of olfactory abilities in tropical clownfish (Dixson et al. 2010; Munday et al. 2009b). Recent research provides more insight on how fishes may respond (or not) to OA: 1) increased otolith size in some but not all species (Checkley Jr. et al. 2009; Franke and Clemmesen

2011; Munday et al. 2011a; Munday et al. 2011b), 2) erosion of auditory based behavior and induction of behavior linked with higher mortality due to predation in a tropical clownfish (Munday et al. 2010; Simpson et al. 2011), 3) decrease in aerobic scope in two tropical coral reef fishes (Munday et al. 2009a), 4) upregulation of some proteins in stickleback and cod and RNA expression in Atlantic herring (Franke and Clemmesen 2011), 5) no impact on early development (survival, growth, skeletal deveopment) in a tropical damselfish and Atlantic herring (Franke and Clemmesen 2011; Munday et al. 2011a).

Two recent modeling papers explored the ecological impacts of OA and other aspects of climate change. Ainsworth et al. (2011) predicted that ocean acidification may cause salmon landings to decrease in Southeast Alaska and Prince Williams Sound food webs and increase in Northern British Columbia and Northern California Current food webs. However, when the authors applied five impacts of global change to these food webs simultaneously (primary productivity, species range shifts, zooplankton community size structure, ocean acidification, and ocean deoxygenation), projected salmon landings decreased in all locales (Ainsworth et al. 2011). Incorporating ocean acidification and ocean deoxygenation into bioclimatic envelop models for harvested fishes in the Northeast Atlantic caused 20-30% declines in projected future harvest, likely due to reduced growth performance and faster range shifts (Cheung et al. 2011). This study is informative to Pacific salmon management as it indicates how changes in physiological performance of finfishes due to ocean acidification may impact harvested populations.

9.4 Ocean ecosystem effects

9.4.1 Evidence of changes in Arctic marine ecosystems

Of the global reviews of documented changes in biota that appear to be responses to climate change, very few have focused on marine ecosystems. Thus the review of the "footprint" of climate change in Arctic marine biota by Wassmann et al. (2010) fills a very important hole. Wassmann reviewed 13 studies of benthos, 9 studies of fish (5 on cod, 2 on pollock, 1 each for turbot and pipefish), 7 studies of birds (5 species), 9 studies of polar bears, 2 seals and 1 whale. Responses ranged from behavioral to growth to range shifts and community reorganization (Greenland cod and shrimp). Most observations are consistent with predictions from climate change simulations: increased primary productivity, declines in endemic, ice-associated species, and invasions or increases in more temperate zone species. One study documenting a change in primary producers was Kahru et al. (2010), who showed that the annual phytoplankton bloom maximum has advanced by up to 50 days in certain areas of the Arctic, with significant trends in 11% of the Arctic Ocean, primarily reflecting the reduction in sea ice. Bloom timing has also advance in the North Pacific.

9.4.2 Ecosystem models

Several very complex models explored the ocean ecosystem dynamics of climate forcing and climate change. Popova et al. (2010) focused on the Arctic Ocean under current conditions, and found that two key processes drove variability in primary production: the extent of winter mixing and short-wave radiation at the ocean surface, which controls phytoplankton blooms.

Two studies analyzed climate change simulations. Rykaczewski and Dunne (2010) used NOAA's Geophysical Fluid Dynamics Laboratory earth system model to study changes in nutrient supply and productivity of the California Current Ecosystem. They focused on nitrate because it is the main nutrient limiting primary production in the CCE. The model predicted a 2ºC rise in ocean temperatures across the basin from 1860 to 2100 under the SRES A2 scenario. They found weaker wind-stress curl, which reduced the strength of upwelling (and downwelling, in the subtropical gyre), but other changes produced a modest increase in upwelling. They note, however, that global models might not have sufficient resolution to fully represent upwelling dynamics. Despite increased stratification, they predicted an 80% increase in nitrate concentration by 2100 in the upper 200m of the CCE, but decreases elsewhere in the Pacific. The increased nitrate concentration in the CCE comes mainly from longer transit times of deep water that are subsequently upwelled.This water is also more depleted in oxygen (18%) and more acidic (0.5 pH units). This produced a net increase in productivity of 10% in the CCE presumably benefitting surface feeding fish, but more frequent hypoxic events threatening benthic and mid-water fauna.

Steinacher et al. (2010) compared four coupled global carbon cycle-climate models that incorporated marine biogeochemcial-ecosystem models. All four models predicted a decreasing trend in global net primary production and particulate organic carbon export. The models all predicted increasing temperature and stratification in all regions and increasing light in the Arctic where sea ice retreats. The high-latitude ocean retained sufficient nutrients to increase primary production and particulate organic carbon export (with increases in the Bering Sea). Nonetheless, they still projected declines in biomass throughout the north Pacific. They discussed differences among the models compared in quantitative predictions. Despite broad agreement on a regional scale, none of the models appear to do exceptionally well at modeling the coastal Pacific Northwest and Alaska (hence the upwelling-specific analyses described previously). Brown et al. (2010a) also predicted increases in primary productivity around Australia, benefitting fisheries and threatened turtles and sharks. They cautioned that the ecological benefit is sensitive to species interactions, which could reverse the benefit for some species.

Several studies in the San Francisco Bay estuary described complex physical and biological processes. MacNally et al. (2010) analyzed the factors affecting the decline of four pelagic fish in the San Francisco estuary. A combination of physical and food web driven factors suggested a diverse array of factors are responsible, but changes in freshwater flow and water clarity had strong effects. The results suggested a relatively good understanding of the ecosystem, but few management options. Cloern et al. (2010) described strong effects of the PDO and the NPGO on demersal fish, crabs and shrimp in San Francisco Bay. They emphasized the interconnectedness of the estuary in linking oceanography and watershed hydrology.

9.4.3 Seabirds, rockfish, and sharks

Several studies explored potential impacts of climate on seabird populations. Wolf et al. (2010) predicted 11-45% declines in Cassin's auklet in response to climate change. Ainley and Hyrenbach (2010) explored bottom-up and top-down drivers of a large number of seabird species in the California Current. Black et al. (2010) analyzed ocean drivers of seabird and rockfish dynamics, emphasizing the importance of February ocean conditions.

Williams et al.(2010) documented very large aggregations of 20,000 sharks in the western Queen Charlotte Sound, British Columbia in a 2004-2006 study. Although it is not absolutely certain that this is a new phenomenon, it has not been documented until recently, and they suggested that the aggregations might be a response to rising sea temperatures. The sharks might present a "feeding gauntlet" deadly for Fraser River salmon, that typically prefer the northern migration route through Queen Charlotte Sound during warm years.

In addition to sharks, other marine fish are likely to shift their distribution in response to rising ocean temperatures. In Australia, coral reef fishes usually limited by winter temperature are predicted to survive as far south as Sydney by 2080 (Figueira and Booth 2010).

9.5 Effects on fisheries

Cheung et al. (2010) combined models that predicted increases in primary productivity with bioclimatic envelop models of species distribution to predicted the impact of climate change on fisheries catch for 1066 species of fish and invertebrates (assuming the geographic location of the fishery doesn't change). They predicted a 30–70% increase in high-latitude catches, including Alaska, a decline of about 10% in the contiguous US, and a drop of up to 40% in the tropics. MacNeil et al.(2010) similarly concluded that Arctic fisheries will benefit from invasions of southern species and increased primary productivity, while there will be species turnover in the temperate zone and significant losses in the tropics.

9.6 Review of hypotheses/frameworks for ocean climate forcing fish populations

Two papers present overviews of the prevailing physical and ecological hypotheses or conceptual frameworks currently in the literature on climate-ocean interactions. Ottersen et al. (2010) focused on three major oceanographic phenomena that drive variability in fish recruitment: temperature, mixing, and advection. They discussed the debate on bottom-up versus top-down population regulation, and trophic cascades, and the key role of forage fish as having both effects. They described immediate and delayed effects of climate, and factors that differentiate local climate drivers from large-scale climate processes such as the NAO and the PDO. They discussed direct, indirect, integrated (i.e., processes that occur over longer time scales than a particular extreme climate event) and translation (i.e., organism movement) effects of climate drivers. Any of these responses might be linear or nonlinear, at the individual or community level. They then detailed specific geographic regions and their particular climate-ecological dynamics. In the Northeast Pacific they emphasized ENSO and the PDO and biological responses. They finally discussed teleconnections and regional differences between the Atlantic and the Pacific.

Bakun (2010) reviews a number of different concepts of population regulation, such as the match-mismatch hypothesis, issues with schooling fish, and the predation risk-nutrient level trade-off (which he calls “loopholes”). Bakun emphasized three major physical processes that provided favorable conditions for fish: nutrient enrichment through upwelling or mixing, concentration through convergence or front formation, for example, and retention processes, such as eddies. Overall this paper emphasized that oceans are complex adaptive systems, and cautioned against assuming simpler concepts from the terrestrial literature adequately capture their complexity.

10 Impact of temperature and flow on adult migrants

10.1 Migration bioenergetic cost

Upstream migrating salmon face several additional stresses due to climate change. Most importantly, rising temperatures increases the metabolic cost of swimming and holding prior to spawning. Cumulative energetic costs or acute thermal stress also increase prespawn mortality. Several papers studied the bioenergetics of migration, which are relevant for calculating these costs. Clark et al. (2010) developed a biologging tag technique for measuring energy expenditure and heart rate in actively migrating sockeye. Cook and Coughlin (2010) found that rainbow trout alter their kinematics around obstructions in the water in a way that improves their efficiency. Forgan and Forster (2010) explored the physiology of oxygen consumption in different tissues. Nadeau et al. (2010) analyzed the relative costs of swimming in the lab against low and high flows that span much of the range typical for Fraser River sockeye. They found that higher flows elevated stress, but not mortality. However, overall females had higher mortality than males. Roscoe et al. (2010) studied the behavior of natural migrants through a lake with cooler bottom water. They found that more mature females with lower energy content preferred the cooler water, while other females and males showed less preference. They posited that use of the thermal refuge slowed maturation and helped maintain energy reserves.

10.2 Migration survival and timing

Migrating upstream is an energetic and thermal bottleneck for many salmon populations. New papers clarified the role of temperature in stimulating upstream migration in a very warm river (the Klamath), and the relationship between timing, temperature, flow, and survival in the cooler Fraser River. Projections in the Fraser River of the consequences of warming over the next century are especially dire.

In the Klamath River, Strange et al. (2010) found that Chinook volitionally migrated through much warmer water than previously thought. Chinook initiated migration at 21.8-24ºC. These high river temperatures produced a mean average body temperature of 21.9ºC, and mean average maximum body temperature of 23.1ºC over the first week of the migration. These temperatures usually cause migration blockages in the Columbia River, but apparently reflect adaptation to the much warmer conditions in the Klamath. Declining temperatures triggered migration, even when the river was still very hot. It is not known whether these fish experienced high prespawn mortality or reduced fecudity or fertility. In the Fraser River, several new papers showed a positive correlation between river temperature and mortality. MacDonald et al. (2010) developed a forecasting model for fisheries managers to facilitate real time predictions of migration survival for various groups of populations. They found that temperature, flow, the timing of entry relative to the average for that population, and fish abundance were good predictors of migration survival. Interestingly, the best predictors did not necessarily match the *a priori* prediction based on the absolute environmental conditions. For example, temperature was an important predictor for Early Stuart sockeye, even though these fish encounter relativley lower temperatures than other fish. The authors point out that these fish still encounter high temperatures upstream, and that they might have lower thermal tolerances than other populations.

Several papers simulating future conditions in the Fraser River predicted signficant declines in sockeye salmon. Hague et al. (2011) found that a 1.0 °C increase in average summer water temperature tripled the number of days per year exceeding critical salmonid thermal thresholds (i.e. 19.0 °C). Martins et al. (2011) found evidence of thermal stress-induced mortality during the migration in three of the four stock-aggregates examined. Under warming scenarios, migration survival in these stocks was projected to decline 9-16%.

Particular attention has focused on the unusual behavior among some Fraser River sockeye populations of migrating much earlier than the historical norm. The early migrants experience much higher temperautres than normally-timed fish, and have significantly lower survival. Mathes et al. (2010) found that early migrants that utilized cool lake habitat as a thermal refuge during their migration had much higher survival than fish that took the river corridor directly to spawning grounds. The early-entry river migrants accumulated extraordinarily high cumulative temperatures and none survived. The early-entry lake migrants had similar cumulative thermal exposure to normally-timed fish that stayed in the river, and similar survival. Donaldson et al. (2010) compared physiological responses to stress (gillnet capture), migration rate and survival in Adams-Shuswap and Chilko populations. The unusually early migrants of the former migrate at the same time as the normal-timed migrants of the latter population. They found delayed effects (near spawning grounds) on survival that differed between the populations. Although the two groups had similar physiological condition when they entered the river, survival among the early-entry Adams-Shuswap group correlated with migration rate (slower migrants had lower survival) and physiological condition (metabolic and osmoregulatory impairment), but not among the Chilko fish.

In the Columbia River, Jepson et al. (2010) studied the migration timing of fall Chinook. They found clear differentiation between the Upper Columbia River and Hanford Reach populations, but Deschutes, Yakima, and Snake River populations migrated throughout the season. They also found harvest was concentrated in late August and early September, and preferentially selected larger fish.

10.2.1 Traditional tribal knowledge and effects of climate change on migration survival and timing

Jacob et al. (2010) described the effects of changes in the salmon runs on native people, and the very serious long-term implications of climate change for both people and fish. Through interviews, they identified changes in salmon abundance (diminished), timing (later in summer and fall), and condition (much less healthy, both in fat content and disease prevalence) from people's recollections of traditional conditions. They discussed potential adaptations, but predicted relatively poor prospects for both people and fish.

11 Impact of high temperatures on prespawn mortality and spawning behavior

11.1 Diseases

The prevalence and virulence of many diseases in fish are much more severe under warmer conditions, and several papers reported disease spread over recent years. Marcos-Lopez et al. (2010) reviewed the increasing risk from a number of diseases (e.g. enteric red mouth, furunculosis, proliferative kidney disease and white spot) due to climate change. The risk from some exotic pathogens that prefer cool water declines (e.g., viral haemorrhagic septicaemia (VHSV), infectious haematopoietic necrosis virus (IHNV) and spring viraemia of carp virus (SVCV), while the risk from warm-loving exotic pathogens (epizootic haematopoietic necrosis and epizootic ulcerative syndrome) increases. They recommended revising management actions to control disease to take into account changing risk levels due to climate change.

Braden et al. (2010) reported spread of proliferative kidney disease (PKD) in natural populations of pink salmon in Quinsam river, Vancouver Island. Bradford et al. (2010) reported widespread prevalence (70% of samples) of the myxozoan parasite *Parvicapsula minibicornis* throughout the Fraser River watershed, and a very advanced stage of infection in most fish on spawning grounds. Ray et al. (2010) quantified levels of *Ceratomyxa shasta* that kill juvenile Chinook salmon in the Klamath River, improving our understanding of this disease. Tonteri et al. (2010) found selection on immune related genes more common than selection on non-immune-related genes in Atlantic salmon, and that allelle frequencies were related to temperature and latitude, suggesting an important role of climate in driving this selection pressure.

Although not directly related to climate change, Koel et al. (2010) reported that Great Blue herons are viable vectors of whirling disease, which affects salmonids in 25 states. Krkosek (2010) warned that sea lice are an increasing threat from farmed salmon in the Pacific, and that the abiotic and biotic factors affecting this disease are not well studied. Pulkkinen et al. (2010) found that fish farms actually select for more virulent strains of *Flavobacterium columnare*, a disease exacerbated by warmer temperatures.

11.2 Prespawn behavior and mortality

Keefer et al. (2010) documented a strong correlation between prespawn mortality in Willamette River Chinook and water temperature and fish condition. Mortality ranged from 0-90%, depending on year and release group. Fish in poor or fair condition had twice the mortality risk of fish in good condition. These fish were transported above a dam, and thus do not represent a natural migration. Nonetheless, they do reflect a dramatic increase in risk due to high temperatures.

Young et al. (2010) found that over summer, brown trout adults in New Zealand tended to hold in deep pools, and only moved during higher flow events and cooler temperatures (below 19ºC). A severe flood killed 60-70% of the tagged population.

11.2.1 A correlation between gene flow and the NAO

Valiente et al. (2010) addressed the population genetic consequences of increased male parr maturation in response to climate change. In addition to describing effects on maturation, they discovered a strong pattern in straying. Specifically, they found a strong correlation between the North Altantic Oscillation Index and immigration from a neighoring stream. I believe that this is the first study system to document this phenomenon, and hence is especially interesting. They found that straying increased linearly when conditions in the natal stream deteriorated (became too warm). This paper is also especially notable in referring specifically to adverse conditions induced by global warming at the southern edge of a species range.

11.3 Spawning behavior

The timing of reproduction is often crucial in determining successful population growth. How climate change will affect spawn timing raises concern because of high risks of prespawn mortality with lengthening freshwater residence, extreme sensitivity of eggs to high temperature (compared to other life stages), and the potential for a mismatch between emergence suitable environmental conditions for fry. Two studies documented long-term shifts in spawn timing in freshwater fish. Wedekind and Kung (2010) showed that European grayling have advanced their spawn timing by more than 3 weeks since 1948, which they attributed to rising temperature. However, a difference between spring and summer warming rates exposed fry to inappropriate temperatures, possibly contributing to population decline. Schneider et al.(2010) showed that walleye are now spawning up to 2 weeks earlier throughout Minnesota (26 populations), with a 0.5-1 day advance for every 1 day advance in ice break up.

Several studies explored the stimulus for spawning. Wilkinson et al. (2010) experimentally manipulated temperature and photoperiod for rainbow trout, and found that under natural photoperiods, elevated winter-spring temperatures only slightly increased maturation rates. Under advanced photoperiod, temperature had a much larger relative effect, but the overall maturation rate was much lower. O'Malley et al. (2010) studied the genetic basis of variation in spawn timing. They compared geographical variation in a gene (OtsClock1b) associated with photoperiod among 53 populations of chum, coho and pink salmon. Combined with a previous study of Chinook salmon, they found that daylength at spawn timing explained much of the variation in allele frequencies of OtsClock1b in chum and Chinook, but not coho and pink salmon.

In addition to affecting juvenile survival and migration success, temperature and flow affect access to and quality of spawning sites. Taylor et al. (2010) documented the distribution of redds over 12 years in a Nova Scotia stream in relation to the timing and intensity of fall rains and beaver dams. They found that stream usage by salmon was linearly related to precipitation, except when blocked by beaver dams. Moir and Pasternack (2010) described a strong positive relationship between substrate coarseness and faster flow in Chinook salmon spawning site selection, demonstrating interactions between habitat characteristics that are not always included in habitat suitability analysis.

12 Direct heat stress

Several papers studied direct heat stress, population variation in heat tolerance, and its genetic basis. Bellgraph et al. (2010) found that juvenile Chinook salmon survived temperatures up to 23.2ºC. The fish increased swimming behavior and heart rate under higher temperatures. Brook char reduced swimming performance at temperatures over 15ºC, especially in combination with ammonia (Tudorache et al. 2010). Feldhaus et al. (2010) found that redband trout amplify production of heat shock proteins (hsp70) between 19 and 22ºC, indicating thermal stress. Healy et al. (2010) studied the genetic basis of variation in the heat shock response in killifish, and found a fairly complicated pattern. They concluded that variation among subspecies must be due to more than simple upregulation of a particular regulator, but involves evolution in a variety of genes. In a comprehensive review, Pankhurst and King (2010) explained the physiological processes mediating the negative effects of high temperature on reproduction.

Sublethal temperature effects interact with other stressors. Boyd et al. (2010) found higher mortality after catch-and-release under elevated temperatures in the evening in rainbow trout. A very large fish kill (25,000 carp) occurred in the St. Lawrence River in 2001, which Ouellet et al. (2010) attributed to a combination of high air temperature and low flow, which depleted oxygen in the lake. They also discussed indirect effects of long-term stress, such as immunosuppression.

Pörtner (2010) reviewed the concept of oxygen supply to the tissues being the fundamental process that determines thermal windows, and as a means for understanding the synergistic effects of multiple stressors. Ocean hypercapnia and acidification interact with warming temperature to further reduce oxygen availability. On the other hand, exposure to high CO_2 also depresses metabolic rates, which might help tolerate reduced availability of oxygen.This fundamental process is general, and hence not species-specific. Seebacher et al. (2010) made an analogous argument that the fundamental limiting factor is cellular damage from the production of reactive oxygen byproducts of metabolism.

13 Higher-level processes

13.1 Population-dynamics modeling

Key to understanding the factors regulating salmon populations (which is essential for predicting effects of climate change) is an appreciation of how different scales of variability interact with the internal periods of variation inherent in populations with overlapping generations. Worden et al. (2010) studied the frequencies of population variability as a function of 1) environmentally-induced variation in survival in the first ocean year only, 2) environmentally-induced variation in survival in all ocean years, and 3) environmentally-induced variation in the age at reproduction. They considered these effects within the larger context of increased variability due to fishing mortality, and different censusing techniques. They found different patterns of fluctuations in all the different scenarios explored. Salmon are more sensitive to some time scales of environmental variability than others, and with fishing they are doubly sensitive to low frequency environmental variability. Long-term changes in climate could thus interact with additional fishing-induced variability to induce fluctuations that pose much greater risks of population collapse than that induced by reduced abundance alone.

Two papers focused on the mathematical properties of population decline to extinction when environmental factors are driving the decline, and provide tools for identifying this trajectory. Drake and Griffen (2010) identified an early warning signal that anticipates a tipping point, beyond which extinction is almost inevitable. The early warning signal is a “critical slowing down”. They demonstrated the statistical properties of this signal using an experimental Daphnia population. A reliable baseline prior to environmental degradation is crucial for successful application of this technique. Ovaskainen and Meerson (2010) reviewed recent advances in theoretical physics that characterized the properties of stochasticity useful for determining mean extinction times under various conditions.

Animals often compensate for environmental variability through phenotypic plasticity, i.e., modifying their behavior or physiology in response to environmental conditions. Reed et al. (2010b) focused on the adaptiveness of phenotypic plasticity. Specifically, they demonstrated that plasticity is only adaptive when there is a reliable cue that anticipates environmental conditions. When the cue becomes less reliable (which might result from different aspects of climate changing at different rates, for example), plasticity shifts from being adaptive to increasing population extinction risk. They emphasized that population models will need to explicitly incorporate plasticity to include this potential effect.

13.2 Population-level effects

13.2.1 Population declines attributed to climatic factors

Clews et al. (2010) studied how environmental variation correlated with population fluctuations of Atlantic salmon and brown trout in Wales from 1985 to 2004. Local catchment processes were not useful in explaining population decline, but broader scale climatic variables correlated strongly with population densities. They found that weather conditions in the previous summer explained most of the variation. Specifically, a principle component analysis showed that reductions in density were highest following hotter, sunnier, and drier conditions. Over the course of the study, summer stream temperatures were estimated to have increased by 0.5ºC in headwaters and 0.6ºC in larger tributaries, and in winter by 0.7ºC and 1ºC, respectively. This amount of warming could explain on the order of a 40% decline in density (or ~3-3.5 fewer salmon per $100m^2$), based on the principle component score (which also includes discharge). Winter warmed more than summer due in part to trends in the NAO, but was not strongly correlated with salmon abundance. The similarity in response between the anadromous salmon and freshwater resident brown trout indicates that freshwater indices are either driving the declines in both species, or are correlated with ocean phenomena in salmon.

After a comprehensive physical and biological assessment, Wiseman et al. (2010) found that warm water tempeature and sedimentation were the primary drivers of habitat decline in the Touchet River in Washington, contributing to contraction of spring Chinook, summer steelhead, and bull trout.

Robinson et al. (2010) reported that stressful summer temperatures (determined by cumulative degree days over 20ºC measured at the bottom of an Adirondack lake) reduced stomach fullness, reproductive activity, and survival of brook trout over one year old, and especially fish over two years old. Like Crozier et al. (2010), they found a positive correlation between temperature and growth at low fish density, and a negative correlation at high fish density.

13.2.2 Expert judgment of overall risks to Fraser River sockeye

A synthetic, expert-opinion analysis of the threat of climate change over the entire life cycle of Fraser River sockeye salmon (McDaniels et al. 2010) found that the cumulative threats are very high. A substantial proportion of responses indicated the fish were highly vulnerable (the highest threat level) at all life stages except the overwintering fry stage. They identified the most vulnerable life stages to be the egg and returning adult stage for populations throughout the Fraser River drainage, especially under a +4ºC warming scenario. They also considered the prospect of reducing the threat through management quite limited.

13.2.3 Paleological perspective

Finney et al. (2010) conducted a major review of the paleological literature on fluctuations in fish abundance (including salmon) over thousands of years. The most relevant topics focused on positive correlations between SST and salmon abundance in Alaska both recently and over most of the past 300 years and again over 2500 years based on sedimentary collection of marine-derived nitrogen carried into freshwater by anadromous salmon. Anomalies in the SST-salmon correlation occurred in several sections of the long-term record, which the authors attributed to changes in ocean-atmosphere circulation during these periods, producing alternate patterns of North Pacific climate variability relative to the PDO and variation in the Aleutian Low. The longer time series showed a bimodel pattern of fluctuations between low and high abundance, with high abundance during the 1250-1890 AD cooler period of the Little Ice Age. This suggests different longer term patterns than suggested from recent data. They also discussed patterns driving anchovy, sardines, and other major ecosystem players throughout the world, and synchronous shifts in all ecosystems. However, specific relationships varied across the time series between in-phase and out-of-phase correlations, indicating alternative modes of climatic forcing of ecosystem dynamics.

13.3 Trends in phenology worldwide

Worth noting here is that phenological responses to climate change have been observed across all taxa, worldwide. A new review out in 2010 (Thackeray et al. 2010) assessed 25,532 rates of phenological change for 726 UK terrestrial, freshwater, and marine taxa. Most taxa showed earlier spring phenomena at rates higher than previously reported. They separated out taxa at different trophic levels, and found that secondary consumers were responding the slowest, and hence were at most risk of a mismatch in timing between predator and prey. Because this trend was so widespread and not restricted to individual species, it highlights a growing risk of the disruption of ecosystem function and services.

14 Habitat

14.1 Stream flow habitat models

Quite a few papers used models of stream flow (or temperature, covered in the next section) to quantify habitat availability for salmonids. Hilker and Lewis (2010) developed a theoretical model of how water velocity affects potential prey populations subject to advection and diffusion downstream, and the minimum flow requirements for drift-feeders like juvenile salmon. Cover et al. (2010) examined the impact of debris flows and debris floods on headwater stream communities. They found that debris flows raised stream temperature, reduced large wood and benthic communities and most vertebrates, with the exception of rainbow trout, which were abundant in recent debris-flooded areas. Escobar-Arias and Pasternack (2010) developed a functional flows model based on shear stress dynamics to characterize fall Chinook spawning habitat; the model could be parameterized for other species. High flow events provided access to new habitat, which can have both positive and negative impacts on salmon. Access to a floodplain that contains pollutants could be detrimental for juvenile salmon. Henery et al. (2010) showed that growth was higher in free swimming Chinook that utilized the Yolo Bypass floodplain than fish that stayed in the Sacramento River, but that the fish in the floodplain accumulated 3.2% more methylmercury per day than fish in the river.

A large group of scientists worked on a new framework for assessing environmental flow needs for many streams and rivers simultaneously to foster development and implementation of environmental flow standards at the regional scale (Poff et al. 2010), and this can be a basis for initiating an adaptive management program.

14.2 Thermally-suitable habitat models and trends

Enhancing riparian vegetation is a major conservation tool recommended for reducing maximum stream temperatures. Two studies showed strong empirical effects of vegetation on stream temperature. In response to high temperature-induced disease-related fish kills, Roth et al. (2010) developed a physical model of stream temperature in Switzerland. They found that existing vegetation (mostly in-stream reeds) lowered the expected temperature by 0.7ºC, but a further decrease of 1.2ºC could be achieved by a mature riparian forest. Brown et al. (2010b) found that coniferous forest plantations lowered summer temperatures in a comparison of 3 forested and 3 moorland sites in northern England.

Statistical models of stream temperature have been used to quantify habitat area that meets particular criteria for species of interest, and to track trends in habitat area over time. Larnier et al. (2010) developed and compared models to identify conditions in the Garonne River in France that are thermally stressful for salmonid migration and survival. Isaak et al. (2010) developed a spatial autocorrelation model to predicted stream temperature throughout the 2500 km^2 upper Boise River Basin in Idaho based on temperatures measured at particular sites. The model performed well against observed temperatures. Historical analysis showed a trend of mean basin stream temperature from 1993 to 2006 rising at a rate of 0.27ºC/decade, and maximum temperatures rose by 0.34ºC/decade. They detected a strong thermal signature of wildfires in the basin: stream temperatures in affected reaches rose 2-3 times more than the basin average due largely to increases in radiation. Rising temperatures shifted rainbow trout habitat to slightly higher elevations but caused 11-20% loss of bull trout habitat.

High temperature already threatens some populations in warmer climates. Null et al. (2010) explored restoration alternatives to migitate stressful temperatures in California's Shasta River. They found that a focused on restoring and protecting cool springs provided the most benefit for salmon (much greater benefit than increasing riparian shading, for example). This conclusion might apply to regions anticipating increasing temperature stress.

14.3 Habitat projections

Wiley et al. (2010) developed a series of models to explore the effects of land cover and climate change on fish habitat in the Great Lakes. They found very significant climate change impacts, and that these impacts were very sensitive to land management. Increasing forest cover and limiting urban development had very large impacts on projected flows, temperatures, and consequently modeled fish habitat. Nonetheless, even the best-case land use scenarios involved destabilization of 57%-76% of the channel system by the end of this century due to increasing rainfall and discharge rates. Summer temperatures rose sharply, with severe consequences for cold-water fish. They projected a loss of ~74% of adult Chinook habitat (but little impact on juvenile Chinook habitat), and the reverse for steelhead: a loss of ~50% of juvenile steelhead habitat, but only ~15% loss of adult habitat. They projected large benefits of climate change for smallmouth bass and walleye.

Several papers explored the potential for riparian vegetation to mitigate future warming. Cristea and Burges (2010) explored climate change impacts in the Wenatchee watershed, a tributary to the Columbia River. They found greater potential for mitigation in smaller tributaries (-1.5ºC in Icicle Creek and -2.8ºC in Nason Creek) compared with the mainstem Wenatchee River (-0.3ºC), due to stream width. The cooling benefit of vegetation restoration will be surpassed by climate change by the 2020s in the mainstem, but postpone stressful temperatures for salmonids in the tributaries until the end of the century, which is a significant benefit.

A study in Scotland (Hrachowitz et al. 2010) produced a comparable result. In this case, however, the highest mean weekly temperatures currently occur in small exposed streams, and these streams are projected to reach extremely stressful temperatures for salmonids in a + 4ºC climate change scenario, which raised the catchment-wide mean stream temperature by 1.4ºC. They suggested that vegetation restoration would ameliorate these stresses.

Hill et al. (2010) showed that certain pristine and environmentally heterogeneous areas in northern coastal British Columbia with salmon have high potential resilience, but relatively low productivity, and hence might not be sufficient to maintain a "salmon stronghold".

14.4 Temperature-driven air pollution

Although mountain areas often support relatively pristine habitat, they are vulnerable to transport of pollutants generated long distances away. In particular, they are especially vulnerable to chemicals that are globally distributed by atmospheric deposition in a temperature-dependent way. Persistent organic pollutants, polycyclic aromatic hydrocarbons, and organochlorine compounds are concentrated in alpine streams because of the strong temperature gradients over short distances. Jarque et al. (2010) studied the reponse to organochlorine compounds in brown trout from the Pyrenees to Norway. They found biologically significant concentrations of pollutants in fish muscle correlated negatively with lake temperature, but biological activity might increase their negative consequences for fish with climate change

15 Policy/human social factors

Several papers addressed policy and management issues in adapting to climate change. All emphasized the need for more applied science and dialogue between researchers, managers, and the public. Some discussed specific climatic and biological information gaps and agreement, and the need for priority setting (Wilby et al. 2010), while others focused more on human social processes (Perry et al. 2010; Slaughter et al. 2010).

More specifically, Wilby et al. (2010) claim there is a lot of confusion about how best to proceed due to uncertainty in regional climate projections, biological responses, and environmental objectives. They emphasized that certain taxonomic groups are underrepresented in baseline data and impact studies, such as macrophytes, and that whole ecosystem responses need to be understood. Environmental objectives differ across managers, the public, conservation groups, etc., who further have different time frames of concern. They argued that even standard advice, such as increasing riparian shading to lower water temperatures and reducing abstraction from river flows, needs site-specific analysis and comparison with alternative actions before implementation. They argued that information gaps include site-specific information, underrepresented taxa, ecosystem goods and services, and risks and definitions of invasive species, given recommendations for increased connectedness. Overall they recommended more applied interdisciplinary research, adaptive management and cost-benefit analysis, in addition to reevaluation of goals and priorities.

Binder et al. (2010) summarized implications for adapation based on the Washington State Climate Change Assessment. They summarized key ingredients in successful adaptation planning, such as political leadership, money, stakeholder engagement, actionable science, tiggering extreme climatic events that motivate action and a long-term perspective. To adapt to changing water resources, they recommended expanding and diversifying water supplies, reducing demand, implementing operational changes, increasing summer drought and winter flood preparedness. To protect salmon, they recommended reducing summer stream temperatures, increasing minimum stream flows, and reducing peak winter flows by various means. They warned that these actions will involve more tradeoffs between water for fish and people.

Perry et al. (2010) emphasized that marine ecosystems and human behaviors are interconnected and showed similar features such as variability at many time scales. They suggested that fisheries focused on opportunistic species (e.g., anchovy) provide a model of flexibility that should be adopted by fisheries focussed on traditionally more stable species (e.g., cod) to adapt to increasing variability due to climate change. They cautioned that spontaneous human responses to increasing ocean variability might further de-stabilize marine ecosystem (e.g., switching to un-fished species). They recommended proactive, flexible management and communication among a broad group of stakeholders to prepare for the diversity of stresses coming to marine ecosystems.

Slaughter et al. (2010) argued that the free market (and reduced subsidies) is a better way to address over-allocation of Pacific Northwest water resources than court or regulator mandates in some respects, although both will be necessary.

The Washington State Integrated Climate Change Response Strategy: Species, Habitats and Ecosystems (Brekke et al. 2010) outlines an integrated approach to climate adaptation strategies that applies to a very wide range of ecosystems and threats. They focused on three conceptual approaches – resistance, resilience and response to faciliate natural system responses, and then building scientific and institutional readiness to support adaptation.

In their book, Climate Savvy, Hansen and Hoffman (2010) considered how a wide range of resource conservation issues—such as managing invasive species, harvest management, or ecological restoration—will need to change in response to climate change. Climate responses of ecosystems or organisms can be one of three types: resistance (stays the same), resilience (recovers after a disturbance), and response (e.g., movement or change). Key adaptation strategies for managing ecosystems in a changing climate included (1) protect adequate and appropriate space, (2) reduce non-climate stressors, (3) manage for uncertainty, (4) reduce local and regional climate effects, and (5) reduce the rate and extent of global climate change.

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Appendix D.3
Literature review for 2011: Biological effects of climate change

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Literature review for 2011 citations for BIOP: Biological effects of climate change

Prepared by Lisa Crozier
Northwest Fisheries Science Center, NOAA-Fisheries
July, 2012

Table of Contents

1 Executive summary

In 2011, the accumulation of more “fingerprints” of global warming continues (Blunden and Arndt 2012). CO_2 concentrations in the atmosphere broke new records, driving radiative forcing to 30% above 1990 levels. Rapid warming in high latitudes produced record losses of snow and ice from ice sheets and sea ice. Average summer temperatures throughout the U.S. were the second warmest on record, and despite the typically cool La Niña, 2011 was one of the 15 warmest years on record in the US, contributing to a very active wildfire season. The rise in 30-year average daily temperatures, reflected in the U.S. “Normals” for 1981-2010, was several degrees above that for the 1971-2000 period, reflecting the longer trends (Arguez et al. 2012). The frequency of extreme precipitation events (1-day and 5-day events) has increased over much of the Northern Hemisphere, despite natural forcing toward a decrease, thus presenting another “fingerprint” of the effects of anthropogenic forcing (Min et al. 2011).

In the PNW, hydrological impacts of warming have been strongest in rain-snow transient watersheds, where discharge has increased in the winter and decreased in the summer, producing earlier peak flows and lower low flows since 1962 (Jefferson 2011). New projections of hydrological responses in the PNW are consistent with the observed historical trends in hydrology (Cuo et al. 2011) and fire frequency and severity (Rogers et al. 2011), and emphasize the additional sensitivity in our region to higher projected rates of summer warming compared with winter warming for total annual discharge (Das et al. 2011). A statistically significant rise in summer sea level over the past century reflects larger patterns of sea level rise, while controlling for the effects of El Niño in winter (Komar et al. 2011). Similarly, summer upwelling intensity at 39º-42ºN has increased (Black et al. 2011), and upwelling has advanced earlier in the year, with a shorter upwelling period off British Columbia (Foreman et al. 2011). Hypoxia in the Columbia River estuary has been linked to upwelling events (Roegner et al. 2011b), and frequently reaches stressful levels for fish (2mg/L, Roegner et al. 2011a). Although some models project that hypoxic water from upwelling will decrease with climate change (Glessmer et al. 2011), sensitivity to hypoxia is much greater in warmer water, so it continues to present a serious risk (Vaquer-Sunyer and Duarte 2011). Numerous papers explore the hydrodynamics of the Columbia River, including sediment transport which might affect salmon survival (Jay et al. 2011; Jay and Naik 2011; Naik and Jay 2011b; Naik and Jay 2011a). Ecological fingerprints of climate change include a strong signal of long-term trends and regime shifts in marine ecosystems, described in a recent review of 300 time series in waters around the UK (Spencer et al. 2011).

A major concern is the extent to which natural responses to climate change must include range shifts or range contractions, because the current habitat will become unsuitable. The rate of range shifts and phenological shifts necessary to track climate change might be significantly larger in the ocean than on land, despite the slower absolute rate of warming in the ocean, due to shallower spatial and temporal gradients in temperature (Burrows et al. 2011). Abdul-Aziz et al (2011) illustrate this point dramatically for PNW salmon by showing that climate scenarios imply an enormous contraction (30-50% by the 2080s) of the summer thermal range suitable for chum, pink, coho, sockeye and steelhead in the marine environment, with an especially large contraction (86-88%) of Chinook salmon summer range (A1B and A2 scenarios). Previous analyses focusing on sockeye salmon (Welch et al.

1998) came to similar conclusions, but updated climate change projections and the multi-species perspective make this a particularly relevant paper.

Most of the other impacts of climate change on salmon reported in 2011 are consistent with the direction of previous studies. Copeland and Meyer (2011) found a positive effect of flow on juvenile Chinook density in the Salmon River Basin. Although demonstrated in Atlantic salmon (Marschall et al. 2011), observations that very long delays at dams can lead to exposure to extremely high river temperatures during smolting also could apply to the Columbia River. Bi et al (Bi et al. 2011a; Bi et al. 2011b) found strong correlations between marine distribution and growth and cold-water flow from the north, which presumably will decline with rising SST.

Numerous papers on adult migration demonstrate that migration timing is both genetically and plastically determined, and that changes in timing have already occurred (e.g., an evolutionary response in Columbia River sockeye, Crozier et al. 2011) and will continue with climate change. Projections of warming in the Fraser River produced much lower estimates of migration survival than occur now (Hague et al. 2011; Martins et al. 2011), although they aren't expected to drive the populations extinct on their own (i.e., acting on this life stage alone, Reed et al. 2011). Much of the current mortality might be due to diseases as yet unidentified (Miller et al. 2011a).

Several papers emphasize that focusing exclusively on effects of individual life stages gravely unrepresents the cumulative impacts of climate change on salmon (Healey 2011; Pankhurst and Munday 2011). Analyses of the factors correlated with salmon extinctions in California (Zeug et al. 2011) and Japan (Fukushima et al. 2011) point to changes in flow regimes and rising air temperatures.

The risk of diseases throughout the life cycle is probably one of the least well quantified areas of concern (e.g., little is known about virus responses to climate change, Danovaro et al. 2011). The best way to protect salmon from disease risk is to maintain large population sizes with high genetic diversity (de Eyto et al. 2011). Species interactions are also poorly predicted, although recent work shows that competition among trout species can significantly alter predicted effects of climate change (Wenger et al. 2011).

On the positive side, some papers found less negative impacts of rising temperatures than expected (e.g., high tolerance of Snake River fall Chinook for 23ºC, Geist et al. 2011), and substantial genetic variation (and thus theoretically, the potential for evolution) in growth parameters, smolt behavior, migration timing, cardiac performance and heat tolerance. However, the existence of genetic variation and local adaptation in physiological traits does not support much optimism that evolution is likely to rescue Chinook salmon from risk of lowered survival due to climate change (unlike migration timing, as mentioned above). Typically, evolution relies on large population sizes and plenty of time. This is especially true if fisheries selection, e.g., on age at return, opposes adaptive responses to climate change or enhances population variability in response to environmental forcing (Botsford et al. 2011; Rouyer et al. 2011).

Adaptation plans for responding to climate change in the Pacific Northwest are being developed (e.g., review in National Wildlife Federation 2011). However, several papers emphasize that institutional barriers are a serious impediment to proactive climate change adaptation in water management (Farley et al. 2011b; Hamlet 2011; Safford and Norman 2011).

In conclusion, new information from 2011 publications was generally consistent with previous analyses in reporting ongoing trends in climate consistent with climate change projections and negative implications for salmon. A few studies focused on areas that did not receive much attention in our previous report, and thus provide new information. These areas include the expected loss of significant portions of the marine distribution, albeit it mainly in the second half of this century, the current risk of hypoxia in the Columbia River estuary, as well as documented and projected rates of evolutionary changes in migration timing. Disease impacts on migration survival documented in Fraser River sockeye warn of the potential for a very rapid decline in survival, unlike the linear projections generally forecasted, with little managerial recourse. Several papers demonstrated how cumulative effects of climate change over the entire life cycle are likely to be much higher than previously predicted from effects on individual life stages. Finally, new adaptation plans for the PNW are being developed but institutional barriers to climate change adaptation for some agencies and water use sectors create challenges for effective response.

Table of acronyms

A1B, A2, B1	Carbon emission scenarios from IPCC Fourth Assessment Report
AOGCM	Coupled Atmosphere-Ocean General Circulation Model
ENSO	El Niño-Southern Oscillation
GCM	General Circulation Model
IPCC	Intergovernmental Panel on Climate Change
PDO	Pacific Decadal Oscillation
PNW	Pacific Northwest
SST	Sea surface temperature

2 Goals and methods of this review

The goal of this review was to identify the literature published in 2011 that is most relevant to predicting impacts of climate change on Columbia River salmon listed under the Endangered Species Act. A large amount of literature related to this topic is not included, because almost anything that affects salmon at all relates to or is altered in some way by changes in temperature, stream flow or marine conditions. We have tried to identify the most directly related papers by combining climatic and salmonid terms in search criteria. Thus many general principles demonstrated in other taxa or with more general contexts in mind have been omitted. This review also does not include potentially relevant gray literature, because the search engine used only includes the major peer-reviewed scientific journals. In total, the methods employed involved review of over 500 papers. Of these, 135 are included in this summary.

This search was conducted in ISI Web of Science in July, 2012. Each set of search criteria involved a new search, and results were compared with previous searches to identify missing topics. The specific search criteria all included PY=2011, plus:

1) TS=(climat* OR temperature OR streamflow OR flow OR snowpack OR precipitation OR PDO) AND TS=(salmon OR Oncorhynchus OR steelhead);

2) TS=(climat* OR Temperature OR Precipitation OR streamflow OR flow) AND TS="Pacific Northwest";

3) TS=(marine OR sea level OR hyporheic OR groundwater) AND TS=climat* AND TS=(salmon OR Oncorhynchus OR steelhead);

4) TS=(upwelling OR estuary) AND TS=climat* AND TS=Pacific;

5) FT=("ocean acidification" OR "California current" OR "Columbia River")

6) TS="prespawn mortality"

The review is organized by first considering physical environmental conditions (historical trends and relationships) and then predictions of future climate, snowpack, stream flow, temperature, ocean conditions, etc. A summary follows of the literature on salmonid responses to these environmental conditions, progressing through the life cycle.

3 Climate

3.1 Global, national, regional climate

3.1.1 1981-2010 U.S. "Normals"

NOAA released a new set of "Normal" temperatures, i.e., 30-year average temperatures for the U.S for the 1981-2010 period (Arguez et al. 2012). The new normals include some methodological and station changes, and thus are not recommended for describing long-term trends in climate. Nonetheless, there is a striking increase in most of the indices. January minimum temperature has risen 2-4ºF throughout the north-central US, with nearly the entire central US seeing at least 1ºF increases compared with 1971-2000 normals. July maximum temperatures have increased at least 0.5ºF in the entire West.

3.1.2 State of the Climate 2011

Despite the cooling effect of La Niña, 2011 was still one of the 15 warmest years on record and above the 1981-2010 average (Blunden and Arndt 2012). Global sea surface temperature (SST) was 0.1ºC cooler than El Niño-driven 2010, but the global upper ocean heat content was still higher than for all prior years. Atmospheric CO_2 concentrations increased by 2.1ppm in 2011, exceeding 390ppm for the first time since instrumental records began. Together with increases in other greenhouse gases, radiative forcing is now 30% higher than in 1990. Ocean uptake of CO_2 was 12% below the long-term average. The Arctic continued to warm at twice the rate of lower latitudes, continuing extreme surface warming and net snow and ice loss on the Greenland ice sheet and the greatest loss in the Canadian Arctic since Gravity Recovery and Climate Experiment satellite measurements began. Arctic sea ice extent in September 2011 was the second-lowest on record, and 4-5yr old ice set a new record minimum of 19% of normal. Similar records were set in Antarctica.

The nationally-averaged summer temperature was the second warmest on record, but the Pacific Northwest (PNW) was cooler than average. The tornado season was one of the most destructive and deadly recorded, and historic flooding soaked much of the central US, surpassing the great floods of the 1920s and 1930s. The US also had a very active wildfire year (Blunden and Arndt 2012).

Observations of weather over the past 60 years (shifts in the position of warm and cold fronts across US) are consistent with projections of climate change associated with elevated greenhouse gas concentrations. The overall shift toward cold fronts and away from warm fronts across the northern US arises from a combination of an enhanced ridge over western North America and a northward shift of storm tracks throughout the mid-latitudes (Hondula and Davis 2011).

3.1.3 Extreme events

General circulation models (GCM) predict that anthropogenic forcing will increase the frequency of extreme events, such as heavy precipitation events, that cause massive flooding in the PNW. Min et al (2011) identified positive trends in extreme precipitation events in GCM projections. These trends were most consistent in the anthropogenic-forcing experiment only (without natural forcing), because natural forcing over the 20th century would have led to decreases in extreme precipitation events in many areas, thus producing a weaker observed signal of the anthropogenic fingerprint (i.e., without correction for natural forcing). Statistical comparisons of model representations and observed data show that coarse-resolution models are not capable of capturing the frequency of extreme events, but regional climate models nested within them greatly improve the dynamics (Duliere et al. 2011). Note that in 2012 the Intergovernmental Panel on Climate Change (IPCC) released a thorough analysis of changes in the frequency of extreme events, which will be included in the 2012 literature review.

3.1.4 El Niño analysis and modelling

The 2009-2010 El Niño differed from classical El Niño because it exhibited a "Modoki phenomenon", or a "warm-pool" El Niño, with most warming in the central Pacific but a rapid transition to La Niña in 2011. Kim et al (2011) postulate the "fast phase transition" is due to a very warm Indian ocean and record-high SST in the central Pacific (see also Barnard et al. 2011).

Much work has been dedicated to improving the oceanographic data going into climate models, e.g., from autonomous gliders (Todd et al. 2011), and the spatial resolution of coupled atmosphere-ocean general circulation models (AOGCM) (Dawson et al. 2011), so that the next round of the IPCC's Fifth Assessment Report models should have better representation of El Nino-Southern Oscillation (ENSO).

The importance of El Niño modeling has been emphasized in many papers, particularly for the PNW. Paleological data indicates that the recent century has been unusually wet in the perspective of much longer time-series. Long-term droughts have occurred throughout the last 6000 years, especially during the last 1000 years. Shifts in the severity of both wet and dry multidecadal events appear to be driven by changes in the ENSO pattern, and its effect on the Pacific Decadal Oscillation (PDO) (Nelson et al. 2011).

3.2 Terrestrial

3.2.1 Historical trends in streamflow in PNW

Like previous studies, new analyses of historical trends in streamflow in the PNW emphasize the sensitivity of transitional watersheds (i.e., where precipitation falls as both snow and rain) and transitional elevations within watersheds to recent (and projected) warming. Specifically, in an analysis of 29 watersheds in the PNW (Jefferson 2011), transitional areas demonstrate the most significant historical trends (i.e., greater winter and lower summer discharge). Snow-dominated watersheds showed changes in the timing of runoff (22-27 days earlier) and lower low flows (5-9% lower) currently than in 1962. Peak flows increased in the more heavily snow-dominated watersheds exposed to more frequent rain-on-snow events at higher elevations, but there was no trend in most of the transient or rain-dominated watersheds.

A series of papers on the impact of climate, dams, water withdrawal, and other human impacts on the Columbia and Willamette Rivers demonstrate that 1) human factors dominate the change in outflow of the Columbia River over the 20th century (Jay and Naik 2011; Naik and Jay 2011a), 2) climate factors, especially ENSO and the PDO, but also more fine-scale details about the timing of winter storms and spring warming rates also drive significant changes in the annual flow, as well as the detailed flow profile and winter and spring freshets (Naik and Jay 2011a) , 3) sediment loads have been strongly reduced due mostly to flow management and withdrawals, but climate-driven flow reductions also lower sediment transport, which has negative impacts on juvenile salmon survival (Jay and Naik 2011; Naik and Jay 2011a).

Many papers explore how habitat generally and flow in particular are related to juvenile salmonid density or growth. We focus here only on those in the Columbia River Basin.

In the lower Columbia, low flows in summer and fall through a tidal channel in the lower Columbia River (from Portland, OR to Vancouver, WA) have gotten lower and tidal range has increased due to both tidal changes and river flow and harbor modifications (Jay et al. 2011).

In Idaho, water diversion patterns vary with water availability in the Snake River Plain over the past 35 years from 1971 to 2005 (Hoekema and Sridhar 2011). Overall trends of declining mid- and late-season diversion is due to lack of water supply due to lower summer flows. Diversions have increased in April in response to unusually wet springs.

In a study of temporal variability in stream habitat characteristics over nine years in 47 headwater streams, Al-Chokhachy et al (2011) used landscape, climate, and disturbance attributes as explanatory factors. Although the factors were significant, most of the variability was difficult to explain.

A high proportion of groundwater input to a basin significantly affects the flow regime. Streams in the Klamath Basin with major groundwater inflow have a smoother and delayed response to snowmelt. However, July to September baseflows decrease under climate change scenarios much faster than mostly surface-input streams (Mayer and Naman 2011).

3.2.2 Projected changes in stream flow and ice-cover

An analysis of how land-cover and climate change in the Puget Sound basin will drive hydrological change (Cuo et al. 2011) showed that land use, leading to younger vegetation and urbanization will likely have more impact at lower elevations than climate change alone. In the rain-snow transition zone, increased winter precipitation and less snow led to earlier winter and spring runoff, with increases in these seasons due to projected increases in precipitation. Reductions in late spring and summer runoff followed, but the net change was a slight increase in annual runoff. Land-cover change had greater impact on the total runoff, especially at lower elevations, due to an increase in impervious surfaces and loss of mature vegetation in forested areas.

Das et al (2011) explore the sensitivty of streamflow across the Columbia Basin (and three other basins) to the seasonality of warming. They find that annual streamflow is much more sensitive to warming in the summer than in the winter. This is because winter warming causes an initial increase in streamflow that partly compensates for the later low flows in the summer. Summer warming dries out soil immediately through greater evapotranspiration rates with no compensation during the next rainy season. Because the A2 scenario predicts greater summer warming (5ºC) than winter warming (3ºC), this has a greater impact than uniform warming or a bias in the other direction would have. Application of a 2ºC cool season warming and 4ºC warm season warming produced a decline in annual streamfow of 9.8% in the Columbia Basin (Das et al. 2011). Work continues (Bohn, Sonessa et al. 2010) on the Variable Infiltration Model hydrology model, downscaling bias correction, and understanding how best to use multi-model ensembles compared with best-fitting individual models.

Scenarios of climate change in the Willamette Basin predicted increases in flows in winter (September through February), and decreases in summer (March through August, Jung and Chang 2011). The spring freshet is expected to advance seasonally, the 7-day low flows decrease, and peak flows increase due to winter flooding, especially at higher elevations.

Similar to watersheds and elevations in the rain-snow transition zone, lakes where winter ice cover is short with winter minimum temperatures closer to 0ºC are most sensitive to warming. Weyhenmeyer et al (2011) predict that "3.7% of the world's lakes larger than 0.1 km^2 are at high risk of becoming open-water systems in the near future."

In an analysis of uncertainty around flooding in urban areas, Jung et al (2011) explicitly focus on the uncertainty at all levels of modeling, from GCM model and emissions scenarios to land use change to hydrological model parameters and natural variability in climate. The development versus conservation land use scenarios in watersheds around Portland, OR made little difference to the overall projections, especially in the more developed watershed. In that watershed, hydrological parameters drove much more uncertainty than in the more pristine watershed. Uncertainty from GCM model structure (i.e., different GCMs) was larger than hydrological model uncertainty, and natural varibility was larger still, especially at long flood frequencies. Overall, flood frequencies are expected to increase by the 2050s.

3.2.3 Fire

Simulations of PNW fire frequency in future climates predict large increases in the area burned (76%-310%) and burn severities (29%-41%) by the end of the twenty-first century (Rogers et al. 2011). The changing fire regime lowers carbon storage west of the Cascades in the absence of fire suppression, but raises it in the dry eastern PNW.
Fire frequency is expected to increase in most areas of the PNW. Fire has a profound effect on steam temperature and nutrient input. An analysis of historical stream changes and trout response in burned and unburned areas of Montana showed stream temperatures increased 2-6ºC right after the fire, but recovery by fish was generally swift (Sestrich et al. 2011).

3.3 Marine

3.3.1 ENSO

State of the California Current System 2010-2011: The 2009-2010 El Niño was relatively weak and short-lived, and it was quickly followed by La Niña. La Niña produced some record-breaking cool conditions throughout the California Current system, with anomalously strong upwelling in summer 2010. Impacts of both El Niño and La Niña were weaker and the transition between them was less abrupt off southern California compared with off Washington and Oregon. Productivity in the pelagic ecosystem enhanced with La Niña off central and southern California, but El Niño-condition copepod assemblies persisted later in the northern California Current system (Bjorkstedt et al. 2011).

Heinemann et al (2011) developed a simplified ENSO and ecosystem (nutrient-phytoplankton-zooplankton) model that demonstrates how the ecosystem itself could moderate ENSO variability by the effect of phytoplankton on the absorption of shortwave radiation in the water column. This biological feedback to the climate system leads to (1) warming of the tropical Pacific, (2) reduction of the ENSO amplitude, and (3) prolonging the ENSO period. In a somewhat similar analysis, Lin et al (2011) showed that the spatial distribution of chlorophyll-a actually influences the mean state of the ocean in the tropical Pacific. Because chlorophyll-a blocks solar radiation to some extent, a shallow thermocline and stronger currents lead to decreased annual mean SST in the eastern equatorial Pacific. They conclude that the seasonal cycle of chlorophyll-a can dramatically change the ENSO period in the coupled model.

3.3.2 Sea Level Rise, wind speed and wave height

Sea level varies seasonally and with significant ocean phenomena, such as El Niño events. Determining whether there has been a significant rise in sea level must first, therefore, account for this effect. Komar et al (2011) separated out the seasonal trends in sea level in the PNW. Strong El Niño events dominate the winter record, but the more stable summer sea levels show statistically significant trends toward higher sea level.

Using satellite data, Young et al (2011) documented increasing oceanic wind speeds and wave height over 23 years globally, with a higher rate of increase in extreme events.

3.3.3 Upwelling

Most analyses published in 2011 found that upwelling has become more intense over the past century. The California Current System demonstrates two seasonal upwelling “modes” (Black et al. 2011). Summer upwelling shows longer frequency variation, reflecting multi-decadal processes. Significant linear trends over 64 years show the intensity of summer upwelling has increased at 39ºN to 42ºN. Winter upwelling reflects North Pacific Index and ENSO cycles. Chinook salmon growth-increment chronology correlated significantly with the summer upwelling mode (Black et al. 2011). Similarly, upwelling off British Columbia (Foreman et al. 2011) starts later and ends earlier, based on trends over the past 50 years. Nonetheless, cumulative upwelling and downwelling has significantly increased, because of the increase in intensity. The intensity of coastal upwelling off California, however, has not increased over the past 60 years (Pardo et al. 2011), based on SST and the upwelling index from the National Centers for Environmental Prediction/ National Center for Atmospheric Research reanalysis project database.

The effects of upwelling off the coast extend into the Columbia River estuary. Roegner et al (2011b) investigated whether the source of chorophyll in the estuary was freshwater or marine. High flows in spring brought freshwater chlorophyll into the estuary, although production was relatively low. In the summer, upwelling winds transported chlorophyll from the ocean. Tidal cycles determined stratification, which was higher during neap tides than spring tides.

3.3.4 Oxygen mimium zones and O_2 sensitivity

Oxygen minimum zones (OMZs), have been expanding over the 20th century. Studies of a 2.4-4.5ºC warming event in the Miocene indicates that similar low oxygen conditions occurred at that time as have recently been observed (Belanger 2011). An analysis of anchovy and sardine oscillations indicates that oxygen levels, rather than temperature or food availability could be the primary factor driving anchovy/sardine oscillations in the Peruvian upwelling region (Bertrand et al. 2011).

The Columbia River estuary experiences low oxygen conditions (2mg/L) when strong upwelling combines with neap tides (Roegner et al. 2011a). Mortality caused by low oxygen is significantly increased by warmer water. In a meta-analysis, Vaquer-Sunyer and Duarte (2011) found that increasing temperature reduced marine benthic macrofauna survival times and increased minimum oxygen thresholds for survival by 74%, and 16%, respectively, on average. They project that 4ºC ocean warming will lower survival times by 35.6% and raise minimum oxygen concentrations by 25.5%, potentially causing many more die-offs in the future.

A separate model of upwelling in an AOGCM predicts a reduction in the impact of OMZs from upwelling. Glessmer et al Glessmer, Park et al. 2011) found that 25% less low oxygen water reached the surface in their double CO_2 scenario, compared with the current climate.

3.3.5 Ocean acidification

Ocean pH is often thought of as being fairly static, but Hofmann et al (2011) demonstrate very high spatial and temporal variability in diverse marine habitats. Others (Joint et al. 2011) similiarly argue that natural variability is very high, pointing out that pH can change much more in freshwater lakes. Models of future pH and biological responses and feedbacks are still challenging (Tagliabue et al. 2011).

Much work has continued on the sensitivity of different organisms and life stages to ocean acidification. Gruber (2011) published an overview of the combined threats of ocean acidification, rising temperatures, and lowered oxygen levels. Many species have been studied in 2011, including herring (Franke and Clemmesen 2011), coral reef fishes (Munday et al. 2011a), clownfish (Munday et al. 2011b), an intact invertebrate community (Hale et al. 2011), crustaceans (Whiteley 2011) plus many studies on pteropods (Lischka et al. 2011) and phytoplankton (Low-DÉCarie et al. 2011). The results are mixed, but many stages and species are not especially sensitive. Pteropods are a concern for salmon because they are a prey item and have an aragonitic shell. They are sensitive to temperature increases in addition to rising acidity (Lischka et al. 2011).

3.3.6 Ecosystem effects

Large-scale climate factors and ocean chemistry drive the distribution and productivity of the entire marine biota. Factors such as the PDO, ENSO, and Northern Oscillation Index are strong predictors of larval fish concentration and diversity in the northern California Current (Auth et al. 2011). Upwelling indices are a significant predictor of herring and surf smelt catches in the Skagit River estuary (Reum et al. 2011). The Aleutian Low Pressure Index is correlated with seabird productivity and timing (Bond et al. 2011). Long-term trends in community composition this past century have been documented in a majority of time series of marine ecosystems. In a study of 300 biological time series from seven marine regions off western Europe, Spencer et al (Spencer et al. 2011) found most regions showed both long-term trends and regime shifts. Pollock, for example, changed its role in the food web during warm periods (Coyle et al. 2011). Regime shifts (i.e., a step in some measure of biological response over a short temporal interval or in response to a small physical change) are also widespread, although they might be overestimated by failure to account for temporal trends (Spencer et al. 2011).

Predicting how ecosystems will change with the climate typically relies on environmental correlates of organism distribution. Lenoir et al (2011) developed a model that explains observed shifts in the distribution of eight exploited fish in the North Atlantic, and projects that these species should continue to move northward, but some might be hindered by barriers and rate limitations. Finally, mesocosm experiments show how warming accelerates the phytoplankton bloom timing by about 1 day/ºC, and decreases biomass (Sommer and Lewandowska 2011).

Using NOAA's Geophysical Fluid Dynamics Laboratory Earth System Model, Polovina et al (2011) project shifts in large marine ecosystems. They use modeled phytoplankton density to distinguish 3 biomes in the North Pacific. Under the A2 emissions scenario, the model predicts that temperate and equatorial upwelling biomes will occupy 34 and 28% less area by 2100. The subtropical biome, on the other hand, expands. Extending this change in area to primary productivity and fisheries catches, they expect a 38% decrease in the temperate biome, and a 26% increase in the subtropical biome catch.

An additional concern throughout the ecosystem is the increasing prevalence of persistent organic pollutants, especially polycyclic aromatic hydrocarbons from fossil fuel burning (De Laender et al. 2011). This direct source of pollution is a major concern for salmon, especially coho, in urban areas, but might become a more widespread marine phenomenon.

Jones (2011) discusses the potential for increasing marine productivity by enriching the oceans artificially with macronutrients (the Haber-Bosch process). He argues that phosphorus appears to limit the carbon storage capacity of nitrogen and hence additional new primary production.

3.3.7 Viruses

A typically overlooked consequence of global change is a potential increase in the impacts from viruses. Danovario et al (2011) review the very large impacts viruses have on phytoplankton, especially, but also throughout the ecosystem. They point out many positive correlations between temperature (and other expected changes in ocean chemistry) and viral abundance, but the relationships are complicated and more work is needed.

3.4 Comparing rates of climate change in marine and terrestrial environments

Burrows et al (2011) compared the rates of historical climate change in marine and terrestrial environments. Focusing on the rates of temperature change that organisms might be expected to track through either range shifts or phenological change, they calculated the velocity of temperature change in terms of the latitudinal distance an isotherm has shifted (km/year), and the seasonal shift in spring and fall temperatures (days per year). These two quantities are ratios of the long-term temperature trend and either the spatial or temporal gradients across the landscape. Using these metrics, they found that although the absolute rate is a little slower in the ocean, because the spatial and seasonal gradients in temperature are shallower, the overall velocity and seasonal rates of change are faster for marine than terrestrial ecosystems, implying faster range shifts will be needed to track cliamte change. The ocean also differs from land because many ocean areas are cooling, especially in areas where upwelling has intensified, generating a bimodal distribution of rates of temperature change.

4 Salmon life-stage effects

4.1 Freshwater stages

4.1.1 Juvenile behavior and survival

Copeland and Meyer (2011) studied the correlations in juvenile salmonid density since 1985 in the Salmon and Clearwater River Basins. Densities in all six species were positively correlated, and flow and Chinook salmon redds were correlated with densities overall. For Chinook salmon, models with spawner density combined with either annual mean discharge or drought (Palmer Drought Severity Index) had similar Akaike information criterion (AIC) weights, and explained 52% of the variation.

Hypoxia limits the suitability of many nesting sites, and is often affected by changes in flow via deposition rate of fine sediments or flushing and groundwater infiltration. Malcolm et al (2011) found that interstitial velocity is not a good predictor of hyporheic dissolved oxygen. Miller et al (2011b) explore how rainbow trout compensate for low oxygen by altering their cardiac ontogenic program.

Heat tolerance varies by life stage in salmon. Breau et al (2011) show that differences in thermal-refuge-seeking behavior between age 0+ and age 1+ and 2+ Atlantic salmon stems from higher tolerance in respiration and cardiac performance in younger fish.

Given the dramatic changes in winter temperature expected throughout the PNW, it is a concern that winter ecology is not well understood. Stream environments create complicated ice dynamics that are very sensitive to fine scale variation in temperature and flow (Brown et al. 2011). Fish responses to thermally elevated areas overwinter (e.g., near nuclear power plants) sometimes have negative consequences for reproduction, but likely responses to long-term, gradual changes throughout the stream are not clear. Undercut banks are critical winter habitat for brook trout in small mountain stream, affected only slightly by winter flow reductions (Krimmer et al. 2011).

4.1.2 Juvenile growth

Salmon growth rates depend on temperature both directly because of temperature-governed chemical reaction rates, and indirectly because of elevated energetic demands of higher metabolic rates. Increased consumption can sometimes compensate for higher metabolic rates, leading to an interaction between ration and temperature effects. Geist et al (2011) tested the growth rate of Snake River fall Chinook below Hells Canyon Dam, and found high tolerance to short periods of high temperature (23ºC) even at relatively low rations (down to 4% of body weight). However, at 1% ration, fish grew better at constant cool temperatures, suggesting that this low consumption rate was insufficient to cover metabolic costs of high temperatures. Natural consumption rates at this location are unknown. Steelhead in Los Angeles County grow year-round and produce large smolts, despite spending a week each year at mean temperatures over 22ºC (Bell et al. 2011). It is important to note that although growth is sensitive to temperature, other factors, such as negative effects of fish density, can be more limiting (Bal et al. 2011).

Bioenergetic models are a primary means of analyzing changes in stream quality on growth. A crucial element of these models is the interaction between metabolic rate and energy supply through food consumption. Individual variation in bioenergetic parameters is generally ignored, but Armstrong et al (2011) show through a modelling exercise that this variation can significantly affect the impact of flow and food variability on growth.

Energetic rates were measured in rainbow trout exposed to various flows in a natural environment. The crucial difference between their environment and a typical laboratory set up was the existence of refuges from high flows, which allowed swim speed to decline at peak flows (Cocherell et al. 2011). Taguchi and Liao (2011) also explored how microhabitat utilization can be very energetically efficient.

By coupling a bioenergetic model with a simplified stream temperature model, Beer and Anderson (2011) demonstrate potential changes in Chinook and steelhead growth rates as a sensitivity analysis of change in mean air temperature and change in snowpack. They describe 4 characteristic stream types in the PNW -- warm winter and cool summer (North Santium); cold stream with high snowpack (Clearwater); warm summer with high snowpack (Salmon River) and warm summer with low snowpack (Snake River). They found that in the streams with cooler summers, warming and loss of snow increased growth rates, but in the warmer-summer streams, growth decreased.

4.1.3 Smolt behavior and survival

Bjornsson et al (2011) review physiological characteristics of smolting and environmental drivers. Acidification, as well as endocrine disruptors and other contaminants could lower survival through interferring with this carefully controlled process. Perkins and Jager (2011) created a development model for Snake River fall Chinook salmon that proposes a mechanism by which delayed growth leads to a yearling smolt behavior.This type of behavioral switch could make a big difference in population responses to climate change, but is hard to predict ahead of time. Other studies (Hayes et al. 2011) of California steelhead document different hormone levels between fish that smolt at different times over the season, and some fish that return upstream before smolting the following year. This rich variety of behavior will be crucial to effective responses to climate change.

Many anthropogenic habitat modifications have the potential to exacerbate effects of climate change on stream temperature. Smolt survival is often reduced at high temperatures, and due to direct and indirect effects of dam passage. Marschall et al (2011) explicitly modeled the interaction between delays at dams and exposure to high temperatures during smolt migration. Assuming that a threshold temperature causes fish to initiate migration in spring, they explore the range of initiation temperatures likely to ensure a successful migration with and without delays caused by dams. They find that even short delays at dams greatly reduce this window of opportunity. Particularly dangerous were irregular warm river sections that occurred downstream, and caused high delayed mortality (i.e., after successful passage through a dam) in late migrants. Their model is based on temperatures, flows, and migration distances measured in the Connecticut River for Atlantic salmon, but bears high relevance to Columbia River salmonids. Finally, conditions during smolting can affect maturation age. Exposure to elevated temp (16ºC) and continuous light can trigger early maturation in male Atlantic salmon (Fjelldal et al. 2011).

4.1.4 Adult migration

The return to freshwater to spawn is a delicately timed behavior. Each population has adapted the timing of return to minimize mortality in freshwater prior to spawning, and to maximize fecundity which depends on marine growth and energetic expenditure during the migration, among other things. Migration mortality is closely tied to environmental conditions, especially temperature, experienced during the migration. Many papers published in 2011 explore the genetic and behavioral controls on timing and resulting morality.

Adult migration timing in sockeye has been progressing earlier in the year in the Columbia River over the 20th century. Crozier et al (2011) explore how changes in river temperature and flow, as well as ocean conditions might be driving this advance. They found evidence that this trait evolved genetically due to mortality of late migrants exposed to higher Columbia River temperatures during the historical migration period. The fish also show a strong annual response to river flow, such that they migrate earlier in low-flow years. These two processes combined suggest both plastic and evolutionary responses are involved in an adaptive shift likely to continue in response to climate change. Genetic studies have identified candidate genetic markers in Columbia River adult Chinook salmon associated with run-timing (Hess and Narum 2011). Liedvogel et al (2011) review the genetics of migration more broadly.

Early migration in Adams and Weaver Creek sockeye in the Fraser River has a very different explanation and result, however. Early migrants in the Fraser experience very high temperatures and have high mortality, so the sudden change in behavior that began in 1995 has been hard to explain. Thomson and Hourston (2011) correlated early entry timing with weaker wind stress for Adams River stocks, and with lower surface salinity for Weaver Creek stocks. They postulate that both factors lead physiologically to earlier entry because the former entails easier swimming against weaker currents and the latter entails earlier osmoregulatory adaptation to freshwater, noting that early migrants were exposed to relatively fresh water earlier in the year.

Several genetic studies of Fraser River sockeye have found that gene expression varies systematically over the course of the migration (Evans et al. 2011), and that certain gene expression patterns were strongly correlated with mortality during the migration (Miller et al. 2011a). The genes that were upregulated are associated with the immune defense system, and the authors propose that viral infection might be to blame for the low survival. Other papers developed statistical correlates of migration survival for in-season fisheries management, in which temperature and flow were strong predictors of survival for some stocks, especially those exposed to harsher conditions (Cummings et al. 2011). Warmer water lowers catch-and-release survival (Gale et al. 2011), and might be important in interpreting tagging studies. A comparison of migration survival of fish tagged at sea versus those tagged in freshwater (which is much warmer) found that those tagged at sea had much higher survival (Martins et al. 2011).

The timing of the adult migration among Yukon River Chinook salmon is correlated with SST, air temperature and sea ice cover. As these factors change with climate change, migration is expected to occur earlier (Mundy and Evenson 2011).

Projected adult migrant survival

Several papers used observed survival of migrating Fraser River sockeye to project survival under future climate scenarios. Martins et al (2011) modeled 9-16% declines by the end of the century. Hague et al (2011) quantified the number of day per year that migrating fish will experience less optimal temperatures. They found that the number of days over 19ºC tripled, reducing their aerobic scope to zero in some cases. They found that exposure varied within each run, such that there is potential for shifts in run-timing to drive adaptive responses to rising temperature. An individual-based simulation model of the evolutionary response to rising river temperatures with climate change showed that Fraser River sockeye with a reasonable heritability (0.5) would theoretically shift their migration 10 days earlier in response to 2ºC warming. Nonetheless, this study did not generally predict extinction of these populations even if they did not respond to selection (Reed et al. 2011). But evolution in run timing has clearly occurred in Chinook salmon introduced to New Zealand, where populations from a common ancestry have diverged 18 days in their spawning-migration (Quinn et al. 2011).

Local adaptation and acclimation in heat tolerance

Evolution in response to rising temperatures could occur in adult migration timing, as discussed above, or in heat tolerance. Eliason et al (2011) studied variation in cardiac tissue. Local adaptation in thermal optima for aerobic, cardiac tissue and performance among populations migrating at different times through the Fraser River. They argue that the heart has adapted to population-specific migration temperatures, in addition to the length of migration. This is consistent with interspecific differences. Pink salmon have higher heat tolerance during migratory stages than sockeye (Clark et al. 2011). Similar differences can also reflect acclimation. Studies of cardiac tissue in rainbow trout identified very distinct morphology and tissue composition in distinct cold-acclimated and warm-acclimated fish (Klaiman et al. 2011).

4.2 Marine stage

4.2.1 Marine survival

Because ocean survival is the strongest correlate of population growth rate for most populations, understanding the factors that drive marine survival has been a high priority for decades.

The primary factors thought to govern survival are growing conditions, which are generally correlated with overall ocean productivity. In a new paper confirming and refining previously recognized patterns for PNW salmon, Bi et al (2011b) explore the relationship between coho early marine survival, copepod species composition, water transport in the California Current, and larger climatic indices (the PDO). Cold copepod biomass correlates with coho survival. Seasonally, they found that lipid-rich copepods associated with cool water are less abundant in the winter, when the current is coming predominantly from the south ("positive alongshore current") and more abundant in summer, when current is coming from the north ("negative alongshore current"). At the annual and decadal scale, when the PDO is positive, more water comes from the south in winter; when PDO is negative, more water comes from north during summer. In a separate paper, Bi et al. (2011a) confirmed the spatial relationships between yearling Chinook and coho distributions and copepod assemblages. Both species are strongly positively correlated with the cold copepod assemblage and chlorophyll a concentration. Yearling coho had similar relationships, but also positively correlated with temperature. Nonetheless, the adult migration does not necessarily track annual varation in zooplankton location. Bristol Bay sockeye do not seem to vary their migration route among years in response to variation in marine productivity and temperature (Seeb et al. 2011).

Salmon growth and survival often correlates with SST (e.g., Norwegian Atlantic salmon growth at sea is positively correlated with SST in the Barents and Norwegian Seas (Jensen et al. 2011), and Japanese chum salmon growth is positively correlated with summer/fall SST in coastal areas while fish stay near shore, and off-shore temperatures later in the year (Saito et al. 2011). Much of the mortality is size-selective, with smaller fish having higher mortality rates. Size-selective mortality could stem from either an energetic constraint (insufficient resources to survive harsh conditions) or size-selective predation. In Alaskan sockeye, Farley et al (2011a) found that the energetic status of juvenile sockeye was adequate to survive winter, and suggest predation-avoidance behavior as a better explanation for size-selective mortality and ongoing energy loss. They suggest that higher temperatures in climate projections might lead to declines in age-0 pollock, a high quality prey for salmon, and lead to lower winter survival.

Marine survival is tightly linked to ocean conditions at the time of smolting. The Rivers Inlet sockeye population in British Columbia has been depressed since the 1990s. High flows in this river decrease marine productivity because the river is nutrient-poor. Thus the negative correlation between high river flow and marine survival appears to result from the impact of low nutrient, brackish water depressing marine plankton growth (Ainsworth et al. 2011b). This system-specific impact on marine productivity explains the difference between a positive correlation for high-nutrient rivers, like the Columbia, and low-nutrient rivers like Rivers Inlet.

More broadly, salmon survival is often correlated with broader indicators of ecosystem productivity. Lower trophic level productivity generally supports better growth and survival all the way up the food chain. Borstad et al (2011) found that regional chlorophyll abundance in April, timing of spring wind transition and phytoplankton bloom are important for survival of Canadian Triangle Island sockeye salmon, sandlance and rhinoceros auklets.

4.2.2 Projected future marine habitat availability

In an important paper, Abdul-Aziz et al (2011) constructed maps of potential salmon marine distributions under climate change scenarios. They developed thermal niche models for summer and winter separately for five Pacific salmon species and steelhead based on high-seas catch records over the last 50 years. These are not mechanistically-determined range limits, e.g. through physiological constraints, and thus might not correlate with future distributions exactly the way they do now. It is likely that changes in the distribution of food availability will play a very large role in future distributions, which might depend on many factors. However, they do indicate how projected changes in SST translate into one characterization of potential salmon habitat. Historical analysis showed that salmon thermal habitat, using observed temperature ranges, changed very little over the 20th century. However, under the A1B and A2 emissions scenarios, the multi-model ensemble average SST imply a reduction in summer habitat for coho 5-32%, where the range goes from the 2020s to the 2080s, Chinook habitat declines 24-88%, and Steelhead habitat area declines 8-43%. Winter habitat area shows much less effect in these species, ranging from 0 to 10% for the 3 species and three future time periods. Sockeye had much greater sensitivity in their winter range, reducing from 6-41%. The B1 scenario had a similar result for 2020s and 2040s, but was less severe by 2080 (-66% for Chinook summer habitat, -21 to -24% for coho and steelhead summer, and 0 to -7% for all three species in winter). One reason for the high percentage reduction in Chinook summer habitat was that their historical absolute area was estimated to be much smaller in summer than the other species (7 million km^2 compared with 10-11 million km^2). But the projection is for a complete loss of Gulf of Alaska habitat by the 2040s, and complete loss of Okhotsk Sea and Subarctic subdomains, and most of the Bering Sea habitat. There is a small extension into the Arctic Ocean that is not currently occupied, but net reductions vastly outweighed this potential expansion.

4.2.3 Ocean acidification

Two recent modeling papers explored the ecological impacts of ocean acidification and other aspects of climate change. Ainsworth et al. (2011a) predicted that ocean acidification may cause salmon landings to decrease in Southeast Alaska and Prince Williams Sound food webs and increase in Northern British Columbia and Northern California Current food webs. However, when the authors applied five impacts of global change to these food webs simultaneously (primary productivity, species range shifts, zooplankton community size structure, ocean acidification, and ocean deoxygenation), projected salmon landings decreased in all locales (Ainsworth et al. 2011a). Incorporating ocean acidification and ocean deoxygenation into bioclimatic envelope models for harvested fishes in the Northeast Atlantic caused 20-30% declines in projected future harvest, likely due to reduced growth performance and faster range shifts (Cheung et al. 2011).

5 Higher-level processes

5.1 Population-level effects

Warming temperatures in Alaska have opened up potential habitat for colonization. Pink salmon and Dolly Varden were among the first fish to colonize one such stream in Glacier Bay (Milner et al. 2011). The stream community has developed over the past 30 years. Having robust populations at the edge of the current range to provide colonists faciliates range expansion.

5.2 Diseases

The negative impact of multiple stressors, such as UV-B exposure and high temperatures, on immune function, together with predicted increases in pathogen load in warmer waters resulting from global climate change, suggest an increased risk of diseases in fishes (Jokinen et al. 2011). De Eyto et al (2011) show that selection on immunological adaptation at the major histocompatibility genes in Atlantic salmon varied with life stage and were strongly correlated with juvenile survival. They emphasize the importance of maintaining genetic diversity to evolve in response to novel disease pressures expected to result from climate change.

Many diseases are more prevalent or virulent at warmer temperatures. Salmonid parasites often require intermediate hosts, and parasite risk to fish can be lower in areas unsuitable for the other host. *Tubifex tubifex*, the host of whirling disease, cannot tolerate very hot streams affected by geothermal processes in Yellowstone National Park, thus reducing infection of rainbow trout in these reaches (Alexander et al. 2011). However, some expected negative effects of rising temperatures have not been detected. In an Alaskan stream summer water temperature has increased 1.9ºC over the past 46 years. However, the presumed increase in consumption rates in sockeye has not led to an increase in tapeworm load (Bentley and Burgner 2011). Algal blooms are affected by environmental conditions, and can kill large numbers of fish. When an algal bloom moved through a fish farm in New Zealand, a large fish kill occurred (MacKenzie et al. 2011). The extent to which wild fish could have avoided the bloom is unknown.

5.3 Population declines and variability attributed to climatic factors

A fairly rare but important element of evaluating the importance of environmental effects is a comparison between environmental and anthropogenic or a variety of alternative hypotheses. Most studies look at only a single type of explanation – i.e., they just compare environmental effects. But Otero et al (2011) conducted a comprehensive analysis of the catch of Atlantic grilse over the whole length of the Norwegian coast as a function of environmental effects during the smolt stage and the return migration, marine, and anthropogenic (fish farms, fishery, dams) potential driving factors. They find water temperature and flow interact with dams to shape catches, and aquaculture and fisheries have negative effects.

Many spring and fall run Chinook salmon populations have been extirpated from the Central Valley of California. Migration barriers completely explain Central Valley California fall Chinook extirpation, but for spring Chinook, habitat loss and altered flow regimes, especially enhanced summer flows, predicted extirpation (Zeug et al. 2011). An analysis of population extinction of Sakhalin taimen (*Parahucho perryi*) in Japan showed that in comparing populations that ranged from extinct to endangered to extant, lower air temperatures and minimal agricultural development set extant populations apart. Lagoons also provided refugia (Fukushima et al. 2011).

When fisheries alter the age structure of a population, it can lose some of its resiliency to environmental variation. Long-term shifts toward a shorter generation time, and reduced age overlap within the population adds variability to population growth rates. Environmental conditions driving that variability thus become more important. Cod show increasing sensitivity to environmental fluctuations, which could ultimately make climate impacts more severe (Rouyer et al. 2011). Age structure can also be important if generation time coincides with the periodicity of a key environmental driving factor. Age-structured models with periodic environmental forcing and fishing pressure generate the cohort resonance effect, which can drive much more variability in population abundance than predicted by an ecosystem or stage-structured model if the frequency of the forcing factor is close to the mean age of reproduction (Botsford et al. 2011).

5.4 Projected cumulative effects throughout the life cycle

A holistic perspective demonstrates that climate change will pose significant stress not just on one or two stages, but potentially on every life stage. Healy (2011) outlines adverse impacts throughout the life cycle, as well as pointing out how responses in one stage can carry over and affect survival or growth in a subsequent stage, and even suequent generations. Cumulatively, he argues they pose enormous risk for Fraser River sockeye. Healy also lists management and policy responses that would reduce these stresses by life stage.

Elevated tempeatures often inhibit reproduction. Pankhurst and Munday (2011) review the entire suite of known endocrine effects in salmonids, as well as the diverse sensitivities in juvenile stages as well. They emphasize that the ramifications of chemical, thermal and hydrological change will be complex and pervasive throughout the life cycle and geographic range of these fish.

5.5 Species interactions

Wenger et al (2011) used thermal criteria, flow frequency, and interaction strengths with other salmonids to predict habitat availability for all trout in the interior west under climate change scenarios. Under A1B scenarios, average habitat decline across all species is 47%. Brook trout loses the most habitat (77%) and rainbow trout the least (35%). Species interactions shaped the outcome negatively for some species and positively for others. It does demonstrate that considering species interactions could significantly alter predicted responses to climate change.

Temperature gradients cause variation in salmon behavior that can either enhance ecosystem productivity, or reduce it. The large spread in Alaskan sockeye salmon spawn timing due to thermal differences among streams supports most of the growth in rainbow trout, who eat salmon eggs over a relatively long temporal window in the fall (Ruff et al. 2011). On the other hand, a study of paleoecological and recent lake productivity in Tuya Lake, British Columbia revealed an interaction between salmon consumption and warming, such that salmon enhanced climate-induce nitrogen deficiencies (Selbie et al. 2011). They emphasize that ecosystem structure is very sensitive to temperature.

6 Human adaptation

Extensive work explores adaptation responses to climate change. This literature is mostly beyond the scope of this review, but we just highlight a few examples here. Several papers concentrate on human responses to climate change. A comprehensive review of marine and aquatic vulnerabilities, adaptation strategies, and existing adaptation plans in the PNW was drafted in 2011 (National Wildlife Federation 2011). This report identified common elements of adaptation plans in the PNW and elsewhere, including: remove other threats and reduce non-climate stressors that interact negatively with climate change or its effects; establish or increase habitat buffer zones and corridors; increase monitoring and facilitate management under uncertainty, including scenario-based planning and adaptive management. The report includes additional approaches from available literature in the broad areas of information gathering and capacity building; monitoring and planning; infrastructure and development; governance, policy, and law; and, conservation, restoration, protection and natural resource management. This information is intended to guide development of climate change adaptation strategies through the North Pacific Landscape Conservation Cooperative. At the national level, adaptation strategies have been proposed for ecosystems including coastal and aquatic systems affecting salmonids (USFWS et al. 2011). The draft inland aquatic ecosystems strategy focuses on protecting and restoring existing habitat; maintaining ecosystem functions that will continue to provide benefits in a changing climate; reducing impacts of non-climate stressors; and including climate considerations in resource management planning, monitoring, and outreach programs. A final national adaptation strategy is expected in 2012. Safford and Norman (2011) describe the institutional forces that shape the way recovery planning groups in Puget Sound develop plans to manage water to improve salmon survival. They found that asymmetrical roles (e.g., tribal veto power), coupled with lack of explicit support for tribal sovereignty (which might reduce the likelihood of tribal vetoes) contribute to institutional problems. Similarly, allowing technical planners to also contribute to citizen committees reduces the ability of the planning groups to achieve diverse social and technical objectives. The lack of broader participation has generally led to calls for increasing water supply for salmon, but there has been a lack of concrete recommendations for accomplishing this. Farley et al (2011b) describe capacity for institutional responses to climate change among four water sectors in Oregon’s McKenzie River basin and found that some sectors have more flexibility (e.g., fish habitat recovery and flood control) than others (e.g., municipal water and fishing guides) for responding to climate change. Hamlet (2011) also examines institutional capacity for water management adaptation, and finds that, although existing institutions have resources to deal with moderate changes, substantial obstacles to climate change adapation exist for large and complex systems such as the Columbia River basin. Lack of a centralized authority for water management decisions, layers of existing laws and regulations, and lack of specificity in some management plans contribute to this concern. He suggests that the most progress in large systems may be expected at smaller geographical scales such as subbasins. He does note that in the last several years, significant progress has been made in surmounting some of these obstacles, and the PNW region's water resources agencies at all levels of governance are making progress in addressing the fundamental challenges inherent in adapting to climate change. Thorpe and Stanley (2011) emphasize that restoration goals must focus on building resilient functioning ecosystems with the capacity to respond to climate change, rather than historical models. Two papers project stress on regional and urban water supplies (House-Peters and Chang 2011; Traynham et al. 2011). House-Peters and Change (2011) identify potential solutions through dense development in urban areas and tree planting. Koehn et al (2011) review the major impacts of climate change on fishes, and step through potential adaptation measures. Scanning the Conservation Horizon: A Guide to Climate Change Vulnerability Assessment is a document produced by the NWF that provides an overview of species and ecosystem sensitivity, exposure, and vulnerability to climate change. They propose a systematic approach to evaluating risks and selecting conservation measures that most efficiently address those risks (Glick et al. 2011).

6.1 Human impact on stream temperature

A review paper (Hester and Doyle 2011) on human impacts on stream temperature describes the most common actions with thermal impacts and calculates the mean temperature change reported. The actions summarized are: loss of riparian shading, loss of upland forest, reductions of groundwater exchange, increased width-to-depth ratio, input of effluent discharges, diversion of tributary input, releases from below the thermocline of reservoirs, and global warming. Cold water reservoir releases in summer were the primary means of cooling streams, although diverting warm tributaries can also lower stream temperatures. Hester and Doyle (2011) also collected thermal performance curves for stream and river species. They summarized the amount of temperature change from the thermal optimum to 50% performance (growth, development, reproductive activity, or survival) both above and below the optimum. They found that most performance curves are asymetrical, and that most species are more sensitive to temperatures above the optimum (typical breadth from optimum to 50% for fish is about 4ºC above the optimum, and 6ºC below the optimum). Most human impacts shift temperature less than 5ºC, but reservoir releases, riparian shading and changes in groundwater exchange can change stream temperature up to 12-14ºC.

In a review of the impact of logging on stream temperature in the Oregon Coast Range, Groom et al (2011b) found that maximum, mean, minimum, and diel fluctuations in summer stream temperature increased with a reduction in shade, longer treatment reaches, and low gradient. Shade was best predicted by riparian basal area and tree height. In a separate paper, Groom et al (2011a) found that typical logging practices on private land generally caused streams to exceed water quality thresholds, but that recent management rules successfully lowered this probability greatly.

Some rivers have management options for lowering stream temperature over a short period of time, which can be crucial for preventing lethal temperatures for fish. For example, Lewiston Dam can release cold water into the Klamath; water can also be protected from withdrawals. These methods can be effective if they are timed precisely. A simulation study found short-term (7-10 day) water temperature forecasts prove useful for increasing fish production in the Klamath and John Day Rivers (Huang et al. 2011).

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Appendix E
2013 Update to Hatchery Effects in the Environmental Baseline

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2013 Update to Hatchery Effects in the Environmental Baseline

In the 2008 BiOp, most benefits and risks from past and present hatchery practices were imbedded in the environmental baseline. However, because estimates of productivity and extinction risk in the 2008 BiOp were based on the performance of populations during a 20-year "Base Period" that ended in most cases with the 1999 brood year (with adults returning through 2003–2006, depending on the population), the Environmental Baseline had to be adjusted to account for the effects of hatchery reform actions, for which empirical data had not yet been gathered or did not yet exist. For example, the empirical data from the Base Period did not fully reflect the effects of hatchery reform actions taken in the latter portion of the Base Period or after the Base Period (e.g., elimination of an out-of-basin broodstock in the Upper Grande Ronde). The Stier and Hinrichsen (2008) methodology was used to make Base-to-Current (i.e. base-to-2008) adjustments in survival from completed hatchery reform actions. Survival adjustments were based on changes in the productivity of the entire naturally-spawning population, which includes hatchery-origin fish when they spawn naturally. Therefore, hatchery management actions that improved the productivity of hatchery-origin fish spawning naturally affected the Base-to-Current adjustment. This methodology was described in Appendix I of the 2008 Supplemental Comprehensive Analysis.[141]

In the 2008 BiOp, Base-to-Current (i.e. Base-to-2008) adjustments for hatchery reform actions were only applied to five populations in the Snake River spring/summer Chinook ESU and four populations in the UCR steelhead DPS (Table E-1). NOAA Fisheries must determine whether there is new information that reveals a change in the Environmental Baseline that would affect conclusions made in the 2008 BiOp. Therefore, NOAA Fisheries updated the data used in the Stier and Hinrichsen (2008) methodology to see if it affected the 2008 BiOp's base-to-2008 integrated productivity increase. The Northwest Fishery Science Center's SPS database[142] was used to identify new data on the fraction of natural-origin spawners (*f*) for these populations. "Future *f*" values were assumed to be an average of recent *f* values. NOAA Fisheries used a variety of sources to estimate the relative reproductive success of hatchery-origin spawners ("*e*" values and "future *e*" values). The rationale for changes in *e* values is summarized in Table E-1 by population. Revised calculations for the integrated productivity increases over the Base Period are included in Table E-2 through Table E-11.

[141] The 2008 BiOp used these base-to-current adjustments to estimate the prospective effects of *then-completed* hatchery reform actions, but there was no quantification of the expected effects of the *prospective* hatchery reform actions identified in the RPA.

[142] http://www.webapps.nwfsc.noaa.gov/apex/f?p=238:home:0

Because the Steir and Hinrichsen (2008) methodology does not account for genetic and ecological effects on natural productivity from naturally-spawning hatchery-origin fish quantitatively (i.e., the model does not account for potential reductions in the productivity of natural-origin fish from interbreeding with hatchery-origin fish), NOAA Fisheries considered these prospective effects qualitatively in the 2008 BiOp's effects analysis.

Table E-1. Summary of the 2008 BiOp's hatchery reform multipliers with a 2013 update.

Population	2008 BiOp's Base-to Current Integrated Productivity Increase as a Ratio	2008 BiOp's Assumptions for Base-to-Current Adjustment	2013 Supplemental BiOp's Base-to-Current Integrated Productivity Increase as a Ratio	2013 Update
Upper Grande Ronde Spring/Summer Chinook Salmon	1.21	The 2008 BiOp assumed that the future fraction of natural-origin fish on the spawning ground would be 0.67. The 2008 BiOp assumed that hatchery-origin spawners would be 0.45 as reproductively effective as natural-origin spawners.	1.29	The recent 5-year average of the fraction of natural-origin fish on the spawning grounds was 0.26 (based on 2007 through 2011), which is lower than what was expected in the 2008 BiOp. New data shows that the reproductive effectiveness of hatchery-origin spawners in Catherine Creek is 0.83 relative to natural-origin spawners in the Catherine Creek. The Upper Grande Ronde hatchery program is similar to the Catherine Creek hatchery program because it releases spring/summer Chinook salmon derived from local stock. Therefore, the relative reproductive success of hatchery-origin spring/summer Chinook salmon in the Upper Grande Ronde is probably similar to the relative reproductive success of hatchery-origin spawners in Catherine Creek, which is higher than what was expected in the 2008 BiOp (Williamson et al. 2010) Based on new data, the Base-to-Current integrated productivity increase has **increased** relative to the 2008 BiOp (Table 2).

Population	2008 BiOp's Base-to Current Integrated Productivity Increase as a Ratio	2008 BiOp's Assumptions for Base-to-Current Adjustment	2013 Supplemental BiOp's Base-to-Current Integrated Productivity Increase as a Ratio	2013 Update
Lostine River Spring/Summer Chinook Salmon	1.03	The 2008 BiOp assumed that the future fraction of natural-origin fish on the spawning ground would be 0.67. The 2008 BiOp assumed that hatchery-origin spawners would be 0.45 as reproductively effective as natural-origin spawners.	1.11	The recent 5-year average of the fraction of natural-origin fish on the spawning grounds was 0.33 (based on 2007 through 2011), which is lower than what was expected in the 2008 BiOp. New data shows that the reproductive effectiveness of hatchery-origin spawners in Catherine Creek is 0.83 relative to natural-origin spawners in the Catherine Creek (Williamson et al. 2010). The Lostine River hatchery program is similar to the Catherine Creek hatchery program because it releases spring/summer Chinook salmon derived from local stock. Therefore, the relative reproductive success of hatchery-origin spring/summer Chinook salmon in the Lostine River is probably similar to the relative reproductive success of hatchery-origin spawners in Catherine Creek, which is higher than what was expected in the 2008 BiOp. Based on new data, the Base-to-Current integrated productivity increase has **increased** relative to the 2008 BiOp (Table 3).

Population	2008 BiOp's Base-to Current Integrated Productivity Increase as a Ratio	2008 BiOp's Assumptions for Base-to-Current Adjustment	2013 Supplemental BiOp's Base-to-Current Integrated Productivity Increase as a Ratio	2013 Update
Catherine Creek Spring/Summer Chinook Salmon	1.20	The 2008 BiOp assumed that the future fraction of natural-origin fish on the spawning ground would be 0.67. The 2008 BiOp assumed that hatchery-origin spawners would be 0.45 as reproductively effective as natural-origin spawners.	1.31	The recent 5-year average of the fraction of natural-origin fish on the spawning grounds was 0.39 (based on 2007 through 2011), which is lower than what was expected in the 2008 BiOp. However, new data shows that the reproductive effectiveness of hatchery-origin spawners in Catherine Creek is 0.83 relative to natural-origin spawners in the Catherine Creek (Williamson et al. 2010), which is higher than what was expected in the 2008 BiOp. Based on new data, the Base-to-Current integrated productivity increase has **increased** relative to the 2008 BiOp (Table 4).
Minam River Spring/Summer Chinook Salmon	1.22	The 2008 BiOp assumed that the future fraction of natural-origin fish on the spawning ground would be 0.96. The 2008 BiOp assumed that hatchery-origin spawners would be 0.20 as reproductively effective as natural-origin spawners.	1.16	The recent 5-year average of the fraction of natural-origin fish on the spawning grounds was 0.85 (based on 2008 through 2012), which is lower than what was expected in the 2008 BiOp. New data shows that the reproductive effectiveness of hatchery-origin spawners in Catherine Creek is 0.83 relative to natural-origin spawners in the Catherine Creek (Williamson et al. 2010). Because the hatchery-origin spawners straying into Wenaha River would likely be from the Catherine Creek, Upper Grande Ronde, and Lostine River hatchery programs, the 2008 BiOp likely underestimated the reproductive effectiveness of hatchery-origin spawners in the

Population	2008 BiOp's Base-to Current Integrated Productivity Increase as a Ratio	2008 BiOp's Assumptions for Base-to-Current Adjustment	2013 Supplemental BiOp's Base-to-Current Integrated Productivity Increase as a Ratio	2013 Update
				Minam River. Although the spring/summer Chinook salmon from Catherine Creek, Upper Grande Ronde, and Lostine River would not be expected to have a reproductive effectiveness of 0.83 when spawning the Minam River, these fish would be more reproductively effective than the highly domesticated Rapid River hatchery-origin fish that previously strayed into the Minam River. The Rapid River stock is no longer released into the Grande Ronde River basin. Based on new data, the Base-to-Current integrated productivity increase has **decreased** relative to the 2008 BiOp (Table 5).
Wenaha River Spring/Summer Chinook Salmon	1.39	The 2008 BiOp assumed that the future fraction of natural-origin fish on the spawning ground would be 0.95. The 2008 BiOp assumed that hatchery-origin spawners would be 0.20 as reproductively effective as natural-origin spawners.	1.36	The recent 5-year average of the fraction of natural-origin fish on the spawning grounds was 0.87 (based on 2008 through 2012), which is lower than what was expected in the 2008 BiOp. New data shows that the reproductive effectiveness of hatchery-origin spawners in Catherine Creek is 0.83 relative to natural-origin spawners in the Catherine Creek (Williamson et al. 2010). Because the hatchery-origin spawners straying into Wenaha River would likely be from the Catherine Creek, Upper Grande Ronde, and Lostine River hatchery programs, the 2008 BiOp likely underestimated the reproductive effectiveness of hatchery-origin spawners in the Wenaha River. Although the spring/summer Chinook salmon

Population	2008 BiOp's Base-to Current Integrated Productivity Increase as a Ratio	2008 BiOp's Assumptions for Base-to-Current Adjustment	2013 Supplemental BiOp's Base-to-Current Integrated Productivity Increase as a Ratio	2013 Update
				from Catherine Creek, Upper Grande Ronde, and Lostine River would not be expected to have a reproductive effectiveness of 0.83 when spawning the Minam River, these fish would be more reproductively effective than the highly domesticated Rapid River hatchery-origin fish that previously strayed into the Minam River. The Rapid River stock is no longer released into the Grande Ronde River basin. Based on new data, the Base-to-Current integrated productivity increase has **decreased** relative to the 2008 BiOp (Table 6).
Wenatchee River Steelhead	1.60	The 2008 BiOp assumed that the future fraction of natural-origin fish on the spawning ground would be 0.38. The 2008 BiOp assumed that hatchery-origin spawners would be 0.45 as reproductively effective as natural-origin spawners.	1.78	The recent 5-year average of the fraction of natural-origin fish on the spawning grounds was 0.47 (based on 2007 through 2011), which is higher than what was expected in the 2008 BiOp. The expected reproductive effectiveness of the hatchery-origin spawners has increased to 0.53 based a new relative reproductive study on the Wenatchee that shows that hatchery-origin steelhead in the Wenatchee River basin are 0.53 as reproductively effective as natural-origin spawners in the Wenatchee River Basin (Berntson et al. 2012)). Based on new data, the Base-to-Current integrated productivity increase has **increased** relative to the 2008 BiOp (Table 7).

Population	2008 BiOp's Base-to Current Integrated Productivity Increase as a Ratio	2008 BiOp's Assumptions for Base-to-Current Adjustment	2013 Supplemental BiOp's Base-to-Current Integrated Productivity Increase as a Ratio	2013 Update
Entiat River Steelhead	0.82 (low) 1.30 (high)	The 2008 BiOp assumed that the future fraction of natural-origin fish on the spawning ground would be between 0.22 (low estimate) and 0.50 (high estimate). The 2008 BiOp assumed that hatchery-origin spawners would be 0.20 as reproductively effective as natural-origin spawners.	0.93	The recent 5-year average of the fraction of natural-origin fish on the spawning grounds was 0.29 (based on 2007 through 2011), which is higher than what was expected in the low estimate in the 2008 BiOp. The reproductive effectiveness of the hatchery-origin spawners is still expected to be 0.20 after considering new data because the hatchery-origin fish are from non-local, domesticated broodstock Based on new data, the current Base-to-Current integrated productivity increase falls withing the range anticipated in the 2008 BiOp (Table 8).
Methow River Steelhead	1.17 (low) 1.55 (high)	The 2008 BiOp assumed that the future fraction of natural-origin fish on the spawning ground would be between 0.30 (low estimate) and 0.45 (high estimate). The 2008 BiOp assumed that hatchery-origin spawners would be 0.10 as reproductively effective as natural-origin spawners.	1.84	The recent 5-year average of the fraction of natural-origin fish on the spawning grounds was 0.18 (based on 2007 through 2011), which is higher than what was expected in both the low and high estimates in the 2008 BiOp. New data shows that the reproductive effectiveness of hatchery-origin spawners in the Wenatchee River is 0.53 relative to natural-origin spawners in the Wenatchee River (Berntson et al. 2012). The Methow River hatchery program is similar to the Wenatchee River hatchery program because it releases steelhead derived from local stock. Therefore, the relative reproductive success of hatchery-origin steelhead in the Methow River is probably

Population	2008 BiOp's Base-to Current Integrated Productivity Increase as a Ratio	2008 BiOp's Assumptions for Base-to-Current Adjustment	2013 Supplemental BiOp's Base-to-Current Integrated Productivity Increase as a Ratio	2013 Update
				similar to the relative reproductive success of hatchery-origin spawners in Wenatchee River, which is higher than what was expected in the 2008 BiOp. Therefore, based on new data, the Base-to-Current integrated productivity increase has **increased** relative to the 2008 BiOp (Table 9).
Okanogan River Steelhead	1.34 (low) 1.88 (high)	The 2008 BiOp assumed that the future fraction of natural-origin fish on the spawning ground would be 0.07 The 2008 BiOp assumed that hatchery-origin spawners would be between 0.30 (low estimate) and 0.45 (high estimate) as reproductively effective as natural-origin spawners.	1.42 (low) 1.87 (high)	The recent 5-year average of the percentage of natural-origin fish on the spawning grounds was 0.10 (based on 2007 through 2011), which is higher than what was expected in in the 2008 BiOp. NOAA Fisheries does not have any new information that would suggest that *e* values from the 2008 BiOp's calculations need to be revised. Based on new data, the current low Base-to-Current integrated productivity increase has **increased** over the low estimate in the 2008 BiOp (Table 10). However, the current high Base-to-Current productivity increase has **decreased** from the high estimate in the 2008 BiOp (Table 11).

Table E-2. Estimates of Base-to-Current survival multiplier for the Upper Grande Ronde population of Snake River spring/summer Chinook salmon.

Year		%Wild (f) from 1/30/13 SPS Data	**e** from 3/5/12 NMFS draft estimates	ln(Proportion of Natural Spawner Equivalents) = ln(f+(1-f)*e)	Proportion of Natural Spawner Equivalents		future e	future f	future ln(f+(1-f)*e)	Integrated productivity increase (from base period) as a ratio	
1981	2008 BiOp Base	1.00	0.2	0	1.00		**0.83**	**0.26**	-0.134446097	1.29	
1982	2008 BiOp Base	1.00	0.2	0	1.00						
1983	2008 BiOp Base	1.00	0.2	0	1.00						
1984	2008 BiOp Base	1.00	0.2	0	1.00		Future e from 3/5/12 NMFS draft estimates				
1985	2008 BiOp Base	1.00	0.2	0	1.00		Future f based on the average f for most recent 5 years of data.				
1986	2008 BiOp Base	0.86	0.2	-0.118783536	0.89						
1987	2008 BiOp Base	0.18	0.2	-1.067113622	0.34						
1988	2008 BiOp Base	0.08	0.2	-1.331806176	0.26						
1989	2008 BiOp Base	0.00	0.2	-1.609437912	0.20						
1990	2008 BiOp Base	0.50	0.2	-0.510825624	0.60		NOTE: This would replace the 1.21 multiplier in the 2008 BiOp				
1991	2008 BiOp Base	0.60	0.2	-0.385662481	0.68		It would not be added to it				
1992	2008 BiOp Base	0.21	0.2	-0.999672341	0.37		The effective change would be:			1.06	
1993	2008 BiOp Base	0.23	0.2	-0.957112726	0.38						
1994	2008 BiOp Base	0.33	0.2	-0.767870727	0.46						
1995	2008 BiOp Base	1.00	0.2	0	1.00				0.84		
1996	2008 BiOp Base	1.00	0.2	0	1.00				0.15		
1997	2008 BiOp Base	1.00	0.2	0	1.00				0.16		
1998	2008 BiOp Base	1.00	0.2	0	1.00				0.05		
1999	2008 BiOp Base	1.00	0.2	0	1.00				0.1		
2000	2008 BiOp Base	1.00	0.2	0	1.00						
2001	New	1.00	0.2	0	1.00				1.3		
2002	New	0.95	0.2	-0.040821995	0.96						
2003	New	0.81	0.83	-0.032833157	0.97				0.26		
2004	New	0.05	0.83	-0.176140698	0.84						
2005	New	0.04	0.83	-0.178170186	0.84						
2006	New	0.48	0.83	-0.092553982	0.91						
2007	New	0.84	0.83	-0.027576768	0.97						
2008	New	0.15	0.83	-0.156069186	0.86						
2009	New	0.16	0.83	-0.154084015	0.86						
2010	New	0.05	0.83	-0.176140698	0.84						
2011	New	0.10	0.83	-0.166054584	0.85						
Base Period Average		0.70	0.20	-0.39	0.76						
Post-Base Average		0.42	0.72	-0.11	0.90						
Last 10-yr Average		0.36	0.77	-0.12	0.89						

Table E-3. Estimates of Base-to-Current survival multiplier for the Lostine River population of Snake River spring/summer Chinook salmon.

Year		%Wild (f) from 1/30/13 SPS Data	e from 3/5/12 NMFS draft estimates	ln(Proportion of Natural Spawner Equivalents) = ln(f+(1-f)*e)	Proportion of Natural Spawner Equivalents		future e	future f	future ln(f+(1-f)*e)	Integrated productivity increase (from base period) as a ratio
1981	2008 BiOp Base	1.00	0.2	0	1.00		**0.83**	**0.33**	-0.120925468	1.11
1982	2008 BiOp Base	1.00	0.2	0	1.00					
1983	2008 BiOp Base	1.00	0.2	0	1.00					
1984	2008 BiOp Base	1.00	0.2	0	1.00		Future e from 3/5/12 NMFS draft estimates			
1985	2008 BiOp Base	1.00	0.2	0	1.00		Future f based on the average f for most recent 5 years of data.			
1986	2008 BiOp Base	0.77	0.2	-0.203340924	0.82					
1987	2008 BiOp Base	0.68	0.2	-0.295714244	0.74					
1988	2008 BiOp Base	0.55	0.2	-0.446287103	0.64					
1989	2008 BiOp Base	0.24	0.2	-0.936493439	0.39					
1990	2008 BiOp Base	0.60	0.2	-0.385662481	0.68		NOTE: This would replace the 1.03 multiplier in the 2008 BiOp			
1991	2008 BiOp Base	0.65	0.2	-0.328504067	0.72		It would not be added to it			
1992	2008 BiOp Base	0.25	0.2	-0.916290732	0.40		The effective change would be:			1.08
1993	2008 BiOp Base	0.49	0.2	-0.524248644	0.59					
1994	2008 BiOp Base	0.75	0.2	-0.223143551	0.80				0.33	
1995	2008 BiOp Base	1.00	0.2	0	1.00				0.28	
1996	2008 BiOp Base	1.00	0.2	0	1.00				0.43	
1997	2008 BiOp Base	0.95	0.2	-0.040821995	0.96				0.27	
1998	2008 BiOp Base	1.00	0.2	0	1.00				0.33	
1999	2008 BiOp Base	0.92	0.2	-0.066139803	0.94					
2000	2008 BiOp Base	0.83	0.2	-0.14618251	0.86				1.64	
2001	New	0.77	0.2	-0.203340924	0.82					
2002	New	0.47	0.2	-0.551647618	0.58				0.328	
2003	New	0.51	0.83	-0.086975014	0.92					
2004	New	0.23	0.83	-0.140297086	0.87					
2005	New	0.25	0.83	-0.136392625	0.87					
2006	New	0.36	0.83	-0.11518641	0.89					
2007	New	0.33	0.83	-0.120925468	0.89					
2008	New	0.28	0.83	-0.13056437	0.88					
2009	New	0.43	0.83	-0.10192199	0.90					
2010	New	0.27	0.83	-0.13250335	0.88					
2011	New	0.33	0.83	-0.120925468	0.89					
Base Period Average		0.78	0.20	-0.23	0.83					
Post-Base Average		0.38	0.72	-0.17	0.85					
Last 10-yr Average		0.35	0.77	-0.16	0.86					

Table E-4. Estimates of Base-to-Current survival multiplier for the Catherine Creek population of Snake River spring/summer Chinook salmon.

Year		%Wild (f) from 1/30/13 SPS Data	**e** from 3/5/12 NMFS draft estimates	ln(Proportion of Natural Spawner Equivalents) = ln(f+(1-f)*e)	Proportion of Natural Spawner Equivalents		future e	future f	future ln(f+(1-f)*e)	Integrated productivity increase (from base period) as a ratio
1981	2008 BiOp Base	1.00	0.2	0	1.00		**0.83**	**0.39**	-0.109480101	1.31
1982	2008 BiOp Base	1.00	0.2	0	1.00					
1983	2008 BiOp Base	1.00	0.2	0	1.00					
1984	2008 BiOp Base	1.00	0.2	0	1.00		Future e from 3/5/12 NMFS draft estimates			
1985	2008 BiOp Base	1.00	0.2	0	1.00		Future f based on the average f for most recent 5 years of data.			
1986	2008 BiOp Base	0.80	0.2	-0.174353387	0.84					
1987	2008 BiOp Base	0.22	0.2	-0.978166136	0.38					
1988	2008 BiOp Base	0.24	0.2	-0.936493439	0.39					
1989	2008 BiOp Base	0.38	0.2	-0.685179011	0.50					
1990	2008 BiOp Base	0.00	0.2	-1.609437912	0.20		NOTE: This would replace the 1.20 multiplier in the 2008 BiOp			
1991	2008 BiOp Base	0.13	0.2	-1.190727578	0.30		It would not be added to it			
1992	2008 BiOp Base	0.25	0.2	-0.916290732	0.40		The effective change would be:			1.10
1993	2008 BiOp Base	0.40	0.2	-0.653926467	0.52					
1994	2008 BiOp Base	0.50	0.2	-0.510825624	0.60					
1995	2008 BiOp Base	1.00	0.2	0	1.00					
1996	2008 BiOp Base	1.00	0.2	0	1.00				0.29	
1997	2008 BiOp Base	1.00	0.2	0	1.00				0.35	
1998	2008 BiOp Base	1.00	0.2	0	1.00				0.46	
1999	2008 BiOp Base	1.00	0.2	0	1.00				0.48	
2000	2008 BiOp Base	1.00	0.2	0	1.00				0.35	
2001	New	0.77	0.2	-0.203340924	0.82					
2002	New	0.50	0.2	-0.510825624	0.60				1.93	
2003	New	0.41	0.83	-0.105693905	0.90					
2004	New	0.17	0.83	-0.152102778	0.86					
2005	New	0.26	0.83	-0.134446097	0.87				0.386	
2006	New	0.37	0.83	-0.113280686	0.89					
2007	New	0.29	0.83	-0.128629143	0.88					
2008	New	0.35	0.83	-0.117095772	0.89					
2009	New	0.46	0.83	-0.09629066	0.91					
2010	New	0.48	0.83	-0.092553982	0.91					
2011	New	0.35	0.83	-0.117095772	0.89					
Base Period Average		0.70	0.20	-0.38	0.76					
Post-Base Average		0.40	0.72	-0.16	0.86					
Last 10-yr Average		0.36	0.77	-0.16	0.86					

Table E-5. Estimates of Base-to-Current survival multiplier for the Minam River population of Snake River spring/summer Chinook salmon.

Year		**%Wild (f)** from 1/30/13 SPS Data	**e** from 3/5/12 NMFS draft estimates	ln(Proportion of Natural Spawner Equivalents) = ln(f+(1-f)*e)	Proportion of Natural Spawner Equivalents		future e	future f	future ln(f+(1-f)*e)	Integrated productivity increase (from base period) as a ratio
1981	2008 BiOp Base	1.00	0.2	0	1.00		**0.5**	**0.85**	-0.077961541	1.16
1982	2008 BiOp Base	1.00	0.2	0	1.00					
1983	2008 BiOp Base	1.00	0.2	0	1.00					
1984	2008 BiOp Base	1.00	0.2	0	1.00		Future e from 3/5/12 NMFS draft estimates			
1985	2008 BiOp Base	1.00	0.2	0	1.00		Future f based on the average f for most recent 5 years of data.			
1986	2008 BiOp Base	0.50	0.2	-0.510825624	0.60					
1987	2008 BiOp Base	0.50	0.2	-0.510825624	0.60					
1988	2008 BiOp Base	0.63	0.2	-0.350976923	0.70					
1989	2008 BiOp Base	1.00	0.2	0	1.00					
1990	2008 BiOp Base	0.44	0.2	-0.594207233	0.55		NOTE: This would replace the 1.22 multiplier in the 2008 BiOp			
1991	2008 BiOp Base	0.62	0.2	-0.362405619	0.70		It would not be added to it			
1992	2008 BiOp Base	0.10	0.2	-1.272965676	0.28		The effective change would be:			0.95
1993	2008 BiOp Base	0.56	0.2	-0.433864583	0.65					
1994	2008 BiOp Base	0.56	0.2	-0.433864583	0.65					
1995	2008 BiOp Base	1.00	0.2	0	1.00					
1996	2008 BiOp Base	0.95	0.2	-0.040821995	0.96					
1997	2008 BiOp Base	0.96	0.2	-0.032523192	0.97				0.88	
1998	2008 BiOp Base	1.00	0.2	0	1.00				1	
1999	2008 BiOp Base	0.95	0.2	-0.040821995	0.96				0.65	
2000	2008 BiOp Base	0.97	0.2	-0.024292693	0.98				0.83	
2001	New	0.94	0.2	-0.049190244	0.95				0.91	
2002	New	0.99	0.2	-0.008032172	0.99					
2003	New	0.99	0.5	-0.005012542	1.00				4.27	
2004	New	0.99	0.5	-0.005012542	1.00				0.854	
2005	New	1.00	0.5	0	1.00					
2006	New	1.00	0.5	0	1.00					
2007	New	1.00	0.5	0	1.00					
2008	New	0.88	0.5	-0.061875404	0.94					
2009	New	1.00	0.5	0	1.00					
2010	New	0.65	0.5	-0.192371893	0.83					
2011	New	0.83	0.5	-0.088831214	0.92					
2012	New	0.91	0.5	-0.046043939	0.96					
Base Period Average		0.79	0.20	-0.23	0.83					
Post-Base Average		0.93	0.45	-0.04	0.96					
Last 10-yr Average		0.93	0.50	-0.04	0.96					

Table E-6. Estimates of Base-to-Current survival multiplier for the Wenaha River population of Snake River spring/summer Chinook salmon.

Year		%Wild (f) from 1/30/13 SPS Data	e from 3/5/12 NMFS draft estimates	ln(Proportion of Natural Spawner Equivalents) = ln(f+(1-f)*e)	Proportion of Natural Spawner Equivalents		future e	future f	future ln(f+(1-f)*e)	Integrated productivity increase (from base period) as a ratio
1981	2008 BiOp Base	1.00	0.2	0	1.00		**0.5**	**0.87**	-0.06720875	1.36
1982	2008 BiOp Base	1.00	0.2	0	1.00					
1983	2008 BiOp Base	1.00	0.2	0	1.00					
1984	2008 BiOp Base	1.00	0.2	0	1.00		Future e from 3/5/12 NMFS draft estimates			
1985	2008 BiOp Base	1.00	0.2	0	1.00		Future f based on the average f for most recent 5 years of data.			
1986	2008 BiOp Base	1.00	0.2	0	1.00					
1987	2008 BiOp Base	0.09	0.2	-1.301953213	0.27					
1988	2008 BiOp Base	0.28	0.2	-0.858021824	0.42					
1989	2008 BiOp Base	0.75	0.2	-0.223143551	0.80					
1990	2008 BiOp Base	0.22	0.2	-0.978166136	0.38		NOTE: This would replace the 1.39 multiplier in the 2008 BiOp			
1991	2008 BiOp Base	0.33	0.2	-0.767870727	0.46		It would not be added to it			
1992	2008 BiOp Base	0.09	0.2	-1.301953213	0.27		The effective change would be:			0.98
1993	2008 BiOp Base	0.54	0.2	-0.458865885	0.63					
1994	2008 BiOp Base	0.20	0.2	-1.021651248	0.36					
1995	2008 BiOp Base	0.67	0.2	-0.30652516	0.74					
1996	2008 BiOp Base	0.98	0.2	-0.016129382	0.98				0.94	
1997	2008 BiOp Base	0.97	0.2	-0.024292693	0.98				1	
1998	2008 BiOp Base	0.98	0.2	-0.016129382	0.98				0.86	
1999	2008 BiOp Base	0.85	0.2	-0.127833372	0.88				0.7	
2000	2008 BiOp Base	0.97	0.2	-0.024292693	0.98				0.86	
2001	New	0.85	0.2	-0.127833372	0.88					
2002	New	1.00	0.2	0	1.00				4.36	
2003	New	1.00	0.5	0	1.00					
2004	New	0.98	0.5	-0.010050336	0.99				0.87	
2005	New	0.97	0.5	-0.015113638	0.99					
2006	New	1.00	0.5	0	1.00					
2007	New	0.96	0.5	-0.020202707	0.98					
2008	New	0.94	0.5	-0.030459207	0.97					
2009	New	1.00	0.5	0	1.00					
2010	New	0.86	0.5	-0.072570693	0.93					
2011	New	0.70	0.5	-0.162518929	0.85					
2012	New	0.86	0.5	-0.072570693	0.93					
Base Period Average		0.70	0.20	-0.37	0.76					
Post-Base Average		0.93	0.45	-0.04	0.96					
Last 10-yr Average		0.93	0.50	-0.04	0.96					

Table E-7. Estimates of Base-to-Current survival multiplier for the Wenatchee River population of Upper Columbia River steelhead.

Year		%Wild (f) from 1/30/13 SPS Data	**e** from 3/5/12 NMFS draft estimates	ln(Proportion of Natural Spawner Equivalents) = ln(f+(1-f)*e)	Proportion of Natural Spawner Equivalents		future e	future f	future ln(f+(1-f)*e)	Integrated productivity increase (from base period) as a ratio
1981	2008 BiOp Base	0.20	0.2	-1.021651248	0.36		**0.53**	**0.47**	-0.286482792	1.78
1982	2008 BiOp Base	0.22	0.2	-0.978166136	0.38					
1983	2008 BiOp Base	0.17	0.2	-1.090644119	0.34					
1984	2008 BiOp Base	0.08	0.2	-1.331806176	0.26		Future e from 3/5/12 NMFS draft estimates			
1985	2008 BiOp Base	0.11	0.2	-1.244794799	0.29		Future f based on the average f for most recent 5 years of data.			
1986	2008 BiOp Base	0.15	0.2	-1.139434283	0.32					
1987	2008 BiOp Base	0.17	0.2	-1.090644119	0.34					
1988	2008 BiOp Base	0.35	0.2	-0.733969175	0.48					
1989	2008 BiOp Base	0.35	0.2	-0.733969175	0.48					
1990	2008 BiOp Base	0.39	0.2	-0.669430654	0.51		NOTE: This would replace the 1.60 multiplier in the 2008 BiOp			
1991	2008 BiOp Base	0.33	0.2	-0.767870727	0.46		It would not be added to it			
1992	2008 BiOp Base	0.40	0.2	-0.653926467	0.52		The effective change would be:			1.11
1993	2008 BiOp Base	0.16	0.2	-1.114741671	0.33					
1994	2008 BiOp Base	0.24	0.2	-0.936493439	0.39					
1995	2008 BiOp Base	0.15	0.2	-1.139434283	0.32					
1996	2008 BiOp Base	0.26	0.2	-0.896488105	0.41					
1997	2008 BiOp Base	0.51	0.2	-0.497580397	0.61				0.44	
1998	2008 BiOp Base	0.42	0.53	-0.318278746	0.73				0.39	
1999	2008 BiOp Base	0.69	0.53	-0.157472859	0.85				0.41	
2000	2008 BiOp Base	0.35	0.53	-0.733969175	0.48				0.36	
2001	New	0.43	0.53	-0.311838162	0.73				0.73	
2002	New	0.39	0.53	-0.33785319	0.71					
2003	New	0.33	0.53	-0.378190466	0.69				2.33	
2004	New	0.22	0.53	-0.456653145	0.63					
2005	New	0.23	0.53	-0.449260268	0.64					
2006	New	0.41	0.53	-0.324761081	0.72				0.466	
2007	New	0.44	0.53	-0.305438794	0.74					
2008	New	0.39	0.53	-0.33785319	0.71					
2009	New	0.41	0.53	-0.324761081	0.72					
2010	New	0.36	0.53	-0.357818455	0.70					
2011	New	0.73	0.53	-0.135705182	0.87					
Base Period Average		0.29	0.25	-0.86	0.44					
Post-Base Average		0.39	0.53	-0.34	0.72					
Last 10-yr Average		0.39	0.53	-0.34	0.71					

Table E-8. Estimates of Base-to-Current survival multiplier for the Entiat River population of Upper Columbia River steelhead.

%Wild (f) from 1/30/13 SPS Data	e from 3/5/12 NMFS draft estimates	ln(Proportion of Natural Spawner Equivalents) = ln(f+(1-f)*e)	Proportion of Natural Spawner Equivalents		future e	future f	future ln(f+(1-f)*e)	Integrated productivity increase (from base period) as a ratio	
0.25	0.2	-0.916290732	0.40		**0.2**	**0.29**	-0.839329691	0.93	
0.17	0.2	-1.090644119	0.34						
0.18	0.2	-1.067113622	0.34						
0.38	0.2	-0.685179011	0.50		Future e from 3/5/12 NMFS draft estimates				
0.40	0.2	-0.653926467	0.52		Future f based on the average f for most recent 5 years of data.				
0.23	0.2	-0.957112726	0.38						
0.40	0.2	-0.653926467	0.52						
0.44	0.2	-0.594207233	0.55						
0.69	0.2	-0.285018955	0.75						
0.38	0.2	-0.685179011	0.50						
0.27	0.2	-0.877070019	0.42						
0.94	0.2	-0.049190244	0.95						
0.76	0.2	-0.21319322	0.81						
0.45	0.2	-0.579818495	0.56		Based on new data, the current base-to-current integrated productivity increase falls withing the range anticipated in the 2008 BiOp				
0.28	0.2	-0.858021824	0.42						
0.31	0.2	-0.802962047	0.45						
0.23	0.2	-0.957112726	0.38						
0.09	0.2	-1.301953213	0.27				0.22		
0.13	0.2	-1.190727578	0.30				0.44		
0.24	0.2	-0.936493439	0.39				0.15		
0.26	0.2	-0.896488105	0.41				0.29		
0.33	0.2	-0.767870727	0.46				0.36		
0.26	0.2	-0.896488105	0.41						
0.09	0.2	-1.301953213	0.27				1.46		
0.13	0.2	-1.190727578	0.30						
0.28	0.2	-0.858021824	0.42				0.292		
0.22	0.2	-0.978166136	0.38						
0.44	0.2	-0.594207233	0.55						
0.15	0.2	-1.139434283	0.32						
0.29	0.2	-0.839329691	0.43						
0.36	0.2	-0.717439873	0.49						
0.36	0.20	-0.77	0.49						
0.26	0.20	-0.93	0.40						
0.26	0.20	-0.93	0.40						

Table E-9. Estimates of Base-to-Current survival multiplier for the Methow River population of Upper Columbia River steelhead.

Year		%Wild (f) from 1/30/13 SPS Data	e from 3/5/12 NMFS draft estimates	ln(Proportion of Natural Spawner Equivalents) = ln(f+(1-f)*e)	Proportion of Natural Spawner Equivalents		future e	future f	future ln(f+(1-f)*e)	Integrated productivity increase (from base period) as a ratio
1981	2008 BiOp Base	0.12	0.2	-1.217395825	0.30		**0.53**	**0.19**	-0.479165471	1.84
1982	2008 BiOp Base	0.12	0.2	-1.217395825	0.30					
1983	2008 BiOp Base	0.08	0.2	-1.331806176	0.26					
1984	2008 BiOp Base	0.02	0.2	-1.532476871	0.22		Future e from 3/5/12 NMFS draft estimates			
1985	2008 BiOp Base	0.03	0.2	-1.496109227	0.22		Future f based on the average f for most recent 5 years of data.			
1986	2008 BiOp Base	0.05	0.2	-1.427116356	0.24					
1987	2008 BiOp Base	0.04	0.2	-1.461017907	0.23					
1988	2008 BiOp Base	0.26	0.2	-0.896488105	0.41					
1989	2008 BiOp Base	0.25	0.2	-0.916290732	0.40					
1990	2008 BiOp Base	0.28	0.2	-0.858021824	0.42		NOTE: This would replace the 1.17 - 1.55 range of multipliers			
1991	2008 BiOp Base	0.32	0.2	-0.785262469	0.46		in the 2008 BiOp. It would not be added to them			
1992	2008 BiOp Base	0.24	0.2	-0.936493439	0.39		The effective change would be:			1.57
1993	2008 BiOp Base	0.15	0.2	-1.139434283	0.32				to	1.19
1994	2008 BiOp Base	0.20	0.2	-1.021651248	0.36					
1995	2008 BiOp Base	0.16	0.2	-1.114741671	0.33					
1996	2008 BiOp Base	0.30	0.2	-0.820980552	0.44					
1997	2008 BiOp Base	0.10	0.2	-1.272965676	0.28					
1998	2008 BiOp Base	0.03	0.53	-0.608622225	0.54					
1999	2008 BiOp Base	0.09	0.53	-0.55809195	0.57					
2000	2008 BiOp Base	0.14	0.53	-1.164752091	0.31				0.11	
2001	New	0.10	0.53	-0.549913012	0.58				0.21	
2002	New	0.06	0.53	-0.583037958	0.56				0.16	
2003	New	0.11	0.53	-0.541800428	0.58				0.14	
2004	New	0.13	0.53	-0.525770071	0.59				0.31	
2005	New	0.12	0.53	-0.533753128	0.59					
2006	New	0.14	0.53	-0.517850239	0.60				0.93	
2007	New	0.11	0.53	-0.541800428	0.58					
2008	New	0.21	0.53	-0.464101084	0.63				0.186	
2009	New	0.16	0.53	-0.502196297	0.61					
2010	New	0.14	0.53	-0.517850239	0.60					
2011	New	0.31	0.53	-0.392006088	0.68					
Base Period Average		0.15	0.25	-1.09	0.35					
Post-Base Average		0.14	0.53	-0.52	0.60					
Last 10-yr Average		0.15	0.53	-0.51	0.60					

Table E-10. Low Estimates of Base-to-Current survival multiplier for the Okanogan River population of Upper Columbia River steelhead.

Year		%Wild (f) from 1/30/13 SPS Data	e from 3/5/12 NMFS draft estimates	ln(Proportion of Natural Spawner Equivalents) = ln(f+(1-f)*e)	Proportion of Natural Spawner Equivalents		future e	future f	future ln(f+(1-f)*e)	Integrated productivity increase (from base period) as a ratio	
1981	2008 BiOp Base	0.07	0.2	-1.362577835	0.26		**0.3**	**0.10**	-0.994252273	1.42	
1982	2008 BiOp Base	0.07	0.2	-1.362577835	0.26						
1983	2008 BiOp Base	0.04	0.2	-1.461017907	0.23						
1984	2008 BiOp Base	0.01	0.2	-1.570217199	0.21		Future e from 3/5/12 NMFS draft estimates				
1985	2008 BiOp Base	0.02	0.2	-1.532476871	0.22		Future f based on the average f for most recent 5 years of data.				
1986	2008 BiOp Base	0.03	0.2	-1.496109227	0.22						
1987	2008 BiOp Base	0.02	0.2	-1.532476871	0.22						
1988	2008 BiOp Base	0.11	0.2	-1.244794799	0.29						
1989	2008 BiOp Base	0.11	0.2	-1.244794799	0.29						
1990	2008 BiOp Base	0.16	0.2	-1.114741671	0.33		NOTE: This would replace the 1.34 low multiplier				
1991	2008 BiOp Base	0.13	0.2	-1.190727578	0.30		in the 2008 BiOp. It would not be added to them				
1992	2008 BiOp Base	0.16	0.2	-1.114741671	0.33		The effective change would be:			1.06	
1993	2008 BiOp Base	0.03	0.2	-1.496109227	0.22						
1994	2008 BiOp Base	0.08	0.2	-1.331806176	0.26						
1995	2008 BiOp Base	0.07	0.2	-1.362577835	0.26						
1996	2008 BiOp Base	0.08	0.2	-1.331806176	0.26						
1997	2008 BiOp Base	0.03	0.2	-1.496109227	0.22						
1998	2008 BiOp Base	0.02	0.3	-1.158362293	0.31						
1999	2008 BiOp Base	0.05	0.3	-1.093624747	0.34						
2000	2008 BiOp Base	0.07	0.3	-1.362577835	0.26						
2001	New	0.06	0.3	-1.072944542	0.34						
2002	New	0.03	0.3	-1.136314156	0.32						
2003	New	0.06	0.3	-1.072944542	0.34						
2004	New	0.08	0.3	-1.032824548	0.36						
2005	New	0.07	0.3	-1.052683357	0.35						
2006	New	0.08	0.3	-1.032824548	0.36						
2007	New	0.06	0.3	-1.072944542	0.34						
2008	New	0.12	0.3	-0.957112726	0.38						
2009	New	0.09	0.3	-1.013352445	0.36						
2010	New	0.09	0.3	-1.013352445	0.36						
2011	New	0.16	0.3	-0.88673193	0.41						
Base Period Average		0.07	0.22	-1.34	0.26						
Post-Base Average		0.08	0.30	-1.03	0.36						
Last 10-yr Average		0.08	0.30	-1.03	0.36						

Table E-11. High Estimates of Base-to-Current survival multiplier for the Okanogan River population of Upper Columbia River steelhead.

Year		**%Wild (f)** from 1/30/13 SPS Data	**e** from 3/5/12 NMFS draft estimates	ln(Proportion of Natural Spawner Equivalents) = ln(f+(1-f)*e)	Proportion of Natural Spawner Equivalents		future e	future f	future ln(f+(1-f)*e)	Integrated productivity increase (from base period) as a ratio	
1981	2008 BiOp Base	0.07	0.2	-1.362577835	0.26		**0.45**	**0.10**	-0.678849876	1.87	
1982	2008 BiOp Base	0.07	0.2	-1.362577835	0.26						
1983	2008 BiOp Base	0.04	0.2	-1.461017907	0.23						
1984	2008 BiOp Base	0.01	0.2	-1.570217199	0.21		Future e from 3/5/12 NMFS draft estimates				
1985	2008 BiOp Base	0.02	0.2	-1.532476871	0.22						
1986	2008 BiOp Base	0.03	0.2	-1.496109227	0.22		Future f based on the average f for most recent 5 years of data.				
1987	2008 BiOp Base	0.02	0.2	-1.532476871	0.22						
1988	2008 BiOp Base	0.11	0.2	-1.244794799	0.29						
1989	2008 BiOp Base	0.11	0.2	-1.244794799	0.29						
1990	2008 BiOp Base	0.16	0.2	-1.114741671	0.33		NOTE: This would replace the 1.88 low multiplier				
1991	2008 BiOp Base	0.13	0.2	-1.190727578	0.30		in the 2008 BiOp. It would not be added to them				
1992	2008 BiOp Base	0.16	0.2	-1.114741671	0.33		The effective change would be:			1.00	
1993	2008 BiOp Base	0.03	0.2	-1.496109227	0.22						
1994	2008 BiOp Base	0.08	0.2	-1.331806176	0.26						
1995	2008 BiOp Base	0.07	0.2	-1.362577835	0.26						
1996	2008 BiOp Base	0.08	0.2	-1.331806176	0.26						
1997	2008 BiOp Base	0.03	0.2	-1.496109227	0.22						
1998	2008 BiOp Base	0.02	0.45	-0.774357236	0.46				0.06		
1999	2008 BiOp Base	0.05	0.45	-0.739191119	0.48				0.12		
2000	2008 BiOp Base	0.07	0.45	-1.362577835	0.26				0.09		
2001	New	0.06	0.45	-0.727738625	0.48				0.09		
2002	New	0.03	0.45	-0.762497259	0.47				0.16		
2003	New	0.06	0.45	-0.727738625	0.48						
2004	New	0.08	0.45	-0.705219762	0.49				0.52		
2005	New	0.07	0.45	-0.716415807	0.49						
2006	New	0.08	0.45	-0.705219762	0.49				0.104		
2007	New	0.06	0.45	-0.727738625	0.48						
2008	New	0.12	0.45	-0.661648514	0.52						
2009	New	0.09	0.45	-0.694147681	0.50						
2010	New	0.09	0.45	-0.694147681	0.50						
2011	New	0.16	0.45	-0.619896719	0.54						
Base Period Average		0.07	0.24	-1.31	0.28						
Post-Base Average		0.08	0.45	-0.70	0.50						
Last 10-yr Average		0.08	0.45	-0.70	0.50						

Appendix F
Estimating Survival Benefits of Estuary Habitat Improvement Projects

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Appendix F.1
History and Development of a Method to Assign Survival Benefit Units

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History and Development of a Method To Assign Survival Benefit Units

RPA 37 Expert Regional Technical Group on Estuary Habitat Actions

Purpose

The purpose of the Expert Regional Technical Group (ERTG) is to *assign survival benefits units* for ocean- and stream-type juvenile salmon from estuary habitat actions implemented by the Action Agencies (AA) as called for in the 2008 Biological Opinion of Federal Columbia River Power System Operations (BiOp).

Background

In the BiOp's Reasonable and Prudent Alternative action #37, the National Marine Fisheries Service (NMFS) stated, "…To support [restoration] project selection the Action Agencies will convene an expert regional technical group. This group will use the habitat metrics to determine the estimated change in survival which would result from full implementation…The expert regional technical group will use the approach originally applied in the FCRPS Biological Assessment (Attachment B.2.2; *Estimated Benefits of Federal Agency Habitat Projects in the Lower Columbia River Estuary*) and all subsequent information on the relationship between actions, habitat and salmon productivity models developed through the FCRPS RM&E to estimate the change in overall estuary habitat and resultant change in population survival..."

ERTG Composition

The ERTG was formed in June 2009 by invitation of the AA. Current ERTG members are Mr. Dan Bottom (Ocean and Estuary Ecologist; NMFS), Dr. Greg Hood (Estuarine Ecologist; Skagit River System Cooperative), Mr. Kim Jones (Fisheries Biologist; ODFW), Dr. Kirk Krueger (Fisheries Biologist; WDFW), and Dr. Ron Thom (Restoration Ecologist; PNNL). ERTG activities are overseen by a Steering Committee currently comprised of Anderson (NMFS), Ebberts (Corps Portland District), Foster (BPA), Krasnow (NMFS), Rose (Corps Northwest Division), and Zelinsky (BPA). Support to the ERTG and the Steering Committee is provided by Johnson (PNNL) and Trask (PC Trask and Assoc.).

Transparency, Accessibility, and Documentation

ERTG meetings are open to all interested parties, with the exception of when the ERTG is in executive session. Meeting announcements are sent at least one week in advance. Meetings are usually held at the Northwest Power and Planning Council conference room. Highlights of key points at meetings are documented in the regular meeting notes, which are made available to all interested parties.

ERTG Chronology

- July 2009 -- Held its first meeting.
- July 2009 to July 2010 -- Convened formal, open meetings with interested parties (10 total) in July, August, October 2009; February (2), March, April, May, June, and July 2010. These meetings often included site visits, presentations, and interchange between the ERTG and project sponsors.
- August 2009 to October 2010 – Worked to establish a quantitative approach to assigning survival benefit units, called the Calculator (see details below).
- February to October 2010 – Developed a standard template for sponsors to use to describe projects.
- June to October 2010 – Worked to improve the scoring criteria initiated in the existing method.
- October 2010 – Revised the Calculator and presented it to the Steering Committee.
- December 2010 – Regional release of the Calculator.
- August 2011 – Revised weighting factors based on fisheries literature review (see Document # ERTG 2011-01).
- December 2011 – Regional release of SBU reports for 20 projects (see Document # ERTG 2011-04).

Existing Method (2008 BiOP)

The ERTG was charged with applying the method used in the 2007 BA and adopted in the 2008 BiOp (called the *existing or the BiOp method*). The existing method (Figure 1) uses NOAA's 2006 Estuary Module and assigned potential survival improvements for juvenile salmon using and transiting through the estuary for each of the 22 actions outlined in the Module (based on a possible 20% total cumulative increases over time in the numbers of both ocean- and stream-type Chinook salmon exiting the estuary relative to annual totals established in the "Ferguson" memo[1]).

In the 2007 Biological Assessment, using the potential survival improvements outlined in the module, the AAs identified habitat restoration projects, scored each project for certainty of success and potential survival benefits, linked the projects to actions/sub-actions from the Module, and then qualitatively assigned survival benefits units (SBUs reported as a proportion of the 20% outlined above) to each project. The sum of project contributions (over the time period the 2008 Biop is in effect) was used as the estimated survival benefit for the estuary habitat actions – 10% for ocean-type and 6% for stream-type Chinook salmon. The key step was "assigning" of survival benefit units.

[1] Ferguson, J.W. 2006. Estimation of Percentages for Listed Pacific Salmon and Steelhead Smolts Arriving at Various Locations in the Columbia River Basin in 2006. NOAA Fisheries Memorandum. April 10, 2006.

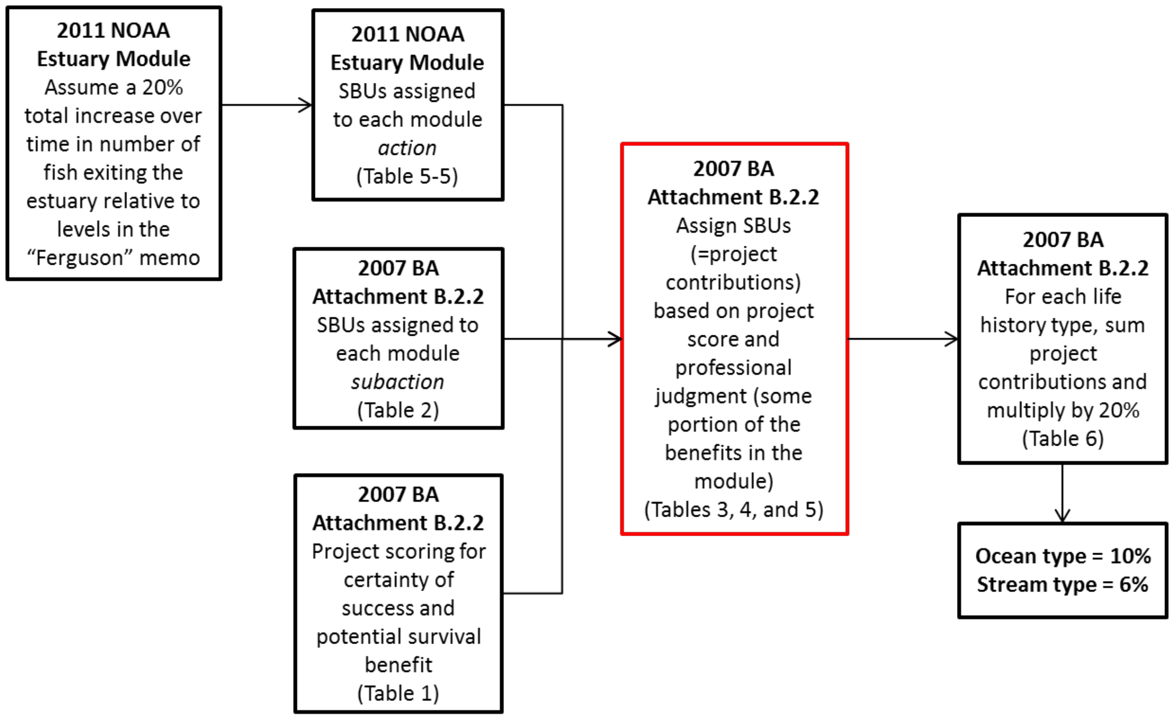

Figure 1. Flow Chart for the Existing Method to Estimate Survival Benefits from Habitat Actions in the Estuary. The red box is qualitative, professional judgment in the existing method. The ERTG quantified this step (see below). (Figure 1 was edited for clarity on 21 January 2013.)

Calculator to Assign SBUs

The ERTG's Calculator to assign survival benefit units (SBUs) by subaction is based on values in the 2010 Estuary Module (revised from the 2006 version) for total possible SBUs, total subaction goal (acres/miles), and total juvenile salmon produced. While it is not possible to predict the actual incremental survival benefit to salmon populations from a restoration project, the ERTG could address the rearing potential of a site. In doing so, though, they identified inconsistencies in the relationships between the potential number of juvenile salmon produced and the total possible SBUs as outlined as goals in the Module/BA. For example, off-channel restoration (CRE 9.4) seemed to be under-valued in total SBUs because the estimated fish densities were overly low, whereas riparian restoration (CRE 1.4) was over-valued in the ERTG's opinion because the expected fish densities were too high.

To alleviate this issue, the ERTG used the Module/BA goals on acreages and survival benefits in terms of total possible fish numbers to compute a "Module Fish Density" value (#/m^2). Then, the ERTG used existing literature to ascribe an "Optimal Fish Density" value for each subaction. A weighting factor was derived by dividing the Optimal Density by the Module Density (see following example for ocean-type). The weighting factor was incorporated into the Calculator as another multiplier.

Module CRE	Description	Module Goal (acres or miles)	Module Fish Production (#/acre or mile)	Computed Module Fish Density (#/m^2)	ERTG Optimal Fish Density (#/m^2)	Weight*
CRE-1.4	Restore and maintain ecological benefits in riparian areas	28	2,500	0.625	0.1	0.16
CRE-9.4	Restore degraded off-channel habitats	6,000	25	0.006	0.1	16.7
CRE-10.1	Breach or lower the elevation of dikes and levees	5,000	65	0.016	0.1	6.25
CRE-10.2	Remove tide gates to improve the hydrology between wetlands and the channel	2,000	35	0.009	0.05	5.56
CRE-10.3	Upgrade tide gates	1,000	50	0.0125	0.025	2.0
CRE-15.3	Remove invasives	10,000	2.5	0.0006	0.0006	1.0

*Note: the relative value of the weights does not imply restoration priority. The weights simply reflect the relationships between the ERTG's view of optimal fish density and what was in the Module.

Thus, the ERTG Calculator may be expressed as follows:

Assigned Survival Benefit Unit =
Total Module SBU * GP * SP * HAP * HCP * WF

Total Possible SBU for that Subaction from the Estuary Module

$$\text{GP=Goal Proportion}=\frac{\text{Project Goal}}{\text{Total Module Goal}}$$

$$\text{SP=Success Proportion}=\frac{\text{Mean Success Score}}{5}$$

$$\text{HAP=Habitat Access Proportion}=\frac{\text{Mean Access Score}}{5}$$

$$\text{HCP=Habitat Capacity Proportion}=\frac{\text{Mean Capacity Score}}{5}$$

$$\text{Weighting Factor}=\frac{\text{Optimal Fish Density}}{\text{Module Fish Density}}$$

Summary of the ERTG Process to Assign SBUs

For a given project, the steps in the process for the ERTG to assign SBUs involves:

Step 1 – Initiation

The Steering Committee prioritizes and selects the project, then requests the sponsor prepare a project template and supporting material.

Step 2 – Project Review

2A. Delivery of the project template and supporting materials to the ERTG for them to study.

2B. Presentation at an ERTG meeting involving interchange between the ERTG and the project sponsor. Additional information requested (optional).

2C. Site visit (optional).

2D. Second presentation at an ERTG meeting (optional).

Step 3 – Scoring

3A. Organization of the project into the appropriate subactions and associated Module goals and total possible SBUs.

3B. Review and potential recalculation of acres/miles for project subactions, culmination with values for project subaction goals.

3C. Scoring for certainty of success using the Scoring Criteria. ERTG's comments are documented.

3D. Same for habitat access.

3E. Same for habitat capacity.

Step 4 – Calculator

The ERTG facilitator compiles the data from Step 3 in an Excel spreadsheet and runs the Calculator.

Step 5 – Review of Results

The ERTG and Steering Committee review and discuss the results.

Step 6 – Dissemination

The results for assigned SBUs and scoring comments are disseminated as appropriate.

Step 7 – Dialogue and Feedback

An opportunity is provided for dialogue and feedback between the ERTG, Steering Committee, project sponsors, and interested parties.

ERTG Accomplishments

Since July 2009, the ERTG has accomplished the following:

- Project Template -- Developed a template for project descriptions to facilitate efficient and standard project review.
- Scoring Criteria -- Revised and enhanced the scoring criteria initiated in the existing method.
- Preliminary Feedback -- Provided preliminary feedback on six projects. (The AA and sponsors need input from the ERTG ahead of committing resources to develop full projects alternative and designs. It was decided the ERTG would review project templates and presentations, then provide comments and feedback on a proposed project.)
- Calculator – Modified the existing method to produce a quantitative, transparent, repeatable way to assign SBUs.

- Assigned SBUs -- Scored and assigned survival benefit units for 14 projects involving 36 subactions.
- Reviewed fisheries literature and revised some weighting factors.
- Released SBU reports for 20 projects (December 2011).

Conclusion

The ERTG has grown to become a cohesive, functional scientific panel. Each member brings unique perspective and expertise that collectively form an effective and credible group for review and assessment of estuary habitat actions to fulfill the AA's obligation defined in RPA 37. The ERTG has developed a quantitative, transparent, repeatable way to assign survival benefit units for estuary habitat projects.

Appendix F.2
ERTG Scoring Criteria

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ERTG Scoring Criteria

ERTG: The Expert Regional Technical Group for Federal Estuary Habitat Actions (RPA 37)

Purpose: The process the ERTG uses to assign survival benefits for habitat restoration projects in the lower Columbia River and estuary (LCRE) involves scoring for three factors:

- Certainty of success
- Potential benefit for habitat access/opportunity[1]
- Potential benefit for habitat capacity/quality[2]

This document provides criteria for scores (1 to 5) for each factor that will help standardize the review process.

Scope: The ERTG scoring criteria apply primarily to restoration and enhancement projects. Acquisition projects are also considered provided there is a vision for restoration in future phases of the project. In addition, conservation projects that have an obvious significant contribution to functioning of the broader ecosystem may also be scored. Ocean- and stream-type fish will not be scored separately because the Estuary Module already differentiates between the two life history strategies.

Certainty of Success

5 -- Restoring a natural process or landforms; proven restoration method; highly likely to be self-maintaining; little to no risk of detrimental effects; highly manageable *project complexity*[3]; minimal to no uncertainties regarding benefit to fish, minimal to no exotic/invasive species expected.

4 – Largely restoring a natural process or landforms; proven restoration method; likely to be self-maintaining; minimal risk of detrimental effects; manageable project complexity; minimal uncertainties regarding benefit to fish; minimal exotic/invasive species expected.

3 – Partially restoring a natural process or landforms; proven restoration method; potentially self-maintaining; minimal risk of detrimental effects; manageable project complexity; moderate uncertainties regarding benefit to fish; exotic/invasive species expected.

2 – Partially restoring a natural process or landforms; poorly proven restoration method; unlikely to be self-maintaining; risk of detrimental effects; moderate project complexity; moderate uncertainties regarding benefit to fish; exotic/invasive species expected.

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[1] *Habitat access/opportunity* is a habitat assessment metric that "appraises the capability of juvenile salmon to access and benefit from the habitat's capacity," for example, tidal elevation and geomorphic features (cf. Simenstad and Cordell 2000).

[2] *Habitat capacity/quality* is a habitat assessment metric involving "habitat attributes that promote juvenile salmon production through conditions that promote foraging, growth, and growth efficiency, and/or decreased mortality," for example, invertebrate prey productivity, salinity, temperature, and structural characteristics (cf. Simenstad and Cordell 2000).

[3] As used here, *project complexity* refers to the number of elements (i.e., steps or actions) required to achieve the anticipated restoration project habitat conditions and the degree of interdependence of elements to achieve the anticipated habitat functionality. More steps and greater interdependence leads to increased complexity, increasing the risk of not achieving the restoration goal. In addition, the amount of engineered control structures and maintenance necessary for project success adds to project complexity.

1 -- Unlikely to restore natural processes and landforms; unproven or risky restoration method; will likely require intervention to maintain; some risk of detrimental effects; excessive project complexity; excessive uncertainties regarding benefit to fish; exotic/invasive species expected.

Potential Benefit for Habitat Access/Opportunity

5 -- High *connectivity*[4] of site for most species, populations and life history types coming down river at most water level stages; located in a mainstem area or a priority (TBD) reach; unencumbered access to site.

4 – Intermediate connectivity of site for most species, populations and life history types coming down river at most water level stages; located in a mainstem area or a priority (TBD) reach; unencumbered access to site.

3 – Intermediate connectivity; only accessible to a few life history types or species coming down river at most water level stages; located in a mainstem area, lower end of tributary or a priority (TBD) reach; moderate site access.

2 -- Intermediate to low connectivity; only accessible to specific life history types or one species coming down river at most water level stages; located in a mainstem area, lower end of tributary or a priority (TBD) reach; moderate site access.

1 – Low to no connectivity for any species, populations or life history types coming down river at most water level stages; located in areas far from main stem or lower ends of tributaries; poor site access.

Potential Benefit for Habitat Capacity/Quality (C/Q)

5 -- Maximum natural habitat *complexity*[5]; well-developed natural disturbance regime and ecosystem functions; extensive channel and edge network and large wood; much prey resource production and export; no invasive species or nuisance predators; water quality/temperature quality excellent; site relatively large (> 100 acres).

4 – Very good natural habitat *complexity*; natural disturbance regime and ecosystem functions; very good channel and edge network and large wood; much prey resource production and export; minimal invasive species or nuisance predators; water quality/temperature quality very good; site moderate to large in size (30-100 ac)

3 -- Moderate habitat complexity; moderately-developed natural disturbance regime and ecosystem functions; some channel and edge network and large wood; moderate prey resource production and export; moderate potential invasive species or predators; water quality/temperature quality moderate; site intermediate in size (~30 to 100 acres).

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[4] As used here, *connectivity* refers to the degree to which water and aquatic organisms can move between the project site and the surrounding landscape. Typical barriers to movement include dikes and levees (complete barrier), tidegates and culverts (complete to partial barriers depending on configuration), jetties, groins, etc. Site proximity to population sources or to migratory corridors also affects connectivity. Assuming no barriers to organismal movement or water flow, sites near tributary junctions to the mainstem Columbia River have high connectivity; likewise sites surrounded by river distributaries are highly connected. Connectivity may also be seasonal. Sites where connectivity occurs only during occasional high flow conditions are less connected than those that are connected during low flows.

[5] As used here, *habitat complexity* refers to the diversity of habitat types and structures within a given area.

2 – Moderate to low habitat complexity; moderately-developed natural disturbance regime and ecosystem functions; some channel and edge network and large wood; moderate to low prey resource production and export; moderate potential invasive species or predators; water quality/temperature quality moderate to low; site intermediate to small in size (≥30 acres).

1 – Low habitat complexity; poorly developed natural disturbance regime and ecosystem functions; poor channel and edge network and large wood; moderate to poor prey resource production and export; moderate to high potential invasive species or predators; water quality/temperature poor; site small in size (<30 acres).

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Appendix F.3
ERTG Template for LCRE Habitat Restoration Project Summary

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ERTG Template for LCRE Habitat Restoration Project Summary

Project Description

The information requested below provides input to the scoring of projects. Refer to the ERTG Scoring Criteria (Attachment 1) and definitions below when developing the project information. Reference to the Columbia River Estuary Conceptual Model (see link below) can also be made to help standardize terminology and to provide descriptions for stressors, habitats, processes and functions.

Header:	
Date	*Date the summary was prepared*
Prepared by	*Name, phone number, and email address*
Sponsoring agency	*Contact name, phone number, and email address*
Funding agency	*Contact name, phone number, and email address*
Site	*Name, location, river, river mile, latitude/longitude*
Project status or stage	*Status or stage of the proposed project*
Proposed Project:	
Problem statement	*Summarize the site-specific problem(s) the proposed restoration(s) is intended to address. What are the causes of the problems?*
Vision/goal	*Describe the expected outcome, i.e., what the site would look like if restoration is successful.*
Objectives	*State the project's objectives in terms of functions for salmon. For example, how will access, capacity etc. be increased or enhanced?*
Project actions, phases, sizes by year	*List the proposed restoration[1] actions and phases by year. For each restoration action, state the number of barriers to be removed, the width of the breach or reconnection, and/or the number of acres/miles to be restored by year. In a multi-year effort, be sure to identify the action(s)/phase(s) that are being proposed at this time.*
Linkage to Estuary Module:	
Estuary module action. subaction(s) and project goal; Maps of the site, landscape, and site location in the LCRE	*Identify the appropriate subaction (Attachment 2) and state the size (number of acres or miles) the project subaction will provide. Document how the value was obtained. Show these subactions on a map of the site. Also include a map of the project site in its landscape and a map of the project's location in the lower Columbia River and estuary.*
Pre-Assessment:	*Whenever possible, provide summary data (values).*
Photo Point	*Provide a digital photograph(s) of the site; note the point and orientation of the photograph, time of year, and tide/water level stage.*
Aerial image	*Provide an aerial image from a satellite or plane. Annotate the image to convey information about the project. Prepare map(s) with landform types delineated.*
Condition of physical metrics	*Describe the major stressors and physical controlling factors[2]. Basically summarize the existing condition of the site. What is the average tidal range, salinity? What is the ordinary-high-water tide elevation? Extreme-high-water elevation? Two-year flood elevation?*
Condition of habitat metrics	*Describe the key results of a vegetation survey.*
Condition of functional metrics	*Assess using existing data whether juvenile salmonids are present in the area*

[1] As used here, the term "restoration" refers to conservation, protection, enhancement, restoration, or creation.
[2] Controlling factors are the basic physical and chemical conditions that construct and influence the structure of the ecosystem.

	and within the site. Describe the species composition and population sizes in the immediate or nearby watershed; use any available historical and current fish species and abundance data. Provide context for the potential of the site for fish availability.
Performance Anticipated:	
Physical change	*Describe how the action(s) will affect physical controlling factors.*
Habitat change	*Describe the expected condition of habitat after restoration.*
Process/Function change	*Describe the expected changes in ecosystem processes and functions, e.g., Juvenile salmon feeding, rearing, refuge, water quality improvement, off site food web support.*
Certainty of Success:	
Landowner support	*Describe the willingness and support of the landowner.*
Constraints or show-stoppers	*Describe potential issues that could inhibit or prevent execution and fulfillment of the project goals and objectives.*
Restoration technique	*Describe the level of acceptance and maturity of the restoration technique; e.g., tried and true or experimental.*
Natural processes and self-maintenance	*Explain the extent to which natural processes would be restored and how well the restoration action(s) are anticipated to be maintained through natural processes.*
Potential, Anticipated Access Benefit:	
Distance of the project to the main stem Columbia River	*State distance in river miles from the main stem Columbia River*
Connectedness to mainstem	*Describe how well the project site is currently connected and will be connected to the main stem after the restoration. Include any historical data on habitat access and quality.*
Species impacted	*Describe which species, stocks, or populations are likely to benefit, based on the best available data.*
Potential, Anticipated Capacity Benefit:	
Habitat complexity	*Describe habitat complexity, channels, large woody debris.*
Water quality	*Describe water quality.*
Invasive species	*Describe impacts from invasive plant and animal species.*
Adjacent lands	*Describe the condition of adjacent lands.*
Comments	*Include comments or other pertinent information.*

***NOTE**: The following material is for the sponsor's information; do not include it with the template submittal for a proposed project.*

Conceptual Model

The Columbia River Estuary Conceptual Model (http://lcrep.org/conceptual_model/START.htm) provides illustrations of the major natural ***ecosystem complexes*** in the estuary. These illustrations can serve as a useful vision for the proposed project. In the project description, please refer to the habitat or ecosystem complexes that will be restored or enhanced by the project. In addition, the information in the conceptual model can help identify and describe the processes and functions that will be restored or enhanced by the project. The conceptual model can also be used to summarize the expected changes in processes and functions realized on the site (i.e., the ***proximal changes***), and those realized off the site (i.e., the ***distal changes***).

ATTACHMENT 1: ERTG Scoring Criteria

(ERTG Document #2010-02)

Purpose: The process the ERTG uses to assign survival benefits for habitat restoration projects in the lower Columbia River and estuary (LCRE) involves scoring for three factors:

- Certainty of success
- Potential benefit for habitat access/opportunity[3]
- Potential benefit for habitat capacity/quality[4]

This document provides criteria for scores (1 to 5) for each factor that will help standardize the review process.

Scope: The ERTG scoring criteria apply primarily to restoration and enhancement projects. Acquisition projects are also considered provided there is a vision for restoration in future phases of the project. In addition, conservation projects that have an obvious significant contribution to functioning of the broader ecosystem may also be scored. Ocean- and stream-type fish will not be scored separately because the Estuary Module already differentiates between the two life history strategies.

Certainty of Success

5 -- Restoring a natural process or landforms; proven restoration method; highly likely to be self-maintaining; little to no risk of detrimental effects; highly manageable *project complexity*[5]; minimal to no uncertainties regarding benefit to fish, minimal to no exotic/invasive species expected.

[3] *Habitat access/opportunity* is a habitat assessment metric that "appraises the capability of juvenile salmon to access and benefit from the habitat's capacity," for example, tidal elevation and geomorphic features (cf. Simenstad and Cordell 2000).

[4] *Habitat capacity/quality* is a habitat assessment metric involving "habitat attributes that promote juvenile salmon production through conditions that promote foraging, growth, and growth efficiency, and/or decreased mortality," for example, invertebrate prey productivity, salinity, temperature, and structural characteristics (cf. Simenstad and Cordell 2000).

[5] As used here, *project complexity* refers to the number of elements (i.e., steps or actions) required to achieve the anticipated restoration project habitat conditions and the degree of interdependence of elements to achieve the anticipated habitat functionality. More steps and greater interdependence leads to increased complexity, increasing the risk of not achieving the restoration goal. In addition, the amount of engineered control structures and maintenance necessary for project success adds to project complexity.

4 – Largely restoring a natural process or landforms; proven restoration method; likely to be self-maintaining; minimal risk of detrimental effects; manageable project complexity; minimal uncertainties regarding benefit to fish; minimal exotic/invasive species expected.

3 – Partially restoring a natural process or landforms; proven restoration method; potentially self-maintaining; minimal risk of detrimental effects; manageable project complexity; moderate uncertainties regarding benefit to fish; exotic/invasive species expected.

2 – Partially restoring a natural process or landforms; poorly proven restoration method; unlikely to be self-maintaining; risk of detrimental effects; moderate project complexity; moderate uncertainties regarding benefit to fish; exotic/invasive species expected.

1 -- Unlikely to restore natural processes and landforms; unproven or risky restoration method; will likely require intervention to maintain; some risk of detrimental effects; excessive project complexity; excessive uncertainties regarding benefit to fish; exotic/invasive species expected.

Potential Benefit for Habitat Access/Opportunity

5 -- High *connectivity*[6] of site for most species, populations and life history types coming down river at most water level stages; located in a mainstem area or a priority (TBD) reach; unencumbered access to site.

4 – Intermediate connectivity of site for most species, populations and life history types coming down river at most water level stages; located in a mainstem area or a priority (TBD) reach; unencumbered access to site.

3 – Intermediate connectivity; only accessible to a few life history types or species coming down river at most water level stages; located in a mainstem area, lower end of tributary or a priority (TBD) reach; moderate site access.

2 -- Intermediate to low connectivity; only accessible to specific life history types or one species coming down river at most water level stages; located in a mainstem area, lower end of tributary or a priority (TBD) reach; moderate site access.

1 – Low to no connectivity for any species, populations or life history types coming down river at most water level stages; located in areas far from main stem or lower ends of tributaries; poor site access.

Potential Benefit for Habitat Capacity/Quality (C/Q)

5 -- Maximum natural habitat *complexity*[7]; well-developed natural disturbance regime and ecosystem functions; extensive channel and edge network and large wood; much prey resource production and export; no invasive species or nuisance predators; water quality/temperature quality excellent; site relatively large (> 100 acres).

4 – Very good natural habitat *complexity*; natural disturbance regime and ecosystem functions; very good channel and edge network and large wood; much prey resource production and export; minimal invasive species or nuisance predators; water quality/temperature quality very good; site moderate to large in size (30-100 ac)

3 -- Moderate habitat complexity; moderately-developed natural disturbance regime and ecosystem functions; some channel and edge network and large wood; moderate prey resource production and export; moderate potential invasive species or predators; water quality/temperature quality moderate; site intermediate in size (~30 to 100 acres).

[6] As used here, *connectivity* refers to the degree to which water and aquatic organisms can move between the project site and the surrounding landscape. Typical barriers to movement include dikes and levees (complete barrier), tidegates and culverts (complete to partial barriers depending on configuration), jetties, groins, etc. Site proximity to population sources or to migratory corridors also affects connectivity. Assuming no barriers to organismal movement or water flow, sites near tributary junctions to the mainstem Columbia River have high connectivity; likewise sites surrounded by river distributaries are highly connected. Connectivity may also be seasonal. Sites where connectivity occurs only during occasional high flow conditions are less connected than those that are connected during low flows.

[7] As used here, *habitat complexity* refers to the diversity of habitat types and structures within a given area.

2 – Moderate to low habitat complexity; moderately-developed natural disturbance regime and ecosystem functions; some channel and edge network and large wood; moderate to low prey resource production and export; moderate potential invasive species or predators; water quality/temperature quality moderate to low; site intermediate to small in size (≥30 acres).

1 – Low habitat complexity; poorly developed natural disturbance regime and ecosystem functions; poor channel and edge network and large wood; moderate to poor prey resource production and export; moderate to high potential invasive species or predators; water quality/temperature poor; site small in size (<30 acres).

ATTACHMENT 2: Guidance on Estuary Module Actions and Subactions Relevant to the ERTG Process

(ERTG Document #2011-01, revised April 2012)

The Expert Regional Technical Group (ERTG) uses actions and subactions from the Estuary Module (NMFS 2011[8]) in its process to assign survival benefit units to habitat restoration projects in the lower Columbia River and estuary (Document # ERTG 2010-03[9]). The actions and subactions were designed and written for purposes of the Estuary Module. To clarify interpretation and use for purposes of the ERTG process, the following guidance is offered. This information supplements and supersedes the table in Attachment 2 of ERTG Doc#2010-01[10].

Guidance Table

Module Action	Module Subactions	Clarification	Comments
CRE-1: Protect intact riparian areas in the estuary and restore riparian areas that are degraded.	CRE-1.4: Restore and maintain ecological benefits in riparian areas; this includes managing vegetation on dikes and levees to enhance ecological function and adding shoreline/instream complexity for juvenile salmonid refugia.	None	Any stream, river, or channel edge treatments, e.g., plantings, fall under subaction 1.4.
CRE-6: Reduce the export of sand and gravels via dredge operations by using dredged materials beneficially.	CRE-6.2: Identify and implement dredged material beneficial use demonstration projects, including the notching and scrape-down of previously disposed materials and placement of new materials for habitat enhancement and/or creation.	None	The distinction between 6.2. and 6.3 is that 6.2 is “demo” work for experimental techniques and 6.3 is not. Both address beneficial use in terms of dredge material removal (e.g., scrapedown) or addition (e.g., creation).

[8] National Marine Fisheries Service (NMFS). 2011. Columbia River Estuary ESA Recovery Plan Module for Salmon & Steelhead. NMFS (National Oceanic and Atmospheric Administration Fisheries) – Northwest Region, Seattle, Washington. Federal Register notice (76FR8345).

[9] Document # ERTG 2010-03. “History and Development of a Method to Assign Survival Benefit Units.” Version 12/3/10, available from B. Ebberts or B. Zelinsky.

[10] Document # ERTG 2010-01. “ERTG Template for LCRE Habitat Restoration Project Summary.” Version 12/3/10, available from B. Ebberts or B. Zelinsky..

Module Action	Module Subactions	Clarification	Comments
	CRE-6.3: Dispose of dredged materials using techniques identified through the demonstration projects and region-wide planning.	None	There is little difference in SBU/acre between 6.2 and 6.3.
CRE-8: Remove pilings and pile dikes	CRE-8.2: Remove priority pilings and pile dikes.		Straightforward; need to establish Module goals for 8.2.
CRE-9: Protect remaining high-quality off-channel habitat from degradation and restore degraded areas…	CRE-9.4: restore degraded off-channel habitats with high intrinsic potential for increasing habitat quality.	Actions to establish or improve channel habitat conditions.	Action needs to be ***in*** a channel, any channel, not necessarily just “off” channel. Subaction 9.4 includes a) adding structure to channels of all kinds, e.g., placement of large woody debris; b) reestablishing historic channels by removing ditches and other artificial drainages and excavating new channels or taking other engineering actions to initiate channel formation.
CRE-10: Breach or lower dikes and levees	CRE-10.1: Breach or lower the elevation of dikes and levees; create and/or restore tidal marshes, shallow-water habitats, and tide channels.	Actions that result in no or ***little***[11] impediment to natural processes, e.g., flows in and out of the restored site.	No or little tidal muting; hydraulic control is returned to a normative, unmanaged state.
	CRE-10.2: Remove tide gates to improve the hydrology between wetlands and the channel and to provide juveniles with physical access to off-channel habitat; use a habitat connectivity index to prioritize projects.	….***moderate*** impediment to natural processes, e.g., flows in and out of the site.	Moderately muted tides; hydraulic control is returned to a partially normative state; it is unmanaged but not normative. Includes culverts as well as tide gates.
	CRE-10.3: Upgrade tide gates where (1) no other options exist, (2) upgraded structures can provide appropriate access for juveniles, and (3) ecosystem function would be improved over current conditions.	……**high** impediment to natural processes, e.g., flows in and out of the site.	Highly muted tides; hydraulic control is still in a non-normative state; remains in a managed state. Includes culverts as well as tide gates.
CRE-12: Reduce the effects of vessel	CRE-12.2: Design and implement projects that are likely to result	None	None

[11] By definition, “little”, “moderate”, and “high” refer to the level of hydraulic control at the restoration point after construction. Hydraulic control is “…any channel feature, natural or man-made, which fixes a relationship between depth and discharge in its neighborhood” (p.174, Henderson. 1966. Open Channel Flow).

Module Action	Module Subactions	Clarification	Comments
wake stranding in the estuary	in the reduction of ship wake stranding events.		
CRE-15: Reduce noxious weeds	CRE-15.3: Implement projects to address infestations on public and private lands.	None	None

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Appendix F.4
Feedback on Inputs to the Calculator to Assign Survival Benefit Units

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Feedback on Inputs to the Calculator to Assign Survival Benefit Units

RPA 37 Expert Regional Technical Group on Estuary Habitat Actions

At the request of its Steering Committee, the Expert Regional Technical Group (ERTG) held a special meeting to discuss and provide feedback on particular topics identified by the Steering Committee. The meeting was held on July 27-28, 2011 at Washington Department of Fish and Wildlife offices in Olympia, Washington and was attended by all five ERTG scientists: Dan Bottom, Greg Hood, Kim Jones (via telephone), Kirk Krueger, and Ron Thom. The meeting's topics related to inputs to the survival benefit unit calculator described in Document # ERTG 2010-03. Topics included:

1. Spatial and scoring separation of sub-actions (i.e., double-counting).
2. Water level or elevation at which sub-action areas are measured.
3. Expected differences in effects of various sub-actions.
4. Use of salmonid density data from scientific literature to weight sub-actions.
5. Simulation of effects of changes in salmonid densities (via weights) on assigned SBU and projected fish numbers (constrained by module assumptions).

The resulting feedback is intended for use by the Steering Committee and restoration practitioners in development of restoration project templates and other planning and development activities. It is *not* intended to be a how-to document on using the Calculator or a guidance document on restoration. The purpose of Document # ERTG 2011-01 is to record the ERTG's feedback from the meeting July 27-28, 2011.

The ERTG referred to the following subactions from the Estuary Module (NMFS 2011):

- Subaction 9.4 – "Restore degraded off-channel habitats with high intrinsic potential for increasing habitat quality."
- Subaction 10.1 – "Breach, lower the elevation of, or relocate dikes and levees; create and/or restore tidal marshes, shallow water habitats, and tide channels."
- Subaction 10.2 – "Remove tide gates to improve the hydrology between wetlands and the channel and to provide juveniles with physical access to off-channel habitat; use a habitat connectivity index to prioritize projects."
- Subaction 10.3 – "Upgrade tide gates or perched culverts where (1) no other options exist, (2) upgraded structures can provide appropriate access for juveniles, and (3) ecosystem function would be improved over current conditions."

1. Spatial and Scoring Separation of Sub-Action

- Issue: The spatial wetted area and scoring separation for subaction 9.4 (off-channel habitat improvements) and the 10.X series (reconnection improvements) is ambiguous.
- The area used to calculate SBU's for sub-action 9.4 effects should be the estimated area of the active channel (i.e., no buffer is used).
- When sub-action 9.4 occurs within an area where a sub-action 10.1, 10.2 or 10.3 (hereafter 10.x) are also proposed, the effect of including the same area in calculation of SBU's for both actions should be accounted for by appropriately weighting sub-actions. That is, including the area of 9.4 in the calculation of area for 10.x is allowable, given how we weight sub-actions and score projects.
- Spatial and scoring overlap of sub-actions, especially when 9.4 (off-channel) occurs in the same project as 10.1 (breach), 10.2 (remove), or 10.3 (upgrade), occurs because the sub-actions are spatially and operationally defined as engineering actions rather than natural changes to a system, which would allow us to consider the entire area affected by the sub-action (e.g., sub-action 9.4 is expected to affect much of a wetland).
- The method of estimating SBU's requires estimation of SBU's by individual sub-actions.
- The ERTG considers sub-actions and their likely effects given the context of the system in which they occur (i.e., holistically) and how habitats form and function. Therefore, a sub-action (e.g., a 9.4) that is very well done might be expected to perform poorly if the system in which it is conducted (e.g., a tidal marsh) is in very poor condition (e.g., the marsh has a functioning levee) and appropriate sub-actions (e.g., 10.1) are not proposed. Thus, sub-action 9.4 is usually considered an enhancement of a sub-action 10.x (see Figure 1).

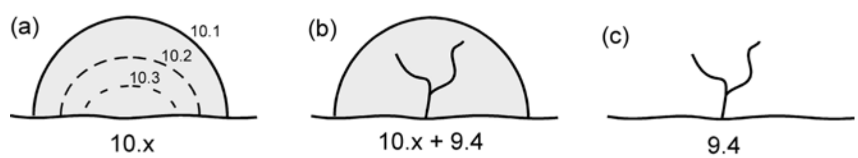

Figure 1. Depiction of (a) the area affected by sub-actions 10.1, 10.2, and 10.3 without an associated sub-action 9.4, (b) the area affected by sub-actions 10.1, 10.2, and 10.3 with an associated sub-action 9.4, and (c) the area affected by sub-action 9.4 without an associated sub-action 10.1, 10.2, or 10.3.

- If possible within the constraint of using the "existing method," we should consider scoring an entire project (i.e., all sub-actions). This will likely provide a simpler, faster and more realistic score for the project.
- The ERTG usually assumes that beneficial channels will eventually form if a sub-action 10.x is correctly implemented, and a channel without a properly functioning contributing area will likely degrade. Therefore, sub-action 9.4 is considered mostly as an improvement to sub-action 10.x, given that sub-action 9.4 will no longer be conducted on stream systems within the purview of the ERTG.
- This method allows the ERTG to estimate SBU's for all sub-actions.

- Conclusion: Subaction 9.4 is strictly the wetted, bank-full channel area with no buffer zone. Wetted areas for subactions 10.X are added to any channel improvements, i.e., "double-counting" is acceptable.

2. Water Level or Elevation at Which Sub-Action Areas Are Measured

- Issue: The water level for which wetted area acreages for projects are measured needs standardization.
- Selection of the elevation or water level for delineation of area for sub-actions can have a large effect on the estimation of SBU's. Methods for delineation of area should be standardized to ensure correct use by project proponents, simple interpretation by the ERTG, and meaningful comparison of projects.
- Appropriate elevation differs among locations. In the past, the 2-year flood elevation has been used less-tidally influenced, upper-river locations, while Mean Higher High Water (MHHW) has been used in tidal, lower-river locations. The ERTG will continue to investigate the efficacy of 1) providing a spatial delineation of the LCRE [lower Columbia River and estuary] into zones where the most appropriate elevation is identified based on the differences in the dominant processes among locations and 2) using Extreme Higher High Water (EHHW[1]) rather than MHHW, as documented in the scientific literature.
- Sub-action 10.1 breaches are for tidal marshes and floodplains; while these are ecologically distinct, we will not distinguish habitat types for this action. So, use 2-yr flood event or EHHW (whichever is higher, but presumably the 2-yr event is always higher) to calculate the area of the 10.1 action. This also applies to tidally-influenced tributary areas.
- Sub-actions 10.2 and 10.3 do not fully restore hydrology, so full flooding potential is not restored. Thus, the calculated area to apply to these actions should be the design flood (e.g., for an SRT which is designed to only allow channel flooding with no overbank flooding the area would be zero).
- Given their knowledge of project sites, we suggest that project proponents calculate area based on these statistics and select the one most appropriate to their project area. This will usually be the larger of the estimated areas.
- Conclusion: Use the 2-year flood elevation or EHHW (mean highest monthly tide), whichever is higher.

3. Expected Differences in Effects of Various Sub-Actions

- Issue: There are nuances and numerous variations possible for specific actions within a given subaction.

[1] The ERTG will prescribe a working definition for EHHW at a later date.

- The ERTG made a minor adjustment to the weight of sub-action 10.3, using density information as a guide.
- The ERTG expects the effects of sub-action 10.1 to be greater and more quickly detected than sub-action 10.2, which has a similar expected relation to effects of sub-action 10.3, if each is conducted in the same location, because, typically, sub-action 10.1 is implemented at several locations and is expected to more completely and rapidly reestablish natural processes.
- The ERTG acknowledges that the effect of sub-actions 10.x might be nearly identical, especially if, for example, sub-action 10.1 were done in only a single location. However, we cannot assign weights to all possible variations of how a sub-action might be implemented. Therefore, we assigned weights based on our expectations for proposed sub-actions, based on projects that have been proposed.
- ERTG scores will sufficiently account for differences in how sub-actions are proposed to be implemented.
- Conclusion: The ERTG will rely on the proponents' explanations, then review and score accordingly.

4. Use of Salmonid Density Data from Scientific Literature to Weight Sub-Actions

- Issue: The science-basis for the density data and resulting weighting factors needs scrutiny and buttressing.
- Data that describe observed densities of salmon in a variety of habitats and locations were procured from the scientific literature and used to 1) assess the relative veracity of predicted effects of sub-actions, and 2) to adjust weights of sub-actions, given expectations of sub-action area and SBU goals as stated in the module.
- The ERTG found this useful because the relative importance of sub-actions in the module were thought to be incorrect, setting expectations for the effect of some sub-actions too low and others too high.
- Weighting does not change the number of SBU possible. It only reallocates SBU among sub-actions.
- Salmonid density data are not used as an expected effect of a sub-action and should not be used to predict the effect of a sub-action, specific project, or cumulative effect of projects.
- Final decision regarding the weight of sub-actions was made based on the results of simulations performed using the SBU Calculator to show the relative effect of each sub-action on SBU and fish as determined in the module.
- Final densities selected were:

Sub-action	Optimal Density	Module Density	Weight
1.4	0.1	0.625	0.16
9.4	0.1	0.006	16.67

Sub-action	Optimal Density	Module Density	Weight
10.1	0.1	0.016	6.25
10.2	0.05	0.009	5.56
10.3	0.025	0.0125	2.00
15.3	0.0006	0.0006	1.00

- The weights of sub-actions 10.x were based on the ability of fish to access the surface of the restored wetland habitat during high tide or flood stage (Hering et al. 2010, Bass 2010). While the channels are rated equally in each case, the presence of dikes or restrictive culverts influences the number of fish that can access the marsh surface.
- The ERTG selected density data that we thought were most appropriate to each sub-action and to the Columbia River Estuary.
- The complexity of this weighting scheme is due to the constraint of the ERTG to use the current scoring process (i.e., existing method).
- Conclusion: See ERTG's revised optimal salmonid densities and weighting factors, presented above, which are based on an extensive literature review.

5. Simulation of Effects of Changes in Salmonid Densities (Via Weights) on Assigned SBU and Projected Fish Numbers (Constrained By Module Assumptions)

- Issue: The sensitivity of the assigned SBUs to weightings and scores needs to be well-understood.
- A copy of the Survival Benefits Workbook was modified to allow calculation of ASU's and Fish Production Estimates (FPE) across a range of scores and salmonid densities for sub-actions 1.4, 9.4, 10.1, 10.2, 10.3, and 15.3.
- Salmonid densities change weights applied to sub-actions.
- ASU's and fish densities calculated were constrained by the assumptions of the module that provides an estimate of the sub-action target.
- Scores were varied from 1 to 5, by 1.
- Effect of scores on ASU's and FPE's is curvilinear (a power function), demonstrating that higher scores have an increasing effect on ASU and FPE as the magnitude of the score increases. For example, for sub-action 9.4 Ocean Type change of a score from 2 to 3 changes ASU from about 0.001 to 0.004 (0.003) and change in score from 4 to 5 changes ASU from 0.009 to 0.017 (0.008).
- Projects that score poor to average provide somewhat similar benefit, but projects that score very well have a very large expected benefit.
- Expected effects of sub-actions differ substantially, as determined by weights.
- Direct comparison of the relative importance of sub-actions is difficult because measures of project size are not commensurate (i.e., area and length are used and they are not directly comparable).

- Salmonid density used for weights varied from 0.0001 to 1 fish/unit.
- Effect of varying salmon density (thus weight) on ASU and FPE is linear, as expected.
- Using a mean score of 3 and area/length of 1, effects of sub-action 1.4 and 9.4 were very similar, and a little greater than 10.1, which was about twice 10.2, which was about twice 10.3, which was about 9 time that of 15.3.
- Conclusion: ERTG performed a sensitivity analysis and is satisfied, as expected, that there is a linear relationship between weightings and SBUs and a nonlinear relationship between scores and SBUs. The ERTG will use the scores to adjust and respond to project-specific features.

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