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

Supplemental Consultation on Remand for Operation of the Federal Columbia River Power System, 11 Bureau of Reclamation Projects in the Columbia Basin and ESA Section 10(a)(I)(A) Permit for Juvenile Fish Transportation Program

Action Agencies: U.S. Army Corps of Engineers
Bonneville Power Administration
U.S. Bureau of Reclamation
National Marine Fisheries Service

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Section 1 Introduction

This supplemental biological opinion documents NOAA Fisheries' determination that the operation of the Federal Columbia River Power System (FCRPS), through 2018, complies with the standards of § 7(a)(2) of the Endangered Species Act (ESA). In a reinitiation of consultation NOAA Fisheries is hereby supplementing the science, actions and conclusions of its May 5, 2008 FCRPS Biological Opinion (2008 BiOp), issued to the Bonneville Power Administration, U.S. Army Corps of Engineers and the U.S. Bureau of Reclamation (hereafter the Action Agencies).

1.1 2008 BiOp and RPA

NOAA Fisheries' 2008 BiOp recommended a reasonable and prudent alternative (RPA) that NOAA Fisheries concluded was sufficient to avoid jeopardy and adverse modification of critical habitat for thirteen species of salmon or steelhead affected by the FCRPS.[1] NOAA Fisheries' RPA identified performance standards for FCRPS actions to limit or offset adverse effects on the listed species and adverse modification of their critical habitat during its ten year term. The RPA specified particular actions to benefit the species but also determined that it was practical to expect the Action Agencies to adaptively manage the FCRPS program in response to new information and study results, and then to design and implement actions so that their implementation actions will achieve the performance standards by 2018.

The actions being implemented under the 2008 BiOp are focused on improving fish survival at federal dams and throughout the salmon lifecycle, incorporating information from recovery plans to address such limiting factors for these species. It is a large and complicated program that is commensurate with the scale of the FCRPS and its impact on the listed species and critical habitat. It calls for increasing survival rates of fish passing through the dams; managing water to improve fish survival, reducing the numbers of juvenile and adult fish consumed by fish, avian, and marine mammal predators; improving juvenile and adult fish survival by protecting and enhancing tributary and estuary habitat; implementing safety net and conservation hatchery programs to assist recovery; and ensuring that hatchery operations do not impede recovery. All of these actions are supported by a robust and extensive research, monitoring, and evaluation program, which aids in adaptive management and provides accountability for performance standards and biological results.

[1] The 2008 BiOp also documents NOAA's concurrence with the Action Agencies' determination that the operation of the FCRPS is not likely to adversely affect listed distinct population segments (DPS') of green sturgeon and killer whales.

1.2 Adaptive Management Implementation Plan

In 2009, after a review of the 2008 BiOp by the Obama Administration, the Action Agencies proposed, and NOAA Fisheries endorsed, the jointly-developed Adaptive Management Implementation Plan (AMIP) which identified specific measures implementing NOAA Fisheries' 2008 RPA. It enhances and strengthens implementation of activities, research, and contingencies within the RPAs adaptive management provisions. The AMIP called for a more precautionary approach to address uncertainties about the future condition of the affected salmon and steelhead, particularly out of concern for how climate change may affect these species and their habitat. After concluding that reinitiation of consultation was not required, and thus the determinations of the 2008 BiOp remained valid, NOAA Fisheries found that the implementation of the 2008 RPA in the manner called for by the AMIP is biologically and legally sound, based on the best available scientific information, and satisfies the ESA jeopardy standard, that is, the effects of the operation of the FCRPS are neither likely to jeopardize the continued existence of the species (i.e. combined with the effects of the environmental baseline and cumulative effects, the species are expected to survive with an adequate potential for recovery) nor destroy or adversely modify designated critical habitat.

1.3 Litigation

In September 2008 the legal adequacy of NOAA's FCRPS 2008 BiOp was challenged in Federal District Court, NWF v. NMFS, CV 01-640 RE. After a March 2009 hearing, the newly-inaugurated Obama Administration requested the Court's permission for a stay of the legal proceedings in order to review the 2008 BiOp, resulting in the AMIP discussed above. This process entailed approximately five months of scientific review and discussion regarding guidance issued by the Court during the interim and was factually akin to an informal remand. After completion of the Administration's review and submission of the AMIP to the Court, procedural objections were made to the Court's consideration of the AMIP in ruling on the merits of the 2008 BiOp. On February 19, 2010, the Court authorized a three month remand "to allow these Agencies [NOAA, the Bureau of Reclamation and the U.S. Army Corps of Engineers] to consider, among other actions, integrating the Adaptive Management Implementation Plan and its administrative record into the 2008 BiOp." The Court stated that the voluntary, limited, remand was granted without any finding concerning the legal sufficiency of the 2008 BiOp and the Court retained jurisdiction throughout this entire process.

1.4 Supplemental Biological Opinion

During the remand, the Action Agencies formally requested that NOAA Fisheries reinitiate consultation on the 2008 BiOp under the ESA. The objective of this Supplemental Biological Opinion is to reconsider the determinations of the 2008 BiOp pursuant to ESA Section 7(a)(2) for each species or designated critical habitat affected by the FCRPS while integrating the AMIP into the BiOp's RPA. To confirm these determinations NOAA Fisheries is using the best science now available and taking into account the effects of the 2008 RPA and the AMIP as amended by the actions described in this supplemental biological opinion.

At the outset of the remand, NOAA staff, including its Northwest Fisheries Science Center (NWFSC) staff, searched for relevant science that became available since the 2008 BiOp was issued, or which subsequently became relevant for NOAA's analysis. NOAA also requested the northwest states, tribes and the parties to the litigation consider NOAA's initial list of scientific references and identify additional science for NOAA to consider. In addition to submitting scientific information to NOAA, some of the parties also provided new comments or renewed existing criticisms of the 2008 BiOp and AMIP. NOAA further requested the Independent Scientific Advisory Board (ISAB) recommend additional references relevant to this analysis.

In advance of the remand NOAA received several independent assessments of the AMIP regarding its program to address the needs of the listed salmonid species. In addition to reviewing these comments, NOAA referred these assessments to four of the independent scientists who had participated in NOAA's 2009 review of the BiOp which informed the AMIP's development. NOAA requested that they individually comment on the points made in these assessments. NOAA received separate advice from three of these scientists for its consideration. NOAA staff, with input from its Northwest Fisheries Science Center, worked with the Action Agencies to develop appropriate additional analysis and actions in light of the comments and information received.[2]

Finally, to supplement their previous biological assessments, the Action Agencies also identified new technical and scientific information including details about actions called for in the several Fish Accord Memoranda of Understanding for NOAA to consider in this reinitiation. Progress in implementing the 2008 BiOp was also taken into account, including consideration of the 2008 Annual Progress Report and the draft 2010-2013 Implementation Plan.

The remainder of the supplemental biological opinion provides the following sections:

Section 2 reviews the science NOAA determined was relevant for this reinitiation. This section discusses the significance of this scientific information and how it relates to the 2008 BiOp's analysis and conclusions as well as the AMIP.

Section 3 amends the AMIP to include additional implementation actions for specific RPA Actions, integrates, the amended AMIP into the 2008 BiOp's RPA and integrates the 2008 BiOp and its RPA, as amended, into this supplemental biological opinion.

[2] While neither ESA Section 7(a)(2) nor the consultation regulations to require solicitation of public comment in connection with any consultation product, NOAA may do so at its discretion. In this instance, NOAA exercised that discretion, seeking comment as described above and taking into account all of this information while formulating the supplemental biological opinion.

Section 4 reviews NOAA's conclusions about how the entire RPA, including the AMIP, as amended, avoids jeopardizing the listed salmon and steelhead species and avoids destroying or modifying designated critical habitat.

Section 5 provides a revised Incidental Take Statement in light of the supplemented actions.

Section 2 Updating the Scientific Information in the 2008 FCRPS BiOp

This section presents NOAA Fisheries' evaluation of the available scientific and commercial data and the analyses that supplement the information considered for the 2008 BiOp. NOAA Fisheries' regional staff and its Northwest Fisheries Science Center gathered additional information relevant to the 2008 BiOp for this remand. On March 12, 2010, NOAA Fisheries circulated a list of these references to other parties in the NWF v. NMFS litigation and to the Independent Scientific Advisory Board (ISAB). NOAA requested that these Parties identify any additional references that they believed NOAA Fisheries should consider. Additional references were submitted by the ISAB, the NWF plaintiffs, the State of Oregon, and among others. NOAA also sought the advice of several independent scientists which is also considered here where relevant.

NOAA Fisheries reviewed the citations it had collected, including those suggested by the ISAB, the plaintiffs, and other parties, to determine their relevance to effects on Columbia River basin salmon and steelhead. Journal articles, technical reports, and papers from proceedings were considered equally reliable. The most relevant citations were grouped by topic and compared to information described in the 2008 BiOp. After summarizing the new information, NOAA Fisheries determined whether it changed the way the 2008 BiOp considered the effects of the RPA on listed species or their critical habitat or if it changed the discussion of adaptive management actions in the AMIP.

The topics reviewed in each subsection are shown below with the location of the summary of the relevance of the information to the 2008 BiOp analysis and of the AMIP in parentheses.

2.1 Status of the species
- 2.1.1 New abundance estimates and run reconstructions for Interior Columbia salmon and steelhead, both at the species level and for some specific populations (**Page 3**)
- 2.1.2 Status of Lower Columbia and Upper Willamette River salmon and steelhead at the species level (**Page 33)**
- 2.1.3 Adult returns and an investigation of potential inbreeding depression in the captive broodstock program for Snake River sockeye salmon (**Page 34**)
- 2.1.4 Status of the species for Southern Resident Killer Whale DPS (**Page 35**)
- 2.1.5 Status of the species for Southern DPS of North American green sturgeon, particularly with respect to spawners in the Sacramento River (**Page 36**)

2.2 Habitat conditions and ecological interactions affecting salmon and steelhead
- 2.2.1 Climate change and ocean conditions including physical and biological impacts (**Page 37**)

2.2.2 Mainstem conditions including new information on both juvenile and adult survival and delayed mortality (**Page 64**)

2.2.3 Tributary habitat restoration including new information on evaluating and prioritizing projects to achieve survival and other benefits (**Page 81**)

2.2.4 Estuary and plume including new information on juvenile salmonid use of estuarine habitats and on seabird predation at the edge of the plume (**Page 84**)

2.2.5 Predation and other ecological interactions including avian predation (**Page 89**); fish predation (especially northern pikeminnow) and other ecological interactions such as competition from non-native species (**Page 93**); and pinniped predation **(Page 97)**

2.2.6 Other stressors including potential effects of chemical contaminants (**Page 100**) non indigenous invertebrates and plants (**Page 105**); and marine derived nutrients **(Page 109)**

2.3 Hatchery programs and ecological interactions between hatchery- and natural-origin stocks (**Page 115**)

2.4 Harvest rates, unchanged from those in the 2008 analysis except for a decrease for tule LCR Chinook salmon (**Page 124**)

2.5 RM&E including new information on the statistical power of tributary improvement datasets (**Page 126**)

2.6 Habitat conditions and ecological interactions affecting the Southern Resident Killer Whale DPS (**Page 130**)

2.7 Habitat conditions and ecological interactions affecting the Southern DPS of North American green sturgeon in the lower Columbia River, including available information on prey and habitat use (**Page 135**)

2.1 Status of the Species

This section describes key summaries of new information regarding the status of listed Columbia Basin salmon and steelhead (Sections 2.1.1, 2.1.2, and 2.1.3), Southern Resident Killer Whales (Section 2.1.4), and the Southern DPS of North American Green Sturgeon (Section 2.1.5). The listing status of UCR steelhead changed from Endangered to Threatened in June 2009 per a U.S. District Court order that upheld NOAA Fisheries' Hatchery Listing Policy.

2.1.1 New Abundance Estimates and Run Reconstructions for Interior Columbia Salmon and Steelhead

This section summarizes new information regarding the status of interior Columbia River Basin salmon and steelhead with respect to their abundance, productivity and risk of extinction, along with a summary of ongoing analyses and additional information expected prior to the 2013 Comprehensive RPA Evaluation (RPA Action 3). NOAA Fisheries looked at three sources of new information derived from dam counts, spawning surveys, and other sources as described in the following sections.

Section 2.1.1.1.1 describes the species-level (i.e., aggregate of populations for an evolutionarily significant unit (ESU) or distinct population segment (DPS)) abundance and trend information summarized in the Action Agencies' first Annual Progress Report (2009). The data evaluated in this report is primarily based on dam counts. These estimates show that for most species, abundance peaked in the early 2000s, declined in the mid-2000s, and began to increase again around 2008. Aggregate abundance trends from 1990 to the most recent year have been stable or positive for interior Columbia River species.

Section 2.1.1.1.2 describes a NOAA Fisheries report to Congress that also focuses on species-level abundance and trends. This report uses available population-level abundance and trend information from a variety of sources and infers species-level trends from the population-level data. It concludes that all Columbia River basin species were "stable" (no trend) based on the last 10 years of available data, except for Snake River (SR) fall Chinook ("increasing") and SR sockeye salmon ("mixed").

Section 2.1.1.1.3 describes the actual population-level spawner estimates used to generate NOAA Fisheries' report to Congress for interior Columbia Basin species. This information is also used for the analyses in Section 2.1.1.4. Updated adult return estimates are available for 22 of the populations previously considered in the 2008 BiOp analyses, but not for 21 others. For the 22 populations, there are two to five additional years of data available.

Section 2.1.1.2.1 re-calculates the "base period" average abundance, considering corrections to the previous data sets and the addition of new years of data. The updated adult return estimates indicate that the most recent 10-year average abundance is 17-160% higher than the 10-year abundance estimated in the 2008 BiOp for all populations except Wenatchee River Upper Columbia River (UCR) steelhead.[1]

Section 2.1.1.2.1 also re-calculates the base period metrics relevant to the 2008 BiOp for those interior Columbia populations, adding in the two to five new years of spawner estimates. The new "extended base period" estimates include 24-year quasi-extinction risk and three metrics indicative of natural productivity (returns-per-spawner [R/S], median population growth rate [lambda], and the trend of log-transformed natural abundance ["BRT trend"]). The new results indicate:

- Extended base period extinction risk estimates generally decreased or remained unchanged, compared to 2008 BiOp estimates, for most populations of UCR steelhead and for half of the available populations of MCR steelhead. Extinction risk estimates increased for most available populations of SR spring/summer Chinook, the single SR fall Chinook population, and the two available populations of UCR spring Chinook. Confidence limits remain very large for these estimates and all new estimates are within the range of statistical uncertainty reported in the 2008 BiOp.

- For most populations, extended base period estimates of R/S and lambda (assuming hatchery-origin spawners are as effective as natural-origin spawners; "HF=1") decreased compared to the original base period estimates in the 2008 BiOp. Base period estimates changed from R/S equal to or greater than 1.0 to R/S less than 1.0 in the 2008 BiOp for four populations of SR spring/summer Chinook but did not change for other populations. Similarly, base period lambda estimates changed from equal or greater than 1.0 in the 2008 BiOp to less than 1.0 for three SR spring/summer Chinook populations and one MCR steelhead population. All estimates were within the range of statistical uncertainty reported in the 2008 BiOp.

- For most populations, average base period lambda estimates (under the assumption that hatchery-origin spawners are unsuccessful; HF=0) remained unchanged or increased slightly, as with the BRT trend, when an additional 2-5 years of data were added (Appendix C).

- Estimates of BRT trend for the extended base period increased for most populations compared to original base period estimates in the 2008 BiOp. One population changed from a base period estimate in the 2008 BiOp of BRT trend less than 1.0 to an extended base period estimate of greater than 1.0. No populations dropped below 1.0 from 2008 BiOp base period estimates that were greater than 1.0. All estimates were within the range of statistical uncertainty reported in the 2008 BiOp.

[1] The decrease for Wenatchee Chinook is based on a recalculation of hatchery fraction and other factors in the original data set. Once the original 2008 BiOp's estimate is corrected, the addition of new years of adult return estimates also results in increased average abundance for this population.

- Caveats regarding the methods and their interpretation that were described in Chapter 7.1 of the 2008 BiOp also apply to these new estimates (e.g., the assumption that all hatchery supplementation stops immediately, which predicts a degree of short-term demographic risk that is not consistent with the expected continuation of safety-net hatchery programs; the use of a 50-fish quasi-extinction threshold [QET] for all populations, even when lower QET may be reasonable; and the lagging nature of metrics based on completed brood cycles like R/S). The base period results are not influenced by assumptions regarding climate change since these empirical observations reflect the conditions that actually occurred. Section 2.1.1.2 includes additional information suggesting that spring Chinook returns will be above the 10-year average in 2009 and 2010, which is likely to increase productivity for the contributing brood years, and suggesting that 2012 returns from the 2010 out-migration are likely to be lower because of river and ocean conditions.

Changes in base period estimates are relevant to the 2008 BiOp analyses, but the critical quantitative information for the 2008 BiOp's conclusions were the "prospective" estimates that included the effects of RPA implementation and continuing current management actions that were not reflected in the base period population performance. In Section 2.1.1.2, NOAA Fisheries qualitatively evaluated the effect of RPA implementation and other continuing current management actions on the extended base period prospective metrics. Under the "recent" climate assumption, it is likely that the prospective estimate for one and possibly two populations of SR spring/summer Chinook may change from the 2008 BiOp's estimates of less than 5% extinction risk to greater than 5% risk. Under the same assumptions, it is likely that one SR spring/summer Chinook population, one UCR Chinook population, and one UCR steelhead population may change from a prospective estimate of R/S greater than 1.0 in the 2008 BiOp to an estimate less than 1.0. Estimates of lambda (HF=1) for two populations of UCR Chinook are likely to change from greater than 1.0 in the 2008 BiOp to less than 1.0. The BRT trend for one UCR Chinook population is expected to increase from less than 1.0 in the 2008 BiOp to greater than 1.0.

Additional new information, including more complete updating of interior Columbia Basin populations, is expected during the next year as NOAA Fisheries prepares its Five-Year Status Review of listed species. Section 2.1.1.3 includes a preview of new information and analyses that are expected prior to the 2013 Comprehensive Review called for by RPA Action 4.

Section 2.1.1.4 summarizes the previous sections and describes the relevance of the new information on interior Columbia Basin salmon and steelhead, excluding SR sockeye salmon, to the 2008 BiOp and AMIP. This section points out that extended base period point estimates change for some populations with addition of new return data, but that all new base period estimates are within the range anticipated in the BiOp. It also points out that the significance of possible prospective analysis changes relative to biological opinion conclusions cannot be determined without a review of additional quantitative and qualitative information in Sections 2.2 through 2.5 and in Section 3.

2.1.1.1 Species Level Analysis and Data sources

2.1.1.1.1 Endangered Species Act Federal Columbia River Power System 2008 Progress Report. (U.S. Army Corps of Engineers et al. 2009)

This document is the first annual progress report produced per RPA Action 2 of the 2008 BiOp. The "Overview by Species" section displays aggregate population estimates of naturally produced salmon and steelhead in the interior Columbia River basin, based primarily on dam counts. These estimates give a general idea of species trends in abundance for two to five years beyond the data considered in the 2008 BiOp and supporting documents. The data sets are the same as those used to calculate interim "triggers" in Appendix 4 of the AMIP, with the exceptions of data for SR sockeye, which are based on dam counts of returning adults, and MCR steelhead, which used a composite dataset compiled from a number of sources. In general, high adult returns between 2001and 2004 have been followed by lower returns between 2005 and 2007. An upturn in abundance occurred in 2008 for SR spring/summer Chinook, SR steelhead, UCR spring Chinook, and UCR steelhead (Appendix A, Figures 20, 22, 23, and 24). The exception to the above pattern is SR sockeye salmon which in 2008 had the highest adult returns since 1968. Trends of the aggregate populations since 1990 are also displayed in this report and reproduced in Appendix A. Trends for all ESUs are stable or increasing over the time period 1990 through the most recent available year (2007, 2008, or 2009, depending upon species).

2.1.1.1.2 U.S. Dept. of Commerce FY 2009 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 2009. Available data varied by species, but in many cases it included two to four years of additional data beyond the time periods considered in the 2008 BiOp. GPRA performance measures were assessed at the species level using the following method (Ford 2009):

> "The trend for each population within an ESU or DPS for which data were available was calculated using the approach described by Good et al. (2005). Briefly, the trend 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 trends 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 seemed most appropriate."

However, the SR sockeye ESU consists almost entirely of artificially propagated fish and thus this method was not appropriate. Instead, the following method was used:

> Based on counts of sockeye at Lower Granite Dam for the ten years through 2008, the trend would be "stable". 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. We therefore recommend a designation as "mixed".

This report found all Columbia River basin species, including lower Columbia River and Willamette species, "stable," with the exceptions of SR sockeye salmon ("mixed") and SR fall Chinook ("increasing"). The trend for southern resident killer whales was also estimated to be "stable." NOAA Fisheries concluded that trends were likely to remain stable through 2011, based on recent ocean conditions and other indicators. However, due to the historic variability in ocean and climate conditions, and the fact that salmon and steelhead abundance is largely driven by conditions in the ocean, the report concluded that stock status after 2011 was "unknown." A summary of the population trends used in the GPRA report is available online[2].

2.1.1.1.3 Northwest Fisheries Science Center (NWFSC) Salmon Population Summary (SPS) Database

Population-level information from state agencies, tribes, and other sources has been collected into a database maintained by the NWFSC[3]. In most cases, multiple populations make up a listed unit of salmonids, whether an ESU of salmon or DPS of steelhead. Therefore information at the population level informs but does not entirely determine the status of the ESU or DPS. The data includes information sufficient to calculate updated recovery metrics consistent with recommendations of the Interior Technical Recovery Team[4] (ICTRT). The ICTRT's recommended metrics also were included in interior Columbia River basin recovery plans. For populations of six interior Columbia River basin species, the database includes estimates of the natural logarithm of returns-per-spawner (ln(R/S)) for completed brood cycles and also includes information needed to calculate metrics assessed in the 2008 BiOp. Two to four new years of estimates were available for a subset of populations considered in the 2008 BiOp. Additionally, adjustments were made 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 1 and 2.

[2] http://www.nwfsc.noaa.gov/trt/pubs_esu_trend.cfm
[3] https://www.webapps.nwfsc.noaa.gov/sps
[4] http://www.nwfsc.gov/trt/trt_documents/ictrt_viability_criteria_review_draft_2007_complete.pdf

Table 1. New Chinook salmon information in the NWFSC Salmon Population Summary Database that has become available since the 2008 BiOp.

ESU	MPG	Population	Years Included In BiOp	New Spawner Data Available?	Years Included in New Data	Number of Additional Years
Snake River Spring/ Summer Chinook Salmon	Lower Snake	Tucannon	1980-2006	Yes	1980-2008	2
		Asotin - Functionally Extirpated				
	Grande Ronde / Imnaha	Catherine Creek	1980-2005	No		
		Lostine/Wallowa Rivers	1980-2005	No		
		Minam River	1980-2005	No		
		Imnaha River	1980-2005	No		
		Wenaha River	1980-2005	No		
		Upper Grande Ronde	1980-2005	No		
		Big Sheep Creek - Functionally Extirpated				
		Lookingglass- Functionally Extirpated				
	South Fork Salmon	South Fork Salmon Mainstem	1980-2003	No		
		Secesh River	1980-2005	Yes	1980-2008	3
		East Fork S. Fork Salmon (including Johnso	1980-2003	Yes	1980-2007	4
		Little Salmon River (including Rapid R.)	N/A	No		
	Middle Fork Salmon	Big Creek	1980-2004	Yes	1980-2008	4
		Bear Valley/Elk Creek	1980-2003	Yes	1980-2008	5
		Marsh Creek	1980-2003	Yes	1980-2008	5
		Sulphur Creek	1980-2003	Yes	1980-2008	5
		Camas Creek	1980-2004	No		
		Loon Creek	1980-2004	Yes	1980-2008	4
		Chamberlain Creek				
		Lower Middle Fork Salmon (below Ind. Cr.)				
		Upper Middle Fork Salmon (above Ind. Cr.)				
	Upper Salmon	Lemhi River	1980-2003	Yes	1980-2008	5
		Valley Creek	1980-2003	Yes	1980-2008	5
		Yankee Fork	1980-2003	Yes	1980-2008	5
		Upper Salmon River (above Redfish L.)	1980-2005	No		
		North Fork Salmon River				
		Lower Salmon River (below Redfish L.)	1980-2005	Yes	1980-2008	3
		East Fork Salmon River	1980-2005	No		
		Pahsimeroi River	1980-2005	No		
		Panther - Extirpated				
Upper Columbia Spring Chinook	Eastern Cascades	Wenatchee R.	1980-2003	Yes	1980-2008	5
		Methow R.	1980-2003	Yes	1980-2008	5
		Entiat R.	1980-2003	Yes	1980-2008	5
		Okanogan R. (extirpated)				
Snake River Fall Chinook Salmon	Main Stem and Lower Tributaries	Lower Mainstem Fall Chinook 1977-	1977-2004	Yes	1977-2007	3

Table 2. New steelhead information in the NWFSC Salmon Population Summary Database that has become available since the 2008 BiOp.

DPS	MPG	Population	Years Included In BiOp	New Spawner Data Available?	Years Included in New Data	Number of Additional Years
Upper Columbia River Steelhead	Eastern Cascades	Wenatchee (Summer A)	1980-2006	Yes	1980-2009	3
		Methow (Summer A)	1980-2006	Yes	1980-2009	3
		Entiat (Summer A)	1980-2006	Yes	1980-2009	3
		Okanogan (Summer A)	1980-2006	Yes	1980-2009	3
Snake River Steelhead	Average "A-Run" Populations (only 14 years)		1986-2004	No		
	Average "B-Run" Populations (only 13 years)		1986-2004	No		
	Lower Snake	Tucannon (A, but below LGR)	*Avg A*	No		
		Asotin (A)	*Avg A*	No		
	Imnaha River	Imnaha R. (A)	1980-2005	No		
	Grande Ronde	Upper Mainstem (A)	1980-2006	No		
		Lower Mainstem (A)	*Avg A*	No		
		Joseph Cr. (A)	1980-2005	No		
		Wallowa R. (A)	1980-2005	No		
	Clearwater River	Lower Mainstem (A)	*Avg A*	No		
		Lolo Creek (A & B)	*Avg B*	No		
		Lochsa River (B)	*Avg B*	No		
		Selway River (B)	*Avg B*	No		
		South Fork (B)	*Avg B*	No		
		North Fork - (Extirpated)				
	Salmon River	Little Salmon/Rapid (A)	*Avg A*	No		
		Chamberlain Cr. (A)	*Avg A*	No		
		Secesh River (B)	*Avg B*	No		
		South Fork Salmon (B)	*Avg B*	No		
		Panther Creek (A)	*Avg A*	No		
		Lower Middle Fork Tribs (B)	*Avg B*	No		
		Upper Middle Fork Tribs (B)	*Avg B*	No		
		North Fork (A)	*Avg A*	No		
		Lemhi River (A)	*Avg A*	No		
		Pahsimeroi River (A)	*Avg A*	No		
		East Fork Salmon (A)	*Avg A*	No		
		Upper Mainstem (A)	*Avg A*	No		
Mid Columbia Steelhead	Yakima	Upper Yakima	1985-2004	Yes	1985-2009	5
		Naches	1985-2004	Yes	1985-2009	5
		Toppenish	1985-2004	Yes	1985-2009	5
		Satus	1985-2004	Yes	1985-2009	5
	Eastern Cascades	Deschutes W.	1980-2005	No		
		Deschutes E.	N/A	No		
		Klickitat	N/A	No		
		Fifteenmile Cr.	1985-2005	No		
		Rock Cr.	N/A	No		
		White Salmon - Extirpated				
	Umatilla/Walla Walla	Umatilla	1980-2004	No		
		Walla-Walla	N/A	No		
		Touchet				
	John Day	Lower Mainstem	1980-2005	No		
		North Fork	1980-2005	No		
		Upper Mainstem	1980-2005	No		
		Middle Fork	1980-2005	No		
		South Fork	1980-2005	No		

2.1.1.2 Base Period Productivity and Extinction Risk Metrics Re-Calculated From Updated Population Information

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

- 24-year extinction risk
- Average recruits-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 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 were considered indicative of the recovery prong of the jeopardy standard. Each of the metrics provides a complementary but slightly different view of the same underlying population processes. As described in 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. NOAA Fisheries looked at all available tools because the Independent Scientific Advisory Board recommended that policy-makers draw on all available analytical tools in reaching decisions. NOAA Fisheries views the current updated data within the context as set out in the 2008 BiOp.

Productivity estimates in the 2008 BiOp are 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 from approximately 1980-2000. The 2008 BiOp referred to these historical empirical observations as the “base period,” to distinguish them from projections that take into account effects of current and future actions, for which empirical data has not yet been gathered or does not yet exist, and which the 2008 BiOp referred to as “prospective” estimates. The ICTRT (2007) 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 time 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.

The base period metrics reflect average population performance over approximately the 1980 through 2000-2006 period, depending upon data availability for the population and the metric (i.e., R/S is based on brood years, i.e., the first [spawning] year of a completed brood cycle, while the BRT trend is based on adult return years for both completed and incomplete brood cycles). As such, the base period estimates may be influenced by management actions that have changed since the end of the base period, such as construction of surface passage structures at hydropower projects and completed habitat restoration actions. Furthermore, the base period estimates do not fully reflect the effects of management changes that have taken place during the latter portion of the base period, such as reductions in harvest rates, construction of bypasses and changes in operations at hydro projects. Therefore, the 2008 BiOp used a "base-to-current" adjustment to the base period metrics to estimate the prospective effects of these changes and arrive at an assessment of the expected status of a population if current management actions continue into the future. Finally, the 2008 BiOp further adjusted the current status metrics to assess the likely future effects of the management actions contemplated in the RPA (current-to-prospective adjustment) and evaluated sensitivity to alternative ocean climate conditions.

In this section, NOAA Fisheries used the SPS population-level datasets 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. NOAA Fisheries extends the base period from the 2008 analysis by adding the two to five years of additional data to that previously available. NOAA Fisheries then analyzed the data of the extended base period to calculate the base period metrics used in the 2008 BiOp; i.e. abundance, extinction risk, and productivity trends.

Changes in base period estimates are relevant to the 2008 BiOp analyses, but the critical quantitative information for the BiOp's conclusions were the "prospective" estimates that included the effects of RPA implementation and of continuing current management actions that were not reflected in the base period population performance. Consistent with the 2008 BiOp analysis, NOAA Fisheries would apply the effects of the new base period estimates in the prospective analyses by estimating base-to-current and current-to-prospective survival changes and using these survival changes to estimate future extinction risk and productivity following implementation of the RPA. This quantitative prospective analysis cannot be done in this reinitiation because all of the information necessary to do this is not currently available. For example, new estimates of tributary base-to-current adjustment factors would require re-convening the expert panels that made the original estimates. For this reason NOAA Fisheries qualitatively evaluated the effect of the new information on the 2008 BiOp's prospective estimates. In doing so, NOAA Fisheries considered information such as the magnitude of the base period changes and how close the 2008 BiOp's prospective estimates were to metrics indicative of a low risk of extinction and a positive population growth rate in determining if the 2008 BiOp's prospective analyses were likely to change. For R/S, lambda, and the BRT trend, the magnitude of the base period change was most appropriately expressed as a ratio of the extended base period vs. the 2008 BiOp base period estimates, since the productivity estimates are essentially survival rates. However, this approach did not apply to extinction risk estimates because survival gaps were not available for new extinction risk estimates. NOAA Fisheries therefore had to draw inferences from absolute differences in new vs. old extinction risk estimates. The ultimate goal of this evaluation was to determine whether any of the 2008 BiOp's prospective productivity estimates were likely to change from a slope or rate greater than 1.0 (the critical value indicative of increasing population growth) to one less than 1.0 and if any of the 2008 BiOp's prospective extinction risk estimates were likely to change from less than 5% risk (the critical value indicative of "low" extinction risk in the 2000 and 2008 BiOps and in the ICTRT's viability analysis) to greater than 5% risk. Changes in values within the low risk category (e.g. less than 5%) were less important relative to 2008 BiOp conclusions than were shifts from low risk to higher risk categories.

The evaluation of the effects of new information on prospective metrics described above assumes that there have been no significant changes from the 2008 BiOp in other factors, such as climate change, hydrosystem survival, and predation. These factors are each reviewed in subsequent sections of Section 2 and the results are considered in reaching conclusions in Section 4.

2.1.1.2.1 Abundance

Using the new data in SPS to update the extended base period, the most recent 10-year geometric mean abundance estimate has increased for all populations except Wenatchee River UCR steelhead. For the other populations, the proportional increases range from 17-160% (Table 3). While these abundance estimates have increased, they remain less than the ICTRT (2007) abundance thresholds, which are associated with achieving recovery, as in the 2008 BiOp.

The decline in the average abundance estimate for the Wenatchee River UCR steelhead population was a result of new information regarding historical hatchery fractions[5] that changed the 2008 BiOp's base period estimate, rather than a result of a decline during the new years added to the extended base period. The 2008 BiOp base period (1997-2006) estimate of 900 fish (ICTRT 2007) is now 559 fish with the corrected historical data (Table 3). When the three new return years are considered, the new 10-year geometric mean abundance is 795, which is higher than the corrected 2008 BiOp estimate (559), indicating that this population has also been increasing in average abundance.

[5] The hatchery fraction is the proportion of naturally spawning fish of hatchery origin, as opposed to the proportion of naturally-spawning fish of natural origin.

Table 3. Change in the 10-year geometric mean abundance from the time period considered in the 2008 BiOp to the most recent 10-year period.

	10-Year Geometric Mean Abundance of Natural-Origin Spawners							
	ICTRT Threshold Abundance Goal	Most Recent 10-Year Period (BiOp)	Return Years (BiOp)	Biop Time Period, Updated With New Data	Most Recent 10-Year Period	Return Years in Most Recent 10-Year Period	Ratio (New/ BiOp)	Ratio (New/ Updated BiOp)
Snake River S/S Chinook								
Lower Snake MPG								
Tucannon	750	82	1997-2006	82	164	1999-2008	2.00	2.00
Grande Ronde/Imnaha MPG								
No updates								
South Fork Salmon MPG								
Secesh R	750	403	1996-2005	403	662	1999-2008	1.64	1.64
South Fork Salmon East Fork	1000	105	1994-2003	105	150	1998-2007	1.43	1.43
Middle Fork Salmon MPG								
Big Creek	1000	90	1995-2004	90	146	1999-2008	1.62	1.62
Loon Creek	500	51	1995-2004	51	68	1999-2008	1.33	1.33
Sulphur Creek[1]	500	21	1994-2003	21	37	1999-2008	1.76	1.76
Bear Valley Creek	750	182	1994-2003	182	363	1999-2008	1.99	1.99
Marsh Creek[2]	500	42	1994-2003	42	109	1999-2008	2.60	2.60
Upper Salmon MPG								
Lemhi R	2000	79	1994-2003	79	96	1999-2008	1.22	1.22
Lower Mainstem Salmon River	2000	103	1996-2005	103	121	1999-2008	1.17	1.17
Yankee Fork Salmon River	500	13	1994-2003	13	29	1999-2008	2.23	2.23
Valley Creek	500	34	1994-2003	34	79	1999-2008	2.32	2.32
UCR Spring Chinook								
Wenatchee R	2000	222	1994-2003	222	449	1999-2008	2.02	2.02
Entiat R	500	59	1994-2003	59	105	1999-2008	1.78	1.78
Methow R	2000	180	1994-2003	180	307	1999-2008	1.71	1.71
Snake R Fall Chinook	3000	1273	1995-2004	1217	1869	1998-2007	1.47	1.54
UCR Steelhead								
Wenatchee R[3]	1000	900	1997-2006	559	795	2000-2009	0.88	1.42
Entiat R	500	94	1997-2006	79	112	2000-2009	1.19	1.42
Methow R	1000	281	1997-2006	289	468	2000-2009	1.67	1.62
Okanagon R	1000	104	1997-2006	95	147	2000-2009	1.41	1.55
Snake River Steelhead								
No Updates								
Middle Columbia River Steelhead								
Yakima MPG								
Satus Creek	1000	379	1995-2004	379	660	2000-2009	1.74	1.74
Toppenish Creek	500	322	1995-2004	322	599	2000-2009	1.86	1.86
Naches River	1500	472	1995-2004	472	840	2000-2009	1.78	1.78
Upper Yakima River	1500	85	1995-2004	85	151	2000-2009	1.78	1.78
Eastern Cascades MPG								
No Updates								
Umatilla/Walla Walla MPG								
No Updates								
John Day MPG								
No Updates								

[1,2] 1 fish assumed for 1999

[3] BiOp estimate of 900 is from ICTRT (2007), which is higher than estimate from ICTRT data sheets used for other BiOp calculations.

2.1.1.2.2 24-Year Extinction Risk

Using the new data in SPS, Hinrichsen (2010a; Appendix B; Table 3) updated "base period" 24-year extinction risk estimates using the same methods applied in the 2008 BiOp (Hinrichsen 2008 which is Attachment 1 to Appendix B of the 2008 SCA). As noted in the 2008 BiOp (Section 7.1.1.1), the Hinrichsen (2008) method of estimating extinction risk is based upon a Beverton-Holt production function for Chinook and a Ricker production function for steelhead and fall Chinook, as opposed to the ICTRT's (2007) use of a hockey-stick function. When estimates of survival gaps needed to achieve a 5% risk of extinction risk in 100 years were compared, the 2008 BiOp (7-19 and 7-20) notes that the Hinrichsen (2008) model estimated similar or much greater survival gaps than those estimated by the ICTRT (2007) using the hockey-stick function, indicating that this is generally a conservative method.

Extinction risk is determined by a combination of abundance, natural productivity, variability, and serial dependence in the data. Because 10-year average abundance increased for all populations (Section 2.1.1.2.1) but productivity (i.e., R/S) generally declined (Section 2.1.1.2.3), these factors tended to partially cancel each other out. Therefore, changes in extinction risk estimates were relatively small compared to changes in some of the other metrics, with the exception of the Methow River UCR steelhead population. Additionally, the changes varied in direction, with risk increasing for most populations but decreasing or remaining unchanged for several. The extinction risk estimates were based on a quasi-extinction threshold (QET) of 50 fish and an assumption that all hatchery production ceases immediately. These assumptions were conservative for some populations, as evidenced by analyses in the 2008 BiOp Chapters 7.1, 8.6, 8.7 and Appendix B, which showed that the short-term extinction risk is much lower when the more realistic scenario of continuing hatchery supplementation is modeled, and which showed that a QET level of 50 fish may overstate risk for some populations. Uncertainty is high for all estimates, as it was in the 2008 BiOp, with 95% confidence limits extending from near 0 to near 1.0 (100%) for many populations. New estimates are all within the 2008 BiOp's confidence limits indicating that they are within the range of statistical uncertainty described in the BiOp. Details for each species follow.

SR Spring/Summer Chinook 24-Year Extinction Risk:

The base period extinction risk estimates increased for six of the nine populations for which new extinction risk estimates were available. Of the populations with increased base period extinction risk estimates, only the South Fork Salmon East Fork population changed from an estimate of less than 5% base period extinction risk to greater than 5% risk.

The 2008 BiOp's prospective estimates are likely to change for the South Fork Salmon East Fork and the Tucannon River populations. The 2008 BiOp prospective estimates indicated that three populations in this ESU would have less than 5% extinction risk after both partial and complete implementation of the RPA and one population would have less than 5% risk after complete implementation of the RPA. This prospective result is likely to change to greater than 5% prospective extinction risk for two populations, but not the others, as a result of the new data.

- The prospective result for one of these four populations, Bear Valley Creek, would improve because the extended base period extinction risk estimate decreased compared to the 2008 BiOp's base period risk.

- The prospective results are not likely to change for the Secesh population because a significant reduction in productivity (30-40%) was necessary to change the 2008 BiOp's conclusion of less than 5% risk (2008 BiOp Table 8.3.6.1-2) and the magnitude of the R/S reductions due to the new data is much less than that for this population (Table 4) and the change in the base period extinction risk estimate is small (1%).

- The prospective results are likely to change for the South Fork Salmon East Fork population. Significant reductions in productivity (22-32%) were necessary to change the BiOp's conclusion of less than 5% risk (2008 BiOp Table 8.3.6.1-2) and the magnitude of the R/S reductions due to the new data is much less than that for this population (Table 4). However, the change in the base period extinction risk estimate is 9%, suggesting that the 2008 BiOp's estimate of the productivity "cushion" for less than 5% risk would need to be adjusted downward considerably.

- The 2008 BiOp's prospective result for the Tucannon population is likely to change to greater than 5% extinction risk, at least under the assumption of incomplete implementation of the RPA[6]. This is because only a 10% survival reduction was necessary for this change and the new data resulted in an 11% reduction (Table 4).

UCR spring Chinook 24-Year Extinction Risk:

Base period extinction risk estimates increased for both the Entiat and Wenatchee populations with the addition of new data. The Wenatchee base period extinction risk estimate changed from less than 5% risk to greater than 5% risk (8%) while the Entiat remained at greater than 5% base period risk.

The 2008 BiOp's prospective estimates are unlikely to change for these populations. The Wenatchee population had a prospective estimate of less than 5% risk and significant productivity declines (49-58%) would be needed to change that result. The magnitude of the productivity declines resulting from the new data are much lower (Table 4) and this, coupled with the relatively low (6%) change in extinction risk, suggests that the prospective result would not change. The prospective estimate for the Entiat in the 2008 BiOp ranged from below 5% risk under one implementation assumption to above 5% risk under the other implementation assumption. A 26% reduction in productivity would be needed to change the full implementation conclusion. Because the reduction in mean R/S survival for the Entiat population

[6] Extinction risk was evaluated under two assumptions regarding implementation of the RPA in the 2008 BiOp. Under the first, no RPA actions were assumed to be completed and under the second all RPA actions were assumed to be completed. The 2008 BiOp stated that the extinction risk was bounded by these RPA implementation assumptions.

was much lower (Table 4) and the change in base period extinction risk estimate is only 4%, it is likely that the full implementation prospective risk estimate would continue to be less than 5%.

SR Fall Chinook 24-Year Extinction Risk:

Base period extinction risk increased, but remained less than 5%. Therefore, the prospective 24-year extinction risk would be expected to remain less than 5%.

SR Steelhead 24-Year Extinction Risk:

No new data are available so there are no updates to the estimates in the 2008 BiOp. NOAA Fisheries continues to rely upon the data in the 2008 BiOp.

MCR Steelhead 24-Year Extinction Risk:

New data were not available for three major population groups (MPGs). In the Yakima MPG, base period extinction risk declined or was unchanged for two populations and increased for two populations. One population remained below 5% base period risk and three populations remained above 5% risk. Prospective extinction risk was not estimated in the 2008 BiOp because of an inability to calculate steelhead survival gaps with available methods. The Yakima MPG had the highest base and prospective extinction risk in the 2008 BiOp analysis. Nine out of the other 10 populations considered in the 2008 BiOp had a base period extinction risk between 0-39%, indicating that the species as a whole has lower extinction risk than that indicated for the Yakima MPG populations.

UCR Steelhead 24-Year Extinction Risk:

Wenatchee, Entiat, and Okanogan base period extinction risk was unchanged or declined, but remained much greater than 5%. Methow extinction risk doubled, increasing from the previous estimate of 47% to a new estimate of 97%. Most of this change was caused by new information regarding the original base period described in the 2008 BiOp. Recalculation of the 2008 BiOp's base period risk using new information such as updated hatchery fractions changed the extinction risk estimate to 90%. Addition of new years increased this new estimate only 7%. Prospective extinction risk was not estimated for any of these populations in the 2008 BiOp because of an inability to calculate steelhead survival gaps with available methods. The BiOp qualitatively concluded that hatchery production reduced the short-term risk of demographic extinction for these populations and the new information would not change that result.

All MPGs 24-Year Extinction Risk:

The results discussed above pertain to mean estimates and the discussion of prospective implications is based on the Recent climate scenario. As described in the 2008 BiOp, the Warm Pacific Decadal Oscillation (PDO) ocean climate scenario and consideration of the lower confidence limits on the extinction risk estimates would lead to more pessimistic results, while consideration of the Historical climate scenario and the upper confidence limits would lead to an expectation of lower extinction risk.

Table 4. Change in 24-year extinction risk calculated from the 2008 BiOp base period (using updated base period data) to an extended base period with 2-5 years of additional adult returns. NA = model parameters were not obtainable for some populations.

	Extinction Risk - 24 Years at QET=50 (BiOp)	Lower 95% Confidence Interval	Upper 95% Confidence Interval	Extinction Risk - 24 Years at QET=50 (Updated BiOp Base Period)	Extinction Risk - 24 Years at QET=50 (Extended Base Period)	Lower 95% Confidence Interval	Upper 95% Confidence Interval	Absolute Difference In (New - BiOp) Extinction Risk	Absolute Difference In (New - Updated BiOp) Extinction Risk
Snake River S/S Chinook									
Lower Snake MPG									
Tucannon	0.07	0.00	0.71	0.07	0.08	0.00	0.71	0.01	0.01
Grande Ronde/Imnaha MPG									
No updates									
South Fork Salmon MPG									
Secesh R	0.02	0.00	0.42	0.02	0.03	0.00	0.42	0.01	0.01
South Fork Salmon East Fork	0.04	0.00	0.48	0.08	0.13	0.00	0.57	0.09	0.05
Middle Fork Salmon MPG									
Big Creek	0.37	0.00	0.93	0.39	0.37	0.00	0.96	0.00	-0.02
Loon Creek	NA	NA	NA	NA	NA	NA	NA	NA	NA
Sulphur Creek	0.55	0.00	0.92	0.58	0.62	0.00	0.95	0.07	0.04
Bear Valley Creek	0.09	0.00	0.71	0.09	0.06	0.00	0.71	-0.03	-0.03
Marsh Creek	0.56	0.00	0.95	0.52	0.57	0.00	0.95	0.01	0.05
Upper Salmon MPG									
Lemhi R	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lower Mainstem Salmon River	0.37	0.00	0.99	0.34	0.37	0.00	0.99	0.00	0.03
Yankee Fork Salmon River	NA	NA	NA	NA	NA	NA	NA	NA	NA
Valley Creek	0.75	0.07	0.99	0.74	0.76	0.04	0.98	0.01	0.02
UCR Spring Chinook									
Wenatchee R	0.02	0.00	0.82	0.04	0.08	0.00	0.87	0.06	0.04
Entiat R	0.19	0.00	0.82	0.19	0.23	0.00	0.82	0.04	0.04
Methow R	NA	NA	NA	NA	0.18	NA	NA	NA	NA
Snake R Fall Chinook	0.01	0.00	1.00	0.07	0.05	0.00	1.00	0.04	-0.02
UCR Steelhead									
Wenatchee R	0.27	0.00	0.92	0.28	0.24	0.00	0.92	-0.03	-0.04
Entiat R	0.99	0.10	1.00	0.92	0.90	0.37	1.00	-0.09	-0.02
Methow R	0.47	0.02	1.00	0.90	0.97	0.21	1.00	0.50	0.07
Okanagon R	1.00	0.77	1.00	1.00	1.00	0.92	1.00	0.00	0.00
Snake River Steelhead									
No Updates									
Middle Columbia River Steelhead									
Yakima MPG									
Satus Creek	0.00	0.00	0.30	0.00	0.00	0.00	0.36	0.00	0.00
Toppenish Creek	0.79	0.00	0.97	0.78	0.71	0.00	0.99	-0.08	-0.07
Naches River	0.34	0.00	0.87	0.34	0.39	0.00	0.86	0.05	0.05
Upper Yakima River	0.68	0.08	1.00	0.68	0.69	0.06	1.00	0.01	0.01
Eastern Cascades MPG									
No Updates									
Umatilla/Walla Walla MPG									
No Updates									
John Day MPG									
No Updates									

2.1.1.2.3 Productivity: Returns-per-Spawner (R/S)

Average R/S was estimated as described in the 2008 BiOp Chapter 7.1. For most populations, the extended base period mean R/S estimates decreased in comparison with the 2008 BiOp base period when an additional two to five years of data were added (Table 5). For the 25 populations for which updated data are available, four had base period estimates with average R/S greater than 1.0 in the 2008 BiOp that changed to less than 1.0 with the extended base period. Uncertainty is high for all estimates, as it was in the 2008 BiOp. New estimates are all within the 2008 BiOp's confidence limits, indicating that the new results are within the range of statistical uncertainty described in the 2008 BiOp. Details for each species follow.

SR Spring/Summer Chinook Returns-per-Spawner:

Base period estimates of mean R/S declined 3-35% for 11 of 12 populations and remained unchanged for the Valley Creek population in the Upper Salmon MPG (Table 5). There is no new information for the Grande Ronde/Imnaha MPG. Base period average R/S estimates changed from greater than 1.0 to less than 1.0 for the Secesh, Loon Creek, Sulphur Creek, and Lemhi populations.

The 2008 BiOp's prospective estimates are likely to change relative to achieving average R/S greater than 1.0 for the Loon Creek population, but remain unchanged for the other populations. Prospective geometric mean R/S estimates in the 2008 BiOp (Table 8.3.6.1-1) were all above 1.0 for SR spring/summer Chinook populations, ranging from 1.09 to 1.88 under the Recent climate scenario. The decline in base period R/S would likely bring prospective R/S estimates for all populations except Valley Creek closer to 1.0, but most would be unlikely to change to less than 1.0 because the reductions in survival necessary to change this result are much higher than the reductions in productivity resulting from the new data (Table 5). However, the Loon Creek population would be very close to an estimate of 1.0 and, given the need to adjust the base-to-current multipliers in response to the new extended base period, it is likely that prospective estimates for at least the Loon Creek population would fall below 1.0 with that adjustment.

UCR spring Chinook Returns-per-Spawner:

Mean base period R/S estimates decreased 11-21% for all three populations with the addition of new data. All three populations had base period R/S less than 1.0 in the 2008 BiOp analysis and this remains unchanged.

The 2008 BiOp's prospective estimates are likely to change relative to achieving average R/S greater than 1.0 for the Wenatchee UCR spring Chinook population. The prospective geometric mean R/S estimates in the 2008 BiOp (Table 8.6.6.1-1) were all above 1.0 (1.17-1.42) under the Recent climate scenario. The decline in base period R/S would likely bring the Methow and Entiat populations closer to 1.0, but would be unlikely to change to less than 1.0 because the reductions in survival necessary to change this result are higher than the reductions in productivity resulting from the new data (Table 5). However, the Wenatchee population had a relatively low prospective R/S estimate, compared to the extended base period's reduction in productivity, so the prospective R/S estimate for this population would likely be less than 1.0.

SR Fall Chinook Returns-per-Spawner:

The ICTRT (2007) identified two base periods for estimating SR fall Chinook productivity and considered these estimates to bound this species' performance. Mean base period R/S estimates increased 1% for the time period beginning in 1977 and decreased 14% for the time period beginning in 1990 with the addition of new data. One time period resulted in base period R/S less than 1.0 while the other resulted in R/S greater than 1.0 in the 2008 BiOp analysis, and this likely remains unchanged.

The 2008 BiOp's prospective estimates are likely to change relative to achieving average R/S greater than 1.0 for SR fall Chinook. The prospective geometric mean R/S estimates in the 2008 BiOp (Table 8.2.6.1-1) were above 1.0 (1.01-1.47) for both time periods, under both harvest assumptions, given the Recent climate scenario. The prospective results would likely remain above 1.0 with inclusion of new data.

SR Steelhead Returns-per-Spawner:

No new data are available so there are no updates to the estimates in the 2008 BiOp. NOAA Fisheries continues to rely upon the data in the 2008 BiOp.

MCR Steelhead Returns-per-Spawner:

New data were not available for three MPGs. In the Yakima MPG, mean base period R/S increased 2-13% for two populations and decreased 2-18% for two populations. Three populations remained at mean base period R/S equal to, or greater than, 1.0 as in the 2008 BiOp, and one population (Satus Creek) remained with R/S less than 1.0.

The 2008 BiOp's prospective estimates are not likely to change relative to achieving average R/S greater than 1.0 for MCR steelhead. The prospective geometric mean R/S estimates in the 2008 BiOp (Table 8.8.6.1-1) were above 1.0 (1.20-2.02) for all Yakima MPG populations, given the Recent climate scenario. If no other factors changed, the prospective results would likely remain above 1.0 for all four populations with inclusion of new data because, for the two populations with reduced base period R/S, the reductions in survival necessary to change this result are higher than the reductions in productivity resulting from the new data (Table 5).

UCR Steelhead Returns-per-Spawner:

Mean base period R/S decreased 6-29% for the four populations with the addition of new data. All four populations had base period R/S less than 1.0 in the 2008 BiOp analysis and this remains unchanged.

The 2008 BiOp's prospective estimates are likely to change relative to achieving average R/S greater than 1.0 for the Entiat population of UCR steelhead. The prospective geometric mean

R/S estimates in the 2008 BiOp (Table 8.7.6.1-1) were below 1.0 under all assumptions for the Wenatchee, Methow, and Okanogan populations, given the Recent climate scenario. The prospective results would likely remain below 1.0 for these populations with inclusion of new data because the reductions in survival necessary to change this result are higher than the reductions in productivity resulting from the new data (Table 5). The prospective R/S estimates in the 2008 BiOp for the Entiat population ranged from below 1.0 under one hatchery assumption to above 1.0 under another. The prospective R/S results for the Entiat population would likely be below 1.0 for both hatchery assumptions with inclusion of new data because of the magnitude of the reduction in base period R/S.

All MPGs Returns-per-Spawner:

The results discussed above pertain to mean estimates and the discussion of prospective implications is based on the recent climate scenario. As described in the 2008 BiOp, the Warm PDO ocean climate scenario and consideration of the lower confidence limits on the mean R/S estimates would lead to more pessimistic results, while consideration of the Historical climate scenario and the upper confidence limits would lead to an expectation of higher mean R/S.

Table 5. Average returns-per-spawner (R/S) calculated for the 2008 BiOp base period (using original and updated base period data) and calculated for an extended base period with 2-5 years of additional adult returns. The ratio of updated base period: extended base period R/S is shown.

	Mean Base Period R/S (BiOp)	R/S Lower95	R/S Upper95	Mean R/S (Updated BiOp Base Period)	R/S Lower95	R/S Upper95	Mean R/S (Extended Base Period)	Ratio (New/ BiOp)	Ratio (New/ Updated BiOp)
Snake River S/S Chinook									
Lower Snake MPG									
Tucannon	0.72	0.48	1.10	0.72	0.44	1.20	0.64	0.89	0.89
Grande Ronde/Imnaha MPG									
No updates									
South Fork Salmon MPG									
Secesh R	1.19	0.81	1.76	1.19	0.75	1.91	0.97	0.82	0.82
South Fork Salmon East Fork	0.97	0.67	1.41	1.10	0.67	1.78	0.94	0.97	0.85
Middle Fork Salmon MPG									
Big Creek	1.20	0.66	2.19	1.16	0.57	2.37	0.92	0.77	0.79
Loon Creek	1.11	0.54	2.31	1.06	0.45	2.53	0.72	0.65	0.68
Sulphur Creek	0.97	0.45	2.09	0.93	0.37	2.37	0.84	0.87	0.90
Bear Valley Creek	1.35	0.82	2.22	1.34	0.74	2.43	1.07	0.79	0.80
Marsh Creek	0.95	0.52	1.75	0.94	0.45	1.97	0.76	0.80	0.81
Upper Salmon MPG									
Lemhi R	1.08	0.63	1.84	1.08	0.56	2.07	0.85	0.79	0.79
Lower Mainstem Salmon River	1.20	0.75	1.92	1.20	0.68	2.13	1.03	0.86	0.86
Yankee Fork Salmon River	0.61	0.28	1.29	0.61	0.23	1.57	0.58	0.95	0.95
Valley Creek	1.07	0.61	1.87	1.07	0.54	2.12	1.07	1.00	1.00
UCR Spring Chinook									
Wenatchee R	0.75	0.46	1.22	0.68	0.38	1.23	0.60	0.80	0.88
Entiat R	0.72	0.49	1.05	0.72	0.45	1.14	0.65	0.89	0.90
Methow R	0.73	0.42	1.27	0.85	0.41	1.80	0.60	0.83	0.71
Snake R Fall Chinook									
1977-1999	0.81	0.46	1.21	0.91	0.68	1.21	0.82	1.01	0.90
1990-1999	1.24	0.93	1.66	1.47	0.96	2.24	1.07	0.86	0.73
UCR Steelhead									
Wenatchee R	0.35	0.22	0.55	0.33	0.20	0.56	0.33	0.94	1.00
Entiat R	0.52	0.37	0.73	0.43	0.23	0.79	0.39	0.75	0.91
Methow R	0.21	0.15	0.30	0.17	0.12	0.25	0.15	0.71	0.88
Okanagon R	0.08	0.06	0.11	0.07	0.05	0.11	0.07	0.88	1.00
Snake River Steelhead									
No Updates									
Middle Columbia River Steelhead									
Yakima MPG									
Satus Creek	0.86	0.62	1.20	0.86	0.57	1.29	0.97	1.13	1.13
Toppenish Creek	1.46	0.89	2.39	1.46	0.80	2.67	1.19	0.82	0.82
Naches River	1.02	0.69	1.51	1.02	0.63	1.64	1.00	0.98	0.98
Upper Yakima River	1.02	0.69	1.51	1.02	0.63	1.65	1.03	1.01	1.01
Eastern Cascades MPG									
No Updates									
Umatilla/Walla Walla MPG									
No Updates									
John Day MPG									
No Updates									

2.1.1.2.4 Productivity: Median Population Growth Rate (Lambda)

Lambda was estimated by the NWFSC as in the 2008 BiOp Chapter 7.1. Detailed results, including those for both the 1980-present and 1990-present time periods and two assumptions about the effectiveness of hatchery-origin spawners, are included in Appendix C. The most conservative hatchery assumption, that hatchery-origin spawners are as effective as natural-origin spawners (HF=1), which increases the number of total spawners relative to returning progeny, thereby decreasing lambda, is displayed in Table 6. As described in the 2008 BiOp Chapter 7.1, the alternative assumption, that hatchery-origin spawners are completely unsuccessful, yields results that more closely resemble BRT trend results described in the following subsection.

For most populations, average base period lambda (HF=1) estimates decreased when an additional 2-5 years of data were added. This reduction was less than that estimated for mean R/S and the decline tended to be greater for Chinook salmon than for steelhead populations. Uncertainty is high for all estimates, as it was in the 2008 BiOp. New estimates are all within the 2008 BiOp's confidence limits, indicating that the results are within the range of statistical uncertainty described in the 2008 BiOp. Details for each species follow.

SR Spring/Summer Chinook Median Population Growth Rate:

There is no new information for the Grande Ronde/Imnaha MPG. All populations with new estimates in the other four MPGs declined 1-12%. Base period lambda (HF=1) was greater than 1.0 for 9 out of the 10 populations with new data. When the new return years are included, three of the populations with new data (Loon Creek, Lemhi River, and the Lower Mainstem Salmon River) change such that lambda (HF=1) is reduced below 1.0.

The 2008 BiOp's prospective estimates are not likely to change relative to achieving average lambda (HF=1) greater than 1.0 for SR spring/summer Chinook. The prospective lambda (HF=1) estimates in the 2008 BiOp (Table 8.3.6.1-1) were above 1.0 (1.13-1.21) for all of these populations except the Tucannon (0.95) under the Recent climate scenario. If no other factors changed, the decline in base period lambda (HF=1) would likely bring all populations previously above 1.0 closer to that value, but none would be less than 1.0 because the reductions in survival necessary to change this result are higher than the reductions in productivity resulting from the new data (Table 6). The Tucannon population would likely remain below 1.0.

UCR spring Chinook Median Population Growth Rate:

Base period lambda (HF=1) estimates decreased 5-10% for all three populations with the addition of new data. All three populations had base period lambda (HF=1) less than 1.0 in the 2008 BiOp analysis and this remains unchanged.

The 2008 BiOp's prospective estimates are likely to change relative to achieving average lambda (HF=1) greater than 1.0 for Wenatchee and Methow UCR spring Chinook populations. The prospective lambda (HF=1) estimates in the 2008 BiOp (Table 8.6.6.1-1) were all at or above 1.0

(1.00-1.08) under the Recent climate scenario. If no other factors changed, the decline in base period lambda (HF=1) would likely reduce the Wenatchee and Methow populations below 1.0, but the Entiat population would likely remain greater than 1.0.

SR Fall Chinook Median Population Growth Rate:

The base period lambda (HF=1) estimate decreased 4% with the addition of new data to the time period beginning in 1977. Base period lambda (HF=1) was less than 1.0 in the 2008 BiOp analysis, and this remains unchanged.

The 2008 BiOp's prospective estimates are not likely to change relative to achieving average lambda (HF=1) greater than 1.0 for SR fall Chinook. The prospective lambda (HF=1) estimates in the 2008 BiOp (Table 8.2.6.1-1) were above 1.0 under one harvest assumption and below 1.0 under another, given the Recent climate scenario and, if no other factors changed, this general result would likely remain unchanged with the inclusion of new data.

SR Steelhead Median Population Growth Rate:

No new data are available so there are no updates to the estimates in the 2008 BiOp. NOAA Fisheries continues to rely upon the data in the 2008 BiOp.

MCR Steelhead Median Population Growth Rate:

New data were not available for three MPGs. In the Yakima MPG, lambda (HF=1) increased 2% for one populations and decreased 1-5% for three populations. Two populations remained at base period lambda (HF=1) equal or greater than 1.0, as in the 2008 BiOp, and two populations are less than 1.0 with inclusion of the new data (0.98 and 0.99).

The 2008 BiOp's prospective estimates are not likely to change relative to achieving average lambda (HF=1) greater than 1.0 for MCR steelhead. The prospective lambda (HF=1) estimates in the 2008 BiOp (Table 8.8.6.1-1) were above 1.0 (1.20-2.02) for all Yakima MPG populations, given the Recent climate scenario. If no other factors changed, the prospective results would likely remain above 1.0 for all four populations with inclusion of new data because the reductions in survival necessary to change this result are higher than the reductions in productivity resulting from the new data (Table 6).

UCR Steelhead Median Population Growth Rate:

Mean base period lambda (HF=1) decreased 1-2% for the four populations with the addition of new data. All four populations had base period lambda (HF=1) less than 1.0 in the 2008 BiOp analysis and this remains unchanged.

The 2008 BiOp's prospective estimates are not likely to change relative to achieving average lambda (HF=1) greater than 1.0 for UCR steelhead. The prospective lambda (HF=1) estimates in the 2008 BiOp (Table 8.7.6.1-1) were below 1.0 under all assumptions for all four populations, given the Recent climate scenario. The prospective results would likely remain below 1.0 for these populations with inclusion of new data.

All MPGs Median Population Growth Rate:

The results discussed above pertain to median estimates and the discussion of prospective implications is based on the Recent climate scenario. As described in the 2008 BiOp, the Warm PDO ocean climate scenario and consideration of the lower confidence limits on lambda (HF=1) estimates would lead to more pessimistic results, while consideration of the Historical climate scenario and the upper confidence limits would lead to an expectation of higher median population growth rate.

Table 6. Median population growth rate (lambda) with HF=1 calculated for 1980 through the most recent year considered in the 2008 BiOp (using original and updated base period data) and calculated with 2-5 years of additional adult returns. The ratio of lambda estimates for the two periods is displayed.

	Base Period Lambda (Biop)	95% CI	Lambda (Updated BiOp Base Period)	Lambda (Extended Base Period)	95% CI	Pr (Lambda>1)	Ratio (New/ BiOp)	Ratio (New/ Updated BiOp)
Snake River S/S Chinook								
Lower Snake MPG								
Tucannon	0.87	0.63-1.21	0.87	0.86	0.66-1.44	0.11	0.99	0.99
Grande Ronde/Imnaha MPG								
No updates								
South Fork Salmon MPG								
Secesh R	1.06	0.85-1.31	1.07	1.02	0.82-1.27	0.57	0.96	0.95
South Fork Salmon East Fork	1.05	0.87-1.26	NA	NA	NA	NA	NA	NA
Middle Fork Salmon MPG								
Big Creek	1.09	0.78-1.53	1.09	1.01	0.74-1.39	0.55	0.93	0.93
Loon Creek	1.12	0.79-1.58	1.12	0.99	0.67-1.44	0.46	0.88	0.88
Sulphur Creek	1.07	0.68-1.68	1.07	1.03	0.77-1.38	0.61	0.96	0.96
Bear Valley Creek	1.11	0.79-1.55	1.11	1.04	0.80-1.35	0.64	0.94	0.94
Marsh Creek	1.09	0.78-1.52	1.09	1.01	0.77-1.33	0.54	0.93	0.93
Upper Salmon MPG								
Lemhi R	1.03	0.66-1.59	1.03	0.96	0.67-1.35	0.37	0.93	0.93
Lower Mainstem Salmon River	1.03	0.76-1.40	1.04	0.99	0.75-1.31	0.47	0.96	0.96
Yankee Fork Salmon River	1.06	0.67-1.68	NA	NA	NA	NA	NA	NA
Valley Creek	1.07	0.72-1.59	1.07	1.02	0.76-1.38	0.58	0.96	0.96
UCR Spring Chinook								
Wenatchee R	0.91	0.61-1.36	0.90	0.86	0.67-1.11	0.09	0.95	0.96
Entiat R	0.92	0.71-1.21	0.92	0.90	0.73-1.11	0.12	0.98	0.97
Methow R	0.94	0.58-1.53	0.92	0.85	0.60-1.21	0.13	0.90	0.93
Snake R Fall Chinook	0.95	0.80-1.12	0.97	0.91	0.75-1.12	0.14	0.96	0.95
UCR Steelhead								
Wenatchee R	0.80	0.62-1.03	0.80	0.79	0.64-0.98	0.02	0.99	0.99
Entiat R	0.81	0.67-0.97	0.83	0.80	0.66-0.96	0.01	0.98	0.96
Methow R	0.67	0.56-0.81	0.68	0.67	0.57-0.77	0.00	0.99	0.99
Okanagon R	NA	NA	0.56	0.56	0.48-0.66	0.00	NA	1.00
Snake River Steelhead								
No Updates								
Middle Columbia River Steelhead								
Yakima MPG								
Satus Creek	0.96	0.75-1.23	0.95	0.98	0.82-1.17	0.38	1.02	1.03
Toppenish Creek	1.07	0.74-1.55	1.07	1.02	0.78-1.33	0.56	0.95	0.95
Naches River	1.00	0.72-1.39	1.00	0.99	0.80-1.23	0.45	0.99	0.99
Upper Yakima River	1.01	0.74-1.39	1.00	1.00	0.80-1.24	0.48	0.99	1.00
Eastern Cascades MPG								
No Updates								
Umatilla/Walla Walla MPG								
No Updates								
John Day MPG								
No Updates								

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

The BRT trend was estimated by the NWFSC as in the 2008 BiOp Chapter 7.1. Detailed results, including those for both the 1980-present and 1990-present time periods are included in Appendix D. For most populations, average base period BRT trend estimates remained unchanged or increased when an additional two to five years of data were added (Table 7). Abundance trends have improved slightly or remained unchanged for 16 of the 25 populations for which updated data are available and declined for the remainder. Updated abundance trends indicate that most populations are stable or increasing in size. Uncertainty is high for all estimates, as it was in the 2008 BiOp. New estimates are all within the 2008 BiOp's confidence limits, indicating that the results are within the range of statistical uncertainty described in the 2008 BiOp. Details for each species follow.

SR Spring/Summer Chinook BRT Trend:

There is no new information for the Grande Ronde/Imnaha MPG. Four populations with new estimates in the other four MPGs remained unchanged and the remaining seven population trends declined 1-3%. Base period BRT trend was equal to or greater than 1.0 for 9 out of these 11 SR spring/summer Chinook populations in the 2008 BiOp and there was no change in this statistic with the addition of the new data.

The 2008 BiOp's prospective estimates are not likely to change relative to achieving average BRT trend greater than 1.0 for SR spring/summer Chinook. The prospective BRT trend estimates in the 2008 BiOp (Table 8.3.6.1-1) were above 1.0 (1.13-1.21) for all SR spring/summer Chinook populations under the Recent climate scenario. The decline in base period BRT trend would likely bring several populations previously above 1.0 closer to that value, but none would be less than 1.0 because the reductions in survival necessary to change this result are higher than the reductions in productivity resulting from the new data (Table 7).

UCR spring Chinook BRT Trend:

Base period BRT trend estimates increased 3-4% for all three populations with the addition of new data. All three populations had base period BRT trends less than 1.0 in the 2008 BiOp analysis and this remains unchanged.

The 2008 BiOp's prospective estimates are likely to improve relative to achieving average BRT trend greater than 1.0 for the Wenatchee population of UCR spring Chinook. The prospective BRT trend estimates in the 2008 BiOp (Table 8.6.6.1-1) were above 1.0 for the Methow and Entiat populations and below 1.0 for the Wenatchee population under the Recent climate scenario. If no other factors changed, the increase in base period BRT trend would likely result in prospective BRT trend estimates greater than 1.0 for all three populations.

SR Fall Chinook BRT Trend:

The base period BRT trend estimate increased 1% with the addition of new data to the time period beginning in 1977. Base period BRT trend was greater than 1.0 in the 2008 BiOp analysis, and this remains unchanged.

The 2008 BiOp's prospective estimates are not likely to change relative to achieving average BRT trend greater than 1.0 for SR fall Chinook. The prospective BRT trend estimates in the 2008 BiOp (Table 8.2.6.1-1) were above 1.0 given the Recent climate scenario and this result would likely remain unchanged with the inclusion of new data.

SR Steelhead BRT Trend:

No new data are available so there are no updates to the estimates in the 2008 BiOp. NOAA Fisheries continues to rely upon the data in the 2008 BiOp.

MCR Steelhead BRT Trend:

New data were not available for three MPGs. In the Yakima MPG, BRT trend increased 1-3% for three populations and decreased 1% for one population. Three populations had a base period BRT trend greater than 1.0 in the 2008 BiOp, and all four populations have base period BRT trends greater than 1.0 with inclusion of the new data.

The 2008 BiOp's prospective estimates are not likely to change relative to achieving average BRT trend greater than 1.0 for MCR steelhead. The prospective BRT trend estimates in the 2008 BiOp (Table 8.8.6.1-1) were above 1.0 for all Yakima MPG populations (1.35-1.51), given the recent climate scenario. The prospective results would likely remain above 1.0 for all four populations with inclusion of new data.

UCR Steelhead BRT Trend:

Mean base period BRT trend was unchanged for the three populations with BRT trend estimates in the 2008 BiOp with the addition of new data. These three populations had base period BRT trend greater than 1.0 in the 2008 BiOp analysis and this remains unchanged. Additionally, base period BRT trend is now available for the Okanogan population and this is also greater than 1.0.

The 2008 BiOp's prospective estimates are not likely to change relative to achieving average BRT trend greater than 1.0 for UCR steelhead, except for the addition of the Okanogan population. The prospective BRT trend estimates in the 2008 BiOp (Table 8.7.6.1-1) were above 1.0 under all assumptions for the three populations with sufficient information, given the Recent climate scenario. The prospective results would likely remain above 1.0 for these populations with inclusion of new data. Additionally, a prospective estimate for the Okanogan population would now be possible and it also would likely be above 1.0.

All MPGs BRT Trend:

The results discussed above pertain to mean estimates and the discussion of prospective implications is based on the Recent climate scenario. As described in the 2008 BiOp, the Warm PDO ocean climate scenario and consideration of the lower confidence limits on BRT trend estimates would lead to more pessimistic results, while consideration of the Historical climate scenario and the upper confidence limits would lead to an expectation of higher BRT trend.

Table 7. Trend in ln(abundance+1) calculated for 1980 through the most recent year considered in the 2008 BiOp (using original and updated base period data) and calculated with 2-5 years of additional adult returns. The ratio of trends for the two periods is displayed.

	Base Period BRT Trend (Biop)	95% CI	BRT Trend (Updated BiOp Base Period)	BRT trend (Extended Base Period)	95% CI	Pr (Trend >1)	Ratio (New/ BiOp)	Ratio (New/ Updated BiOp)
Snake River S/S Chinook								
Lower Snake MPG								
Tucannon	0.92	0.85-0.99	0.85	0.92	0.84-0.99	0.02	1.00	1.08
Grande Ronde/Imnaha MPG								
No updates								
South Fork Salmon MPG								
Secesh R	1.05	1.01-1.10	1.05	1.04	1.00-1.07	0.98	0.99	0.99
South Fork Salmon East Fork	1.02	0.97-1.08	NA	NA	NA	NA		
Middle Fork Salmon MPG								
Big Creek	1.02	0.94-1.10	1.01	1.01	0.85-1.07	0.63	0.99	1.00
Loon Creek	1.07	0.98-1.16	1.06	1.04	0.97-1.11	0.84	0.97	0.98
Sulphur Creek	1.02	0.94-1.11	1.01	1.02	0.95-1.10	0.69	1.00	1.01
Bear Valley Creek	1.05	0.98-1.13	1.05	1.04	0.99-1.09	0.95	0.99	0.99
Marsh Creek	1.01	0.92-1.10	0.99	1.00	0.93-1.07	0.47	0.99	1.01
Upper Salmon MPG								
Lemhi R	0.98	0.92-1.05	0.98	0.97	0.93-1.01	0.08	0.99	0.99
Lower Mainstem Salmon River	1.00	0.95-1.05	1.00	1.00	0.96-1.04	0.52	1.00	1.00
Yankee Fork Salmon River	1.05	0.96-1.15	1.03	1.03	0.96-1.10	0.80	0.98	1.00
Valley Creek	1.03	0.96-1.11	1.02	1.03	0.97-1.09	0.85	1.00	1.01
UCR Spring Chinook								
Wenatchee R	0.89	0.83-0.95	0.89	0.93	0.89-0.97	0.00	1.04	1.04
Entiat R	0.93	0.89-0.98	0.93	0.96	0.93-1.00	0.01	1.03	1.03
Methow R	0.90	0.80-1.01	0.89	0.93	0.88-0.98	0.01	1.03	1.04
Snake R Fall Chinook	1.09	1.06-1.13	1.10	1.10	1.07-1.14	1.00	1.01	1.00
UCR Steelhead								
Wenatchee R	1.04	1.00-1.11	1.03	1.04	1.01-1.07	0.99	1.00	1.00
Entiat R	1.04	1.01-1.12	1.04	1.04	1.01-1.07	1.00	1.00	1.01
Methow R	1.07	1.03-1.14	1.06	1.07	1.04-1.1	1.00	1.00	1.01
Okanagon R	NA	NA	1.01	1.03	1.01-1.06	0.99	0.99	1.02
Snake River Steelhead								
No Updates								
Middle Columbia River Steelhead								
Yakima MPG								
Satus Creek	0.98	0.93-1.12	0.97	1.01	0.98-1.05	0.74	1.03	1.04
Toppenish Creek	1.09	1.02-1.32	1.08	1.08	1.03-1.12	1.00	0.99	1.00
Naches River	1.02	0.96-1.18	1.01	1.03	1.00-1.07	0.97	1.01	1.03
Upper Yakima River	1.01	0.95-1.17	0.99	1.03	0.99-1.06	0.93	1.02	1.04
Eastern Cascades MPG								
No Updates								
Umatilla/Walla Walla MPG								
No Updates								
John Day MPG								
No Updates								

2.1.1.3 Additional Work in Progress and Schedule for New Analyses

While the new information described in Sections 2.1.1.1.1 and 2.1.1.1.2 is relevant to the 2008 BiOp, additional work is in progress to provide further updates for NOAA's Five-Year Status Reviews and for the planned review of the BiOp in 2013.

- New population-level adult return data are continuously being produced by states, tribes, and other entities and provided to NOAA for inclusion in the SPS database.
- A new Five-Year Status Review, required to update listing decisions under the ESA, will include updated spawner returns and run reconstructions for a more comprehensive range of populations. It is scheduled for completion late in 2010.
- The AMIP adult triggers will be evaluated based on new dam count information in 2010 and each year thereafter. This exercise will collate information that will update the analyses described in Section 2.1.1.1.1.
- The five-year Review specified by RPA Action 4 must be complete by June 2013, which means that analyses will likely begin in early to mid-2012 and use new information available at that time.

2.1.1.4 Overall Relevance to 2008 BiOp Analysis and/or AMIP

Estimates of aggregate population abundance and trend are available for all species, as described in Sections 2.1.1.1.1 and 2.1.1.1.2. The dam count information in Section 2.1.1.1.1 indicates that all interior Columbia Basin species have been stable or increasing in recent years. While the overall trend has been upward, there has been year-to-year variability, including the highest abundance of the period in the early 2000s, lower abundance in the mid-2000s, and increasing abundance again in 2008 for most species. Another species-level analysis, described in Section 2.1.1.1.2, combined population-level information to reach species conclusions that are consistent with those of the aggregate population analysis in Section 2.1.1.1.1. NOAA Fisheries' GPRA Report indicates that most species have been "stable" (no trend) or increasing (SR fall Chinook) during the most recent 10 years available. The exception is SR sockeye salmon, which is "mixed."

The new information in Sections 2.1.1.1.1 and 2.1.1.1.2 does not directly inform the 2008 BiOp's quantitative metrics for interior Columbia River species because the BiOp metrics are based on individual populations, not aggregates, and they take into account not only the past management actions that have influenced recent abundance and trends, but also "prospective" estimates of the effects of implementing the RPA and of continuing current management practices (such as current harvest rates) into the future. However, this new information in Sections 2.1.1.1.1 and 2.1.1.1.2 is important because it shows that at the aggregate population level, species have been stable or increasing over the last decade rather than declining. This suggests that the actions in the RPA, which are expected to improve survival in various life-history stages, should continue to improve the species' status such that they will generally trend upwards when the RPA is implemented, as anticipated in the 2008 BiOp[7]. The information in Sections 2.1.1.1 and 2.1.1.2 is also important because it provides information on abundance and trends for each species, whereas the incomplete population-level information described in subsequent sections does not.

Estimates of adult returns to spawning grounds are available for two to five additional years for a subset of interior Columbia Basin populations that were analyzed quantitatively in the 2008 BiOp. When "base period" estimates in the 2008 BiOp are extended to include this new information for the populations with new data, the following changes are estimated:

- New 10-year geometric mean abundance estimates are 17-160% higher than the abundance estimates considered in the 2008 BiOp for all populations with updated information except the Methow population of UCR spring Chinook (which increased by adding three more years, but decreased because of adjustments to the historical data). The increase for most populations is a result of adding new returns from years of higher abundance in the early and mid-2000s to the 10-year average, while dropping lower abundance years in the early and mid-1990s.
- Extended base period extinction risk estimates generally decreased or remained unchanged, compared to 2008 BiOp estimates, for most populations of UCR steelhead and for half of the available populations of MCR steelhead. Extinction risk estimates increased for most available populations of SR spring/summer Chinook, the single SR fall Chinook population, and the two available populations of UCR spring Chinook.
- Although NOAA Fisheries could not re-calculate prospective extinction risk estimates due to a lack of some critical information, examination of the magnitude of the change in base period extinction risk estimates, coupled with an evaluation of how close the 2008 BiOp's prospective estimates were to the critical value of 5% risk, indicated that the new information would have limited influence on prospective extinction risk estimates. Prospective estimates for only two of the populations with updated data would be likely to change relative to the 5% extinction risk target in the 2008 BiOp. Based on the qualitative methods described above:
    - The Tucannon population of SR spring/summer Chinook (under the assumption that no RPA actions are implemented in time to contribute to reducing 24-year extinction risk) had a prospective estimate of less than 5% extinction risk in the 2008 BiOp that would be likely to change to greater than

[7] Subject to the cautions in the 2008 BiOp Section 7.1.1.2, which states that the estimates in the BiOp analysis represent the initial productivity that would be expected following an instantaneous survival rate change. That initial change in productivity would lead to greater abundance of spawners, which in turn would lead to density-dependent interactions that would reduce the productivity rate over time.

5% risk as a result of the new data. The prospective estimate for Tucannon spring Chinook under the alternative implementation assumption (that all RPA actions are implemented in time to contribute to reducing 24-year extinction risk) is likely to remain less than 5% risk. The change in risk under one implementation conclusion reduces the certainty that short-term extinction risk will be low for this population. However, there is a safety-net program for this population, which will continue under the RPA, reducing the likelihood of short-term extinction.

    - The East Fork population of the South Fork Salmon MPG may also change to greater than 5% prospective risk. If this occurs, two other populations in the MPG are likely to remain at low risk. Additionally, there is a safety-net hatchery program for this population that will continue to reduce the likelihood of short-term extinction.

- Although estimated extinction risk for Methow UCR steelhead nearly doubled, the risk was already high in the 2008 BiOp and that result remains unchanged. Note that, as in the 2008 BiOp, these calculations assume that all hatchery production ceases immediately. This overstates the actual short-term extinction risk, as shown by modeling in the 2008 BiOp Chapter 7.1 and the Aggregate Analysis Appendix.

- For most populations, average base period R/S estimates decreased when an additional 2-5 years of data were added. Based on the qualitative methods described above, a number of populations with prospective estimates of R/S greater than 1.0 in the 2008 BiOp are likely to have prospective estimates closer to 1.0 with inclusion of the new data. Three populations are also likely to have prospective R/S reduced from greater than 1.0 in the 2008 BiOp to less than 1.0 as a result of the new information:

    - The Loon Creek population of SR spring/summer Chinook: Loon Creek and Camas Creek are populations within the Middle Fork MPG that can substitute for each other as a viable population for recovery (2008 BiOp, Table 8.3.6.1-1). Although new data are not available for Camas Creek, it is likely that at least one will continue to have positive population growth. Additionally, all other populations with new data in this ESU continue to have R/S greater than 1.0, indicating that conclusions for the ESU as a whole would be little changed by this result.

    - The Wenatchee population of UCR spring Chinook. The Wenatchee population is important for viability of the UCR Chinook ESU. NOAA Fisheries and the Action Agencies are watching this closely with respect to AMIP triggers and various monitoring protocols.

    - The Entiat population of UCR steelhead: The 2008 BiOp conclusions for this species did not rely on demonstrating that natural productivity would be greater than 1.0 within the term of the BiOp. Legacy hatchery effects reduce natural productivity and will take a long time to be corrected. The conclusions focus on ways the RPA will increase productivity and abundance of natural spawners and how this represents a reasonable approach over the next 10 years. In short, the new data do little to alter the 2008 BiOp conclusions for this species.

- For most populations, average base period lambda estimates (under the assumption that hatchery-origin spawners are as effective as natural-origin spawners; HF=1) decreased when an additional two to five years of data were added. Based on the qualitative methods described above, a number of populations with prospective estimates of lambda (HF=1) greater than 1.0 in the 2008 BiOp are likely to have prospective estimates closer to 1.0 with inclusion of the new data. At least two populations are also likely to have prospective lambda (HF=1) reduced from greater than 1.0 in the 2008 BiOp to less than 1.0 as a result of the new information:
    - The Wenatchee and the Methow populations of UCR spring Chinook: The Wenatchee and Methow populations are important for the viability of this ESU. NOAA Fisheries and the Action Agencies are watching this closely with respect to AMIP triggers and various monitoring protocols.
- For most populations, average base period lambda estimates (under the assumption that hatchery-origin spawners are unsuccessful; HF=0) remained unchanged or increased slightly, as with the BRT trend, when an additional 2-5 years of data were added (Appendix C).
- Base period BRT trend estimates were unchanged or increased slightly for 16 of the 25 populations for which an additional 2-5 years of data were added. The remaining populations declined 1-3%. Updated base period trend estimates for most populations are stable or increasing. Based on the qualitative methods described above, a number of populations with prospective estimates of BRT trend greater than 1.0 in the 2008 BiOp are likely to have prospective estimates closer to 1.0 with inclusion of the new data. However, most populations are likely to remain the same or have prospective estimates even greater than 1.0. No populations are expected to drop from a prospective estimate greater than 1.0 to an estimate less than 1.0 with inclusion of the new data.
    - The Wenatchee UCR Chinook population is expected to increase from a BRT trend less than 1.0 in the 2008 BiOp to a trend greater than 1.0 with inclusion of the new data.

In summary, two to five new years of adult return data for a subset of populations indicates higher average abundance for all but one population and stable or increasing extended base period abundance trends for most populations. Other metrics, including estimates of extended base period natural productivity expressed as R/S and lambda (HF=1) declined with addition of the new adult returns and estimated extinction risk increased for a number of populations. When viewed in terms of potential impacts on the 2008 BiOp's prospective estimates, the UCR spring Chinook ESU, the Middle Fork Salmon MPG of the SR spring/summer Chinook ESU, and the UCR spring Chinook DPS are those most affected by the new data.

Caveats regarding the methods and their interpretation that were described in the 2008 BiOp also apply to these new estimates (e.g., the assumption that all hatchery supplementation stops immediately, which predicts a degree of short-term demographic risk that is not consistent with the expected continuation of safety-net hatchery programs; the use of a 50-fish quasi-extinction threshold [QET] for all populations, even when lower QET may be reasonable; and the lagging nature of metrics based on completed brood cycles like R/S). The base period results are not influenced by assumptions regarding climate change since these empirical observations reflect the conditions that actually occurred; however, the comments on possible prospective estimate changes are based on the "Recent" climate assumption in the 2008 BiOp and would be more pessimistic under the "Warm PDO" assumption and more optimistic under the "Historical" assumption. Note that Section 2.2.1.3.1.5 reviews new climate information indicating that the PDO has been cooler than assumed in either the "Recent" or "Warm PDO" scenario for the last decade.

The updated base-period metrics resulting from addition of the new return years, while resulting in updated point estimates that differ from estimates in the 2008 BiOp for some populations, all are within the range of statistical variation reported in the 2008 BiOp and are consistent with the patterns of returns based on dam counts that were described in both the AMIP and the Action Agencies' 2008 Progress Report. Variations in annual abundance and productivity were anticipated in the 2008 BiOp – in particular, the BiOp in Chapter 7.1 described the expectation that productivity would decline as abundance increased. These variations are expected to continue in the future and to fluctuate both positively and negatively. For example, the dam counts and new population data described in this section indicate high adult returns in the early 2000s, lower returns in the mid-2000s, and an upturn in adult abundance beginning in 2008 for most species. Not reflected in the updated metrics, preliminary data from 2009 indicate above-average returns for some species, and predictions based on ocean conditions (Section 2.2.1) and jack counts lead to an expectation of above average adult returns for some species in 2010 and possibly 2011 These anticipated higher returns represent progeny from the mid-2000 spawning years, which had lower abundance, so they will likely result in increasing productivity estimates for one or more of the mid-2000 brood cycles. This is because, if more naturally-spawning adults return than the adults that produced them, the R/S estimate will be greater than 1.0. However, low river flows and waning El Niño conditions during spring 2010 (Section 2.2.1.3.1.6) are predicted to result in reduced survival of outmigrating juveniles during 2010, which could lead to a downturn in 2012 adult returns and productivity.

As described earlier, inferences about the effect of the new data on the BiOp's prospective estimates made in Section 2.1.1.1.1 assume that only the base period estimates have changed since completion of the BiOp. However, the 2008 BiOp Chapter 7 states that prospective estimation is a three-step process: for each of the 2008 BiOp metrics, NOAA Fisheries first determined what the values had been during the base period. Then, because some management actions had changed over this time period, the metrics were adjusted to reflect "current" management practices. Finally, the metrics were further adjusted to reflect new management actions that were included in the RPA and other Prospective Actions addressed in concurrent biological opinions and to represent a range of expectations regarding future climate and other environmental factors. Sections 2.2 through 2.7 describe new information regarding environmental effects such as climate, new information regarding hydrosystem survival and other RPA actions, and the Amended RPA in Section 3, that need to be taken into account to reach conclusions in Section 4 per these additional steps in estimating prospective performance.

The conclusions in the 2008 BiOp also relied upon more than just the quantitative metric estimates. As described in the 2008 BiOp Chapter 7.1.2, qualitative factors such as the presence of safety-net hatcheries to reduce short-term extinction risk, the degree to which actions address limiting factors and recovery "threats," and sufficiency of monitoring and adaptive management were also important in reaching conclusions in the 2008 BiOp. Additionally, some conclusions (e.g., for UCR steelhead in 2008 BiOp Chapter 8.7.7.1) took into consideration the magnitude of problems that need to be overcome to achieve recovery, such as legacy hatchery issues, the length of time that it is likely to take to fully address those problems, and whether the RPA represented significant improvements that could be reasonably implemented within ten years.

2.1.2 Status Information for Lower Columbia and Upper Willamette Salmon and Steelhead

2.1.2.1 New Information Relevant to 2008 FCPS BiOp and AMIP

In NOAA Fisheries' report to Congress on GPRA performance measures for listed species in the Pacific Northwest, Ford (2009) described the status of lower Columbia Basin (including Upper Willamette) salmon and steelhead as well as those from Interior ESUs/DPSs (see Section 2.1.1.1.1 for discussion of performance measures for Interior species). For four species (Lower Columbia River (LCR) coho salmon, LCR steelhead, Upper Willamette River (UWR) Chinook salmon, and UWR steelhead), no additional data on adult returns were available beyond those used in the 2008 BiOp analyses.

For Columbia River (CR) chum salmon, one additional year of data was available and Ford stated that "trends for the two populations with available data (of 17 historical populations) were both 'stable." NOAA Fisheries therefore categorized the ESU trend as "stable." With respect to spatial structure, between March 25 and April 12, 2010, Fish Passage Center staff recorded 30 chum fry in the fish bypass system at Bonneville Dam (Bellerud 2010), the first reported since 2007 when one fry was observed. This is evidence that there is successful spawning somewhere in the Gorge (or further upstream) [8] although the location and size of the spawning aggregation are unknown.

NOAA Fisheries was able to add two years of data to the productivity estimates for LCR Chinook salmon in its GPRA report and stated that of the 17 populations with trend data (of 32 historical populations), 14 were "stable" and three were "increasing" (Ford 2009). NOAA Fisheries therefore categorized the overall ESU trend as "stable," although noting that there was considerable variability in spawning abundance over the 10-year period. In addition, NOAA Fisheries has been working with the NWFSC, the states, and recovery planners on a new life-cycle modeling effort related to the tule run component of this ESU. The Salmon Life-cycle Modeling (SLAM) analysis focused on eight of the nine tule populations that have been designated for high viability through recovery planning (NWFSC 2010a). The results show that some populations, including the Coweeman, East Fork Lewis, and Washougal, appear likely to be able to sustain harvest at current levels (38%; see Section 2.4) and remain at low risk. Others, including the Clatskanie, Scappoose, and Elochoman populations in the Coastal MPG, appear likely to remain at very high risk even at very low harvest rates. All populations need to improve, but these coastal populations are most problematic.

2.1.2.2 Relevance to 2008 FCRPS BiOp Analysis and AMIP

There is little scientific information on the status of the lower river species more recent than that used in the 2008 BiOp analysis, and none that indicates a change in the status of these species.

2.1.3 Status of Snake River Sockeye Salmon

2.1.3.1 New Information Relevant to 2008 FCPS BiOp and AMIP

Adult sockeye returns to Lower Granite Dam (1,219) were nearly 9.7 times the 10-year average (FPC 2010a). For this ESU, adults that return to spawn are almost entirely produced by the captive broodstock program. The population had already experienced an extreme genetic bottleneck before the program was initiated. Kozfkay et al. (2008) described the mating strategy employed to minimize any further depression due to inbreeding. More recently, scientists at the NWFSC and Montana State University have evaluated the success of the program described by Kozfkay et al. using the broodstock's pedigree history (Waples 2010). Their results show that the current population contains over 90% of the genetic variation of its founders. Thus, the program's efforts appear to have been effective in minimizing additional losses of genetic variation.

2.1.3.2 Relevance to 2008 FCRPS BiOp Analysis and AMIP

The new scientific information supports the statement in the 2008 BiOp that the methods used in this captive broodstock program are maintaining much of the genetic diversity of the founders (p. 8.4-6 in the 2008 BiOp).

[8] Eighty-six chum were counted in the ladders at Bonneville during fall 2009 and seven at The Dalles Dam (FPC 2010 = http://www.fpc.org/adultsalmon/adultqueries/Adult_Annual_Totals_Query_form.html).

The AMIP (p. 32) states that "[t]he Administration does not propose any triggers for Snake River sockeye salmon at this time." The heading of that subsection (Contingency Plan Implementation for Snake River Sockeye Salmon) was intended to convey that the Significant Decline Trigger for this species had already been tripped at the time of listing and that the initiation of the captive broodstock program was the first step in implementing the contingency plan for this species. In their February 2010 comments, Western Division of the American Fisheries Society (WDAFS) expressed concern that it was "inappropriate to not have biological triggers for this species or to rely on a captive broodstock program indefinitely to avoid extinction," showing NOAA that the AMIP was not clear on this point. The RPA, as amended, describes the contingency steps that will be implemented during the term of this BiOp (continuation of the safety net program and further expansion of the program to releases of up to 1 million smolts per year; investigation of the feasibility of transporting adults from Lower Granite Dam to the Sawtooth Valley during late summer when temperatures rise in the lower Salmon River; and investigation of juvenile mortality rates between the Sawtooth Valley and Lower Granite Dam). The next steps to ensuring the survival of the species in the wild will be described in NOAA's recovery plan, due in 2011.

2.1.4 Status of the Species for Southern Resident Killer Whale DPS

2.1.4.1 New Scientific Information Related to the 2008 FCRPS Biological Opinion

Abundance, Productivity and Trends

There were increases in the overall population from 2002-2007 as was reported in the 2008 BiOp, however the population declined in 2008 with 85 individuals counted. Between the 2008 census and the present (i.e., as of February 2010) the population totals 89 individuals including new calves—28 in J pod, 19 in K pod, and 42 in L pod (Center for Whale Research 2010).

Health Status

NOAA Fisheries supports research currently in progress to evaluate the health status of individual Southern Resident killer whales by using photogrammetry to assess size and body condition (Durban et al. 2009) and by measuring fecal hormone levels to assess nutritional stress.

2.1.4.2 Relevance to the 2008 FCRPS Biological Opinion Analysis & RPA

Since the 2007 census (87 whales, reported in the 2008 BiOp) the population size of Southern Resident killer whales has increased by two whales; however, the slight increase does not change the assessment of the status and trends of this small population reported in the 2008 BiOp. Research in progress highlighted above will improve our understanding of the health status of the population and whether and when the Southern Resident DPS may be affected by inadequate prey availability. These ongoing studies will improve our understanding and in the meantime NOAA Fisheries makes conservative assumptions about Southern Resident prey requirements, discussed in more depth in Section 2.6.

2.1.5 Status of the Species for Southern DPS of North American Green Sturgeon

2.1.5.1 New Information Relevant to the 2008 FCRPS BiOp and AMIP

There are no empirical data on population size and trends for green sturgeon in the Southern DPS. Lacking this information, Beamesderfer et al. (2005) attempted to characterize the relative size of the Sacramento-San Joaquin green sturgeon population (Southern DPS) by comparison with the Klamath River population (Northern DPS). Using Klamath River tribal fishery harvest rate data and assuming adults represent 10% of the population at equilibrium, they roughly estimate the Klamath population at 19,000 fish with an annual recruitment of 1,800 age-1 fish. Given the relative abundance of the two stocks in the Columbia River estuary based on genetic samples, they speculate abundance of the Sacramento population may equal, or exceed the Klamath population estimate.

Based on genetic data from juvenile green sturgeon trapped above Red Bluff Diversion Dam (RBDD) on the lower Sacramento River, Israel and May (2010) identified five to 14 families, indicating the presence of ten to 28 adult spawners in this reach. This can only be a small portion of the spawners in the Southern DPS because the gates at RBDD are lowered by May 15th of each year, before most migrating adults have moved that far upstream. Based on tagging data and visual observations of adults in pools further downstream, Woodbury (2010) estimates a total of 1,500 spawners. Assuming that spawners represent 10% of the population, the number of individuals in the Southern DPS would be about 15,000, somewhat smaller than the estimate for the Klamath population.

However, spawners may make up more than 10% of the total population. That estimate was based on observations of subadults and non-spawning adults in coastal estuaries each year, indicating a large pool of potential recruits in the ocean. More recently, tagging studies have shown that individuals move rapidly between estuaries and thus may have been subject to "double counting." Moser and Lindley (2007) stated "the fact that they move quickly over large areas may have contributed to the perception that there is a large marine 'reservoir' of green sturgeon." Thus, the size of the Southern DPS is uncertain.

2.1.5.2 Relevance to the 2008 FCRPS BiOp Analysis and AMIP

Based on recently published tagging and genetic studies, the size of the spawning population in the Sacramento River could be smaller than NOAA assumed in its 2008 analysis. However, the issues of concern in the Columbia River pertain to prey availability and habitat use below Bonneville Dam by subadults and non-spawning adults, which are assumed to be foraging (see Section 2.7).

2.2 Habitat Conditions and Ecological Interactions Affecting Salmon & Steelhead

2.2.1 Climate Change and Ocean Conditions

2.2.1.1 2008 FCRPS BiOp and AMIP Methods:

The primary resource for evaluating effects of climate change on listed species was the ISAB (2007a) review. This was incorporated by reference and summarized in 2008 BiOp Sections 7.1.1, 7.1.2, and 8.1.3, and Section 5.7.3 of the SCA. Other references, particularly regarding El Niño and the Pacific Decadal Oscillation (PDO), and studies incorporating climate change into life-cycle modeling were also included in Sections 5.7.1 and 5.7.2 of the SCA, and Section 7.1.1 of the 2008 BiOp. RPA Actions related to climate change were summarized in 2008 BiOp Section 8.1.3. The AMIP included additional monitoring for climate effects, including development of a model that incorporates the latest climate change information, development of an annual report to review new climate change information relevant to listed species in the Columbia River basin, and enhanced population and habitat monitoring to detect effects of climate change. No additional climate change literature was cited in the AMIP.

2.2.1.2 2010 Voluntary Remand Methods:

As described in the introduction to Section 2, NOAA Fisheries released a list of references it was considering for the 2010 Remand to other parties in the NWF v NMFS litigation and to the ISAB. Citations from this process were included under several topics, with 191 listed under “Climate Change.” In addition, NOAA Fisheries performed a literature search for climate change using two database search engines. The first was CSA Illumina, which searched Aquatic Sciences and Fisheries Abstracts, Oceanic Abstracts, Meteorological and Geoastrophysical Abstracts, Water Resources Abstracts, Conference Papers Index, and BioOne Abstracts and Indexes using the search term “(salmon OR steelhead OR Oncorhynchus) AND (climate OR temperature)” for all fields. A total of 1,020 citations from 2007-2010 were displayed and the titles and some abstracts were reviewed to reduce this list to the 139 documents (including several duplicates) on climate change that appeared most relevant to Columbia River basin salmon and steelhead. When it was noticed that some conservation biology journals were poorly represented in this search, a second search was performed using the ISI Web of Knowledge database search engine and the same search term. The most common journals displayed in the first literature search were excluded. The second search produced 875 documents, some of which were duplicates from the first search. Inspection of titles and abstracts, and in some cases full articles, led to an additional 50 citations that appeared most relevant to climate change impacts on Columbia River basin salmon and steelhead. The initial federal Climate Change Collaboration in the Pacific Northwest (C3) database and recommendations by NOAA Fisheries staff yielded additional citations of potential relevance.

NOAA Fisheries reviewed the collected citations on climate change to determine relevance to effects on listed Columbia River basin salmon and steelhead. New studies that specifically addressed climate observations and projections in the Columbia River basin and the California Current or biological effects of those observations and predictions to listed Columbia River basin salmon and steelhead were considered most relevant to this review. Studies from other regions or studies that focused on other species generally were considered less relevant. However, many of these studies were included in the review because they appeared to be representative of effects that may be experienced by Columbia River basin salmon and steelhead. After summarizing the new information, NOAA Fisheries determined whether it changed the way the 2008 BiOp considered effects of the RPA on listed species or their critical habitat or if it changed the discussion of adaptive management actions in the AMIP.

2.2.1.3 New Information Relevant to the 2008 FCRPS BiOp and AMIP

This section reviews new reports on the potential physical and biological effects of climate change on salmon in the Columbia River. The climate change summary can be found in section 2.2.1.4 and 2.2.1.5. In general this section covers:

- Recent observations and future expectation of physical effects of climate change in the Pacific Northwest (2.2.1.3.1)
- Observations and future expectations of biological effects of climate change in the Pacific Northwest (2.2.1.3.2)
- Effectiveness of climate change mitigation and adaptation actions (2.2.1.3.3)
- Monitoring climate change and species responses (2.2.1.3.4)

2.2.1.3.1 Recent Observations and Future Expectations of Physical Effects of Climate Change in the Pacific Northwest

2.2.1.3.1.1 Global Climate Projections

ISAB (2007a) relied upon global climate information and projections from the Intergovernmental Panel on Climate Change (IPCC 2007). There has not been a subsequent IPCC report with updated global projections.

2.2.1.3.1.2 Air and Stream Temperature

Approach in 2008 FCRPS BiOp and AMIP:

ISAB (2007a) and the 2008 BiOp (Section 7.1.1) noted that average air temperature has risen approximately 1ºC in the last century and is predicted to rise approximately 0.1-0.6ºC per decade. The 2008 BiOp also described Crozier et al. (2008a) estimates of summer stream temperature changes in the interior Columbia River basin, based on downscaled global climate model results.

New Information Relevant to the 2008 FCRPS BiOp and AMIP:

Northern hemisphere anomalies from NASA indicate that average northern hemisphere temperatures went down slightly in 2007-2008 compared to the previous three years, but were still approximately 0.8ºC higher than the 1951-1980 average[9]. Schwartz et al. (in press) found that global temperatures have risen only 40% as quickly as expected over the industrial era, indicating that significant uncertainties remain regarding the rate of future increases. Recent projections for future temperature changes in the Pacific Northwest remain 0.1-0.6ºC per decade (Mote and Salathe 2009) as described in the 2008 BiOp. More than 200 stations have been used to model stream temperature projections by basin for Washington State (Mantua et al. 2009a). Maximum weekly water temperatures are expected to increase generally <1ºC by 2020s, but 2-5ºC by the 2080s, such that >40% of stations (double the current number) in eastern Washington will exceed 21.5ºC, a critical threshold for juveniles, including much of the lower Columbia Basin. Thermal migration barriers in the Columbia, Yakima, and Snake Rivers of temperatures over 21ºC are predicted to increase in duration from 1-5 weeks in the 1980s, to 10-12 weeks by 2080s.

Kaushal et al. (2010) analyzed historical records from 40 sites throughout the US (none in the Columbia Basin) and found that 20 major streams and rivers have shown statistically significant, long-term warming. Annual mean water temperatures increased by 0.009–0.077°C per yr, and rates of warming were most rapid in, but not confined to, urbanizing areas. Long-term increases in stream water temperatures were typically correlated with increases in air temperatures.

2.2.1.3.1.3 Precipitation

ISAB (2007a) indicated an expectation of small changes in total precipitation, indistinguishable from natural variability until the late 21st century, but with more falling as rainfall than snowfall because of increased temperatures. Recent projections continue to indicate a small (+1-2%) expected change in total precipitation in the Pacific Northwest, although some models also predict an enhanced seasonal cycle with wetter autumns and drier summers (Mote and Salathe 2009).

2.2.1.3.1.4 Hydrology (Stream Flow) and Other Freshwater Predictions

Approach in 2008 FCRPS BiOp and AMIP:

ISAB (2007a) and the 2008 SCA (Section 5.7.3) indicated 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. The 2008 SCA also described Crozier et al. (2008a) estimates of late summer stream flow changes in the Salmon River basin, based on downscaled global climate model results.

[9] http://data.giss.nasa.gov/gistemp/tabledata/NH.Ts.txt

New Information Relevant to the 2008 FCRPS BiOp and AMIP:

Several papers have documented declines in snowpack over the 20th century. Stewart (2009) found that globally mid-elevation regions have reduced snowpack due to decreasing snow-to-rain ratios, but higher elevations have increased snowpack due to precipitation increases. Casola et al. (2009) attribute 8-16% of the decline in spring snow-water equivalent in the Cascades to global warming, and project another 11-21% by 2050. However, these projections are statistically indistinguishable from background variation with only 30 years of data. Mote et al. (2008a) found 15-35% declines since mid-century, and argue that a long-term effect of rising temperature is inevitable, but it is not yet possible to quantify exactly how much of the trend is due to anthropogenic effects. Stoelinga et al. (in press) assembled a longer dataset, back to the 1930s, and found that spring snowpack in the Cascades has declined 23%, which is nearly statistically significant. The recent decline since 1948 of 48% is significant, but is due largely to variation in the PDO. Importantly, the residual after correcting for the effect of the PDO, indicates a steady loss of 2%/decade, or 16% since 1930. Most snow (90%) now melts 5 days earlier than in the 1930s, but the trend is not significant. This model predicts that snowpack will decline 11% per degree rise in air temperature. Yarnell et al.(2010) presents a conceptual model of general effects of changes in snowmelt magnitude (mostly abiotic, channel effects) and timing (mostly biotic effects) vs the rate of change in both.

Corresponding changes in streamflow have also been observed. Kalra et al. (2008) found evidence of a step change in streamflow in the Pacific Northwest corresponding with the 1976/1977 regime shift in the PDO. Luce and Holden (2009) found that dry years (i.e., 25% flows) have been getting drier since 1948, although there has been no change in mean or median annual flow. Woo and Thorne (2008) determined that streamflow in the Pacific Northwest is more strongly correlated with decadal shifts (e.g., PDO) than with the long-term climate trend. Dai et al. (2009) found that annual discharge from the Columbia River exhibited a significant decrease in trend over time and claimed that year-to-year variability is related to ENSO-type events, and overall trends are consistent with widespread drying but are not necessarily due to human influence (i.e., water withdrawals). Van Kirk and Naman (2008) compared changes in Klamath base flows caused by climate vs water withdrawals and concluded that water withdrawals had a greater impact.

Predictive modeling of the effects of climate change are consistent in direction. Modeling by Hamlet and Lettenmaier (2007), Mantua et al. (2009a) and Elsner et al. (2009) project more winter flooding in transitional and rainfall-dominated basins, and historically transient runoff watersheds will experience lower late summer flows throughout Washington State. Mantua et al. (2009a) project a steady trend toward an entire loss of snowmelt-dominant basins in Washington State, and predict that only 10 basins will remain as transient between snowmelt and rainfall-dominated basins by 2080. The Columbia and Snake Basins are predicted to remain snowmelt dominant, but shift toward more transitional behavior (Elsner et al. 2009). April 1 snowpack is projected to decrease by 28% in Washington State by the 2020s (Elsner et al. 2009). Mastin (2008) modeled hydrology of the Yakima basin using two estimates of increased future air temperatures. Lee et al. (2009) refined an existing optimization/simulation procedure for rebalancing flood control and refill objectives for the Columbia River Basin for anticipated global warming of 2ºC.

Numerous new analyses of projected changes in stream temperature and flow in the Columbia Basin either are or will soon be available. Detailed models of flow and temperature have been completed for specific salmon studies in small watersheds using the Distributed Hydrology Soil Vegetation Model (e.g., Battin et al. 2007). New analyses apply this model to various sites in the Wenatchee Basin and Salmon River Basin. A large new dataset with historical naturalized and projected future streamflows for the Columbia Basin is now available from the Climate Impacts Group on the Columbia Basin Climate Change Scenarios Project website[10]. This data set applies a new "hybrid delta" downscaling technique, which combines the advantages of the simple delta approach with the statistical controls of the Bias Corrected and Statistical Downscaling approach. A new dataset that models stream temperatures as well as flows throughout the range of Pacific salmon under various climate change scenarios is being prepared by Nate Mantua and colleagues for the Moore Foundation and the National Center for Ecological Analysis and Synthesis (NCEAS).

The Reservoir Management Joint Operating Committee (Bureau of Reclamation, Bonneville Power Administration (BPA), and U. S. Army Corps of Engineers (Corps)), in cooperation with the University of Washington Climate Impacts Group, has been developing climate and hydrology datasets to simulate effects of future climate on mainstem Snake and Columbia River hydrology. This research is scheduled for completion in 2010.

The National Science Foundation is also funding a major initiative for interdisciplinary study of water resources in Idaho, focusing on the Salmon River Basin and Snake River Plain. Research will include extensive hydrological, biological, economic and social modeling.

2.2.1.3.1.5 Pacific Decadal Oscillation (PDO)

Approach in 2008 FCRPS BiOp and AMIP:

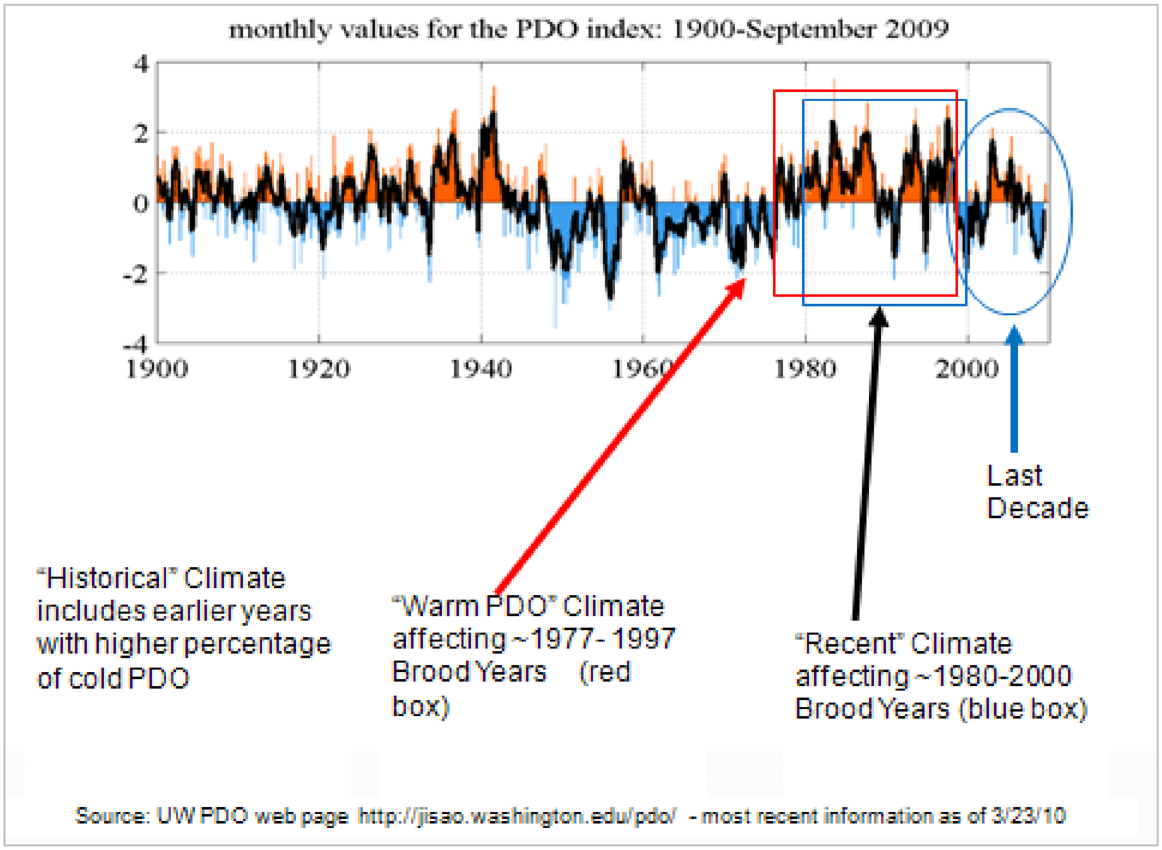
The PDO is a measure of north Pacific sea surface temperature variability, but the index is correlated with both terrestrial and oceanic climate effects. The 2008 SCA included a general discussion of the PDO in Section 5.7.2 and Figure 5.7.1-2 displayed a time series of estimates through Jan 2008. ISAB (2007a) also included a general discussion of PDO observations and stated that future effects of climate change in coastal ecosystems may be "similar or even more severe than those experienced during past periods of...warm PDO." The 2008 BiOp Section 7.1.1 referred to an e-mail from the ISAB chair clarifying that, in referring to general circulation models that predict increased global warming in the future, "We are not referring to regional models for ocean conditions in the Northeast Pacific that predict future conditions (5-10 years from now) such as the frequency and intensity of PDOs and ENSOs and coastal upwelling that

[10] www.hydro.washington.edu/2860/

will affect ocean survival of Columbia River salmonids. We are not aware of any such models." The Interior Columbia River Technical Recovery Team (ICTRT and Zabel 2007) and the 2008 BiOp considered three historical time periods with different average PDOs to reflect a reasonable bound on future climate conditions (see Section 2.2.1.3.2.7 for details).

New Information Relevant to the 2008 FCRPS BiOp and AMIP:

The most recent available information is displayed below. There has been a much larger percentage of cool PDO conditions (i.e., values less than zero in blue shading) during the last decade than occurred in either the "Recent" or "Warm PDO" periods used for modeling future ocean survival in the 2008 BiOp.



2.2.1.3.1.6 El Niño-Southern Oscillation (ENSO)

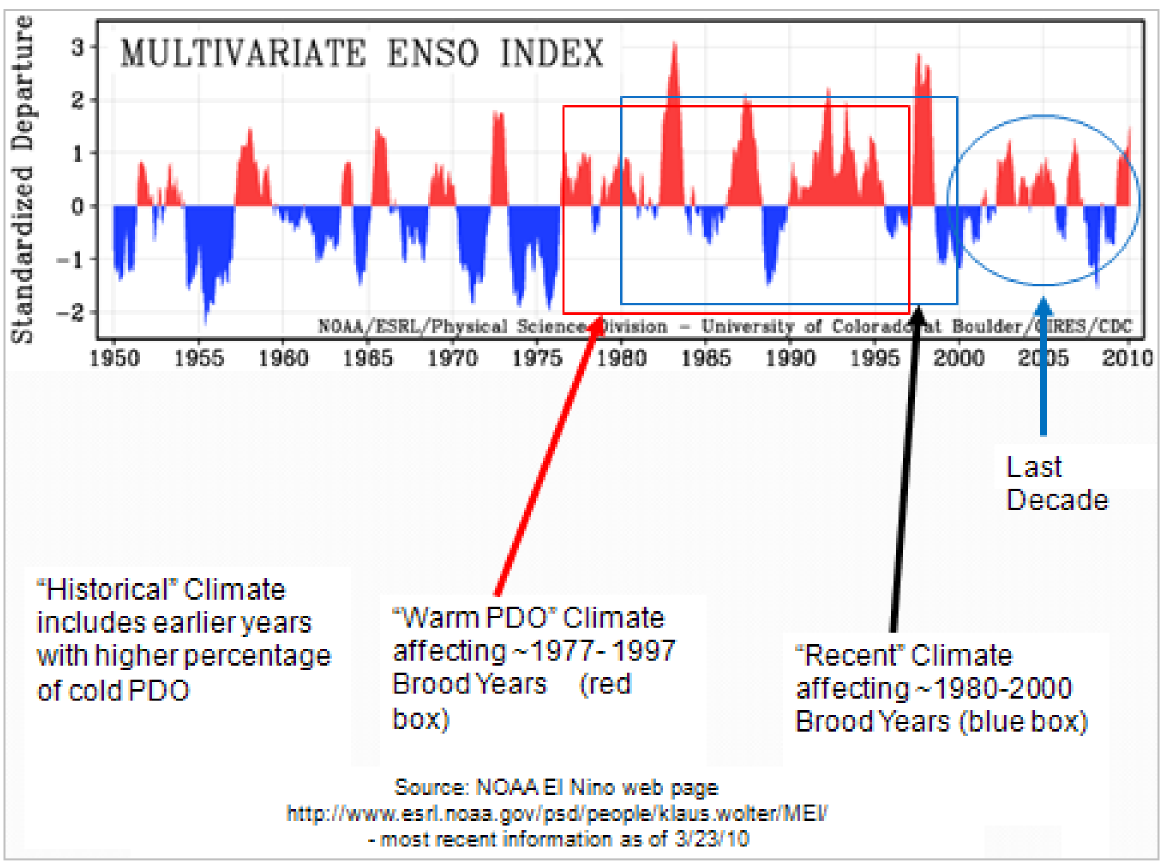
Approach in 2008 FCRPS BiOp and AMIP:

The Multivariate ENSO Index is a measure of differences in atmospheric pressure across the Pacific. El Niño conditions result in warm surface waters in the California Current and affect Pacific Northwest weather patterns. The 2008 SCA included a general discussion of the ENSO Index in Section 5.7.2 and Figure 5.7.1-1 displayed a time series of estimates through November 2007. ISAB (2007a) also included a general discussion of El Niño observations and stated that future effects of climate change in coastal ecosystems may be "similar or even more severe than those experienced during past periods of strong El Niño effects."

<u>New Information Relevant to the 2008 FCRPS BiOp and AMIP:</u>

The most recent available information is displayed below. An El Niño is currently occurring but is dissipating. El Niño conditions weakened during April 2010 and temperature anomalies decreased across the equatorial Pacific. According to NOAA's Climate Prediction Center's May 6, 2010 report, nearly all models predict decreasing sea surface temperature anomalies in the Niño-3.4 region through 2010, with an April-June transition followed by ENSO-neutral conditions through the end of 2010. Nearly a third of model predictions indicate the development of cold La Niña conditions later in the year[11].

El Niño conditions in the past decade (i.e., positive values and red shading in figure) have not been as strong as the El Niños that occurred in either the "Recent" or "Warm PDO" periods used for modeling future ocean survival in the 2008 BiOp. General circulation models still produce conflicting projections regarding whether increasing greenhouse gases will increase, decrease, or have no effect on ENSO patterns. Although none of the models have simulated so-called "tipping-point" behavior in this phenomenon, abrupt shifts in biological responses to incremental changes in ENSO have been observed, and cannot be ruled out (Latif and Keenlyside 2009). Yeh et al. (2009) found that El Niños have shifted in character in the late 20th century, such that Central Pacific El Niños have become more predominant than the classical Eastern Pacific El Niños. Their models predict that this trend will continue with climate change due to flattening of the thermocline.



2.2.1.3.1.7 Alaskan Gyre, North Pacific Gyre Oscillation (NPGO)

Approach in 2008 FCRPS BiOp and AMIP:

ISAB (2007a) generally discussed the effect of Alaskan gyre oscillations on Pacific Northwest salmon survival: strong Aleutian Low winters are favored during warm PDO and El Niño conditions.

New information relevant to the 2008 FCRPS BiOp and AMIP:

DiLorenzo et al. (2008) describe the North Pacific Gyre Oscillation (NPGO) as a climate pattern that emerges as the 2nd dominant mode of sea surface height variability in the Northeast Pacific. The NPGO tracks changes in strength of the central and eastern branches of the North Pacific gyres and of the Kuroshio-Oyashio Extension and is significantly correlated with previously unexplained fluctuations of salinity, nutrients and chlorophyll-a measured in long-term observations in the California Current and Gulf of Alaska. DiLorenzo et al. (2009) evaluated the long-term time series of upper ocean salinity and nutrients collected in the Alaskan Gyre along Line P and found significant decadal variations that are shown to be in phase with variations recorded in the Southern California Current System. The fact that large-amplitude, low-frequency fluctuations in salinity and nutrients are spatially phase-locked and correlated with a measurable climate index (the NPGO) open new avenues for exploring and predicting the effects of long term climate change on marine ecosystem dynamics.

2.2.1.3.1.8 Other Local and Regional Physical Indicators of Salmon Marine Survival in the California Current

Approach in 2008 FCRPS BiOp and AMIP:

ISAB (2007a) and the 2008 SCA (Section 5.7.3) generally discussed the importance of other ocean climate factors, such as coastal upwelling, and their importance to salmon survival and described possible effects of climate change on these factors.

New Information Relevant to the FCRPS BiOp and AMIP:

NOAA Fisheries' Northwest Fisheries Science Center established a web page that summarizes local and regional ocean conditions relevant to survival of listed, stream-type salmon (spring Chinook and coho), including sea surface temperature anomalies, coastal upwelling, timing of the physical spring transition, dissolved oxygen levels, and deep–water temperature and salinity[12]. Peterson et al. 2010 documents this information through 2009. Colder than normal surface temperatures off Oregon, which had been observed for the previous two years, switched to warmer than normal temperatures in the late summer and fall of 2009. Mote and Salathe (2009) estimate that by 2030-2059 Pacific Northwest ocean temperatures are expected to be 1.2C greater than the 1970-99 average. April observations off Oregon indicate that normal sea surface temperatures have returned in northern California current waters[13].

[12] http://www.nwfsc.noaa.gov/research/divisions/fed/oeip/a-ecinhome.cfm
[13] http://coastwatch.pfel.noaa.gov/cgi-bin/elnino.cgi

Checkley and Barth (2009) reviewed forcing mechanisms for the California Current System (CCS), considered variability characteristic of the CCS, and concluded by considering future change. High surface production results in deep and bottom waters depleted in oxygen and enriched in carbon dioxide. Future climate change will differ from past change and thus prediction of the CCS requires an understanding of its dynamics. Of particular concern are changes in winds, stratification, and ocean chemistry.

Peterson et al. 2010 also noted that upwelling anomalies between May-September were generally positive between 2001-2006, but have been negative in 2007-2009. In 2009, this was a result of five makor events during which upwelling relaxed and warm water was transported onshore. Peterson et al. (2010) also noted that the spring transition to upwelling was later than normal in 2008 and 2009, following four years of earlier transitions. An early transition is associated with increased ecosystem productivity.

Rykaczewski and Checkley (2008) discuss mechanisms of upwelling that may be affected by climate change. Two atmospheric conditions induce different types of upwelling in coastal upwelling ecosystems: coastal, alongshore wind stress, resulting in rapid upwelling (with high vertical velocity, w); and wind-stress curl, resulting in slower upwelling (low w). The authors show that the level of wind-stress curl has increased and that production of Pacific sardine (*Sardinops sagax*) varies with wind-stress curl over the past six decades. The extent of isopycnal shoaling, nutricline depth, and chlorophyll concentration in the upper ocean also correlate positively with wind-stress curl.

2.2.1.3.1.9 Sea Level Height

Approach in 2008 FCRPS BiOp and AMIP:

Increasing sea level height was discussed generally in ISAB (2007a) and 2008 SCA (Section 5.7.3). ISAB (2007a) describes a predicted 0.18-0.59 m rise for the world ocean by the end of the 21st century.

<u>New Information Relevant to the 2008 FCRPS BiOp and AMIP:</u>

Mazzotti et al. (2008) found an average 1.8 mm/year rise in sea level height over the 20th century. They predict 20-38cm rises by 2100 at various locations including Seattle, Astoria, and Newport. Abeysirigunawardena and Walker (2008) described an annual average mean sea level trend of a 1.4 mm/yr increase in sea level height observed in British Columbia for the period (1939-2003), as opposed to a lower longer term trend. This suggests that a possible acceleration in sea level rise occurred during the latter half of the twentieth century. Sea level height in coastal areas of Washington state is now expected to be 0.35-0.55m higher by 2050 and 0.88-1.28 m higher by 2100, depending on location (Mote and Salathe 2009; Mote et al. 2008b). Glick et al. (2007) modeled sea level rise at several specific sites in Washington and Oregon using the Sea Level Affecting Marshes Model (SLAMM).

2.2.1.3.1.10 Ocean Acidification

Approach in 2008 FCRPS BiOp and AMIP:

Increasing acidification and decreased carbonate ion availability from the increasing concentration of CO2 dissolved in ocean waters was discussed generally in ISAB (2007a) and the 2008 SCA (Section 5.7.3).

New Information Relevant to the FCRPS BiOp and AMIP:

Since the start of the industrial revolution, the oceans have absorbed about a third of anthropogenic carbon dioxide emissions (Sabine et al. 2004). New information indicates that, globally, ocean pH has dropped about 0.1 due to ocean acidification (reviewed in Feely et al. 2008). Samples from the continental shelf of North America have confirmed this 0.1 pH drop (Feely et al. 2008; Hauri et al. 2009). Ocean acidification also decreases the amount of carbonate ions available to organisms that build calcium carbonate shells. The saturation state for one type of calcium carbonate widely used by marine organisms has decreased 0.5 in the California Current System (Hauri et al. 2009). Ocean acidification is expected to accelerate in the near-term future given continued carbon dioxide emissions (Byrne et al. 2010; Caldeira and Wickett 2003; Doney et al. 2009).

2.2.1.3.2 Recent Observations and Future Expectations of Biological Effects of Climate Change in the Pacific Northwest On Listed Columbia River Basin Salmon and Steelhead

2.2.1.3.2.1 Impacts of Climate Change on Salmon in Columbia Basin Tributaries (Spawning and Egg-to-Emergence Survival)

Approach in 2008 FCRPS BiOp and AMIP:

ISAB (2007a), summarized in the 2008 SCA (Section 5.7.3), noted that increased winter flooding can reduce egg survival, some redds might be dewatered, spawners may change to less productive timing or areas for spawning, there may be earlier fry emergence which may cause lower survival, there may be smaller fry size at emergence, and increased temperatures could cause direct egg mortality or susceptibility to disease.

New Information Relevant to the 2008 FCRPS BiOp and AMIP:

Spawner Distribution:

Geist et al. (2008) determined that chum salmon and fall Chinook spawning distribution below Bonneville Dam is influenced by hyporheic temperatures and gradients. Variability of temperature was increased by load-following (fluctuations in power production). Connor et al. (2003) found that Snake River fall Chinook egg development time was well-predicted by thermal units, and sites outside the current spawning distribution appeared limited by cold temperature. If cold winters are the primary limiting factor for these populations, new sites might become suitable with warmer winters. Angilletta et al. (2008) examined how dams changed thermal regimes on the Willamette, Rogue, and Cowlitz Rivers (cooler summer, warmer fall and winter), and postulated that resultant changes in emergence time could drive evolution in spawn timing. Hanrahan (2008) found that variation in operations at Hells Canyon Dam had minimal impact on hydraulic and temperature gradients between the river and riverbed at nearby Snake River fall Chinook spawning sites.

Spawner Success:
Yates et al. (2008) determined that climate change will exacerbate effects of warm temperatures on poor spawning success in the Sacramento River, but reservoirs such as Shasta provide a cool-water pool through the summer that may help counter this effect.

Methods for Assessing Climate Change:
Groves et al. (2008) found that surface water temperature predicts intra-redd temperatures for salmon embryo developmental timing in the Snake River, facilitating models of development time and potential spawning distribution.

2.2.1.3.2.2 Impacts of Climate Change on Salmon in Columbia Basin Tributaries (Fry-Smolt Rearing)

Approach in 2008 FCRPS BiOp and AMIP:

ISAB (2007a), summarized in the 2008 SCA (Section 5.7.3), noted that reduced flows may impact quality and quantity of rearing habitat, strand fish, or make fish more susceptible to predation. Warmer spring-fall temps may reduce quality and quantity of rearing habitat, cause a reduction in size (hence survival) if habitats are food-limited or an increase in size if habitats are not food-limited, and increase predation rates. In colder high-elevation streams, higher temperatures may be beneficial and result in larger fish. Higher winter temperatures may increase fish size and survival, but may also increase predation rates. Higher winter flows are likely to increase mortality if winter flood refuge habitat is not available.

Crozier et al. (2008a; 7-14, 2008 SCA) predicted an 18-34% decline in parr-smolt survival of SR spring/summer Chinook populations by 2040. This information was not used to adjust quantitative 2008 BiOp metrics because the time period was outside that of 2008 BiOp, there was uncertainty about direct comparison to the 2008 BiOp base condition, and uncertainty about the way to treat partial density-dependent compensation described by Crozier et al. (2008a).

<u>New Information Relevant to the 2008 FCRPS BiOp and AMIP:</u>

Survival:
Geist et al. (2010) described mainstem temperature tolerances of juvenile Snake River fall Chinook, finding high survival over 30 days at constant temperatures up to 22ºC, and moderately high survival (83-88% over 30 days) when daily maximum temperatures reached 27ºC.

Growth:
Crozier et al. (2010) found positive effects of warmer temperatures on parr growth in Salmon River Basin Chinook at low fish densities, but the effect reversed at higher densities. Boughton et al. (2007) found negative effects of warm temperatures on growth in California steelhead in field enclosures, and an interaction with food availability, although in some analyses these

effects were not significant. Rundio and Lindley (2008) found that, unlike many temperate streams where terrestrial inputs provide an alternate prey source when aquatic invertebrate abundance is low, terrestrial inputs to two California streams with Mediterranean climate apparently provide a year-round additional source of prey. The terrestrial prey (like aquatic prey) peaks when water temperature is warmest and hence when fish growth potential is high. Beauchamp (2009) analyzed the bioenergetics of allometric relationships between fish size, temperature, and ration, and found that smaller fish have higher optimal and maximum temperatures for growth relative to larger fish, and that improving food quality (composite energy density) can raise the optimal temperature for growth. Beauchamp concluded that juveniles are more likely to be limited by prey quality and quantity than temperature directly, whereas adults will be more sensitive to temperature change. McCarthy et al. (2009) predicted decreased steelhead growth rate in the Trinity River under three climate scenarios based on bioenergetic analyses.

Behavior:
Spina (2007) showed that California steelhead occupy relatively hot pools and remain active over summer. Apparently thermal refugia cannot be found or are not available.

Disease:
Dionne et al. (2007) found that among Atlantic salmon in eastern Canada along 12º of latitude, allelic diversity within the Major Histocompatibility Complex is correlated with pathogen and bacterial diversity, which in turn is correlated with thermal regimes. Thus warmer temperatures are associated with more diverse and virulent pathogen communities, which in turn has presumably selected for greater immune resistance. Bowden (2008) found that an increase in temperature, salinity, pH, particulates, oxygen and light increases immune function. Kocan et al. (2009) found that swimming stamina was reduced above 15ºC in rainbow trout exposed to ichthyophoniasis infection, and argue that the high migration mortality observed in Yukon River Chinook might be caused by this interaction between disease and high temperature exposure.

2.2.1.3.2.3 Impacts of Climate Changes on Multiple Life Stages in Tributaries

New Information Relevant to the 2008 FCRPS BiOp and AMIP
Nelitz et al. (2009) modeled climate change impacts on potential Chinook habitat in the Cariboo-Chilcotin region of southern British Columbia. They generated climate change scenarios by inputting downscaled temperature and precipitation projections into a hydrological model, and classifying historic and future potential habitat using temperature and flow criteria, as well as other habitat criteria, such as access barriers, channel characteristics, etc. They found that habitat suitability is likely to decrease due to rising temperatures and decreasing flow in the northeastern portion of the study region, but increase in the southern section, where certain areas are currently considered too cold for Chinook. Although the results are site-specific, the methods are relevant to studies in the Columbia Basin.

Some ongoing studies of tributary restoration and recovery potential are also of interest. NWFSC staff (T.Cooney and D. Holzer) are working with R. Carmichael (Oregon Department of Fish and Wildlife) to develop maps of vulnerability to climate change for interior Columbia steelhead populations. Cooney and Holzer have developed relatively simple models to relate summer stream temperatures in steelhead rearing habitats to projections based on the general climate change models. Carmichael has adapted available regional assessments of stream flow characteristics to incorporate into the assessment. The combined analyses will be used to identify sensitivity of recovery strategies to current climate model projections, highlight watersheds within each population that are particularly vulnerable, and compare these with recovery strategies.

Christine Petersen with the Moore Foundation/ NCEAS workgroup is working on population viability analyses of the Wenatchee Basin and the Grande Ronde Basin, identifying critical life history stages threatened by climate change. Preliminary results suggest that for Wenatchee Basin Chinook, mainstem Columbia summer temperatures are likely to have negative impacts on summer runs, although probably not in the next 25 years, whereas spawning habitat is more likely to constrain some spring Chinook populations. For Grande Ronde populations, thermally suitable summer holding areas may already be limiting population recovery, and this constraint will intensify with warmer temperatures.

Tributary Habitat Effects:

Dunham et al. (2007) showed that physical stream habitats can remain altered (for example, increased temperature) for many years following wildfire, which is predicted to increase with climate change, but native aquatic vertebrates can be resilient. Pollock et al. (2009) showed that stream temperatures are significantly correlated with the percent of harvest in watersheds.

Thermal Refugia for Multiple Life Stages:

Reid (2007) described thermal refugia for adult spring Chinook and juvenile Chinook and steelhead in the Rogue River. Refugia were approximately 2° C cooler than adjacent areas and current levels of motor boat activity had minor effects on water temperature, fish behavior, and fish metabolism.

Effects of Temperature on Population Distribution:

Lindley et al. (2007) used results of downscaled global climate models, linked to a regional hydrologic model, to predict that the forecast rise in summer stream temperatures may allow spring-run Chinook salmon to persist in some California streams, but make other areas unsuitable. At the upper end of predictions, very little spring-run Chinook habitat is expected to remain suitable.

2.2.1.3.2.4 Impacts of Climate Change on Mainstem Juvenile Migrations and Mainstem Spawning

Approach in 2008 FCRPS BiOp and AMIP:

ISAB (2007a), summarized in the 2008 SCA (Section 5.7.3), noted that fall Chinook and chum salmon will have similar egg-fry effects in the mainstem as described above for warmer, low-elevation, streams. Yearling smolts may reach the estuary earlier because of high spring flows and warm temperatures and there may be mismatch with ocean conditions and predators. Higher temperatures may cause earlier migration (which could be an advantage or disadvantage), may cause higher predation rates, and may cause higher mortality of reservoir-type SR fall Chinook. Warm temperatures may favor food competitors of juvenile fall Chinook, such as American shad. Higher temperatures also stress fish so that they are more susceptible to disease and infection from pathogens. Reduced flow in the late spring and summer may lead to delayed migration of fall Chinook smolts, higher predation in dam forebays, and changes in vertical distribution that could lead to reduced dam passage survival.

New Information Relevant to the 2008 FCRPS BiOp and AMIP:

Genetics and Life History Strategy:
Williams et al. (2008) document a potential evolutionary adaptation to the altered thermal regime and reservoirs created by Snake River dams. Currently, nearly half of returning SR fall Chinook adults employed a yearling juvenile residence pattern, which differs from dominant historical pattern of subyearling migration. Models indicate that this shift is due to thermal changes caused by dams.

Juvenile Migration Timing and Triggers:
Achord et al. (2007) found earlier smolting of SR Chinook in warmer years. Sykes et al. (2009) found similar patterns among Chinook from Central British Columbia. Sykes and Shrimpton (2010) clarified experimentally that temperature and photoperiod trigger smolting.

Juvenile Migration Survival:
Zabel et al. (2008) found lower migration survival at temperatures over 13ºC for both Chinook and steelhead, in addition to flow effects.

2.2.1.3.2.5 Impacts of Climate Change on Mainstem Adult Migrations

Approach in 2008 FCRPS BiOp and AMIP:

ISAB (2007a), summarized in the 2008 SCA (Section 5.7.3), noted that higher temperatures may increase mortality or reduce spawning success through direct mortality at lethal temperatures, delayed migration or delay entering fish ladders, increased fallback past dams, and loss of energy reserves because of increased metabolism. Higher temperatures may also cause higher mortality or reduced spawning success due to susceptibility to disease and pathogens.

New Information Relevant to the 2008 FCRPS BiOp and AMIP:

Adult Migration Survival:
Keefer et al. (2008a) and Fryer (2007, 2008, 2009) found that late-migrating Columbia sockeye are less likely to survive migration than early-migrating fish due most likely to high river temperatures. Mann (2007) found low migration success in Chinook exposed to the highest temperatures (sometimes >23ºC). Keefer et al. (2009) show that steelhead that migrate during high temperature periods are 8% less likely to successfully home to natal tributaries, but suggest it is likely due to high harvest in thermal refugia in the lower Columbia River tributaries, rather than direct exposure to high temperatures. The latest migrants are more likely to overwinter in the hydrosystem (Keefer et al. 2008b), where they have higher survival than in tributaries. The timing and location of harvest thus has a very strong impact on the utility of thermal refugia.

Clabough et al. (2008) quantified the actual temperatures experienced by salmon and steelhead at Columbia and Snake River dams and found that summer and fall Chinook and steelhead frequently encounter stressful temperatures (>20ºC). Wood et al. (2008) analyzed the evolutionary history of major sockeye ecotypes, arguing that climate change likely will put the anadromous types at greatest risk because of increased river temperatures experienced during migration.

Mann et al. (2008) described the influence of sublethal temperatures on spawning success. SR fall Chinook and SR steelhead exposed to the highest temperatures during migration had the lowest embryo viability. There is evidence, however, that adult Chinook and steelhead use cooler water within the Lower Granite Reservoir that comes from releases from Dworshak to lower their body temperatures (Clabough et al. 2006)

Physiological Effects of High Temperatures on Adult Migration:

Recent studies have elucidated mechanisms by which high temperature lowers survival of adult salmonids. Farrell et al. (2008) and Farrell (2009) show aerobic scope varies among populations as a function of migration temperature, with unusually high temperatures for a given population resulting in collapse of aerobic scope. A model of aerobic scope vs. temperature successfully predicts the collapse of Fraser sockeye in 2004. Crossin et al. (2008) and Steinhausen et al. (2008) conducted physiological studies to elucidate mechanisms of high adult mortality during high temperature events in Fraser River sockeye salmon.

Timing of Adult Migrations:

Keefer et al. (2008c) found that different Chinook salmon populations in the Columbia River migrate in a consistent order each year. Annual variation in timing reflects earlier migration in years of low flow or high temperature, with secondary effects of ocean conditions, as characterized by the PDO and North Pacific Index. Quinn et al. (2007a) described a shift to earlier adult sockeye migration in Alaska that was correlated with fishing pressure selection, not temperature. Crozier et al. (2008b and in prep) show advancing migration timing in Columbia River Basin spring/summer Chinook and sockeye salmon, and later migration in fall Chinook, consistent with adaptation to avoid high temperatures. Using genetic data on fitness, Ford and Ellis (2006) showed selection for an earlier optimum migration timing compared with the historical timing in a coastal population of coho. However, this population is currently migrating earlier than the optimum due to hatchery selection.

Prespawn mortality:

Quinn et al. (2007b) showed that pre-spawning mortality in some Alaskan sockeye salmon populations correlated with both density and warm temperature (average August daily maximum up to 20.6ºC) in holding habitat. Keefer et al. (in press) found that Chinook transported to potential spawning habitat above dams in the Willamette River basin had much higher prespawn mortality (up to 93%) when released during higher temperature periods (mean July and August temperatures at some locations exceeded 22ºC). Mann (2007) observed a correlation between pre-spawn mortality and daily temperature fluctuations in summer Chinook that spawn in the South Fork of the Salmon River Basin in 2003.

2.2.1.3.2.6 Impacts of Climate Change on Estuary Migration and Rearing

Approach in 2008 FCRPS BiOp and AMIP:

ISAB (2007a), summarized in the 2008 SCA (Section 5.7.3), noted that there may be physiological effects of warmer waters in shallow estuary habitats, including changes in growth, disease susceptibility, direct lethal or sublethal effects. Arrival and residence time of adults and juveniles may be altered, predator community structure may change, there may be reduced shallow habitat in spring and increased habitat in fall/winter, and a possible decrease in upriver detritus input to the estuary food chain. Sea level height increase and storm surges could change effectiveness of restoration actions such as dike breaching and culvert placements.

New Information Relevant to the 2008 FCRPS BiOp and AMIP:

The Estuary chapter describes new information about the Columbia River estuary. Although most of the studies do not directly address climate change the new information about fish behavior, habitat use and survival have implications relative to climate change factors such as sea level height. Additionally, that section reviews information regarding effectiveness of mitigation actions and concludes that reconnecting shallow water estuarine habitat to cold water refugia is expected to protect juveniles against expected impacts of climate change.

2.2.1.3.2.7 Impacts of Climate Change on Survival in the Oceans

Approach in 2008 FCRPS BiOp and AMIP:

ISAB (2007a), summarized in the 2008 SCA (Section 5.7.3), noted that if the regional impacts of global warming are expressed in El Niño-like and warm PDO-like ways, there is likely to be decreased production of salmon in the Pacific Northwest. Warming increases stratification which results in decreased primary production and abundance of zooplankton. Peak upwelling may be delayed, causing a mismatch with timing of salmon ocean entry. O_2 content of upwelled waters may decline, reducing productivity. Global warming may change coastal wind patterns, resulting in hypoxic areas on the Oregon and Washington shelf that affect salmon prey. Ocean acidification may reduce some types of salmon prey. Ocean warming may change migration patterns, increasing migration distances to feeding areas. Higher temperatures may increase metabolism, reducing growth if food is limited and possibly changing maturation rates.
The 2008 BiOp also described the ICTRT's simulation of ocean survival under three possible future climate conditions for recovery planning purposes (ICTRT 2007; ICTRT and Zabel 2007). The three future scenarios represented ocean conditions experienced by 1978-1999 complete brood cycles ["recent"; also representing 1980-2001 outmigration years], 1975-1997 brood years ["warm PDO"], and approximately 1937-1997 brood years ["historical"; first year varies by availability of specific index data]. The 2008 BiOp explicitly modeled these future climate scenarios and the results were considered in the 2008 BiOp. The "warm PDO" assumption reduced survival by 2-12%, compared to the "recent" assumption, depending upon species. The "historical" assumption increased survival by 11-44%.

New Information Relevant to the 2008 FCRPS BiOp and AMIP:

Effects of juvenile migration conditions on ocean survival:

Scheuerell et al. (2009) studied predictors of smolt to adult return rate as a function of juvenile migration conditions and timing, finding that generally early arrival at Bonneville Dam and cooler river temperatures were better for marine survival, but the optimal arrival date varied by year. Ongoing studies are working to tease apart potential mechanisms driving the day and year effects.

Forecasts of Marine Survival:

The NWFSC's webpage[14] summarizes local and regional ocean conditions (Section 2.2.1.3.1.8) and biological factors indicative of marine salmon survival. Peterson et al. (2010) documents this information through 2009 and includes predictions for coho and Chinook salmon. Local and regional biological information affecting salmon survival includes copepod biodiversity, the prevalence of highly nutritious copepod species vs. less nutritious warm-water species, indices of the prey community and the biological spring transition to the summer copepod community and catches of yearling Chinook and coho salmon in ocean surveys. The combination of physical and biological indicators in 2008 were the highest of the 12 years surveyed, indicating high ocean survival of juvenile Chinook that entered the ocean that year and which will mainly return to spawn in 2010. Ocean conditions in 2009 were the 6th best of the 12 years surveyed, suggesting intermediate returns in 2011.

Marine migration behavior and survival:

Weitkamp (2010) noted that Chinook ocean migration patterns appear very stable between years despite wide variation in ocean conditions. Teo et al. (2009), contrary to other studies, did not find an inverse survival relationship between Alaska and California Current hatchery coho salmon. Chittenden et al. (2009) reviewed current knowledge on the relationship between climate and salmon, and emphasize the importance of modern technology, especially acoustic and physiological and environmental monitoring tags for improving our understanding of the effects of environmental change on salmon survival and behavior.

Marine Growth:

Wells et al. (2007, 2008) found that growth during ocean residence of a northern California Chinook population was negatively correlated with summer sea surface temperature and other factors indicative of a strong and productive California Current. Growth of Alaska Chinook populations was positively correlated with winter sea surface temperature and other factors indicative of a strong and productive Alaska Current. Puget Sound Chinook grew best in conditions in which the transition zone was dominated by neither the Alaska Current nor California Current.

Ocean Acidification:

Understanding the impact of ocean acidification on marine organisms is still in its infancy. At least one study that has tested the response of a salmonid, *Salmo salar*, to ocean acidification (Fivelstad et al. 1998). In this study, post-smolts exposed to pH of 7.0 for 41 days did not differ

[14] http://www.nwfsc.noaa.gov/research/divisions/fed/oeip/a-ecinhome.cfm

from the control group in their mortality, growth, condition, metabolism, or plasma pH, hematocrit, sodium, or chloride. Work on another fish species has found that ocean acidification impairs olfactory ability (Dixson et al. 2010; Munday et al. 2009). Should this olfactory impairment occur in salmon, it could impact their ability to home to their natal river networks and avoid swimming predators. Ocean acidification is likely to impact salmon via trophic interactions. Experimental work has shown that many invertebrate species on which salmon prey (e.g., pteropods, euphausiids, copepods) suffer direct effects of ocean acidification on development, calcification, and mortality (Comeau et al. 2009; Dupont and Thorndyke 2009; Kurihara 2008; Kurihara et al. 2004a; Kurihara et al. 2004b; Mayor et al. 2007; Nicol 2008; Orr et al. 2005). Brodeur et al. (2007) noted that pteropods and copepods were important prey of juvenile coho salmon in the northern California current during weak upwelling or El Niño years.

Patterns in Plankton:

Coyle et al. (2008) argue that if climate on the Bering Sea shelf continues to warm, the zooplankton community may shift from large to small taxa which could strongly impact apex predators and the economies they support. Moran et al. (2010) found a strong relationship between temperature and phytoplankton body size in the North Atlantic, which is consistent with common ecological relationships between temperature, body size, and population abundance. They predict a gradual shift towards smaller primary producers as temperatures warm. Mackas et al. (2007) analyzed variation in plankton in the North Pacific from 1979-2004. They found that under warm conditions, copepod distributions shift northward and life cycle timing of *Neocalanus plumchrus* is advanced by several weeks. They caution that with consistent warming, life cycle events might become mismatched with food supply. Johannessen and Macdonald (2009) review potential risks of climate change combined with other anthropogenic stressors for the Strait of Georgia ecosystem.

Trophic interactions:

Ocean predators such as Pacific hake, jack and chub mackerel, are more abundant in the Pacific Northwest in warmer years (Emmett et al. 2006), which might lower salmon survival (Emmett and Sampson 2007). Emmett and Sampson (2007) found that the abundance of Pacific hake and forage fish, combined with Columbia River flows and possibly ocean turbidity can explain much of the annual variation in marine survival of fall Chinook and coho, but that sea surface temperature upon ocean entry is the best predictor of survival in spring/summer Chinook salmon. Okey et al. (2007) suggest that warmer temperatures might have favored salmon shark along the Alaska coast, increasing their predation of salmon. However, many of these species interactions are not well understood and predicting effects with climate change remains speculative.

Life-history comparisons:

Yatsu et al. (2008) compare population-dynamic responses to climate of five marine species with contrasting life-history characteristics. Marine climatic regime shifts may influence recruitment by changing local environmental conditions, phenological shifts in zooplankton life-history, and stochastic episodic events in both top-down and bottom-up processes. Species differed in the direction, extent and timing of their response, implying very individualistic responses to climate change. Fisher et al. (2007) reviewed information on the first-year ocean distribution of salmon and note that different species go to different places (e.g., ocean-type Chinook are more coastal while steelhead are further offshore), which would lead to an expectation of different effects of ocean climate change on different species.

Carrying Capacity:
Mantua et al. (2009b) describe life-cycle modeling results that represent interactions among salmon stocks, including wild versus hatchery. They conclude that models that contained density-dependent interactions in the ocean fit the historical data better, indicating the existence of an ocean carrying capacity, particularly in the North Pacific. Kaeriyama et al. (2009) found that large-scale climate forcing such as the PDO can influence carrying capacity of the North Pacific for some species of salmon.

2.2.1.3.2.8 Impacts of Climate Change on Multiple Life Stages

<u>New Information Relevant to the 2008 FCRPS BiOp and AMIP:</u>

Evolutionary responses to climate change:
Because environmental conditions have such a profound effect on fitness, in response to climate change salmon will either evolve, modify traits by phenotypic plasticity, shift their geographic range or go extinct. Although phenotypic plasticity is well documented in Pacific salmon (e.g., Beckman and Dickhoff 1998), its limits are not. Similarly, Pacific salmon have been shown to have a heritable component to the expression of many life history traits (reviewed by Carlson and Seamons, 2008). However, we lack a general understanding of how rapidly and under what conditions, evolutionary change can be expected to occur. Conover et al. (2009) found that environmental and genetic influences may work together to accentuate phenotypic adaptations or may cancel each other out to reduce adaptations. Orr and Unckless (2008) examined the response of populations to sudden shifts in climate and, based on theoretical models, concluded that it will be difficult for populations to adapt to sudden changes in the environment via the mechanism of mutations at single or few loci. However, they note that these conclusions may be somewhat limited because they do not consider the possibility of mutations at multiple loci. In general, the larger the effective population size and the larger the number of loci that can mutate, the greater the capacity of a population to adapt to sudden environmental changes. Waples et al. (2008) document the diverse ways in which the hydropower system has changed the selective pressures on Columbia River salmon. Many of these changes are similar in direction and sometimes larger in magnitude than near-term changes imposed by climate change (e.g., reduction in magnitude and earlier peak flows). Crozier et al. (2008b) reviewed potential evolutionary and plastic responses to climate change in different life history stages. Although climate change might produce conflicting selection pressures in different life stages, most of the expected plastic responses to climate change are likely to be adaptive, and reduce the demographic cost of selection on salmon. Importantly, some anthropogenic impacts impose selection in the opposite direction as climate change (e.g., hatchery selection for earlier spawning when later spawning would be adaptive in a warmer climate, Quinn et al. 2002). Morbey and Hendry (2008) and Beechie et al. (2008a) describe diversity in salmonid life history, morphology and behavior, which reflects adaptations to spawning habitats and review these adaptations.

Changing climate might cause a mismatch between local adaptations and environmental conditions.

Survival Patterns and Climate Effects:
McKinnell (2008) determined that the main factors explaining lowered Fraser River sockeye productivity since 1989 occurred in freshwater habitat, including density-dependent fecundity, and that climate is of lesser importance. They also found that stormier winters (more intense winter Aleutian lows) are associated with lower productivity rather than higher productivity, contradicting previous studies.

Sublethal temperature effects:
McCullough et al. (2009) reviewed new thermal research and found that recent studies move away from evaluating lethal tolerances to more emphasis on growth, disease, gene expression, etc. Noyes et al. (2009) found that elevated water temperatures may alter the biotransformation of contaminants to more bioactive metabolites and impair homeostasis.

Invasive species:
Please see the chapter on non-indigenous fishes (Section 2.2.5.2) for additional information. Several major native (e.g., pikeminnow) and non-native (e.g., smallmouth and largemouth bass, Channel catfish, walleye) predators of salmon in the Columbia River are currently limited by cool temperatures (Sanderson et al. 2009a), and are likely to expand geographically (Sharma et al. 2009a; Sharma and Jackson 2008; Sharma et al. 2009b; Sharma et al. 2007) or increase their predation rates within their current distribution as water temperatures warm. For example, Channel catfish require spawning temperatures above 21ºC (Sanderson et al. 2009a), so potential spawning areas could increase as more of the Columbia Basin exceeds this threshold. Bass are more active when temperatures exceed 15ºC (Tabor et al. 2007), so predation rates tend to rise in this range. Rahel and Olden (2008) list numerous mechanisms and processes by which climate change might increase threats from invasive species, including advantages from altered flow or thermal regimes, loss of ice cover for native fish, increased salinity, and anthropogenic activities in the water. Not all invasive species will benefit from climate change, but a few can be extremely influential.

2.2.1.3.3 Effectiveness of Climate Change Mitigation and Adaptation Actions

Approach in 2008 FCRPS BiOp and AMIP:

The 2008 BiOp, Section 8.1.3 included mitigation options for various life stages that were recommended by ISAB (2007a). These ISAB recommendations include:

Planning Actions

1. Assessing potential climate change impacts in each subbasin and developing a strategy to address these concerns should be a requirement in subbasin plan updates. Providing technical assistance to planners in addressing climate change may help ensure that this issue is addressed thoroughly and consistently in the subbasin plans.

2. Tools and climate change projections that will aid planners in assessing subbasin impacts of climate change are becoming more available. Of particular interest for the Columbia Basin is an online climate change streamflow scenario tool that is designed to evaluate vulnerability to climate change for watersheds in the Columbia Basin. Models like this one can be used by planners to identify sensitivities to climate change and develop restoration activities to address these issues.

3. Locations that are likely to be sensitive to climate change and have high ecological value would be appropriate places to establish reserves through purchase of land or conservation easements. Landscape-scale considerations will be critical in choice of reserve sites, as habitat fragmentation and changes of habitat will influence the ability of such reserves to support particular biota in the future. These types of efforts are already climate change concerns.

Tributary Habitat

1. Minimize temperature increases in tributaries by implementing measures to retain shade along stream channels and augment summer flow
   - Protect or restore riparian buffers, particularly in headwater tributaries that function as thermal refugia
   - Remove barriers to fish passage into thermal refugia
2. Manage water withdrawals to maintain as high a summer flow as possible to help alleviate both elevated temperatures and low stream flows during summer and autumn
   - Buy or lease water rights
   - Increase efficiency of diversions
3. Protect and restore wetlands, floodplains, or other landscape features that store water to provide some mitigation for declining summer flow
   - Identify cool-water refugia (watersheds with extensive groundwater reservoirs)
   - Protect these groundwater systems and restore them where possible
   - May include tributaries functioning as cool-water refugia along the mainstem Columbia where migrating adults congregate
   - Maintain hydrological connectivity from headwaters to sea

Mainstem and Estuary Habitat

Remove dikes to open backwater, slough, and other off-channel habitat to increase flow through these areas and encourage increased hyporheic flow to cool temperatures and create thermal refugia

Mainstem Hydropower

1. Augment flow from cool/cold water storage reservoirs to reduce water temperatures or create cool water refugia in mainstem reservoirs and the estuary
   - May require increasing storage reservoirs, but must be cautious with this strategy
   - Seasonal flow strategy
2. Use of removable spillway weirs (RSW) to move fish quickly through warm forebays and past predators in the forebays.
   - Target juvenile fall Chinook salmon
3. Reduce water temperatures in adult fish ladders
   - Use water drawn from lower cool strata of forebay
   - Cover ladders to provide shade
4. Transportation
   - Develop temperature criteria for initiating full transportation of juvenile fall Chinook salmon
   - Explore the possibility of transporting adults through the lower Snake River when temperatures reach near-lethal limits in later summer
   - Control transportation or in-river migration of juveniles so that ocean entry coincides with favorable environmental conditions
5. Reduce predation by introduced piscivorous species (e.g., smallmouth bass, walleye, and channel fish) in mainstem reservoirs and the estuary

Harvest

1. Harvest managers need to adopt near-and long-term assessments that consider changing climate in setting annual quotas and harvest limits
   - Reduce harvest during favorable climate conditions to allow stocks that are consistently below sustainable levels during poor phase ocean conditions to recover their numbers and recolonize areas of freshwater habitat

- Use stock identification to target hatchery stocks or robust wild stocks, especially when ocean conditions are not favorable

Hatcheries

- Control juvenile migration to ensure that ocean entry coincides with favorable ocean conditions

Those ISAB recommendations that were incorporated into the RPA are described in the same section. Section 7.1.2.1 in the 2008 BiOp explains that the degree to which the RPA incorporates ISAB recommendations is one of the factors upon which the RPA was evaluated. The 2008 BiOp also described the work of Battin et al. (2007), which looked at effectiveness of different restoration actions in face of climate change in Puget Sound.

<u>New Information Relevant to the 2008 FCRPS BiOp and AMIP:</u>

Appropriate Management Responses to Climate Change:
Waples et al. (2009) report that over the past two centuries, anthropogenic changes to salmon ecosystems have altered disturbance regimes outside the range of the historical template, so resilience of salmon populations might be compromised. The authors discuss appropriate management responses such as actions that release constraints on processes that sustain habitat diversity, actions that attenuate anthropogenically exaggerated disturbance regimes and reduce the frequency of high mortality events, and actions that restore emigration pathways to historical habitats to increase the diversity of habitats available to salmon. These are consistent with adaptation recommendations for a variety of taxa. For example, Mawdsley et al. (2009) reviewed 16 broad adaptation strategies for climate change, applicable to a range of species.

A number of studies have recommended responses to climate change in tributary salmonid habitat. Bisson (2008) is a web site that reviews recent literature and makes the following management recommendations for responding to climate change in aquatic environments: maintain river flow in low flow periods; maintain floodplain connections; maintaining habitat connections among suitable habitat sites; protect and enhance riparian forests. Forest management recommendations from Bisson (2008) include: minimizing anthropogenic increases in water temperature by maintaining well-shaded riparian areas; maintaining a forest stand structure that retains snow, reduces the "rain on snow" effect associated with forest openings, and promotes fog drip; disconnecting road drainage from the stream network to soften discharge peaks during heavy rainstorms; ensuring that fish have access to seasonal habitats, e.g., off-channel wintering areas or summer thermal refugia; and protecting springs and large groundwater seeps from development and water removal, as these subterranean water sources will become increasingly important when surface flows are altered by climate change. Bisson et al. (2009) provide similar advice on restoration approaches to maintain natural diversity and resilience to factors such as climate change.

Ward et al. (2008a) found that effects of watershed restoration on salmonid populations were detectable in the Keogh River basin of British Columbia. The authors conclude that habitat restoration may help salmon respond to climate shifts. Jorgensen et al. (2009) found that prespawning and incubation stream temperatures were especially sensitive to total forest cover, impervious surface area, and mean annual precipitation in the Wenatchee River Basin. The percent of fine sediment in the water was also sensitive to precipitation, and had the greatest role in population declines. Thus restoration actions focusing on improving forest cover and impervious area produced the greatest increase (or prevented the greatest loss) in population productivity (Honea et al. 2009).

Schindler and Rogers (2009) recommended preserving life-history diversity within and among populations to respond to enhanced juvenile growth and accelerated juvenile life histories in response to warming water temperature.

Palmer et al. (2008, 2009) reviewed climate effects on freshwater ecosystems, projected changes in river flow under various climate change scenarios, and determined that impounded rivers will be impacted more than free-flowing ones. Parts of the Columbia River basin will probably need intervention in the future. Suggested actions in the mainstem and tributaries include: stormwater and sediment management, channel reconfiguration, dam removal/retrofit, floodplain restoration, water-quality management, groundwater/surface-water management, enhanced fish passage, flow modification, bank stabilization, riparian management, and in-stream habitat improvements.

Schindler et al. (2008) note that there is considerable uncertainty in predicting climate change effects on salmon, so an appropriate management response, similar to those in the studies cited above, is needed. Lawler et al. (2010) discuss strategies for management under uncertain future climate. Their main recommendations for making salmon populations more resilient to climate change are to: 1) develop adaptive management plans with prescribed alternative strategies; 2) implement actions to remove other threats to populations, such as removing non-indigenous species and maintaining habitat connectedness and availability; and 3) conduct extensive monitoring of climate conditions and population's response to climate.

Management Responses to Climate Change in the CVP/SWP BiOp:

The June 4, 2009, biological opinion on "Long-Term Operations of the Central Valley Project and State Water Project" (CVP/SWP BiOp) (NMFS 2009a) developed a reasonable and prudent alternative that includes a number of measures to reduce impacts of the projects in the face of climate change. These include managing water releases from storage reservoirs to maintain cool temperatures downstream, developing new models and decision-support tools for determining appropriate reservoir operations, specifying minimum end-of-season storage to ensure that a minimum volume of cool water is available for the next year in the event of a multi-year drought, and developing or improving temperature-control devices at dams. The CVP/SWP BiOp concludes that these measures may not be sufficient to reduce temperature-related mortality of fish and eggs below the projects in light of climate change through 2030 action duration, so studies and pilot programs to evaluate and implement reintroduction above impassible dams are required. The 2008 BiOp contains similar measures to manage water temperature such as flow provisions as described below.

Progress Implementing Climate Change Mitigation Actions in the 2008 FCRPS BiOp:
Action Agency progress in implementing actions to reduce temperatures and implement other measures that respond to climate change are detailed in Appendix E. These measures include cold-water releases from Dworshak reservoir in July and August to maintain temperatures at or below 68°F at Lower Granite Dam; lowering reservoir elevations at the Snake River projects to minimum operating pool to reduce heating; project operations such as spill, use of spillway weirs, and bypass systems to reduce exposure of juveniles to warm temperatures; and development of a Water Management Plan and in-season management procedures to ensure that water is released and stored in a manner that optimizes survival of listed species. Progress is also well under way to develop a long-term Columbia Basin hydrology data set to be used to model climate change through various reservoir regulation models and tools and link this to biological models such as COMPASS. Appendix F also documents Action Agency progress in implementing tributary actions that will reduce impacts of climate change (e.g., Methow project improving access to spring-fed thermal refugia) and temperature monitoring to improve the ability to select future habitat improvement projects.

2.2.1.3.4 Monitoring Climate Changes and Species Responses

Approach in 2008 FCRPS BiOp and AMIP:

The 2008 BiOp and the AMIP described a general monitoring program to detect climate changes and species responses. This includes fish status and habitat action effectiveness monitoring, Intensively Monitored Watersheds, and forecasting and water management assessments related to climate change. In addition, under the AMIP, NOAA Fisheries will update and enhance a life-cycle model for Columbia and Snake River species, specifically to address climate change information. Under the AMIP, NOAA Fisheries will provide the Action Agencies with a climate change report each year for use in adaptively managing RPA actions. All of these actions are ongoing or under development.

New Information Relevant to the 2008 FCRPS BiOp and AMIP:

See the Research, Monitoring, and Evaluation chapter for a review of new information related to this subject. Other new information relevant to monitoring climate change effects includes Fleming and Quilty's (2007) risk-based approach to establishing screening-level, site-specific water temperature objectives and Doyle et al.'s (2010) protocol for monitoring climate change in Pacific Northwest National Parks and forests. Beamish et al. (2009a) developed a Long-term Research and Monitoring Plan (LRMP) for the North Pacific Anadromous Fish Commission that synthesized past research and identified critical areas for new research to understand impacts of future climate and ocean changes on the population dynamics of Pacific salmon. This study identified six climate change issues involving ecological resources that are important for integrated ecosystem assessments: 1) determining climate signals (long term change versus natural variation) impacting ecosystems; 2) the impact of ocean warming on distribution and productivity of living marine resources; 3) the impacts of loss of sea ice on living marine resources; 4) ocean acidification impacts on marine biota; 5) freshwater supply and resource management; and 6) sea level rise. Beamish et al. (2009b) produced a bibliography of papers describing climate effects on Pacific salmon that accompanies Beamish et al. (2009a).

2.2.1.4 Relevance to 2008 FCRPS BiOp Analysis and AMIP

New observations and predictions regarding physical effects of climate change, as described in Section 2.2.1.3.1, are within the range of assumptions considered in the 2008 BiOp and the AMIP.

- Temperature and precipitation projections for the Pacific Northwest have not changed in the last two years.
- A great deal of new information is available, or will soon become available, on flows in Columbia basin tributaries and the mainstem Snake and Columbia Rivers as temperatures warm. This new information will allow predictions at the watershed scale to be coupled with biological models. The new flow information available to date, however, does not appear to fundamentally differ from general regional patterns previously considered (i.e., higher winter and spring flows in transitional and rainfall-driven basins; lower summer and fall flows in most basins).
- Broad-scale climate patterns reflected in the PDO and Multivariate ENSO index indicate that conditions during the past decade have clearly been within the range, and below the average, of both the base period and the "Warm PDO" climate conditions considered in 2008 BiOp modeling. We are currently experiencing a weakening El Niño condition, and most models predict a return to ENSO-neutral conditions by summer. To date, predictive models of longer-term effects of climate change on the PDO and El Niño provide conflicting results.
- Other ocean indicators are also within the range considered in the 2008 BiOp.

New studies of biological effects of climate change on salmon and steelhead, as described in Section 2.2.1.3.2, provide 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.

- ISAB (2007a), which was the basis for most of the climate information considered in the 2008 BiOp, indicated that warming temperatures could have positive or negative effects on juvenile growth, depending on available food and density. New studies confirm a range of responses and provide greater details regarding responses, but do not provide substantively different information than that considered in the 2008 BiOp.
- New studies are in progress which should help to elucidate potential responses of juveniles to climate change at the watershed level. At this time, however, the

available information does not differ substantively from that available in the 2008 BiOp.

- Juvenile studies confirm general expectations in the 2008 BiOp of changes in mainstem migration timing and life history strategies in response to higher temperatures. As previously noted and incorporated into 2008 BiOp modeling, arrival timing in the estuary is at least as important as cool temperatures in predicting smolt-to-adult survival for Snake River Chinook and steelhead.

- The new information on non-indigenous fishes (Section 2.2.5.2) provides additional detail to the general response of warm-water predators considered in the 2008 FCRPS BiOp: their ranges are expected to expand and predation rates are likely to increase as temperatures warm.

- Several 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.

- A new area of study investigates recent historical and potential future evolutionary responses and phenotypic plasticity in juvenile and adult salmon and steelhead migration timing and life history strategy, suggesting that major shifts in run and spawn timing may accompany continuing climate change. While the direction of phenotypic adaptation is generally known, the degree to which it will occur is not clear at this time. Some studies document that the timing of harvest and collection for hatchery broodstock can either undermine or accelerate evolutionary responses.

- A major initiative launched by NOAA (Fisheries, Pacific Marine Environmental Laboratory, and Office of National Marine Sanctuaries) the West Coast Ocean Acidification Research Plan, will greatly improve our understanding of the effects of ocean acidification in the coming decade.

- Most studies related to climate effects on estuary and ocean productivity indicate that, while new information on biological effects in these areas is available, it does not differ substantively from factors previously considered in the 2008 BiOp.

New information indicates that RPA actions that should help to monitor and mitigate climate change are being implemented as expected per the 2008 BiOp and the AMIP. The types of potentially beneficial actions identified by ISAB (2007a) and implemented through the RPA are consistent with the types of adaptation actions described in current literature.

The new information concerning climate change indicates the potential for the functioning of PCEs in spawning and rearing areas, juvenile and adult migration corridors, and areas for growth and development to adulthood (i.e., the estuary) to change over time due to increased temperatures (water quality) and altered seasonal flows related to shifts in the timing of precipitation (water quantity). However, the physical effects are likely to be within the range considered in the 2008 BiOp. A number of actions in the mainstem migration corridor and in tributary and estuarine areas will proactively address the effects of climate change. Some of these improvements have already been implemented and others are scheduled for implementation over the term of the RPA (Appendices E and F).

2.2.2 Mainstem Conditions

NOAA Fisheries reviewed the new scientific information relating to the survival and behavior of juvenile and adult salmon migrating through the mainstem FCRPS dams and reservoirs. The new scientific information generally supports NOAA's conclusions in the 2008 BiOp that the RPA will address factors that have limited the functioning and conservation value of the mainstem migration corridor habitat that Interior basin salmon and steelhead use to migrate to and from the ocean. Specifically, the study results indicate that the survival benefits assessed in the 2008 FCRPS BiOp are generally being attained or exceeded, adaptive management processes are engaged in those cases where survival rates are somewhat lower than expected, and consequently, biological performance standards are likely be met within the span of the BiOp.

2.2.2.1 Configuration Changes at Mainstem Dams

New fish passage structures have been recently installed and several mainstem Snake and Columbia River dams and have already proven to improve dam passage survival in nearly all cases. All of the lower Snake River dams have had surface passage installed under the BiOp and attention is now focused on improvements at the lower Columbia dams. Some notable recent dam improvements include:

- A removable spillway weir at Lower Monumental Dam (2008);[15]
- Two temporary spillway weirs at John Day Dam (2008);[16]
- An adjustable spillway weir at Little Goose Dam (2009);[17] and
- A tailrace spillway wall at The Dalles Dam (2010).

Pre-and post construction evaluations of these surface passage oriented structures, as well as others implemented in the recent past,[18] allow several general conclusions to be drawn. In

[15] Absolon et al. 2009; Ham et al. 2010; Hockersmith et al. 2008a; Hockersmith et al. 2008b; and Hockersmith et al. 2010, McMichael et al. 2008.
[16] Liedtke et al. 2009
[17] Beeman et al. 2008; Beeman et al. 2010.
[18] Also including studies at Lower Granite (Puls et al. 2008); Ice Harbor Dam (Axel et al. 2008; Axel et al. in prep); McNary Dam (Adams et al. 2008; Adams et al. 2009; Adams and Counihan, 2009; Adams and Liedtke, 2009;

general, good progress is being made toward achievement of hydro performance standard levels of 96% for spring migrants and 93% for summer migrants. Study results from 2008 and 2009 indicate that, with installation of surface passage, in most cases, performance standards are likely being met or nearly so. Additional dam improvements are still underway, and performance standards testing will begin soon.

In 2008, these studies were conducted at Lower Monumental, Ice Harbor, McNary, and John Day Dams. Conventional paired-release steelhead survival estimates were all above 96%. Yearling spring Chinook salmon estimates were all above or within 0.5% of the 96% standard. Sub-yearling Chinook estimates were all above the 93% standard with the exception of John Day Dam where survival was 85-86% (likely due to avian predation). Dam survival estimates were generally high, but some fell below targets. In 2009, studies were conducted at Lower Monumental, Little Goose, Ice Harbor, McNary, and John Day Dams. Survival was very high for most species at Lower Monumental and Little Goose, but sub-yearling fall Chinook survival fell 0.2% below the 93% target at Lower Monumental. Spring survival at McNary Dam was very high, although the results may include some bias. Summer survival was high early in the season, but high temperatures reduced survival later in the season pulling the overall survival estimate below 93%. Survival rates at John Day and Ice Harbor Dams were not measured using performance standard style tests; however, results were encouraging as survival was high.
For steelhead smolts, surface passage routes - compared to conventional spill routes - are clearly more effective (pass a higher proportion of juveniles for each percent of flow passing through the passage route) and reduce forebay residence times by many hours (likely resulting in increased survival by decreasing exposure to predators). Surface passage routes are proving to be safe and effective passage routes (typically 98-100% survival) and are resulting in improved juvenile dam passage survival rates for steelhead smolts.

For yearling Chinook salmon, the effectiveness (proportion of fish passing through a passage route divided by the proportion of water passing through the passage route) appears to be equal to or greater than that of conventional spillway bays at most projects. Surface passage routes are also contributing towards relatively short residence times in the forebays of most projects (typically < 3 hours) for yearling Chinook salmon. Survival rates through surface passage routes (typically 98-100% for spring migrants) are as high as or higher than through conventional spill bays, and are contributing towards improved juvenile dam passage survival rates.

For subyearling Chinook, passage effectiveness and survival through surface passage routes is typically similar to or somewhat higher than for conventional spill routes. But at McNary Dam it appears that survival rates may actually be somewhat lower through the surface passage weirs than through the conventional spill routes. Thus, the effect of surface passage routes on juvenile subyearling Chinook salmon vary by dam, ranging from slight negative impacts, to little or no

Adams and Liedtke 2010; Ham et al. 2008; Ham et al. 2010; Hardiman et al. 2009); and Bonneville Dam (Evans et al. 2008).

effect, to positive effects on survival rates of smolts passing the dams. However, improvements designed to achieve performance standards (93%) for summer migrating fish are still underway.

Information from these studies is being used to guide subsequent configurational and operational modifications at each dam (e.g., alternative spillbays for Temporary Spillway Weirs, spill patterns to improve tailrace egress conditions, or avian deterrents) in preparation for performance standards testing. While Juvenile Dam Passage Survival performance standard testing has not been completed for all of the dams, it appears that the successful installation of these structures is on track to achieve the performance standards required by the 2008 BiOp.

At the Dalles Dam, the tailrace spillway wall was completed in March, 2010, prior to the juvenile outmigration season. The performance of this structure (primarily survival rates of juveniles passing through the spillway bays north of the spillway wall) will be evaluated in 2010.

Relevance to 2008 FCRPS BiOp Analysis and AMIP

Surface passage routes are more normative than other passage routes because they use the natural behavior of fish to migrate past obstacles in the top 20 feet of the water column – as opposed to their diving to depths of 40 or more feet in order to pass dams via conventional spillway bays, turbine units, or juvenile bypass facilities.

Taken together, structural improvements to the mainstem dams are occurring in accordance with the expectations set forth in the 2008 BiOp. The Adaptive Management process (which includes performance standards, testing, and technical committees that evaluate research results to recommend configurational and operational modifications to meet performance standards) appears to be working well to assure that there is a high likelihood of achieving Juvenile Dam Passage Survival standards within the timeframe specified by the 2008 BiOp.

2.2.2.2 Juvenile Survival

Empirical estimates of juvenile survival through reaches of the Snake and Columbia Rivers indicate that survival of inriver migrating yearling Chinook and sockeye salmon and steelhead smolts has nearly attained levels anticipated by the 2008 BiOp (see Table 8). Estimated survival rates are generally falling within the ranges (Current and Prospective analysis) anticipated by the 2008 BiOp (and 2008 SCA).

Table 8. Survival estimates for juvenile salmon and steelhead the mainstem Federal Columbia River Power System projects in 2008 and 2009. Source: Faulkner, et al. 2010.

ESU/DPS	Survival (s.e.) from Lower Granite to Bonneville Dam		Survival (s.e.) from McNary to Bonneville Dam	
	2008	2009	2008	2009
SR spring-summer Chinook salmon[1]	0.465 (0.052)	0.555 (0.025)	NA	NA
SR steelhead[1]	0.480 (0.027)	0.676 (0.059)	NA	NA
SR sockeye salmon[1]	0.404 (0.0179)	0.573 (0.073)	NA	NA
UCR spring Chinook salmon[2]	NA	NA	0.626 (0.133)	0.895 (0.116)
UCR steelhead[2]	NA	NA	*	0.756 (0.105)

[1] Hatchery and wild fish combined.
[2] Hatchery fish only.
* Not enough juveniles were detected to make a reliable estimate of survival.

It is worth noting that SR steelhead survival from Lower Granite to Bonneville dam in 2009 was much higher (67.6%) than was anticipated in the 2008 BiOp - the previous high survival estimate was 50.0% in 1998 (Faulkner et al. 2010). Further analysis will be necessary to understand what factors contributed most significantly to these high observed survival rates for SR steelhead. Faulkner et al. (2010) suggested factors that likely contributed include: 1) the new Adjustable Spillway Weir at Little Goose Dam, 2) decreased travel times resulting from the cumulative effect of surface passage routes at seven of the eight mainstem projects may have decreased the propensity for steelhead smolts to revert to parr or decreased the susceptibility of steelhead smolt to avian predators, 3) earlier overall migration timing (the migration experienced generally cooler water temperatures), 4) increased numbers of juveniles migrating inriver instead of being transported, 5) reduced avian predation at John Day Dam, 6) the partially completed spillway wall at The Dalles Dam (Faulkner et al. 2010).

Also, of note, increased tagging in 2009 allowed for a relatively accurate estimate of survival (57.3%) from Lower Granite to Bonneville dam for SR sockeye smolts. This estimate was nearly identical to that of SR spring-summer Chinook smolts (55.5%) through this reach.

Juvenile Survival Estimates: Comparisons from Free-flowing Rivers to other Systems

Juvenile Survival Estimates in the Fraser River

Welch et al. (2008) compared survival rates of acoustically tagged juveniles in the impounded Columbia River system (and unimpounded estuary) with juveniles from the free-flowing Fraser River. They found that “survival during the downstream migration of at least some endangered Columbia and Snake River Chinook and steelhead stocks appears to be as high or higher than that of the same species migrating out of the Fraser River in Canada, which lacks dams. Equally surprising, smolt survival during migration through the hydrosystem, when scaled by either the time or distance migrated, is higher than in the lower Columbia River and estuary where dams are absent.”

Juvenile Survival Estimates in the Grande Ronde River

Monzyk et al. (2009) estimated survival rates of both hatchery and naturally produced juvenile spring-run Chinook salmon migrating between locations within the Grande Ronde river basin to Lower Granite Dam (2000 to 2006). They also found that survival rates ranged varied substantially between the release sites and between years. For example, survival rates of fish released in the Upper Grande Ronde and Catherine Creek ranged from 23.3% (in 2005) to 87.4% (in 2002) for hatchery fish and from 37.5% (2001) to 78.1% (2002) for naturally produced fish. Survival rates of fish released in the Lostine River ranged from 38.2% (in 2006) to 71.4% (in 2002) for hatchery fish and from 50.7% (2003) to 69.0% (2001) for naturally produced fish. The authors found that the majority of the mortalities suffered by Catherine Creek fish (32.8% to 65.8%) occurred within a 91 km reach immediately below their summer rearing habitat. In contrast, Lostine River fish experienced lower mortalities (3.6 to 46.1%) in a 174 km reach below their summer rearing habitat. They found that smaller fish 1) took longer to migrate (presumably feeding to attain a larger size before continuing to migrate) in the upper reaches and 2) smaller fish – especially those from the upper reaches – were less likely to survive to Lower Granite Dam than were larger fish.

Juvenile Survival Estimates in the Alsea River

Juvenile steelhead survival estimates through 59.7 km of the free-flowing Alsea River (from release to the head-of-tide receiver array) were 84% for naturally reared and 78 to 87% for hatchery reared fish. These equate to average survival rates of about 0.997/km for naturally produced steelhead smolts and about 0.996/km to 0.998/km for hatchery produced steelhead smolts (Johnson et al. 2010).

Similar estimates of per kilometer survival rates are observed wild and hatchery steelhead (combined) migrating through the FCRPS dams and reservoirs (derived from 2006-2009 NWFSC survival studies using wild and hatchery fish). Recent survival estimates [and per km estimates] from Lower Granite Dam to Bonneville Dam (a distance of 461 km) were 45.5% [0.998/km] in 2006, 36.4% [0.998/km] in 2007, 48.0% [0.998/km] in 2008, and 67.6% [0.999/km] in 2009.

Juvenile Survival Estimates from Other Locations Upstream of Lower Granite Dam

Faulkner et al. (2010) provides survival estimates from locations throughout the Snake River Basin downstream to Lower Granite Dam in 2009. Survival estimates ranged from 44.6% to 100% for wild yearling Chinook salmon, 26.7% to 50.9% for wild sockeye salmon, and 64.1% to 100% for wild steelhead. Survival of hatchery yearling Chinook salmon released at seven locations (1998-2009) is correlated strongly (R2 = 0.877, p = 0.002) with distance to Lower Granite Dam.

Relevance to 2008 FCRPS BiOp Analysis and AMIP

Ongoing reach survival studies indicate that the survival rates of inriver migrants are meeting or exceeding expectations for yearling Chinook salmon, sockeye salmon, and steelhead set forth in the 2008 BiOp.

Survival estimates from free-flowing reaches (or other non-dammed river systems) continue to indicate that substantial mortalities – similar in magnitude to those observed in juveniles migrating through the mainstem FCRPS projects – are occurring in these systems as well. Understanding the mechanisms that result in these losses, and consideration of potential effects of climate change (see Section 2.2.1.3.2.4.), could provide opportunities to increase overall juvenile survival rates and the productivity of affected Snake River basin populations.

2.2.2.3 Adult Survival

The conversion rate method used by NOAA Fisheries to assess adult survival through the mainstem Columbia and Snake Rivers accounts for estimated harvest and straying rates of adults within the FCRPS migration corridor. They also capture all other sources of mortality manifested within the identified reaches, including those resulting from the existence and operation of the FCRPS as well as mortalities from other sources (e.g., unreported or delayed mortality caused by fisheries, marine mammal predator attacks, etc.), and “natural” mortalities (i.e. levels of mortality in the migratory corridor that would have occurred “naturally” without human influence) (2008 BiOp Incidental Take Statement, 14-4).

Table 9 summarizes NOAA Fisheries’ updated adult conversion rate analysis which was the basis for Adult Performance Standards in the 2008 BiOp (see 2008 RPA Table, Table 7 and 2008 SCA Appendix A). Conversion rates of SR fall Chinook salmon and UCR steelhead exceeded average 2008 BiOp expectations in both 2007 and 2008. Conversion rates of SR spring-summer Chinook salmon, SR steelhead, SR sockeye salmon, and UCR spring Chinook salmon were lower than average BiOp expectations for both 2007 and 2008. 2007 estimates were within the observed ranges with two exceptions: 2008 SR steelhead and sockeye salmon conversion rates were about 4-5% lower than the lowest estimates made since 2003 for SR steelhead and 2006 for sockeye. As survival rates appeared to be higher than typical in the Bonneville to McNary reach for SR steelhead, it would appear that these losses occurred primarily in the Snake River. For sockeye salmon, losses appear to have been higher in the Bonneville Dam to McNary reach than in the past two years for which there are data. As this estimate is expanded to include the

McNary to Lower Granite reach, it is not surprising that the overall Bonneville to Lower Granite conversion rate estimate would also be lower than the 2008 BiOp average. Additional assessments will need to be conducted to assess possible causes of these lower than expected values.

Table 9. Conversion rate estimates (adjusted for harvest and straying) of known origin adult salmon and steelhead (which migrated inriver as juveniles) through key reaches of the mainstem Federal Columbia River Power System in 2007 and 2008. Bold text indicates numbers used for the adult performance standard. Source: NOAA Fisheries, Analysis dated Sept. 29, 2009.

ESU/DPS	Conversion rate from Bonneville to McNary Dam			Conversion rate (s.e.) from Bonneville to Lower Granite Dam		
	BiOp Avg (range)	**2007**	**2008**	**BiOp Avg (range)**	**2007**	**2008**
SR fall Chinook salmon[1]	88.0%	89.1%	95.7%	81.0% (58.8% - 98.6%)	83.5%	91.9%
SR spr-sum Chinook salmon[1]	94.9%	94.1%	88.9%	91.0% (81.6% - 97.9%)	89.1%	86.0%
SR steelhead[2]	95.3%	95.7%	99.4%	90.1% (85.6% -93.8%)	86.6%	80.8%
SR sockeye salmon[3]	91.4%	90.4%	88.3%	81.1% (79.1% - 83.2%)	79.1%	74.9%
UCR spring Chinook salmon[1]	90.1% (86.1% - 96.1%)	87.5%	87.6%	NA	NA	NA
UCR steelhead[2]	84.5% (77.6% - 90.7%)	85.3%	86.9%	NA	NA	NA

[1] 2007 estimates of Chinook Salmon were adjusted to reflect updated harvest estimates
[2] 2007 estimates for SR steelhead and UCR steelhead were reported in the 2008 SCA – but were not used in the calculated average because returns were incomplete as of May 2008. These numbers have been adjusted to reflect the completed migration and updated harvest estimates, if applicable.
[3] Uses mostly adults from the Okanogan River and Lake Wenatchee ESUs as surrogates (and expands the BON to MCN conversion rate estimate [3rd root] to estimate a BON to LGR conversion rate for SR sockeye [7th root]).

Factors That Influence Adult Survival Rates

As noted in the 2008 SCA (Appendix A), transported SR spring/summer Chinook salmon and steelhead stray at higher rates than fish that migrated inriver as juveniles. In recent years, this typically reduces conversion rates of adult salmon and steelhead migrating between Bonneville and Lower Granite dams by up to 3-5% (ISAB 2008a – and materials provided for their review).

Straying and Thermal Refugia

In addition, to their migration experience as juveniles, adult salmon and steelhead may seek to avoid relatively high mainstem water temperatures by seeking out cool water areas in adjacent tributaries. Keefer et al. (2009) re-evaluated adult steelhead telemetry data (fish tagged from May or early June through October in 1996-1997 and 2000-2003) and found, as expected, that substantial numbers of adult steelhead are using thermal refugia and that use of these areas increases increased rapidly after mean daily water temperatures reached ≈19 ^{o}C. When Bonneville reservoir temperatures were <19 ^{o}C, median travel times to The Dalles Dam were about 3 days and 10% of the adults were recorded in cool water tributaries. When reservoir temperatures were 19-21 ^{o}C, median travel times to The Dalles Dam were about 6 days and 49% of the adults used tributaries. When reservoir temperatures >21 ^{o}C, median travel times to The Dalles Dam were about 25 days and 71% of the adults were recorded in cool water tributaries. This pattern was also evident in The Dalles to John Day dam reach – where over 25% of the adult steelhead passing The Dalles Dam were recorded in The Deschutes River.

Keefer et al. (2009) also found that mean annual homing success was 4.5% lower for wild steelhead (68.5% versus 73.0%) and hatchery steelhead (73.0% versus 83.6%) that used tributaries compared to those that did not. Using 1285 known-origin adult steelhead, they found that fish using thermal refugia also had greater unknown mortalities in the mainstem, and were harvested at relatively high rates in refugia tributaries – both factors that would affect conversion rates estimates (see Table 10).

Delayed Mortality Associated with Injuries from Marine Mammal Attacks

Another factor identified in the 2008 SCA that could affect adult conversion rates upstream of Bonneville Dam are delayed mortalities of fish injured- but not killed - by marine mammals downstream of Bonneville Dam. Scordino (2010) notes that "fish passage monitors at the Bonneville Dam salmon viewing windows documented scars on salmonids attributable to pinnipeds on 11% to 37% of the returning spring Chinook salmon and steelhead passing the dam from 1999 to 2005." These injury rates are substantial enough that even relatively small rates of mortality (10% of injured fish) would reduce conversion rates from Bonneville Dam to McNary or Lower Granite dams by approximately 1-4%.

Relevance to 2008 FCRPS BiOp Analysis and AMIP

Conversion rates of SR fall Chinook, and UCR steelhead in 2007 and 2008 exceeded the average expectations presented in the 2008 BiOp. Conversion rates of SR spring/summer Chinook, SR steelhead, SR sockeye, and UCR spring Chinook were lower in 2007 and 2008 than the average values presented in the 2008 BiOp. NOAA Fisheries will calculate conversion rates for the 2009 adult migrants this summer, which will provide another year of data to assess whether or not these early trends are continuing. Also, ongoing adult evaluations required by RPAs 52, 54, and 55; and consideration of potential effects of climate change (see Section 2.2.1.3.2.5), should be adequate to identify factors that could be contributing to these lower than average conversion rates, as well as potential corrective actions for addressing these factors. The potential for additional adult PIT tag detection at The Dalles and John Day dam fishways should be evaluated to assess whether additional detections at either or both of these dams could substantially improve inter-dam adult loss estimates in the lower Columbia River, and detectors should be added, if warranted.

2.2.2.4 Smolt-to-Adult Returns

Tuomikoski et al. (2009) estimated annual average Smolt to Adult Returns (SARs) for PIT-tagged Comparative Survival Study fish released upstream of Lower Granite Dam. SARs for wild SR spring/summer Chinook and steelhead juveniles outmigrating in 2005 to 2007 (aggregated for each study category) are presented in Table 10. SARs of transported fish exceeded those of non-detected or bypassed fish in 2005 for both spring/summer Chinook and steelhead and in 2007 for spring/summer Chinook. In 2006, SARs of undetected fish exceeded those of transported fish for spring/summer Chinook and were virtually identical for steelhead.

Table 10. Average annual Smolt to Adult Return (SAR) estimates (LGR to LGR) % for PIT-tagged wild Chinook and steelhead in annual aggregate for each study category, 2005-2007. Source: Tuomikoski et al. 2009, Table 4.7 and 4.19.

Smolt Migration Year	Estimates SARs for Wild Snake River spring / summer Chinook			Estimates SARs for Wild Snake River Steelhead		
	SAR(T0) %	SAR(C0) %	SAR(C1) %	SAR(T0) %	SAR(C0) %	SAR(C1) %
2005	0.23	0.11	(0.07 – 0.15)	0.84	0.17	
2006[1]	0.77	0.97	0.51	1.34	1.37	0.64
2007[2]	0.93	0.81	0.59			

Key:
T0 = transported juveniles
C0 = juveniles were not detected at any of the Snake River collector projects (LGR, LGS, or LMN)
C1 = juveniles were detected at one or more of the three Snake River collector projects.

[1] Preliminary estimate; the adult migration to LGR for 2-salt adults is incomplete.
[2] Incomplete with only 2-salt adult Chinook returns through August 3, 2009.

NWFSC (2010b) examined annual patterns in SARs of both juveniles released upstream of Lower Granite Dam (consistent with the CSS study method) and juveniles tagged and released at Lower Granite Dam. This analysis indicated that SARs of both spring/summer Chinook and steelhead inriver migrants (juveniles detected at the three Snake River collector projects) tends to decrease after April. SARs of transported fish often remain relatively high, or increase through this period. SARs of undetected fish (C0) are almost always higher than those of fish detected in the juvenile bypass systems at Lower Granite, Little Goose, and Lower Monumental dams (C1).

Recent Fish Passage Center (FPC) reports and memos (FPC 2008a, FPC 2008b, FPC 2008c, FPC 2008d, FPC 2008e, FPC 2008f, FPC 2009a, FPC 2009b, FPC 2009c, FPC 2010b, FPC 2010a, FPC 2010c, and FPC 2010d) and Comparative Survival Study (CSS) reports (Berggren et al. 2008; Tuomikoski et al. 2009) present analysis that recent (higher) spill and (reduced) transport operations (2006-2009) have resulted in reduced travel times, higher juvenile inriver survival rates, and lower relative transport benefits (reduced Transport:Migrant ratios) and that these factors contributed substantially to the higher adult return rates observed in 2008 and 2009 – especially for SR sockeye and SR fall Chinook salmon. NWFSC reports (NWFSC 2009, NWFSC 2010b) indicate that 1) ocean productivity largely explains the increase in adult returns and 2) that adult return rates of SR sockeye are highly correlated with those of sockeye from the upper Columbia River reaches from which smolts are not transported, indicating that transport rate is not likely a causative factor in the recent high returns of SR sockeye salmon. The FPC, CSS, NWFSC, and the ISAB agree that recent dam improvements and operations appear to have increased the survival of juvenile fish migrating inriver and that this contributes to decreased Transport:Migrant ratios (T:M) compared to previous years. However, T:M ratios are still typically higher than 1:00 (ISAB 2010), meaning that steelhead, and to a lesser extent yearling spring/summer Chinook salmon, return at higher rates if transported than if left to migrate inriver.

Petrosky and Schaller (2010) correlated indices of ocean conditions and in-river freshwater conditions to estimates of first year ocean survival and SARs of Snake River spring/summer Chinook salmon and steelhead (1964-2006 out-migrations). They found that increased first ocean survival and SARs of Chinook salmon were associated with cooler ocean conditions, stronger spring upwelling events, reduced water travel times, and fewer passages through powerhouses at the mainstem dams.

Increased first ocean survival and SARs of steelhead were associated with cooler ocean conditions, stronger spring upwelling events, reduced water travel times, and reduced in-river water temperatures. The authors suggested that given projections of warming ocean conditions, managers should focus on actions that reduce juvenile travel times to the ocean.

ISAB Review of Snake River Transport Operations and SARs

The ISAB (2008a) reviewed information relating to the efficacy of Snake River spill / transport operations, and recommended several lines of research relating to transport effects on SR sockeye salmon, increased straying of SR steelhead on MCR steelhead populations, and lamprey. They also advised that 1) "whenever conditions allow… a strategy allowing for concurrent transportation and spill is prudent;" 2) recent court-ordered spill-transport operations should be continued to improve future evaluations of spill and transport decisions; and 3) "all juvenile passage alternatives should be evaluated against the baseline of spill."

Based on this advice, and after consultation with the Regional Implementation Oversight Group (RIOG) parties, the Action Agencies and NOAA Fisheries agreed that information relevant to transport/spill operations should be assessed annually for the duration of the 2008 BiOp and proposed operations should be discussed with the RIOG prior to the juvenile outmigration.

To assist in this process, the NWFSC (2010b) analyzed patterns of smolt-to-adult return rates (SARs) relative to in-season migration timing of smolts that were either transported from Lower Granite or Little Goose dams compared to SARs of non-transported fish that migrated through the lower Snake and Columbia rivers in the years 1998 to 2008[19]. They found, as expected, that in most cases, prior to 2006, estimated T:M for both yearling Chinook and steelhead remained constant or increased throughout the migration season and was higher than 1.0 (meaning transported fish returned at higher rates compared to detected fish migrating inriver) for fish that arrived at LGR on May 1 or later, and the difference was usually statistically significant.

They also found that:

> "In migration years 2006-2008 there have been some exceptions to the previously identified post-May 1 pattern: estimated T:M still usually increased through the season, but there were instances when the estimate did not exceed the standards until later in May, and for hatchery Chinook in 2006 the estimated T:M was less than 1.0 throughout the season. It is difficult to determine at this point whether altered spill operations and returning all bypassed smolts to the river during the early part of the migrations in 2006-2008 have resulted in changed T:M ratios compared to earlier years. Estimated T:M ratios for some groups at LGR were apparently lower, at least early in the season (e.g., hatchery steelhead and hatchery Chinook 2006, wild Chinook 2006, and hatchery Chinook in 2008). Adult returns are incomplete for some of these migration years, and final results cannot be evaluated for another year or two."

Based on the NWFSC (2010b) analysis of adult returns from the 2007 outmigration (a low flow condition on the Snake River) and extremely low runoff forecasts for both Snake River and Columbia River in 2010, NOAA recommended that it would not be "prudent"[20] to continue the spread-the-risk spill/transport option under these flow conditions and that the Action Agencies implement a maximum transport operation starting no later than May 1 at Lower Granite Dam. NOAA requested that the ISAB review this proposal and advise "whether NOAA Fisheries had correctly interpreted the ISAB's recommendation. If not, NOAA requested further explanation of ISAB's reasoning in the 2008 recommendation" (see Thom 2010 "Questions for ISAB" for details). NOAA, NWFSC, Oregon Department of Fish and Wildlife (ODFW), Fish Passage

[19] Note: All of the fish in this study (either the upstream releases or those tagged and released at the two projects) passed through at least one juvenile bypass system – allowing for assessment of seasonal trends in SAR relationships. These fish are not the same as the "undetected" or "C0" fish that are analyzed in the Comprehensive Survival Study reports, for which only annual averages can be calculated.

[20] In 2008, the ISAB (2008a) recommended that "whenever river conditions allow during the late April-May period, a strategy allowing for concurrent transportation and spill is prudent."

Center, U.S. Fish and Wildlife and others provided briefings or materials[21] for the ISAB's consideration.

In their review, the ISAB (2010) agreed that "available evidence indicates that there are overall benefits of transportation for steelhead and spring/summer Chinook under most environmental conditions" and summarized the "additional information available since the 2008 ISAB review, smolt to adult return ratios (SARs) for transported fish (T), relative to those for in-river migrants (M), produce T:M ratios" as follows:

- Steelhead, T:M (hatchery stocks) > T:M (wild stocks)
- Spring/Summer Chinook, T:M (hatchery stocks) > T:M (wild stocks)
- T:M (steelhead) >> T:M (spring/summer Chinook) > 1
- T:M ratios increase from early April through the end of May
- Increasing spill reduces the transportation SAR, relative to the in-river migrant SAR, but T:M ratios generally remain > 1.

However, based on other species-specific and ecological considerations (primarily concerns for SR sockeye salmon, Mid-Columbia River steelhead [as a result of increased straying of Snake River steelhead], and Pacific lamprey, the ISAB reached the same conclusion that they had arrived at previously, namely that "from a scientific standpoint, a mixed strategy for spill and transport is best supported by the available science."

Effect of Snake River Spill-Transportation Operations on MCR steelhead populations

The effects of additional straying of SR steelhead into MCR steelhead populations (primarily those within the Deschutes and John Day rivers) resulting from transportation operations was not explicitly assessed in the 2008 BiOp.[22] These impacts are, however, of concern (ISAB 2008a and 2010) and are captured by the productivity and extinction risk metrics for these populations under the Base and Current periods analyzed in the 2008 BiOp.

The 2008 BiOp estimated that SR steelhead transport rates during the Base and Current periods were 88.7% and 81.7%, respectively – a reduction of about 7% (2008 SCA Appendix E). Analysis of the proposed spill and transport operations in the 2008 FCRPS BiOp indicated the Prospective spill and transport operations would further reduce the proportion of juvenile steelhead transported by nearly 5%, to 77.1 percent. However, since 2006, the Action Agencies have operated in accordance with court ordered spill operations – even in low flow conditions

[21] FPC 2009a, FPC 2010c, FPC 2010d, FPC 2010e, Muir et al. 2001, Thom 2010, NWFSC 2009, NWFSC 2010, Northwest River Partners 2010, ODFW 2010, Ruzycki and Carmichael 2010, Taki 2010.

[22] Straying resulting from transportation as juveniles is in addition to that observed for many hatchery produced fish (compared to naturally produced fish).

like 2007. Transport rates of SR steelhead in these years (2006-2008) ranged from about 40 to 75% for both wild and hatchery smolts (NWFSC 2010b). These transport rates are substantially lower than assumed in the 2008 BiOp and would be expected to result in substantial reductions in the proportion (and absolute number) of both hatchery and naturally produced SR steelhead adults straying into the affected MCR steelhead populations. This should substantially reduce any negative impacts to the genetic integrity of MCR steelhead due to SR steelhead straying (as a result of transportation operations at the Snake River collector dams).

Physiological Effects of Transportation

Halvorsen et al. (2009) found that transporting juvenile Chinook salmon for up to 58.5 hours temporarily compromises their auditory capabilities (for at least 7 days). This would increase their vulnerability to predators and contribute to delayed mortality effects on transported fish indicated by many studies. Post-release survival of transported fish could potentially be improved if the holding tanks could be made quieter (reduced engine noise and holding tank vibrations).

There was no indication that transporting juvenile Chinook salmon injured their olfactory sensory neurons, indicating that their olfactory systems should be intact and functional (Halvorsen et al. 2009).

Delayed / Latent Mortality

With respect to latent mortality, the ISAB (2007b) advised that:

> "the hydrosystem causes some fish to experience latent mortality, but strongly advises against continuing to try to measure absolute latent mortality. Latent mortality relative to a damless reference is not measurable. Instead, the focus should be on the total mortality of in-river migrants and transported fish, which is the critical issue for recovery of listed salmonids. Efforts would be better expended on estimation of processes, such as in-river versus transport mortality that can be measured directly."

Recent studies have focused on comparisons of barged and inriver migrating fish and physiological, biological, and physical factors that could reduce the survival of both inriver migrating and transported fish.

Dietrich et al. (2008) and Eder et al. (2009a and 2009b) evaluated delayed mortality associated with barge or inriver outmigration histories and determined that both barged and inriver migrating yearling Chinook salmon arrive below Bonneville dam in a compromised condition (fish were stressed and responding to infections) that likely decreases their probability of survival during extended freshwater residence time.

Dietrich et al. (2008) challenged barged and inriver migrating spring/summer Chinook salmon with an infectious agent (e.g., *Listonella anguillarum*) and found that inriver migrants were more susceptible than barged fish. The rapid onset of mycotic and bacterial kidney disease- associated mortality in barged fish indicate that these diseases were likely contracted prior to arrival at the net pens. They also determined that barged fish held for less than 10 days exhibited greater net pen mortalities than inriver migrating fish; but this pattern reversed after fish were held in net pens for 28 or more days. Dietrich et al. (2008) concluded that conditions in the barges exacerbate disease, stress associated with inriver migration exacerbate disease, and that environmental conditions in the estuary (which degrade over time as pathogen exposure increases, contaminant exposure increases, and water temperatures increase) exacerbate disease.

Eder et al. (2009b) found that juvenile spring/summer Chinook salmon (based on prevalence of pathogens or clinical signs of disease) from both Rapid River and Clearwater hatcheries in 2008 were healthier prior to release than after completing their outmigration. They hypothesized that "the various pathology, pathogen prevalence, smoltification, and condition factor metrics analyzed in this study would further suggest that the health of the outmigrant population may be playing a contributing role in differential mortality in the Lower River estuary."

Eder et al. (2009a) found that the main cause of death in barged fish held in freshwater net pens was mycotic infection and metabolic disease. The main cause of death for inriver migrating fish held in freshwater net pens was ceratomyxosis. Mortalities for barged and inriver migrants were not significantly different when held in saltwater net pens –suggesting that there may be little difference in mortalities between the two groups once they enter the ocean environment.

Eder et al. (2009a) also found that travel times from Bonneville Dam to the ocean did not vary substantially for inriver migrating fish across the migration season, but that fish barged early in the outmigration season took longer to reach the Pacific ocean and had higher rates of mortality than those barged later in the season (based on mortalities observed for fish held in net pens). The pattern for barged juvenile Chinook salmon is consistent with inseason SAR patterns of PIT tagged fish (see discussion above) and increased mortalities as a result of increased exposure to avian predators in the Columbia River estuary.

The survival of acoustically tagged Snake River spring/summer Chinook salmon from Dworshak hatchery (which migrate past eight mainstem dams) was similar to that of Mid-Columbia River spring Chinook salmon reared at the Yakima River at the Cle Elum Supplementation and Research Facility (which migrate past four mainstem dams) was similar to Bonneville Dam tailrace and to Willapa Bay (29% vs 28%, respectively). Although these results do not apply to the run at large (tagged fish were > 140 mm in length); the authors suggested that they do provide some evidence that any delayed mortality resulting from juveniles passing multiple reservoirs and dams, is likely occurring in the ocean, after juveniles have left the freshwater environment (Rechisky et al. 2009).

Recent Ocean Conditions

For discussion on recent ocean conditions indicative or early marine survival, please see Section 2.2.4 (Factors Affecting Survival in the Plume).

Relevance to 2008 FCRPS BiOp Analysis and AMIP

Smolt to Adult return rates for SR steelhead and spring/summer Chinook salmon in 2005 and 2006 were lower than the average values estimated in the 2008 BiOp. Those from 2007 appear to be closer to average. Based on ocean conditions and early 2010 dam counts, it appears likely that returns from 2008 will far exceed the average values estimated in the 2008 BiOp and that 2009 will be about average or slightly below.

Delayed/latent mortality is noted as a critical uncertainty (RPA Action 55) targeted for additional research. Recent research results on this topic suggest several mechanisms that could be affecting SARs directly or indirectly (through delayed or latent mortality). The ISAB (2010) advised continuing spread-the-risk operations (which have been adopted by the Corps for the 2010 outmigration). Continued evaluation of this information and consideration of potential effects of climate change (see Section 2.2.1.3), should allow for better future management decisions (inriver conditions and transportation strategies that will provide increased SARs).

Compared to assumptions in the 2008 BiOp, recent spill operations at the Snake River collector projects have resulted in substantially lowered transportation rates (compared to either the Base or Current conditions). This should substantially reduce the number of SR steelhead adults straying into the affected MCR steelhead populations (primarily those in the Deschutes and John Day rivers) as a result of juvenile transportation operations, and thus reduce negative genetic impacts to these MCR steelhead populations.

2.2.2.5 Tagging Effects

PIT Tags

Feldhaus et al. (2008) evaluated cortisol levels and hepatic hsp70 levels in PIT-tagged and untagged rainbow trout. They found no change in hsp70 levels between the test and control groups during the study, and differences in plasma cortisol levels were observed for no longer than 6 hours. Their results suggested that "PIT tagging is a low-impact tagging procedure for juvenile salmonids."

Tatara (2009) found that juvenile steelhead parr greater than 75 mm exhibited positive growth rates over a four-week period following PIT tagging. Parr less than 74 mm failed to grow over the same period. This study suggests that, to minimize biases due to tagging, only steelhead parr larger than 75 tagging should be PIT tagged.

Knudsen et al. (2009) used a double tag (PIT tags and coded wire snout tags) study with hatchery-reared juvenile spring Chinook salmon (1997 to 2001 brood years) to test the assumption that tags are not lost and do not affect post-release survival. They found that about 2% of the tags were lost before release and 18.4% were lost in recaptures returning in 6 months (jacks) to 4 years after release.[23] SAR estimates of the PIT tagged fish were 25.0% lower than those of non-PIT-tagged fish because of tag loss and reduced survival. The mean estimate of tag-induced mortality (SARs of PIT-tagged fish were lower than SARs of non-tagged fish after correcting for tag loss) was estimated to be 10.3% over all brood years.

The ISAB (2009) cited Knudsen et al. (then in press) and Williams et al. (2005) when it noted that "SARs may be affected by PIT tagging in the juvenile life stage, as it appears that fewer PIT-tagged fish are returning as adults than would be expected." Ultimately, as Knudsen et al. (2009) indicate that their study was likely a best case scenario, SARs measured with PIT tags may be substantially lower (>25%) than actual rates for the great majority of the populations which are untagged.

Telemetry Tags

Brown et al. (2009) found that exposure to simulated pressure changes associated with passage through a large Kaplan turbine resulted in higher mortality and injury rates for juvenile Chinook salmon bearing surgically implanted telemetry tags than for non-tagged fish. Thus, untagged (run-of-river) juvenile Chinook salmon and steelhead (especially subyearling Chinook salmon) are likely surviving at higher rates through mainstem turbine units than are indicated by studies using telemetry tags (acoustic or radio).

Relevance to 2008 FCRPS BiOp Analysis and AMIP

The 2008 BiOp analyzed the effects of an All-H approach to mitigating for the continuing effects of the FCRPS and assessed how these factors would affect productivity and extinction risk at the population, meta-population, and ESU/DPS levels. The tag effects studies, collectively, indicate that it is likely the results of studies employing these tags are underestimating the true survival rates of the untagged population through longer reaches and for estimates of SARs. Thus, the SAR and reach specific survival estimates based on these technologies are likely conservative in the sense that they are somewhat pessimistic representations of what the populations are experiencing as a whole.

2.2.2.6 COMPASS Model

The ISAB (2008b) favorably reviewed the COMPASS Model (Version 1.1) that was used in the 2008 SCA to assess hydro operations. They also provided "constructive suggestions to facilitate the continuing development of a valuable modeling tool." They specifically indicated that the model was of about the right complexity to be useful without becoming unmanageable; mostly captures the impacts of the variables considered, permitted the evaluation of a reasonable range of management options; provides and improved treatment of uncertainty; does a credible job of reflecting a dynamic reality where the data permits; uses generally sound statistical

[23] An estimated 3.4% of the coded wire tags were also lost before release, and an estimated 6.7% were lost in recaptures returning in 6 months to 4 years after release. This suggests that SARs based on coded wire tags are also biased, but likely to a much smaller extent than SARs based on PIT tags.

methodologies; and has good documentation – thought the User's Guide had not yet been finished at the time of their review. They also noted that, because of the absence of reliable data from below Bonneville Dam, the Bonneville to Bonneville survival component of the model is still poorly characterized.

Relevance to 2008 FCRPS BiOp Analysis and AMIP

Validation of the COMPASS model has no effect on the analysis incorporated into the 2008 BiOp. Addressing, to the extent possible, constructive suggestions by the ISAB will improve future versions of the model and enhance the information available for future decision-making.

2.2.2.7 New Information Relevant to Effects of the RPA on Designated Critical Habitat in the Mainstem Lower Columbia and Snake Rivers

The recent installation of surface passage routes at Lower Monumental, John Day, Little Goose, and The Dalles dams, as anticipated in the 2008 BiOp analysis, is contributing to safe passage by providing a normative route and reducing forebay delay. Ongoing studies from free-flowing reaches or other river systems indicate that substantial mortalities, similar in magnitude to those observed in juveniles migrating through the mainstem FCRPS projects, are occurring in these systems as well. Understanding these losses could provide opportunities to further enhance safe passage in the FCRPS as a juvenile migration corridor.

Recent conversion rates for adult salmon and steelhead from Interior subbasins have exceeded the average expectations in the 2008 BiOp, indicating that efforts to meet performance standards for safe passage are on track.

In summary, the new scientific information indicates that the RPA, as amended is continuing to improve the functioning of safe passage in the juvenile and adult migration corridors.

2.2.2.8 Overall Relevance to 2008 FCRPS BiOp Analysis and AMIP

In summary, actions are being implemented at the mainstem FCRPS projects (especially the installation of surface passage routes) in accordance with the expectations set forth in the 2008 FCRPS BiOp and are generally improving juvenile survival rates of fish passing these dams (enhancing normative passage conditions and behaviors) and reducing forebay delay which should result in reduced delayed or latent mortality effects. Together, these actions are resulting in juvenile reach survival estimates that meet or exceed BiOp expectations. Per kilometer survival rates through the FCRPS for several Snake River ESUs are similar to those observed in free-flowing river reaches upstream of the mainstem FCRPS projects or in other river systems. Recent adult conversion rate estimates have exceeded average expectations for SR fall Chinook and UCR steelhead, but have been lower than averages expected for SR spring-summer Chinook, SR sockeye, SR steelhead, and UCR spring Chinook. Ongoing Research, Monitoring and Evaluation (RM&E), assessments of available information, and potentially additional PIT tag detection capabilities at some dams should be sufficient to assess causative agents (dam passage effects, harvest effects, injuries from marine mammal attacks) and recommend corrective actions, if warranted, to maintain or improve adult conversion rates in accordance with 2008 BiOp expectations.

Recent court ordered operations - based on the available Smolt-to-Adult information - will likely result in reduced returns of SR steelhead, and to a lesser extent SR spring-summer Chinook salmon than those estimated in the 2008 BiOp. However, the ISAB (2008a and 2010), after reviewing information prepared by NOAA, USFWS, ODFW, and FPC and considering affects to other ESA-listed and unlisted species, recommended spread-the-risk operations to collect information necessary for better long-term decision-making. The Action Agencies, after receiving input from the RIOG favoring this operation – has agreed to operate in this manner, and will recommend future operations on a year by year basis.

Recent spill-transport operations at the Snake River collector projects should substantially reduce straying of SR steelhead into Deschutes and John Day river populations of MCR steelhead; reducing any resultant genetic impacts to these populations (compared to impacts resulting from straying under the Base or Current periods evaluated in the 2008 BiOp).

Evaluations of physiological effects of transport and potential mechanisms of delayed and latent mortality are generally consistent with inseason SAR patterns of PIT tagged fish assumed in the 2008 BiOp. New information on tagging effects indicates that juvenile reach survival estimates and SAR estimates for tagged fish (used in the BiOp analysis) are likely biased low due to tag loss and differential mortalities of PIT tagged verses untagged juveniles. Thus, the untagged majority of fish in the ESUs are likely experiencing higher survival rates and adult return rates than was estimated using the COMPASS model.

The studies reviewed above support NOAA’s assumptions in the 2008 BiOp that the RPA, as amended, will address factors that have limited the functioning and conservation value of mainstem migration corridor habitat that Interior basin salmon and steelhead use to migrate to and from the ocean.

2.2.3 Tributary Habitat Improvement

NOAA Fisheries reviewed the new scientific information on the best methods for achieving the benefits needed from tributary habitat restoration (RPA Actions 34 and 35 including Table 5, in the 2008 BiOp). These studies support the Action Agencies’ approach for selecting goals for habitat improvement projects based on addressing limiting factors, including Reclamation’s ongoing Tributary and Reach Assessment effort to assess the natural potential of selected river/habitat systems in their current form to help direct project implementation. Thus, as explained in the following sections, the new scientific information supports NOAA’s conclusions that the RPA, as amended, addresses factors that have limited the functioning and conservation value of spawning and rearing habitat and will increase the survival of the affected populations.

2.2.3.1 New Information Relevant to the 2008 FCRPS BiOp and AMIP

Recent peer reviewed papers have discussed elements tied to determining the appropriate scale, context, analytical approach, and decision-making process needed to successfully restore or rehabilitate tributary habitats used by Columbia River salmon and steelhead. Olden and Naiman (2010) emphasizes the importance of understanding natural processes—in this case focusing on the role of thermal regimes in habitat restoration. Similarly, Palmer (2009) identified several ways in which ecological knowledge should influence restoration. As an example, he cites the interest in removing sediments in order to restore channel function in mid-Atlantic streams where there are large, agriculturally-derived sediment deposits on the floodplains. In this case, the use of an ideal (pre-development) reference condition to guide restoration projects led to failure primarily because massive regional changes in land-use and water infrastructure were acting as an on-going "disturbance" event, keeping channel morphology in a perpetual state of disequilibrium.

Roni et al. (2008) reviewed 345 studies on the effectiveness of stream rehabilitation, but found it difficult to draw conclusions about many specific techniques. Limited information was provided on physical habitat, water quality, and biota and most of the published evaluations were of short duration and limited in scope. Nonetheless, the authors stated that the failure of rehabilitation projects to achieve objectives could often be attributed to an inadequate assessment of the historical conditions and the factors limiting biotic production, a poor understanding of watershed-scale processes that influenced local projects, and monitoring at inappropriate spatial and temporal scales. The authors suggested that as an interim approach, high-quality habitats should be protected and connectivity restored before implementing instream habitat improvement projects.

The latter recommendation is supported by the work of Isaak et al. (2007), who modeled linkages between habitat quality, size, and connectivity and the occurrence of Chinook redds in Idaho streams. Connectivity was the strongest predictor of redd occurrence, but interacted with habitat size, which became more important when populations were reduced. The authors concluded that size and connectivity should be maintained wherever possible and should be used to strategically prioritize areas for habitat improvement.

Beechie et al. (2008b) in a review of the methods of planning and prioritizing restoration actions, suggested that restoration groups often confuse watershed assessment, project identification, and project prioritization. Their paper states that a clear sequencing of identifying restoration goals, conducting watershed assessments, identifying restoration opportunities, and then prioritizing actions is needed to assure effective programs. They also review six general ways of prioritizing restoration actions (project type, refugia, decision support systems, single-species analysis, multispecies analysis, and cost effectiveness) and concluded that decision support processes that incorporated stakeholder values were probably the most flexible and transparent. Alternately, where priorities were based on cost-effectiveness, more assessment information was required up front, but funding agencies had more confidence that scarce funds would be used effectively to achieve restoration goals. In a more recent review, Beechie et al. (2010) outlined four principles that would ensure river restoration was guided toward sustainable actions: 1) address the root causes of degradation, 2) be consistent with the physical and biological potential of the site, 3) scale actions to be commensurate with the environmental problems, and 4) clearly articulate the expected outcomes.

Several authors offer tools for evaluating the potential benefits of combinations of specific actions. The modeling framework developed by Jorgensen et al. (2009) converted suites of restoration actions into changes in habitat condition and then linked these to Chinook population status. Honea et al. (2009) used a model to predict that actions reducing fine sediment in the streambed would have a large influence on the size of the Wenatchee population of UCR spring Chinook through improved egg survival. Opening access to habitat in good condition would also have a positive but smaller effect on spawner numbers. Pollock et al. (2007) and Beechie et al. (2008c) identified a key recovery mechanism for incised channels—sediment retention by beaver dams, assuming time frames similar to those for riparian forest restoration (decades to low centuries).

Potential effects of climate change on conditions in tributary habitat used for spawning and rearing are described in Section 2.2.1.3.2.2 through 2.2.1.3.2.3.

2.2.3.2 Relevance to 2008 FCRPS BiOp Analysis and AMIP

The studies reviewed above emphasize the need to incorporate proper planning, sequencing, and prioritization into decision frameworks to best achieve habitat program objectives. Additionally, the papers recommend that planners assess the natural potential of the system and use this information to direct project location, design and selection. This corresponds with the approach taken in the RPA, as amended, to improving tributary habitat. The RPA focuses on priority populations and draws upon the menu of tributary habitat actions and the key limiting factors identified in ESA recovery plans. Across the Interior Columbia basin, project selection incorporates the recommendations of Expert Panels, made up of local biologists with professional knowledge of the habitat conditions within their geographic area. The Expert Panels have met several times over the past year to develop a common understanding of the array of physical attributes that can be used to describe the restoration capacity of aquatic and riparian habitats. They have incorporated information from recovery planning documents on current landscape condition, intrinsic potential (capacity to provide spawning and rearing habitat), and limiting factors and threats into their decision framework for project selection and design.

In the 2006 -2007 and 2008 Annual Progress Report for the FCRPS, the Action Agencies reported that they had improved 3,264 acres of fish habitat; increased tributary stream flows by a cumulative 1,082 cubic feet per second; opened up access to 582 miles of spawning and rearing habitat; improved 92 miles of streams; and protected over 700 miles of riparian habitat through land purchase or lease. Reclamation's Tributary and Reach Assessment effort 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 assessments and recovery plans. These assessments analyze biological conditions (including fish and riparian communities), geologic setting, subbasin hydrology, hydraulic and sediment transport processes, and anthropogenic constraints. The recent studies described above emphasize the need to assess the natural potential of the river/habitat system in its current form and use this information to help direct project implementation, indicating that this information will be critical to the ultimate success of the tributary habitat program. Reclamation completed the Middle Fork and Upper John Day assessments in 2008 and is currently working in the Yankee Fork of the Salmon River in Idaho, the Grand Ronde River/Catherine Creek in eastern Oregon, and the middle reach of the Methow River in Washington. These assessments are scheduled to be completed by the end of 2011 and additional assessments will be planned for the following years. Additional assessments are scheduled for the Entiat, Wenatchee, and Methow rivers. The Yakima Tribe is working on reach assessments in Icicle Creek and the Twisp and Chewuch rivers.

The RPA, as amended, includes the 2008 Columbia Basin Fish Accords (Appendix G). The Accords support and enhance the tributary habitat program by securing a number of Columbia Basin tribes and the State of Idaho as implementing partners. The Accords' habitat improvement objectives are beyond those required by Table 5 of RPA Action 35, which adds to NOAA Fisheries' confidence that habitat improvements over the term of the BiOp will meet or exceed those expectations for the affected populations.[24]

In summary, the studies reviewed above support NOAA Fisheries' assumptions in the 2008 BiOp that the RPA, as amended, will address factors that limit the functioning and conservation value of habitat that Interior basin salmon and steelhead use for spawning and rearing. The PCEs expected to be improved are water quality, water quantity, cover/shelter, food, riparian vegetation, space, and safe passage/access, as described in the 2008 analysis.

2.2.4 Estuary and Plume

NOAA Fisheries reviewed the new scientific information relevant to the rationale for RPA Actions 36 and 37. As explained in the following sections, the studies on estuarine ecological services and habitat diversity support NOAA's assumption that estuary habitat projects will improve the survival of juvenile salmon and steelhead. Thus, the new scientific information supports NOAA's conclusions that the RPA, as amended, will address factors that have limited the functioning and conservation value of habitat that basin salmon and steelhead use for

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[24] The following populations are expected to benefit from Accord tributary habitat actions. Based on calculations of benefits by the Accord Tribal partners (using the same method as the Collaboration Habitat Workgroup), the survival benefits of these actions will exceed those called for in RPA Action 35, Table 5.
Mid-Columbia River Steelhead DPS: All populations in this DPS with the exception of Touchet River steelhead.
Snake River Steelhead DPS: The Upper Grande Ronde River steelhead population.
Snake River Spring/Summer Chinook Salmon ESU: The Upper Grande Ronde and Lemhi River spring Chinook salmon populations.
Upper Columbia River Spring Chinook Salmon ESU: The Wenatchee spring Chinook salmon population.
Upper Columbia River Steelhead DPS: The Entiat, Wenatchee and Okanogan River steelhead populations.

migration and rearing. Although preliminary, one additional piece of new scientific information indicates that there may be a relationship between the size and position of the plume, seabird predation, and the early ocean survival of juvenile salmon and steelhead. An understanding of the links between plume dynamics and avian predation in the nearshore ocean could be important to developing more accurate forecasts of adult returns.

2.2.4.1 New Information Relevant to the 2008 FCRPS BiOp and AMIP

The Columbia River estuary (encompassing the tidally influenced freshwater region below Bonneville Dam to the more saline region at the mouth and including the plume) is now recognized as a critical part of the landscape, providing rearing as well as transitional habitat for juvenile salmon. All of the listed species have been shown to use estuarine habitat, although this use varies in time and space depending on the species' dominant juvenile life history strategy. Stocks that use a subyearling strategy (ocean type Chinook and chum salmon) are likely to reside in estuarine habitats more extensively than those with a yearling juvenile strategy (spring-run Chinook and steelhead from Interior subbasins).

Estuarine Ecological Services

Using PIT-tag detectors deployed in Oregon's Salmon River estuary, Hering et al. (2010) tracked fine-scale movements of small (< 90 mm) subyearling Chinook salmon into and out of the wetland channels over the summer period. The authors found that peak movement occurred roughly one to two hours before and three to four hours after high slack tides (rather than during slack tide) and that fish at times swam against tidal currents. The researchers hypothesized that if active habitat choices represented tradeoffs between foraging opportunities, predation risks, and physiological stress, the patterns observed in the Salmon River study could benefit juvenile Chinook by limiting the risk of predation (i.e., the longest tidal residence times in the shallow channels were during nighttime tides) and bioenergetic costs (most fish exited the channels as on receding tides when water temperatures were increasing) while potentially positioning smolts to encounter invertebrate prey drifting out of the marsh channel network. Because most of the tagged salmon occupied the intertidal channel only when water reached a minimum depth, restored channels intended as salmon rearing habitat should be designed to maintain sufficient depth during low tides. The researchers report that higher elevation tidal channels could support and export salmon prey to other areas of the estuary, but might not be used by salmon directly.

Maier and Simenstad (2009) used stable isotopes to track the sources of nutrients supporting subyearling Chinook salmon in the Columbia River estuary. Overall, food web linkages of Chinook were broadly distributed among nutrient source types. Hatchery food was the dominant source, with an average fractional contribution of 32%. Vascular plants were the most common source of natural organic matter (average contribution of 19%). Fluvial phytoplankton (represented by particulate organic matter collected in the mainstem channel and in Bonneville Reservoir) averaged 16% and aquatic plants averaged 12%. The authors concluded that many of the estuarine food web linkages to ocean type Chinook appear to be based on primary production by estuarine marsh plants despite the overall reduction of marsh habitat in the estuary over the last 150 years.

More direct support for the dependence of estuary-rearing subyearling Chinook salmon on marsh food production comes from examination of Chinook stomach contents during 2002-2007 (Zamon 2010). These diet collections included both hatchery and non-hatchery fish in a variety of locations in the estuary. Mean stomach fullness across all years, months, and habitats was 86% (Table 2 in Zamon 2010), indicating that fish from a variety of subyearling stocks are actively feeding in the estuary during all seasons. When accounting for both numerical and biomass contributions to stomach contents, the most important prey items for juvenile subyearling Chinook were flies and midges, followed by the benthic amphipod crustacean *Americorophium salmonis*, regardless of location of capture (i.e., within or outside of wetland habitat in the estuary). These results indicate that the fish recently fed within the wetlands, were feeding on prey exported from the wetlands, or both.

Estuarine Habitat Diversity Supports the Viability of Listed Species

Population biologists have predicted that life-history diversity should spread risk across different segments of a population, thereby buffering it from environmental variation over long time periods. Greene et al. (2009) note that although Bristol Bay, Alaska, stocks of sockeye salmon have varied in age composition over time, populations have replaced others in dominance such that the entire system has continued to support a productive fishery. Based on scale samples, the authors found that growth rates of nine populations of Bristol Bay sockeye were positively correlated with the amount of variation in their freshwater and ocean residency periods over long time horizons (ten or 20-40 years). Hypothesizing that the life history types that are favored by natural selection are likely to change between years, they suggest that practices that help diversify population structure, such as maintaining large population sizes and habitat protection and restoration, help populations flourish.

Teel et al. (2009) assessed the potential benefits that wetland restoration activities in the lower Columbia River might provide for Chinook salmon. The researchers note that the benefits of off-channel and seasonal floodplain habitats for Chinook are poorly documented compared to those for juvenile coho salmon. Genetic identification methods were used to determine which stocks produced the subyearling Chinook collected in restored wetlands at the Willamette confluence with the Columbia River. These Chinook were predominantly from the Upper Willamette River ESU, but westside Cascade populations (Lower Columbia River ESU) and the Spring Creek National Fish Hatchery in Bonneville pool made large contributions. Subyearlings from summer–fall Chinook populations in the middle and upper Columbia River made up 26% of those found in wetland samples collected during spring 2006. The results suggested that floodplain restoration projects intended to improve fish habitats during winter and spring periods in the lower Willamette River may benefit Chinook salmon populations produced in the upper Willamette, lower Columbia, and upper Columbia rivers.

Research in the Columbia River estuary has led to opposing hypotheses about the estuary as a salmon rearing environment. Many contemporary tagging studies indicate that salmon residency within the estuary is short (less than one week). On the other hand, life history interpretations from fish scales collected early in the twentieth century suggest that juvenile Chinook salmon reared extensively in the estuary, leading some to hypothesize that life history variation has been constrained by anthropogenic changes in the Columbia River basin. To test these hypotheses, Campbell (2010) measured strontium^{86} and calcium^{43} in salmon otoliths collected in the lower Columbia River estuary in 2003-2005 to quantify the period of salt-water residency and to back calculate their size at salt-water entry. The estimated salt-water residency of juvenile Chinook ranged from 0-176 days with mean residence times of 54, 67, and 30 days in 2003, 2004, and 2005, respectively. Campbell also found a negative relationship between size and time of entry with residency. On average, smaller earlier migrants resided for longer periods than larger late migrants. Thus, a high proportion of small subyearling Chinook salmon use the saline portion of the estuary for extended periods of time. This is in contrast to the short residency times reported for subyearlings in some contemporary tagging and marking studies, but these tend to use larger individuals that can accommodate the tags.

Potential effects of climate change on conditions in rearing and migration habitat in the Columbia River estuary are discussed in Section 2.2.1.3.2.6.

Columbia River Plume

The Columbia River plume, an extension of the estuarine mixing zone, is part of the transitional environment for salmon smolts. The role of the plume has been the focus of recent research because all ESU listed stocks must pass through the plume to enter the ocean and begin their marine life stage. The plume also has the potential to protect juveniles by dispersing them farther offshore, away from predators concentrated at the mouth of the Columbia River (Pearcy 1992).

Using PIT-tagged smolts from the Snake River, released below Bonneville Dam (1999-2004), Burla et al. (in press) found that steelhead survival was significantly higher when the plume was large, detached from the coastline, and extending in a southerly direction (versus smaller, attached to the coastline, and extending northward). Chinook survival also was higher when the plume was larger, but not significantly. This corresponds with new unpublished information that seabird predators are most highly concentrated to the north of the river entrance, on the leading edge of the most recently discharged river water (Zamon et al. 2010).

Sooty shearwaters (*Puffinus griseus*) and common murres (*Uria aalge*) are the most abundant bird species in the plume during the May through September smolt outmigration period. Regional population monitoring data indicate that numbers of common murres (Naughton et al. 2007) have increased significantly during the past decade, indicating a potential increase in predation pressure. Both previously published information on bird diet in the plume (Varoujean and Matthews 1983) and more recent unpublished data (Zamon et al. 2010) indicate that juvenile salmon occur in up to 10-11% of murres sampled. In addition, a PIT tag from a Columbia River steelhead smolt (Ringold Hatchery stock) was recovered from a sooty shearwater chick at a nesting colony in New Zealand, 7,700 miles away (NOAA 2007).

Hypothetically, high turbidity could shield smaller juveniles from visually-oriented piscine and avian predators during the final period of adjustment to the marine environment. However, analyses show marine birds feeding in productive frontal areas like the plume are likely to be well-adapted to foraging in low-light, turbid environments (Haney and Stone 1988), and the relationship between light levels and prey vulnerability is more complex than previously thought (Lovvorn et al. 2001).

2.2.4.2 Relevance to the 2008 FCRPS BiOp Analysis and AMIP

Estuarine Habitat Restoration

The principal justification in the 2008 BiOp for requiring restoration of estuarine habitat (RPA Actions 36 and 37) was to enhance the survival of juveniles as they prepare for ocean entry. In addition, reconnecting shallow water habitat to cold water refugia is expected to protect this life stage against expected impacts of climate change. The new scientific information supports these goals, and reinforces the importance of a diverse portfolio of life history strategies to support the stability and resilience of salmonid populations.

In the 2006 -2007 and 2008 Annual Progress Reports for the FCRPS, the Action Agencies reported that they restored 57 acres of riparian area and 60 acres of floodplain, improved and restored 6 miles of streams, planted or maintained 285 acres of vegetation, removed invasive plants on 303 acres, installed 5 miles of fencing and acquired 380 acres of land that will be protected and managed for fish habitat. The RPA, as amended, describes a Memorandum of Agreement (Estuary MOA) between the Action Agencies and the State of Washington, which secures the state as an implementing partner. It includes a Research Monitoring and Evaluation (RM&E) component for evaluating progress toward implementation objectives. The RM&E will also assist in projecting the biological benefits of the estuary habitat projects by the existing expert regional technical panel. Therefore, the process is in place to incorporate the new findings identified above through adaptive management as well as future advancements from RM&E activities.

Factors Affecting Survival in the Plume

RPA Action 61 requires that the Action Agencies fund RM&E to define the ecological importance of the plume and nearshore ocean environments to the viability of listed salmonids. As part of this effort, the Northwest Fisheries Science Center maintains a Web site that describes indicators of salmon marine survival in the ocean ecosystem of the Northern California Current off Oregon and Washington. [25] Based on the "good" nearshore conditions for smolts

[25] http://www.nwfsc.noaa.gov/research/divisions/fed/oeip/a-ecinhome.cfm. The factors considered in making these forecasts include both physical and biological indicators as described in Peterson et al (2010).

outmigrating during 2008, the indicators forecasted high returns for coho salmon in 2009 and spring Chinook salmon in 2010 (Peterson et al. 2010). Conditions for juveniles entering the ocean in 2009 were less favorable than in 2008 and more average overall. The indicators forecast moderate returns for LCR coho in 2010 and spring Chinook salmon in 2011. El Niño conditions, which result in poor recruitment of salmon, began developing during summer 2009 and conditions for juvenile migrants in 2010 are expected to again be average to poor as winter-like conditions have extended through April into May. However, the majority of climate prediction models predict a transition to neutral conditions (i.e., favoring neither El Niño or La Niña) near the onset of summer in the Northern Hemisphere.[26] Although a great deal of new information is available on the biological effects of ocean productivity, it does not differ substantively from factors previously considered in the 2008 BiOp (see 2008 SCA Section 5.7).

The patterns in juvenile salmonid survival described in Burla et al. (in press) (higher in a southward flowing Columbia River plume) conform with recent data demonstrating that common murres and sooty shearwaters are most concentrated on the northern face of the plume. Developing a mechanistic understanding of the link between plume dynamics, avian predators in the nearshore ocean, and early marine survival could be important to developing more accurate forecasts of adult returns.

In summary, the studies reviewed above support NOAA Fisheries' assumptions in the 2008 BiOp that the RPA will address factors that have limited the functioning and conservation value of habitat that Interior basin salmon species use for migration and rearing. PCEs expected to be improved are water quality and safe passage in the migration corridor for yearling Chinook and steelhead migrants and in rearing areas for subyearling Chinook and chum salmon as described in the 2008 analysis.

2.2.5 Predation & Other Ecological Interactions

The 2008 RPA included actions to reduce predation in the mainstem Columbia River and estuary by Caspian terns, double-crested cormorants, predacious northern pikeminnows, and California sea lions. The RPA, as amended, includes the option of more aggressive, targeted predator control actions in the event of a significant decline in the natural abundance of one or more Interior basin species. The value of these measures is supported by the new scientific information described below. In addition, the RPA recognizes the potential effects of non-indigenous fishes that are predators or competitors, alter food webs, etc., also addressed in the new scientific information described below. Effects beyond those considered in the 2008 analysis include predation on steelhead and subyearling chinook salmon (and to a lesser extent, yearling Chinook and sockeye salmon) by double-crested cormorants in the estuary. Adult Chinook and steelhead losses due to marine mammal predation in the Bonneville Dam tailrace appear to have stabilized or decreased. However, increased numbers of ESA-listed Steller sea lions and observations of California sea lions in the fall need to be monitored. Adult losses due

[26] http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/enso_advisory/ensodisc.html

to marine mammals in the estuary are unknown,[27] but West Coast sea lion populations are increasing.

Adaptive management activities designed to reduce overall cormorant predation in the estuary will be evaluated through the ongoing development of the Corps' cormorant management plan (RPA Action 46). Marine mammal monitoring at Bonneville Dam will continue to assess take of adult salmonids in the tailrace and will be modified as necessary to assess take later in the season.

2.2.5.1 Avian Predation

2.2.5.1.1 New Information Relevant to the 2008 FCRPS BiOp and AMIP

Caspian Terns

Despite some early management efforts, Caspian terns remain a major predator of juvenile salmon. Relocating the estuary colony from Rice Island to East Sand Island in 2000, the most significant effort to date, reduced the percentage of salmonids in tern diets by 40 to 50% (Roby et al. 2008). However, it did not reduce the overall population of terns in the estuary; population levels have remained between 10,000 and 11,000 pairs (Collis et al. 2009). Efforts to relocate Caspian terns to other sites outside the Columbia Basin and then reduce the amount of habitat available in the estuary have been underway for the past two years. Nesting islands were constructed in interior Oregon and are planned for the San Francisco Bay area. To date, the efforts in eastern Oregon have been somewhat successful in attracting nesting terns, but the relocated numbers are low.

The interior basin Crescent Island and Potholes Reservoir Caspian tern colonies are much smaller than the estuary colony and number in the hundreds of pairs each (Collis et al. 2009). Nevertheless, their consumption of salmonids can be significant. The Crescent Island colony diet is typically between 60 and 70% salmonids (Roby et al. 2008). Also, much of this consumption consists of steelhead from the listed Snake and Upper Columbia River DPSs. While the size of each colony has fluctuated somewhat, the overall interior population has remained stable. Increases in these colonies could be possible if terns from the estuary relocate to the interior basin.

Double-crested Cormorants

The 2008 BiOp only partially addressed increased predation by double-crested cormorants in the current period, compared to the 2008 BiOp's base period (Fredricks 2008). This means that juvenile survival decreased from the 1980s to the current period and this change was not fully

[27] The NWFSC initiated a pilot study in 2010 to develop methods to assess adult losses from the estuary to Bonneville Dam. This work is not funded by the Action Agencies, and therefore, is not considered in this consultation. However, work is being conducted that NOAA expects will provide better information for future decision-making with respect to this issue.

reflected in the 2008 BiOp's "base-to-current" multipliers. This change primarily affects steelhead but, to a lesser degree, also affects Chinook salmon.

Current average annual estimates for 2001 through 2009 are 6, 2, and 6% for steelhead, yearling Chinook and sub-yearling Chinook, respectively (Fredricks 2010). Steelhead and yearling Chinook consumption levels have remained fairly stable during this period and may have even declined slightly. Rates of consumption of subyearlings were higher than anticipated in the 2008 analysis; based on PIT tags recovered from East Sand Island, a large proportion of them were from the LCR Chinook ESU (Sebring et al. in prep). Although these estimates are based on data with a large amount of variability, they probably reflect the stability of the double-crested cormorant population in the estuary, which has fluctuated between 10,000 and 14,000 nesting pairs since 2002 (Roby et al. 2008, Collis et al. 2009). Given this stability, it is unlikely that these predation rates will change much in the next few years. While the researchers have been able to move double-crested cormorants short distances within the estuary, initial efforts to attract them to sites outside the basin have not been successful. Active disturbance methods have been used to disrupt nesting activities at the estuary colony with mixed results and at this point, there is no evidence that this action would significantly decrease predation rates on Columbia Basin salmonids.

A pile and pile dike removal program is called for in RPA Action 38 to help increase habitat connectivity and reduce avian predation. While RPA Action 38 focuses on the removal of these structures, initial efforts have focused on assessing the overall importance of pile dikes and pile fields to salmon survival and ecosystem function. A pilot project investigating pile manipulation (removal versus modification) methods is planned for 2010. The results will be used to inform the development of a programmatic approach for addressing this RPA requirement.

In the interior basin, the Foundation Island cormorant colony has remained somewhat stable since 2006 at 300 to 400 breeding pairs (Roby et al. 2008, Collis et al. 2009). Salmonid consumption by this colony is similar to that of the nearby Crescent Island tern colony. Overwintering cormorants in the lower Snake River have also been a concern. Recent research results indicate that the diet of these birds consists of a relatively low proportion of salmonids (<15%), however the samples were small (Collis et al. 2009). This research is continuing through winter 2009-2010.

Interior Basin Gulls

Interior gull populations (ring-billed and California), while quite large (>10,000 pairs), have not been shown to be as significant to salmonid predation losses as terns or cormorants (Collis et al. 2009). Gull predation rates at mainstem projects have been estimated in the range of 1 to 2% (Zorich et al. 2010). Most of the data were collected from gulls foraging in the tailraces of dams and it is unknown how many of these fish were alive when consumed.

Other Species

Interior basin American white pelicans nesting on Badger Island have been studied in past years. Even though the population level is substantial at >1,000 individuals, per capita consumption rates on salmonids are much lower than for the nearby tern and cormorant colonies (Collis et al. 2009). While overall salmon predation rates have not been high (<0.1% of all PIT-tagged fish released above McNary Dam), the Badger Island colony continues to grow (about 1,700 birds in 2009).

There are several other fish eating bird species in the estuary including western/glaucous-winged gulls and brown pelicans. There are little data in the literature regarding whether these species are significant predators of juvenile salmonids, researchers are continuing to focus at least some effort on western/glaucous-winged gulls. See Section 2.2.5.1 for a discussion of avian predators (especially common murres and sooty shearwaters) in the Columbia River plume.

2.2.5.1.2 Relevance to the 2008 FCRPS BiOp Analysis and AMIP

Caspian Terns

NOAA Fisheries' 2008 analysis assumed that the Action Agencies would reduce the amount of nesting habitat for terns on East Sand Island, thereby further reducing tern consumption rates. Significant habitat reduction in the estuary is planned for the next few years per RPA Action 45. Recent information has refocused some research to the upper Columbia specifically focusing on the Potholes tern colony. The Action Agencies are continuing development of the inland avian predator management plan called for in RPA Action 47.

Double-crested Cormorants

The Action Agencies are developing a cormorant management plan to reduce predation in the estuary per RPA Action 46. The pile dike removal program (RPA Action 38) is intended to remove perches for cormorants.

No specific management activities are planned for double-crested cormorants at Foundation Island, although an evaluation of options is included in the Action Agencies' inland avian predation management plan (RPA Action 47) and research on possible options (RPA Action 68) will continue during 2010.

Interior Basin Gulls

As required by RPA Action 48, specific management actions include active hazing at the dams and bird wires hung in high predation risk areas of the tailraces. For the 2010 outmigration, the Corps has installed a new extensive wire array in the tailrace at John Day Dam. A similar array was installed and evaluated in 2009 at Wanapum Dam by Grant County PUD (Turner et al. 2008), which combined with active hazing was successful in reducing gull and tern presence in the tailrace. The John Day array in combination with an active hazing effort will be evaluated for effectiveness in 2010.

Other Species

Monitoring of white pelicans nesting at Badger Island will continue during 2010 (RPA Action 68). No specific management activities planned for this population at this time. There has been some interest in attracting nesting pelicans to the Malheur Basin which, if successful, could reduce the colony size on Badger Island. No management activities are planned for western/glaucous-winged gulls or brown pelicans.

See Section 2.2.4 for a discussion of ongoing research on avian predators in the Columbia River plume.

In summary, the new scientific information indicates that efforts to reduce avian predation rates are moving forward as anticipated for this point in the 10-year term of the 2008 BiOp. Juvenile salmon predation rates in the estuary are higher than analyzed in the 2008 BiOp, particularly for upriver steelhead ESU's and the LCR Chinook ESU, largely due to predation by double-crested cormorants. Adaptive management activities designed to reduce overall cormorant predation in the estuary will be evaluated through the ongoing development of the Corps' cormorant management plan (RPA Action 46).

2.2.5.2 Fish Predation and other Ecological Interactions

2.2.5.2.1 New Information Relevant to the 2008 FCRPS BiOp and AMIP

Northern Pikeminnow Management Program

The native northern pikeminnow has been the focus of the predatory fish management in the basin since 1990. Porter (2008) reported that this program was continuing to meet exploitation goals (i.e., removal of pikeminnows large enough to prey on smolts) in 2008. However, Weaver et al. (2008) reports that for the first time since the program began, there is an indication that intra-specific compensation may be occurring; pikeminnow removals below Bonneville Dam due to the Northern Pikeminnow Management Program (NPMP) may have allowed smaller individuals to grow faster and refill that niche. Observations were limited, so annual monitoring will be needed to see if this observation is repeated.

Keller et al. (2010) summarized the results of pikeminnow removals within the Chelan Public Utility District's (Chelan PUD) operating area from 2003 to 2008. Removal methods were similar to those used in BPA's NPMP, except the Chelan PUD removal program has had better success with long-lining gear.

Management of Non-indigenous Predatory Fishes

Non- indigenous fishes affect salmon and their ecosystems through many mechanisms. A number of studies have concluded that many established non-indigenous species (in addition to smallmouth bass, channel catfish, and American shad) pose a threat to the recovery of ESA-listed Pacific salmon. Threats are not restricted to direct predation; non-indigenous species compete directly and indirectly for resources, significantly altering food webs and trophic structure and potentially altering evolutionary trajectories.

The ISAB's (2008c) review of Non-Native Species Impacts on Native Salmonids in the Columbia River basin provides an overview of predation, competition, food-web changes, interbreeding, and disease transmission between native and non-native species.[28] The ISAB provides eight specific recommendations intended to elevate the priority of addressing non-native species to that of habitat loss and degradation, climate change and human population growth and development. Recommendations specific to non-native fish species include fisheries management, prevention, research, education and planning. Within the topic of fisheries management, the ISAB recommends that state fisheries agencies stop adopting management policies (e.g., stocking and angler regulations) that could be enhancing populations of non-native predators of and competitors with juvenile salmonids. Implementing this recommendation would require the cooperation of state fisheries agencies in Washington, Oregon and Idaho. The ISAB's research recommendations are consistent with improving the understanding of the effects of competition between non-native and native species.

Sanderson et al. (2009a) documented the number, taxonomy and distribution of non-indigenous species, including fishes, in the Pacific Northwest. Some subbasins in the Pacific Northwest have nearly 500 non-indigenous species, including up to 40 non-native fishes. The authors summarized reports from published and grey literature on the percentage of salmon in predator diets, the number of salmon consumed, and the percent of salmon runs consumed by individual predator species (channel catfish, crappie, largemouth bass, smallmouth bass, walleye, and yellow perch). Their results indicate that "the effect of non-indigenous species on salmon could equal or exceed that of four commonly addressed causes of adverse impacts—habitat alteration, harvest, hatcheries, and the hydrosystem; they suggest that managing non-indigenous species may be imperative for salmon recovery."

Macneale et al. (2010) examined behavioral interactions between brook trout and Chinook in Idaho streams that could explain lower Chinook survival where the two co-occur (Levin et al. 2002). They concluded that there was little evidence for direct competition for prey, but suggested that intraspecific interactions were important. Of note, feeding rates of Chinook declined with increasing rates of brook trout encounters. The authors suggest that brook trout could be displacing Chinook from priority habitats (interference competition).

Research by Peven (2007) detailed radio-tracking of walleye, smallmouth bass, and northern pikeminnow from the tailrace of Wells Dam to approximately 13 miles downstream for the purpose of estimating population size. Peven's population estimates for smallmouth bass and walleye were higher than expected, leading to the recommendation sport fish limits on both bass and walleye be increased to remove a number of the larger predators within that reach of the Columbia River.

[28] Recent scientific information on non-invasive plants and invertebrates is discussed in Section 2.2.6.2.

Commonly stocked for recreational fishing opportunities into areas where they were not historically present, rainbow trout pose problems for both salmon and native trout species. Several recent publications document introgression and competition with salmonids (e.g., Bennett et al. 2010, Gunnell et al. 2008, Seiler and Keeley. 2009).

Food Web Interactions between Native and Non-native Predators: Feedbacks to Salmon

Interactions between native/non-native predators and other components of the food web can have implications for salmon populations. Wiese et al. (2008) examined predation by avian predators in the mid-Columbia River. They noted that pikeminnow were the dominant prey species after smolts have left and they suggest that removal of avian predators could result in increased predation by pikeminnows. They suggested that "smolt survival could be maximized by deterring birds from the river when smolts were present, allowing bird presence after the diet switch to act as a tool for salmonid-predator control, and conducting adult-pikeminnow control throughout." Similarly, Roby et al. 2008 examined cormorant diets in the winter and found that non-native juvenile shad were the most prevalent prey type (47.7% of weight) found in fore-gut contents. The extent to which cormorants may prey on shad when smolts have emigrated from the system has not been addressed.

2.2.5.2.2 Relevance to the 2008 FCRPS BiOp Analysis and AMIP

Northern Pikeminnow Management Program

In the 2008 analysis, NOAA assumed that the continued implementation of the NPMP and the increased reward structure in the sport fishery would reduce smolt consumption rates. Recent information indicates that the program is meeting these goals (Weaver et al. 2009). Annual monitoring to assess pikeminnow exploitation rates will continue. The prey of smallmouth bass and walleye will also continue to be assessed to determine if inter- and intra-specific compensation is occurring as a result of pikeminnow removals.

Non-native Predator Species Workshop

The 2008 RPA required the Action Agencies to host a non-native species workshop to develop strategies to manage these predatory fishes. The workshop convened in September 2008 with about 100 in attendance representing 18 federal, state and tribal entities, and several regional universities. A report on the proceedings entitled "Review, Evaluate, and Develop Strategies to Reduce Non-Native Piscivorous Predation on Juvenile Salmonids" (Halton 2008), identified a number of predation management strategies, most requiring a level of basic field research as a first step toward implementing full-scale management actions. At follow-up meeting in May 2009, participants narrowed the focus from the full range of problems described in the ISAB review to a few high priority concerns that warranted further development. Based on this regional consensus, the Action Agencies and NOAA Fisheries will move forward in these high priority areas to establish baseline information for future predator control activities:

- American shad: document the influence of juvenile shad on the growth and condition of non-native fish predators in the fall as they (the predators) prepare for overwintering
- Channel catfish: document the distribution and predation rates of channel catfish
- Smallmouth bass: document whether removals of smallmouth bass in areas of intense predation could reduce the mortality of juvenile salmonids

The U. S. Geological Survey (USGS) –Biological Resources Division and ODFW have developed a research proposal for this work and submitted it to the NPCC's Fish and Wildlife Program for funding. The proposal includes examining the potential for site-specific removals of non-native predators (specifically smallmouth bass) and updating current scientific information on channel catfish abundance and consumption. If the results of the proposed research support a specific management strategy, the Action Agencies could implement measures such as site-specific removals of smallmouth bass and could exclude adult shad from upper mainstem dams. The project proposal was recently reviewed by the Independent Scientific Review Panel (ISRP) (2010) and will be revised to address the ISRP recommendations.

Additional Recommendations from the Independent Science Advisory Board

Based on the ISAB report and the 2009 workshop, the AAs are evaluating the potential for implementing programs similar to the successful native predator control program to reduce populations of non-native game fishes in targeted regions. Although the ISAB (2008c) stated the need to relax or eliminate regulations that may be enhancing populations of non-native sport fishes and address inconsistencies in management of native and non-native predators, additional efforts will be needed before the state fisheries agencies are willing to pursue these actions under their respective conservation concerns/mandates. For example, the states may require spatially explicit documentation of abundance, distribution and impacts of nonnative sport fish species before they can consider such changes.

Enhanced Life-cycle Modeling

The RPA, as amended, describes enhanced life-cycle modeling for the purpose of evaluating contingencies that will augment the 2008 BiOp modeling. Based on available and emerging data, the models will be expanded to evaluate a variety of factors including interactions between salmonids and both native and invasive species that are predators, prey, competitors, etc. If sufficient data exist, potential effects will be evaluated through food web or bioenergetics models.

In summary, the new scientific information indicates that NOAA Fisheries' expectations in its 2008 analysis for reducing pikeminnow predation at this point in the 10-year term of the 2008 BiOp are largely met. Additional progress has been made in defining priority issues for non-native fish species and the process for describing impacts and potential management strategies are under way.

2.2.5.3 Pinniped Predation

2.2.5.3.1 New Information Relevant to the 2008 FCRPS BiOp and AMIP

Lower Columbia River and Estuary

Angliss and Allen (2009) summarized the available stock information for North American populations of California sea lions and Steller sea lions – species which prey upon ESA-listed salmon and steelhead in the lower Columbia River and estuary. Steller sea lions in Washington and Oregon total around 6,000 individuals and appear to be stable or increasing slowly (at about 3% per year since the mid-1970s). NOAA Fisheries estimated the U.S. population of California sea lions at 238,000 in 2005. Pup counts obtained in 2006 and 2008 indicate that the population may still be growing and has not yet reached carrying capacity. However, long-term systematic monitoring will be needed to assess if growth continues and at what level carrying capacity is reached (Scordino 2010). The Washington / Oregon harbor seal stock is stable (abundance estimates of roughly 28,000 to 34,000 individuals since 2001), appears to have reached its carrying capacity, and is no longer increasing (Scordino 2010).

The likely effect of marine mammals on the productivity and abundance of Columbia River basin ESA-listed salmon and steelhead populations cannot be quantitatively assessed. The available information clearly indicates that adult salmon contribute substantially to the diets of pinnipeds in the lower Columbia River and estuary – especially in the spring and late-summer and fall seasons when Chinook salmon are most abundant (Scordino 2010). However, the proportion of the pinniped populations (absolute number of animals preying upon salmon and steelhead) that reside within the lower Columbia River and estuary is not known.

Bonneville Dam Tailrace

Stansell et al. (2009) summarizes the recent information available regarding the abundance of California sea lions, Steller sea lions, and harbor seals in the tailrace of Bonneville Dam and their estimated consumption (total number of fish and proportion of the fish passing Bonneville Dam) of salmonids.

Minimum estimates of the number of individual California sea lions in the Bonneville tailrace during the winter and spring were only 54 animals in 2009 compared to 71 to 82 animals observed in 2006-2008. The mean daily count of California sea lions decreased to 10.0 per day (maximum count of 26 animals observed in one day) in 2009 compared to 12.5 to 14.3 per day (maximum count of 44 to 52 observed in one day) in the previous three years.

The estimated minimum number of Steller sea lions increased to 26 animals in 2009 from an estimated 9 to 17 animals in 2006-2008. The mean daily count similarly increased to 9.4 per day in 2009 compared to 2.1 to 5.5 animals per day in 2006-2008.

The number of harbor seals in the Bonneville tailrace remains low (2-3 each year).

For the first time, California sea lions (3) were observed feeding on fall Chinook salmon (and likely other fall migrating salmon and steelhead ESUs) in the Bonneville Dam tailrace between September 18 and December 31, 2008 (Stansell et al. 2009).

Based on the observational data, 2009 expanded consumption estimates of salmonids[29] (primarily spring-run Chinook salmon) by marine mammals in the Bonneville tailrace (2.4%) were lower than estimates for 2006-2008 (2.8%-4.2%) (Stansell et al. 2009, Table 1). This was likely due to two factors: 1) a relatively large return of adult Chinook and steelhead in 2009 (186,000 adults) compared to the three previous years (88,000 to 148,000 adults); and 2) a substantial reduction in the number (both total and mean daily averages) of California sea lions in the tailrace compared 2006-2008.

As expected, non-lethal hazing has proven largely ineffective at deterring foraging sea lions in the Bonneville Dam tailrace (ISRP 2009; Stansell et al. 2009; Scordino 2010). [30] However, the removal of individual California sea lions since 2006 appears to be substantially reducing both the total numbers and mean daily counts of California sea lions in the Bonneville tailrace (Stansell et al. 2009).

Preliminary observations in 2010 (Stansell and Gibbons 2010) have identified 55 different California sea lions, at 53 Steller sea lions, and one harbor seal in the Bonneville tailrace through April 28. The increased numbers of sea lions may be due to the large returns of spring Chinook salmon to Bonneville Dam this spring. Large numbers of salmon and steelhead (3,435 expanded by interpolating for weekends) has been observed this year, however, because of the large number of adult salmon and steelhead passing the dam, the percentage of the run taken to date is the lowest since 2004. Steller sea lions have been observed swallowing adult salmon whole at the surface - so consumption estimates of Chinook salmon, and certainly of steelhead, for these animals are likely underestimating the true rates. Increased incidence of cleptoparasitism (Steller sea lions stealing fish from California sea lions) has also been observed in 2010 than in past years; likely because of the increased numbers of larger Steller sea lions in the area.

2.2.5.3.2 Relevance to the 2008 FCRPS BiOp Analysis and AMIP

Lower Columbia River and Estuary

The 2008 SCA and BiOp did not attempt to assess base-to-current or current-to-prospective adjustments for marine mammal predation on ESA-listed salmon and steelhead in the lower Columbia River and estuary. However, the productivity (Recruit per Spawner, lambda, etc.) and abundance metrics used in the SCA and 2008 BiOp completely capture this factor for the base and for much of the current periods. By not explicitly identifying a current-to-prospective

[29] These estimates formed the basis of the analysis conducted in the 2008 Supplemental Comprehensive Analysis and FCRPS Biological Opinion.
[30] Use of non-lethal control methods are required by the Marine Mammal Protection Act before removal of individually identifiable nuisance animals may be permitted.

adjustment multiplier in this analysis, the default assumption is that future impacts of marine mammals in this area will be equivalent to those that are currently occurring (a de facto current to prospective adjustment multiplier of 1.00).

At present, other than observing the overall productivity and abundance metrics, there is no way to assess if this assumption is correct, as we do not know how many sea lions or harbor seals are frequenting the lower Columbia River and estuary, how long they stay, or which ESUs/DPSs or component populations they are feeding on. However, because California sea lion populations are growing rapidly, there is potential that these animals could substantially reduce the productivity and abundance of several salmon and steelhead ESUs/DPSs. This might occur through either direct (immediate death of individual fish) or indirect or delayed (injured adults die within the hydrosystem or above the hydrosystem prior to spawning) impacts.

Bonneville Dam Tailrace

NOAA Fisheries estimated base-to-current and current-to-prospective adjustments to account for marine mammal (California sea lions and Steller sea lions) predation on adult Chinook salmon and steelhead migrating upstream past Bonneville Dam (Appendix G in the 2008 SCA).

For UCR spring-run and SR spring/summer-run Chinook salmon populations, the overall base-to-current adjustment due to increased marine mammal predation in the Bonneville Dam tailrace was estimated to be 0.915 (an impact of about 8.5%). For LCR winter-run steelhead populations, the overall base-to-prospective adjustment was estimated to be 0.782 (an impact of about 21.8%).

For UCR spring-run and SR spring/summer-run Chinook salmon populations, the overall base-to-prospective adjustment (including continuation of hazing and lethal removal actions) was estimated to be 0.970 (a continuing impact of about 3%) after full implementation over the course of the 2008 BiOp. For LCR winter-run steelhead populations, the overall base-to-prospective adjustment was estimated to be 0.924 (a continuing impact of about 7.6%).

Overall, it appears that losses of adults (as a proportion of the fish passing Bonneville Dam) to marine mammals in the Bonneville tailrace in 2009 are likely less than the "Current" estimates made by NOAA Fisheries in 2008 BiOp and SCA, indicating that progress is being made in reducing marine mammal predation impacts down to the levels of continuing impact that were assessed in NOAA Fisheries' "Prospective" analysis. However, the increased numbers of Steller sea lions will have to be monitored carefully, as continued high numbers (as observed in 2010) would result in increased predation rates in future years, especially in those years with lower adult Chinook salmon and steelhead returns.

Observations of California sea lions frequenting the Bonneville tailrace during the fall period should be continued to assure that ESA-listed fall Chinook salmon, chum salmon, coho salmon, and steelhead migrating past Bonneville Dam are not being substantially affected by marine mammal predation.

In summary, the studies reviewed above reinforce the importance of continuing efforts to reduce predation and other adverse ecological interactions, including those with non-indigenous fishes, to ensure safe passage in juvenile migration areas and adequate prey resources in juvenile rearing areas.

2.2.5.4 Overall Relevance to the Prospective Assumptions in the 2008 FCRPS BiOp

The new scientific information indicates some avian, fish, and pinniped predation rates that are beyond those considered in NOAA Fisheries' 2008 analysis of effects: predation rates on subyearling Chinook salmon (and to a lesser extent, yearling Chinook, sockeye salmon and steelhead) by double-crested cormorants in the estuary; and by small numbers of California sea lions preying upon adult salmon steelhead in the fall period in the Bonneville Dam tailrace. Adaptive management activities designed to reduce overall cormorant predation in the estuary will be evaluated through the ongoing development of the Corps' cormorant management plan (RPA Action 46). Marine mammal monitoring at Bonneville Dam will continue to assess take of adult salmonids in the tailrace and will be modified as necessary to assess take later in the season. Adult losses due to marine mammals in the estuary are unknown, but West Coast sea lion populations are increasing.[31]

With respect to the lower Columbia species, NOAA Fisheries described Caspian tern and cormorant predation in the estuary as limiting factors in its 2008 analysis, stating that these species may take up to 6% of the outmigrating stream-type juveniles. Avian predation was assumed to have a minimal effect on small subyearlings such as CR chum. Prospectively, NOAA Fisheries noted that RPA Action 46 required the Action Agencies to develop a cormorant management plan including implementation of actions, if warranted, in the estuary, which was expected to reduce or minimize predation rates, improving both survival and the PCE of safe passage. The new scientific information updates this analysis by estimating slight reductions in cormorant predation rates for yearling smolts between 2001 and 2009, but higher than expected rates for subyearling Chinook (especially those from the LCR Chinook salmon ESU). NOAA Fisheries still expects the cormorant management plan in RPA Action 46 to be the appropriate mechanism for identifying and implementing specific management measures.

2.2.6 Other Stressors

2.2.6.1 Chemical Contaminants

NOAA Fisheries' 2008 analysis did not explicitly consider the role of chemical contaminants in limiting the viability of salmon and steelhead populations. If these substances are limiting

[31] NOAA Fisheries' Northwest Fisheries Science Center initiated a pilot study in 2010 to develop methods to assess adult losses from the estuary to Bonneville Dam. Although this work is not funded by the Action Agencies, NOAA expects that it will provide better information for future decision-making with respect to this issue.

factors, they have been affecting the abundance and productivity of the stocks described in Section 2.1.1. NOAA Fisheries reviews the recent scientific information pertaining to these effects below. The literature indicates that if chemical contaminants are affecting the survival and productivity of individual fish, the intrinsic productivity of affected populations also could be reduced. In addition to toxic effects of a variety of chemicals, pesticides could indirectly affect viability by reducing non-target insect species that are important prey for juvenile salmonids. Toxics could limit the productivity of related stocks in regions outside of known contaminant hotspots through straying and population connectivity. This information has implications for the success of the Action Agencies' tributary habitat restoration efforts in boosting survival. NOAA Fisheries therefore recommends that the Action Agencies require the expert panels to investigate toxicological concerns during project selection. The Action Agencies will include site-specific toxicological issues as a consideration in the expert panel project evaluation process (Amendment 5 in Section 3).

New Information Relevant to the 2008 FCRPS BiOp and AMIP

Although not described as a factor affecting the survival and productivity of Columbia Basin salmonids in the 2008 BiOp or the AMIP, chemical contaminants are increasingly being recognized as a factor that has contributed to the decline of the listed species. Recent studies have documented the presence of elevated concentrations of bioaccumulative contaminants (polychlorinated biphenyls (PCBs), dichlorodiphenyltrichloroethane (DDTs), polycyclic aromatic hydrocarbons (PAHs)and polybrominated diphenylethers (PBDEs)) in bodies or prey of juvenile salmon in the lower Columbia (Johnson et al. 2007; LCREP 2007; Sloan et al. 2010). Levels of some compounds are high enough to alter salmon growth, reduce disease resistance, and contribute to increased juvenile mortality (Meador et al. 2004, 2008; Arkoosh and Collier 2002; Arkoosh et al. in press). These bioaccumulative contaminants are stored in lipid deposits in the bodies of juvenile salmon, from which they can be released and redistributed to other tissues, increasing the risk of harmful effects during weight loss from the stress associated with outmigration and smoltification (Arkoosh et al. in prep).

Fall Chinook stocks appear to be especially at risk for exposure to industrial contaminants such as PCBs and PBDEs because of their more extended use of tidal freshwater and estuarine habitats in the lower river where these contaminants tend to be concentrated (Sloan et al. 2010). Chum salmon may also be at risk because of their extensive use of the estuary; no data are available for the Columbia River, but elevated exposure in this species has been documented in Puget Sound (Stehr et al. 2000; Olson et al. 2008). Preliminary data suggest that spring Chinook tend to have relatively low concentrations of these compounds, but higher concentrations of DDTs, consistent with their more extended residence in agricultural areas in the middle and upper Columbia basin (Arkoosh et al. in prep).

Salmon are also being exposed to chemicals associated with pharmaceuticals and personal care products. USGS studies have identified drugs such acetaminophen, and erythromyocin, as well as other wastewater compounds such as the synthetic musks and the plasticizer bisphenol A, in lower Columbia waters. The yolk protein, vitellogenin, an indicator of exposure to environmental estrogens, has been detected in plasma of juvenile salmon (Morace 2006; LCREP 2007).

Polluted surface water runoff is also a problem in the Columbia Basin, especially in the lower Columbia and lower Willamette where urban development and industrialization are the greatest. Copper and other pollutants are deposited on paved surfaces and transported to aquatic habitats via stormwater runoff; copper is also used as a pesticide and is found in mining areas. Dissolved copper is highly neurotoxic to fish, and has the potential to disrupt behaviors that are critical for the survival, migration, and reproduction (Baldwin et al. 2003; Hecht et al. 2007; Sandahl et al. 2007). Washington State has become the first in the nation to pass a law to phase out the use of copper in brake pads (Senate Bill 6557).

Much of the Columbia Basin is agricultural land so exposure to current use pesticides is an additional threat to salmon health. Organophosphates and other current use pesticides can disrupt salmon olfactory function, and this can interfere with activities that depend on the sense of smell including predator avoidance, prey capture, homing, and mating behavior (Scholz et al. 2006; Sandahl et al. 2005, 2007; Tierney et al. 2010). Common mixtures of these pesticides in salmon habitats have additive and in some cases even synergistic toxicity; one study indicated combinations of these pesticides may even cause acute mortality at environmentally relevant concentrations (Laetz et al. 2009). The sublethal effects of pesticides alone may have the potential to influence salmon abundance. A recent study (Baldwin et al. 2009) indicates that effects on feeding behavior associated with short-term (i.e., four-day) exposures that are representative of seasonal pesticide use in the Columbia Basin may be sufficient to reduce the growth and size at ocean entry of juvenile Chinook. The consequent reduction in individual survival over successive years would reduce the affected population's intrinsic productivity.

In addition to direct toxicological effects, pesticides may have a significant impact on the aquatic communities that that support juvenile chum in estuary during resident freshwater life stages concern because of their toxicity to non-target insect species that are important prey items for juvenile salmonids (Macneale et al. in press). The indirect impacts of degraded water quality on the salmonid prey base is a critical information gap with implications for restoring salmon habitat, and anticipating and mitigating the impacts of future development on currently productive aquatic systems.

Organophosphates and related pesticides have been detected in Columbia and Willamette River basins in various surveys (Wentz et al. 1998; Morace 2006; LCREP 2007). Currently, the Sargent et al. (2010) are conducting a multi-year monitoring study to evaluate pesticide concentrations in salmon bearing streams during a typical pesticide-use season. They selected three subbasins in the lower Yakima basin to represent eastern Washington irrigated agricultural practices and four basins in the Wenatchee and one in the Entiat to represent fruit tree agricultural practices. In the lower Yakima basin, concentrations of the organophosphate insecticides Azinphos-methyl and Malation, and DDT (banned in the U.S. since 1972), exceeded the chronic National Recommended Water Quality Criteria (NRWQC). DDT and Endosulfan (an organochlorine pesticide) exceeded the chronic NRWQC in the Wenatchee and the endosulfan levels were periodically above the Endangered Species Level of Concern for fish. The authors specifically recommended that the Washington State Department of Agriculture continue to work with stakeholders to explore mitigation measures for endosulfan concentrations in the Wenatchee basin and conduct monitoring to assess the effectiveness of mitigation measures.

Mercury has also been identified as a contaminant of concern for fish and wildlife populations in the Columbia Basin (USEPA 2009), and some studies show that, in contract to PCBs and DDTs, concentrations of mercury in the region are stable or increasing (Henny et al. 2009b). There is little information available on concentrations of total or methyl mercury, the toxic form of the compound, in Columbia River salmon, but elevated levels have been detected in cutthroat and rainbow trout at some locations in the Willamette and the Lower Columbia River (Scudder et al. 2009).

Various actions have been or are being taken that may reduce the risk of toxics for listed Columbia River salmon (USEPA 2009). Bans of DDTs, PCBs, and OC pesticides that occurred in the 1970s, and process changes at pulp mills to reduce outputs of dioxins and furans, have resulted in declines in concentrations of these chemicals in species such as osprey and river otters that have been monitored over the long term (Grove et al. 2008; Henny et al. 2009a).

Both Washington and Oregon have programs to reduce and eventually eliminate persistent toxic chemicals, including mercury, dioxins, and PCBs (Mullane et al. 2009; WDOE 2009). For examples, the Oregon Department of Environmental Quality (ODEQ) has established a priority persistent pollutant list of 117 chemicals, which includes PAHs, halogenated flame retardants (e.g., PBDEs), current use pesticides, and industrial chemicals such as plasticizers, as well as legacy contaminants such as OC pesticides, PCBs, dioxins, and furans (Mullane et al. 2009). By June 1, 2010, ODEQ will submit a report to the Legislature identifying sources of pollutants on the list and opportunities to reduce their discharge to water. Oregon's 52 large municipal wastewater treatment plants (WWTPs) must also develop toxics reduction plans by July 2011 to reduce persistent pollutants occurring in their effluent at levels above “trigger levels” set by ODEQ (Mullane et al. 2009). Both Washington and Oregon have banned some of PBDEs (penta- and octa-types), which should reduce releases of these compounds into the environment over time.

Changes in regulatory guidelines may also help to protect salmon health. The State of Oregon is in the process of changing its fish consumption standards for protection of human health, which could result in much stricter controls on allowable concentrations of persistent organic pollutants in fish tissues (ODEQ 2008). Efforts are also underway to improve sediment quality standards so they take into account effects associated with bioaccumulation and biomagnifications, and are more protective of fish and wildlife, including listed salmon (USACE 2009). Recent biological opinions should help provide protection for salmon from effects of several current-use pesticides (NMFS 2008a, 2009a).

Cleanup activities are underway at sites along the Columbia River under EPA Superfund or state toxic cleanup programs (USEPA 2009). Some examples in the upper Columbia include the Bunker Hill Mining and Metallurgical Superfund site in the Coeur d'Alene Basin, and multiple waste sites between the U.S./Canadian border and Grand Coulee Dam. In the Middle Columbia River, the U.S. Department of Energy (DOE) is working to prevent contaminated groundwater on the Hanford Nuclear Reservation from reaching the Columbia River. Work is also under way to clean up contaminated sediment from the Portland Harbor Superfund site in the lower Willamette River. Two additional examples of PCB-contaminated sites on the Columbia River are the Bradford Island site at Bonneville Dam[32] and the Alcoa plant in Vancouver, Washington. Various state and local programs are underway to improve agricultural practices by reducing soil erosion and pesticide runoff, and take-back programs have been instituted to facilitate safe disposal of DDTs and other organochlorine pesticides and pharmaceuticals (USEPA 2009).

Relevance to 2008 FCRPS BiOp Analysis and AMIP

Although not explicitly considered in the 2008 analysis, direct or indirect effects of chemical contaminants on the listed species contribute to the observed returns per spawner and thus to numbers of adults and to population trends. Current research is showing that contaminants affect the survival of individual salmon and the effect is great enough to depress population viability (Baldwin et al. 2009; Loge et al. 2005). In addition, an analysis by Spromberg and Johnson (2008) predicted that toxic effects could limit the productivity of related stocks in regions outside of known contaminant hotspots through straying and population connectivity. For example, a habitat restoration project in an area where contaminant exposure is minimal may not result in the expected increased productivity due to effects of contaminants on a nearby area that acts as a population sink. Conversely, cleanup of a contaminant hotspot affecting only one or two populations might lead to unexpected increases in productivity in populations from sites not directly affected by the contaminants by converting a sink population to a source.

[32] Bradford Island lies within the Bonneville Dam complex near Cascade Locks. The Corps has worked with ODEQ to evaluate various contamination sources on the island. These include a half-acre landfill, a shooting range, and disposal areas for sand blast grit and light bulbs. Electrical equipment, some of which contained PCBs, was removed from the river bottom adjacent to the island in 2000 and 2002. Contaminated sediment was removed in 2007 and the Corps is completing its Remedial Investigation and Risk Assessment this year (2010). The Corps' Record of Decision on the investigation and risk assessment will recommend any further remedial action needed for implementation in 2012 and beyond. PCB levels in the sediment have dropped dramatically since the electrical equipment and sediment were removed—in 2003, the highest PCB reading exceeded 690,000 parts per billion (ppb), but in 2008, the highest reading was 140 ppb (Peters 2010).

Thus, where industrial or agricultural contaminants are present, these may limit the restoration potential of habitat projects intended to offset effects of the FCRPS on survival and to improve the functioning of critical habitat in spawning and rearing areas. To address this concern the Action Agencies will work with the expert panels to consider site-specific toxicology issues based on the information made available by the appropriate state and federal agencies.

In terms of the PCEs of critical habitat, Columbia basin Chinook, coho, and chum salmon and steelhead require freshwater spawning and rearing sites and migration areas with water quality conditions that support spawning, incubation, juvenile development, juvenile forage, juvenile and adult mobility, and survival. Where their concentrations reach water and sediment concentrations that affect adversely affect aquatic life, or result in tissue residues in salmon or their prey that exceed benchmarks for toxic effects, contaminants may limit the conservation value of critical habitat.

In summary, chemical contaminants around the Columbia basin appear to be having both direct and indirect effects on the survival and productivity of salmonid populations. These include reduced survival and productivity of individual fish and potentially reduced intrinsic productivity of affected populations, decreased food availability where pesticides kill non-target insect species that are important prey for juvenile salmonids, and effects on the survival benefits of tributary restoration projects where hotspots affect populations linked through straying and connectivity. This information could have implications for the success of the Action Agencies' tributary habitat improvement efforts in boosting survival. NOAA Fisheries therefore recommends that the Action Agencies require the expert panels to investigate toxicological concerns during project selection. The Action Agencies will include site-specific toxicological issues as a consideration in the expert panel project evaluation process (Amendment 5 in Section 3).

2.2.6.2 Non-indigenous Invertebrates and Plants

Although not explicitly considered in the 2008 analysis, direct or indirect effects of non-indigenous invertebrates and plants on the listed species contribute to the observed returns per spawner and thus to numbers of adults and to population trends. The information reviewed below indicates that interactions with some non-indigenous invertebrates and plants (including species not specifically identified in this review) could limit the success of habitat restoration projects in improving the survival of the listed species. NOAA therefore recommends that the Action Agencies consider the presence of invasive species during project selection. Where novel invasive species are noted during implementation, this should be documented and where possible, specimens should be collected for action by the appropriate federal and state agencies. The Action Agencies will include the presence of invasive species as a consideration in the expert panel project evaluation process (Amendment 5 in Section 3).

The means by which non-indigenous species can deter the recovery of ESA listed Pacific salmon are not restricted to direct predation. Non-indigenous species compete directly and indirectly for resources, altering food webs and trophic structure. Where significant, these changes could alter evolutionary trajectories. The ISAB (2008c) stated that this was especially true of non-indigenous invertebrates (e.g., freshwater Asian clam (*Corbicula fluminea*), New Zealand mud snail (*Potomopyrgus antipodarum*), red swamp or ringed crayfish (*Orconectes neglectus neglectus*), and quagga mussels (*Dreisssena rostriformis bugensis*)) and plants (e.g., Eurasian milfoil (*Myriophyllum spicatum*), purple loosestrife (*Lythrum salicaria*), and reed canary grass (*Phalaris arundinacea*), which already have been observed in the Columbia basin.

Non-indigenous Aquatic Invertebrates

The first collection of the Asian clam (*C. fluminea*) in the United States occurred in 1938 along the banks of the Columbia River near Knappton, Washington (USGS 2010). It has been abundant in sediments of the lower Columbia River where it displaces native clams, but is "an important food of white sturgeon" (McCabe et al. 1997) for many years. In other systems, *C. fluminea* has caused millions of dollars worth of damage to intake pipes used in the power and water industries.

Bersine et al. (2008) document the occurrence of the invasive New Zealand mud snail (*Potamopyrgus antipodarum*) in Baker, Trestle, Youngs, Grays, and Cathlamet bays in the Columbia River estuary. In Youngs Bay, Oregon, New Zealand mud snails reached densities of more than 6,000 per square meter, much higher than had been observed for native snails. The New Zealand snail is now widely distributed throughout the estuary. Bersine et al. (2008) reported that it occurred in the guts of three subyearling Chinook (out of hundreds) collected in the upper estuary during 2004 and 2005. Recent work in Utah comparing rainbow and brown trout fed on *P. antipodarum* versus a native freshwater amphipod indicated that a diet of mud snails would not promote fish growth (Vinson and Baker 2008).

Several Asian planktonic copepods have invaded the Columbia-Snake River system. The calanoid copepod *Pseudodiaptomus inopinus* appeared in the 1980s, but has since been replaced by two other Asian species, *P. forbesi*, and *Sinocalanus doerrii* (Cordell et al. 2008). *P. forbesi* was found in samples from the first four reservoirs in the Columbia River (Bonneville, The Dalles, John Day, McNary, and Priest Rapids), but not in the free-flowing Hanford Reach where native calanoid copepods dominated. Reservoirs on the Snake River were dominated by native cladocerans and cyclopoid copepods. Cordell et al. (2007) found that in the Chehalis River estuary, Washington, *P. inopinus* was eaten by the mysid crustacean *Neomysis mercedis*, which in turn was found in the guts of both juvenile Chinook salmon and the sand shrimp *Crangon franciscorum*. The latter could be an important prey of listed green sturgeon (Dumbauld et al. 2008). These food web relationships have not been documented in the Columbia River estuary.

Olden et al. (2009) document the first observation of the rusty crayfish (*O. rusticus*) west of the Continental Divide in the John Day River, Oregon. Rusty crayfish have had numerous ecological and evolutionary impacts to plants, invertebrates and fish in areas where they have invaded.

Adams (2005) conducted surveys during 2005 for the presence of the ringed crayfish (*O. neglectus*) in the John Day River. The author found a very dense population at the Clyde Holliday State Park, between John Day and Mt. Vernon and a few individuals at other locations. The very high densities of *O. neglectus* "suggest disproportionate utilization of the aquatic fauna and flora by the introduced species" and thus the potential for competition with juvenile salmonids for invertebrate prey.

More recently, Larson et al. (2010) documented the widespread distribution of the non-native northern crayfish *O. virilis* in the Columbia River basin. Native over a large part of the central and eastern U.S. and Canada, *O. virilis* has been confirmed as an introduced species in California since at least 1940 when laboratory specimens escaped from ponds at Chico State College (Cohen and Carlton 1995, as cited in Larson et al. 2010). However, the species has recently been documented in the Pacific Northwest; confirmed collections of *O. virilis* by biologists and private citizens in Washington have expanded the known distribution of this species to include the reservoirs Lake Rufus Woods and Lake Roosevelt on the Columbia River, North Twin Lake in the upper Columbia River basin, Lake Patterson in the Methow River basin, Wapato Lake in the Lake Chelan basin, and Moses Lake in central Washington. Larson et al. state that uncertainty remains as to the source, extent of current distribution, and potential impacts of *O. virilis* in the Columbia River basin.

Established *O. virilis* populations are likely to naturally disperse further in the Columbia River, its tributaries, and the irrigation infrastructure of central Washington's Columbia Basin Project. For example, Moses Lake and many other waterbodies of central Washington are modified or formed by water diverted from Lake Roosevelt and Grand Coulee Dam, and the canals connecting these systems might facilitate the dispersal of *O. virilis* in an otherwise arid environment. Among the most common concerns related to crayfish introductions is the tendency of non-native crayfish to displace native species leading to range contractions and occasional extinctions. The distribution and population status of Washington's only native crayfish, the signal crayfish (*Pacifastacus leniusculus*), is poorly known in the Columbia River basin, but *P. leniusculus* has been infrequently collected from sites occupied by *O. virilis*. *Orconectes virilis* could also affect salmonid populations through competition for food, predation on eggs, and modification of habitat via consumption of macrophyte beds.

Quagga & Zebra Mussels

Quagga (*Dreissena rostriformis bugensis*) and zebra (*Dreissena polymorpha*) mussels, collectively referred to as dreissenids, are small, freshwater bivalves that attach to substrates including plants, rocks, and man-made materials and structures such as docks, dams, canals, and aqueduct walls. A mature female dreissenid mussel can produce over one million eggs per year (Western Regional Panel on Aquatic Nuisance Species 2010). In the warmer waters of the Western U.S., there is the potential for year-round spawning. Eggs develop into microscopic larvae called veligers. Veligers float in the water column and can be transported within water distribution systems as well as in watercraft bilges, ballasts, and live wells, and in any other equipment that holds water. Juvenile and adult mussels secrete byssal threads (small, thin fibers) to attach themselves to substrates and can survive on substrate removed from one body of water and transferred to another. Adults can also be easily spread between water bodies by watercraft, especially when protected in the crevices of trim tabs, keels, engines, propellers, and anchors. They may also be moved with equipment, trailers, water tanks, construction equipment, fish for stocking, waterbased aircraft, firefighting equipment, bait buckets, anglers, and other recreational water equipment. Survival out of water can be prolonged by proximity to damp objects, such as coiled rope, or in damp enclosed areas.

The ecological ramifications of these mussels include effects on aquatic biodiversity; reducing food sources for native mussels, fish larvae, and zooplankton; and changing water quality. Many other aquatic organisms rely on plankton for survival. The presence of quagga or zebra mussels in an environment can disrupt the food chain and out-compete other species resulting in the displacement of native threatened or endangered species. Given their ability to filter large volumes of water, and in combination with extremely high densities, these mussels can significantly reduce the amount of nutrients and particles in the water, resulting in increased water clarity. This increased clarity allows for greater light penetration, promoting increased algae and vegetation growth. As reported by the Government Accountability Office, zebra mussel invasions will reduce native mussel species by as much as 50 percent in the next decade, causing the extinction of up to 140 species. Recovery efforts for salmon and other threatened and endangered western fish would be significantly hindered by the establishment of zebra and quagga mussels.

The Western Regional Panel (2010) created an action plan for preventing and dealing with introduction of these invasive organisms. The highest priority actions in this plan include: coordination, prevention, early-detection monitoring, rapid response, containment and control, outreach and education, and research. The ongoing effort to minimize the range expansion of zebra and quagga mussels in to the Columbia River basin is one of the most aggressive campaigns to prevent the introduction of a non-native species in the Pacific Northwest.

Non-indigenous Aquatic Plants

The ISAB (2008c) described several non-native aquatic plants that can change habitat by occupying shoreline space, shading, clogging salmon substrates, reducing currents, and creating conditions favored by non-salmonid fishes. The Eurasian milfoil (*M. spicatum*) is the most widespread non-indigenous macrophyte in the Columbia River basin, occupying low energy areas of rivers and streams and brackish water areas of protected tidal creeks and bays. Its dense cover can protect young fish from predators, but its foliage supports a lower abundance and diversity of invertebrates, organisms that are likely to serve as juvenile salmonid food (USGS 2010). The purple loosestrife (*Lythrum salicaria*), reed canary grass (*Phalaris arundinacea*), yellow iris (*Iris pseudacorus*) and Japanese knotweed (*Fallopia japonica*) are also wetland plants that can crowd out native vegetation (ISAB 2008c) and may reduce the availability of preferred prey for juvenile salmonids.

Riparian ecosystems are also vulnerable to disruption by invasive species. For example, Urgenson et al. (2009) describe the effects of the non-native herb, giant knotweed (*Polygonum sachalinense*) on the abundance and diversity of forest understory plants and leaf-litter inputs to riparian forests in western Washington. Among 39 sampling locations, the both the richness and abundance of native herbs, shrubs, and juvenile trees (63 m tall) were negatively correlated with knotweed density. Where knotweed was present, the litter mass of native species was reduced by 70%. The carbon:nitrogen ratio of knotweed litter was 38 to 58% higher than that of native woody species (red alder [*Alnus rubra*] and willow [*Salix* spp.]). By displacing native species and reducing nutrient quality of leaf litter, invasive knotweed has the potential to cause long-term changes in the structure and functioning of riparian forests and adjacent aquatic habitats.

Relevance to 2008 FCRPS BiOp Analysis and AMIP

The information reviewed above indicates that interactions with some non-indigenous invertebrates and plants (including species not specifically identified in this review) could affect the success of habitat restoration projects in improving the survival of the listed species. The Action Agencies will therefore include the presence of invasive species as a consideration in the expert panel project evaluation process (Amendment 5 in Section 3). In addition, the RPA, as amended, identifies inter-species interactions including invasive species ("competitors, predators, or pathogens") as factors that could be evaluated through food web or bioenergetics modeling or other analyses to estimate the magnitude of their impact on species status.

2.2.6.3 Marine Derived Nutrients

NOAA Fisheries' 2008 analysis considered the potential importance of returning adult salmon as sources of marine-derived nutrients to interior basin streams. The recent scientific information described in the following paragraphs provides further support to NOAA Fisheries' discretionary conservation recommendation in the 2008 BiOp for a long-term, large-scale nutrient addition study by showing a variety of responses to additions of marine-derived nutrients from salmon carcasses or analogues. In these studies, effects on salmonid habitat and productivity were generally positive, although the magnitude of the response varied with salmon biomass, stream discharge, sediment particle size, and even spawning activity, which can resuspend fine-grained sediment and low density organic material. Thus, information gained from a nutrient addition study would be useful in species conservation efforts in the Columbia basin.

New Information Relevant to the 2008 FCRPS BiOp and AMIP

A large number of published papers were produced since the completion of the 2008 BiOp that address the roles of marine derived nutrients (MDN), or salmon carcasses and carcass analogues, in the nutrient cycle of estuaries and freshwater stream systems. Several recent papers discuss various elements of salmon carcasses (naturally-returning spawners or augmented/placed) in the nutrient cycle (Hood et al. 2007, Reichert et al. 2008, Scott et al. 2008), the more encompassing food web (Adams et al. 2010, Christie et al. 2008, Christie and Reimchen 2008, Quinn et al. 2009), or the overall functioning of freshwater streams (Holtgrieve et al. 2009, Tiegs et al. 2008) and lakes (Hill et al. 2009, Selbie et al. 2009, Uchiyama et al. 2008). In general, these papers describe multifaceted roles of salmon carcasses in the long-term health of riparian and aquatic ecosystems. These include nutrient deposition on land or in water, the use of carcasses as a seasonal food source either directly (bears, wolves, birds) or indirectly (fish or birds feeding on macroinvertebrates), soil enrichment of riparian areas, and lake nutrient cycling.

Chow (2007) discussed the linkage of salmon-derived nutrients within and from the headwaters of coastal streams back to the estuary and the implications for the productivity of those systems. This study demonstrated that substantial amounts of marine-derived nutrients are exported back downstream where they appear to become integrated into the estuarine food web (e.g., clams, as shown in this study). As such, the downstream effects of salmon-derived nutrients appeared to directly influence estuarine productivity and community composition. Chow also describes potential positive feedback mechanisms by which enhanced estuarine productivity benefits the survival of salmon (e.g., if emergent vegetation in the estuary such as sedges and rushes benefits from salmon-derived nutrients imported from further upstream, the estuary could provide better habitat and food sources for juvenile salmon as they migrate toward the open ocean).

Kelly et al. (2007) presented information from the Fraser River, British Columbia, on the release of persistent organic pollutants (POP) and diseases into headwaters from deposition by salmon carcasses. The study also suggests marine contaminant distribution, food-chain dynamics, and ocean-migration pathway are likely important factors controlling levels and patterns of POPs in returning Pacific sockeye. Kohler et al. (2007) and Pearsons et al. (2007) discussed the possible use of salmon carcass analogues, which could help address the potential for POP and disease caused by returning salmon. The results suggest that the salmon carcass analogue additions successfully increased periphyton and macroinvertebrate biomass with no detectable response in ambient nutrient concentrations. Sanderson et al. (2009b) investigated nutrient limitation in 13 Idaho streams and recommended that prior to nutrient augmentation, understanding the type of nutrient limitation is essential for managers considering nutrient additions as a tool to improve stream productivity.

Janetski et al. (2009) compared the responses of stream ecosystems to nutrients derived from live spawning runs with nutrients from artificially added salmon carcasses. In their synthesis of 37 publications, the authors found that streams responded differently to anadromous spawners than to carcasses. Results obtained from 37 publications that collectively included 79 streams revealed positive, but highly inconsistent, overall effects of salmon on dissolved nutrients, sediment biofilm, macroinvertebrates, resident fish, and isotopic enrichment. Variation in these response variables was commonly influenced by salmon biomass, stream discharge, and sediment size. For example, carcass additions increased chlorophyll a (chl*a*) and macroinvertebrate abundance by 50 and 200% more than natural runs, respectively, probably due to the absence of spawner disturbance of the substrate during redd construction. Chow (2007) found that human land use also increased downstream nutrient concentrations and raised baseline marine-derived nitrogen ($\delta^{15}N$) concentrations in stream ecosystems, an additional cause for caution in interpreting salmon-derived nutrient studies in land use-affected watersheds.

Wipfli et al. (2010) investigated the influence of artificial nutrient pellets and salmon carcasses on dissolved nutrients, ash free dry mass and chl*a*, macroinvertebrate density, growth, and body condition of juvenile coho salmon, and whole-body lipid content of invertebrates and coho. In this 6-week experiment, carcasses and artificial nutrient pellets were placed alone (at both low and high amounts), and together in mesocosm experiments. Most of the variables were significantly affected by the presence of carcasses; however, only soluble reactive phosphorus was significantly affect by the presence of the artificial nutrient pellets. Within the carcass treatments, ammonium-nitrogen was the only variable significantly affected by the number of carcasses. This research suggests that inorganic nutrients do not have the same ecological influence as carcasses. The authors attribute this to the absence of carbon-based biochemicals and macromolecules. While this experiment was conducted in a mesocosm and may have limited applicability to natural systems, it does provide some insight into what might be expected in natural systems if true replication was indeed possible.

In Williams et al. (2009), Atlantic salmon carcasses were introduced to 12 upland, oligotrophic streams in the Scottish Highlands to determine whether the addition of nutrients would increase juvenile Atlantic salmon biomass. Salmon biomass in treatment reaches was approximately twice that in reference reaches, and in general the response to carcass placement was stronger for parr (age 1+) than for fry (age 0). The authors attributed this trend to competition between the two age classes, but were uncertain of the mechanisms driving this response.

Hood et al. (2007) found that during Pacific salmon spawning in southeast Alaska, concentrations of dissolved organic carbon and dissolved organic nitrogen were significantly higher in the spawning reach compared with the upstream reference site. In contrast, concentrations of nitrate increased by only two to three times during spawning and were not significantly higher than at an upstream reference site without salmon.

Moore and Schindler (2008), Moore et al. (2007), and Moore et al. (2008) investigated the effects of redd development and substrate disturbance on the physical environment and the associated aquatic invertebrates with regard to nutrient cycling. Moore and Schindler (2008) suggested that when salmon populations exceed threshold spawning densities, they become an important component of stream disturbance regimes and influence seasonal dynamics of benthic communities. Conversely, salmon densities below threshold densities can also lead to altered seasonal dynamics of stream communities. Moore et al. (2007) demonstrated that salmon not only move nutrients upstream on large spatial scales via their migration from the ocean and subsequent death, but also redistribute matter and nutrients on finer spatial scales through their spawning activities. In addition, Moore et al. (2008) demonstrated that small changes in salmon abundance can drive large changes in subsidies to stream food webs, such as egg displacement from territoriality or superimposing of salmon nests.

Kohler et al. (2008), Lessard et al. (2009), and Moore and Schindler (2008) investigated macroinvertebrate biomass and aquatic invertebrate production resulting from spawning activities and salmon carcasses. Honea and Gara (2009) documented a strong negative response to salmon redd construction and a weak response to salmon-derived nutrient uptake; macroinvertebrate production from the nutrient and energy subsidy from salmon was restricted to the recovery period following the disturbance due to redd construction. Six months after spawning, no clear density or biomass differences were found between reaches with and without salmon.

Rex and Petticrew (2008) showed that the addition of salmon organic matter and clay to the stream bed (i.e., in the controlled environment of a recirculating laboratory flume) increased the formation of organic–inorganic aggregates in the water column. Organic material released from salmon supports surface-living bacteria, which have extracellular adhesive substances that can attach the organic material to silt and clay particles resuspended during redd excavation. The aggregated particles have a different size, shape and density from either the salmon-derived organic matter or the silt and clay alone. These structural modifications can enhance sedimentation onto, and infiltration into the streambed, and consequently the delivery of the attached organic material including marine-derived nutrients to benthic food webs.

Similarly, Gregory-Eaves et al. (2008) presented an overview of their paleolimnological (the study of the biological, chemical, and physical indicators preserved in lake and river sediments) approach for tracking the sizes of past sockeye salmon populations and a synthesis of the work that has been conducted in this field to date. Adkison et al. (2010), Tiegs et al. (2008), and Uchiyama et al. (2008) discussed different ways of interpreting salmon returns and the use of carcass-derived nutrients in stock assessments or fisheries management decision-making. Piccolo (2009) discussed the potential costs and benefits of increasing salmon escapement goals as a source of marine-derived nutrients to enhance production. They concluded that even under the best of circumstances, it would be a long-term process and the results were likely to be site-specific.

In the Columbia basin, the ISRP has emphasized the importance of documenting responses in wild fish populations (growth, survival, productivity), the significance of quantifying nutrient and food limitation in these ecosystems, the value of comparing analog and inorganic nutrient amendments, the need to avoid conflicting manipulations (i.e., use of egg boxes), the need to link each response variable being measured to the overall objectives, and the ability of the results of this research to guide larger scale nutrient addition applications.

Relevance to 2008 FCRPS BiOp Analysis and AMIP

The potential importance of returning adult salmon as sources of marine-derived nutrients was explicitly considered in the 2008 analysis of effects of the FCRPS on the PCEs of critical habitat for species from the Interior Columbia Basin. For example, "[T]o the extent that the hydro Prospective Actions result in more adults returning to spawning areas, water quality and forage for juveniles could be affected by the increase in marine-derived nutrients" (8.2-19 in the 2008 BiOp). The 2008 analysis for each of the Interior species goes on to remark that the loss of marine-derived nutrients was not identified as a limiting factor by the Remand Collaboration Habitat Technical Subgroup.

The diversity of findings in the recent scientific information described above indicates that efforts to augment productivity by placing carcasses or carcass analogues would be complicated by interactions between fish or carcass biomass, stream discharge, sediment size, human land use, and spawning activity among other factors. If a long-term, large-scale nutrient addition study could be implemented in a way that quantified growth and survival benefits for juvenile salmonids, this information would be useful in species conservation efforts in the Columbia basin. However, the ability to implement an experiment that would result in tangible and meaningful results for the Columbia Basin is inherently constrained by many factors including:

- Limited scientific information available to guide managers in basic methods and protocols
- Concern for spreading pathogens, which leads most programs to permit only the addition of carcasses that originate from the same watershed
- Need for a long-term commitment to investigate a positive feedback cycle in which added nutrients stimulate production, salmonid growth and survival, and ultimately result in increased numbers of adult returns bringing more nutrients back to the spawning grounds
- Uncertainties associated with the use of carcass analogs, although pasteurized to minimize pathogen transfer and easily transportable (e.g., when and how often to apply, at what loading rate, etc.)
- The feasibility of applying treatments in roadless or wilderness areas, permitting requirements (including water quality), inter-agency and -jurisdictional coordination, as well as cost.

Recognizing both the potential benefits and logistical difficulties of nutrient supplementation, NOAA identified the following as a discretionary conservation recommendation in the 2008 FCRPS Biological Opinion (13.8-4):

"Coordinate with NOAA Fisheries and other interested regional parties to design and implement research (in appropriately selected locations) to evaluate the use of nutrient supplementation as a means to increase the productivity and survival of certain interior basin steelhead or Chinook salmon populations. Studies should target priority populations with low productivity where known areas of reduced nutrient availability exist and studies can be implemented consistent with federal, state, and local regulatory requirements."

The new scientific information reviewed for this supplemental biological opinion continues to support this recommendation.

In summary, the information reviewed above indicates a variety of upstream, downstream, and lateral (riparian to stream or vice versa) responses to additions of marine-derived nutrients from salmon carcasses or analogues. Effects on salmonid or habitat productivity have generally been positive, although the magnitude of the response varied with factors such as salmon biomass, stream discharge, sediment particle size, human land use, and even spawning activity. If a long-term, large-scale nutrient addition study could be implemented in a way that quantified growth and survival benefits for juvenile salmonids, this information would be useful in species conservation efforts in the Columbia basin. The ability to implement an experiment that would result in tangible and meaningful results is inherently constrained by many factors, but NOAA Fisheries continues to support the discretionary conservation recommendation in the 2008 BiOp for an evaluation of nutrient supplementation for interior salmon and steelhead populations.

2.3 Hatchery Programs and Ecological Interactions

2.3.1 Overview

The origins and evolution of artificial propagation programs for Pacific salmon provide important context for understanding the roles and analyzing the effects of hatchery programs. From their origin more than one hundred years ago, hatchery programs were tasked with compensating for factors that limited salmon and steelhead abundance. The first hatcheries, established in the late 19th century, provided additional fish for harvest on top of large, relatively healthy salmon and steelhead populations. It was not long before the role of hatcheries shifted to replacing losses in fish production attributable to water and hydroelectric construction and operation, and land use practices that blocked access to important production areas or that degraded habitat and reduced salmon and steelhead survival. Hatchery programs were funded and operated to maintain returns of adult salmon and steelhead, usually for cultural, social or economic purposes, because the capacity of habitat to produce salmon and steelhead was reduced. As development proceeded in the Columbia River Basin (including the construction of the mainstem hydroprojects between 1939 and 1975) and the capacity for the basin to produce fish declined, hatchery production increased. For example, National Fish Hatcheries were constructed in the upper Columbia River watershed after federal dams blocked access to approximately 50% of the production area used by UCR spring Chinook salmon and steelhead. In the Snake River, the Columbia's largest tributary, hatchery programs were expected to replace losses of fall Chinook from inundation of their spawning habitat and reduced survival during their migration to and from the ocean because of the four federal dams on the Lower Snake River. The scope and level of hatchery production increased greatly during this period throughout the Pacific Northwest as impacts from development projects and the requirement to compensate for those impacts increased. Today, largely because nearly 90% of the Chinook salmon and steelhead habitat originally available in the Columbia Basin has been lost or degraded (Brannon et al. 2004), fish produced by hatcheries comprise the vast majority of the annual returns to the basin (CBFWA 1990). In the Puget Sound region, returns of Chinook salmon have been reduced from estimated historic levels of 600,000 per year to a recent year average return of 180,000 fish, of which approximately 74% originate from State and tribal hatcheries.

Natural populations collapsed to such low abundance during the 1980s and 1990s that the authorized hatchery mitigation for FCRPS impacts became a risk factor itself. At the same time, the potential for artificial propagation to help conserve salmon and steelhead came into question (Hard et al. 1992). NMFS (2005) states that "[t]he presence of hatchery fish within the ESU can positively affect the overall status of the ESU, and thereby affect a listing determination, by contributing to increasing abundance and productivity of the natural populations in the ESU, by improving spatial distribution, by serving as a source population for repopulating unoccupied habitat, and by conserving genetic resources of depressed natural populations in the ESU. Conversely, a hatchery program can affect a listing determination by reducing adaptive genetic diversity of the ESU, and by reducing the reproductive fitness and productivity of the ESU."

During this period, artificial propagation was used to help conserve several ESUs and populations (e.g., SR sockeye, SR fall Chinook, and several populations of SR spring/summer Chinook salmon in Northeast Oregon) and the condition of these populations is much improved twenty years later. On the other hand, the benefits of the hatchery interventions have not been proven (Waples et al. 2007); salmon and steelhead populations that have not been subject to hatchery supplementation (e.g., spring Chinook salmon in the Middle Fork Salmon River) have also rebounded from their low abundance levels during the mid-1990s. It is clear that additional research is warranted that can help managers quantify the demographic benefits, if any, of hatchery supplementation. It should be noted that in some cases, such as SR sockeye salmon, the captive propagation was instrumental in avoiding extinction in the short term (Flagg et al. 2004), although NOAA Fisheries recognizes that the long-term viability of this ESU remains far from certain.

The new scientific information described below (Section 2.3.2) reinforces themes in the 2008 BiOp and SCA that risks posed by artificial propagation should be given careful consideration when deciding the role and operation of hatchery mitigation programs. NOAA Fisheries' goal is twofold: increasing the effectiveness of hatcheries in supporting the survival and recovery of listed species and satisfying the mitigation requirements of the FCRPS. Currently, NOAA Fisheries' treaty trust responsibilities and commitment to support sustainable fisheries also depend on hatchery mitigation.

NOAA Fisheries' strategy is to provide the technical basis for identifying improvements in hatchery management and a mandatory process, including monitoring and evaluation to determine whether improvements are sufficient. NOAA Fisheries' review of recently published hatchery related papers for this remand appears to support the approach from the 2008 BiOp. In general, these papers show that hatcheries remain a viable tool in salmon and steelhead conservation, but greater consideration must be given to the application, intensity, and longevity of hatchery interventions. Implementation of site-specific best management practices, currently being defined in Section 7(a)(2) consultations with the FCRPS funding agencies per RPA Action 39, is the mechanism for identifying and ensuring the implementation of hatchery reforms.

Genetic resources that represent the ecological and genetic diversity of a species can reside in fish spawned in a hatchery as well as in fish spawned in the wild (NMFS 1991; Hard et al. 1992, NMFS 2005). Hatchery programs can be designed to preserve the raw materials (i.e., genetic resources) that ESU and steelhead DPS conservation depends on and buy time until the factors limiting salmon and steelhead viability are addressed. In this role, hatchery programs reduce risk by mitigating the immediacy of an ESU's extinction risk (NMFS 2005). In the absence of such hatchery programs, genetic resources important to ESU or steelhead DPS survival and recovery would disappear at an accelerated rate or be lost altogether. Hatchery programs that conserve genetic resources do not however substantially reduce the extinction risk of the ESU in long term or even the foreseeable future. To achieve short-term survival of the species or population, these hatchery programs must be designed and implemented in a manner that minimizes effects on the genetic structure and evolutionary trajectory of the target population (i.e., to conserve population or ESU/DPS-level variability and patterns of local adaptation (McClure et al. 2008)). 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 ultimately 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. At some point, the species or population must be become self-sustaining in the wild.

Besides the role hatchery programs play in conserving genetic resources, the potential for hatcheries to help improve other aspects of viability, particularly spatial structure, is being tested. In selected areas, hatchery programs are being used to accelerate the re-colonization of habitats where salmon and steelhead have been extirpated (e.g., tributaries of the Willamette River for spring Chinook and Imnaha and Grande Ronde River tributaries for spring/summer Chinook in Northeast Oregon). Natural re-colonization is being evaluated in other cases (e.g., in the White Salmon River for steelhead and Chinook). The 2008 SCA and the Salmon Hatchery Inventory and Effects Evaluation Report (NMFS 2004) provide an overview of the pros and cons, and benefits and risks of recent hatchery operations.

In the course of fulfilling mitigation agreements, reducing short-term extinction risk, and promoting survival, there also is the potential for hatchery programs to threaten the long-term viability of natural populations. The benefit and risk evaluations for hatchery programs in the Interior Columbia (upstream from Bonneville Dam) in NMFS (2004) were discussed by the Hatchery and Harvest Workgroup of the FCRPS remand collaboration and their input was incorporated into the 2008 BiOp). The latter document: 1) summarizes the major factors limiting salmon and steelhead recovery at the population scale, 2) provides an inventory of existing hatchery programs including their funding source(s) and the status of their regulatory compliance under the ESA and National Environmental Policy Act , 3) summarizes the effects on salmon and steelhead viability from current hatchery operations, and 4) identifies new opportunities or changes in hatchery programs likely to benefit population viability.

2.3.2 New Information Related to the 2008 FCRPS BiOp

2.3.2.1 Effects on Reproductive Success and Fitness

Araki et al. (2009) looked at the relative reproductive success of the progeny of first-generation hatchery fish that spawned in Hood River, Oregon, during 1995 through 1998. They asked whether the progeny of hatchery fish that successfully survive a full generation of selection in the wild can leave as many adult offspring as wild fish that have not been influenced by captive breeding. The individuals compared in this study were all born in the Hood River, Oregon, presumably experiencing the same environment, and spawned in the river the same year. The relative reproductive success (RSS; the number of offspring that returned as adults) of the fish for which both parents were naturally-spawning hatchery fish was 37% of that of the progeny of two wild parents. The performance of naturally-spawning fish for which one parent was a naturally-spawning hatchery fish was 87% of that of the progeny of two wild fish.

Araki et al. (2008) summarized studies that evaluated the relative fitness of hatchery and wild salmonids. They used quantitative genetic theory to evaluate the conditions under which domestication selection alone was sufficient to explain the rapid fitness declines that have been observed in some studies. The authors concluded that selection alone could be a sufficient explanation, either when it operated on several traits throughout the life cycle or when extremely strong selection works on a single trait with very high heritability. Traits that could cause the observed fitness declines include domestication selection, enhanced mutation rates, relaxation selection, chromosomal abnormality, and epigenetic effects.

An analysis of spawner and recruit data for Oregon coast coho populations demonstrated that naturally-spawning hatchery coho had an adverse impact on net population productivity (Buhle et al. 2009). The findings showed that productivity was related to the number of hatchery smolts released, independent from other factors, suggesting an ecological effect of hatchery fish. Hypothetically, even if the reproductive success of hatchery-origin fish can be increased to match that of wild fish, ecological interactions could still result in a net loss in population productivity.

Chilcote and Goodson (In prep) examined data sets on population abundance for 121 populations of coho, steelhead, and Chinook in Oregon, Washington, and Idaho. They found that population productivity was inversely related to the average proportion of hatchery fish in the naturally-spawning population, consistent with the findings of Buhle et al. (2009). The magnitude of this effect was substantial. For example, a population comprised entirely of hatchery fish would have one tenth the intrinsic productivity of one comprised entirely of wild fish. There was no indication that the significance or strength of this relationship was different among the three species examined. In addition, there was no indication that the type of broodstock (integrated with the local natural-origin population versus segregated) affected the significance or intensity of the response.

Berejikian et al. (2009) compared the adult to fry reproductive success of natural-origin Hood Canal summer chum salmon with that of first- to third-generation hatchery-origin salmon in an experiment that included four replicate breeding groups. Hatchery- and natural-origin chum salmon of both sexes exhibited similar reproductive success. The ratio of hatchery-origin/natural-origin reproductive success was 0.83. The authors note the similarities to the findings of other studies where the broodstock was founded from the local natural population and that this ratio was much higher than in studies evaluating the lifetime relative reproductive success of nonlocal hatchery populations. Results show that a supplementation effort designed to restore a listed fish could be carried out, over the short-term (i.e., approximately one generation) without a large reduction in relative fitness, and provide another RRS estimate for use in analyzing immediate fitness depression caused by hatchery fish. However, this study does not address the potential for ecological interactions or the possible loss in fitness in the entire population over the three-generation course of the supplementation program.

Knudsen et al. (2008) compared hatchery and natural-origin female spring Chinook from the Yakima River from four brood years to determine whether their reproductive traits had diverged after a single generation of artificial propagation. Fecundity, relative fecundity, individual egg mass and total gamete mass were all significantly correlated with body length, although reproductive effort (mass of a female's eggs as a proportion of body weight) was not. Hatchery-origin fish were significantly smaller than natural-origin females. The latter had an average of 8.8% more total gamete mass, 0.8% more individual egg mass, and 7.7% greater fecundity than hatchery females. Egg-to-fry survival rates varied among years, with no consistent difference between hatchery and natural-origin fry.

2.3.2.2 Best Practices for Managing Hatchery Programs

In a study of mating policies, Hankin et al. (2009) observed the age-at-return of the progeny resulting from test crosses of Chinook of various ages at Elk River Hatchery in Oregon. They modeled several mating strategies: 1) completely random, 2) completely random but excluding jacks (age 2 males), and 3) male length > female length. According to the study, the first two mating types will produce younger and smaller populations than the third, regardless of exploitation (harvest). The authors inferred that the currently accepted policy of random mating is selective and that the third type, which more closely mimics natural behavior, does a far better job of producing populations with "normal" age structures. They recommended that large-scale hatcheries replace unnatural completely random mating regimes with mating regimes that emulate the outcomes of natural spawning behaviors.

The research and review conducted by Kostow (2009) highlighted major ecological risk factors for hatchery programs and proposed 12 actions that can reduce the ecological risk:

- Operate programs within an integrated management context
- Only implement hatchery programs that provide a benefit
- Reduce the size of releases
- Scale programs to carrying capacity
- Limit the total number of fish released
- Release only juveniles that are actively smolting and will promptly outmigrate
- Release smaller hatchery fish, provided they are smolting
- Use acclimation ponds and volitional releases
- Locate large releases away from important natural production areas

- Time releases to minimize interactions
- Restrict the number of hatchery adults allowed on spawning grounds
- Mark 100% of the hatchery fish and monitor the effects of hatchery programs

Scale pattern analysis was used at the Forks Creek hatchery in Washington to determine whether the ratio of hatchery-produced adults to wild adults on the spawning grounds met recommended levels for a segregated program (Dauer et al. 2009). In this river, all hatchery-produced adults should be captured at the hatchery on their first spawning migration. However, scales from 8.3% (58 of 699) of female and 2.6% (22 of 844) of male hatchery steelhead showed evidence of previous spawning migrations. These records nevertheless indicated significant reproductive opportunities in the wild for hatchery-produced fish. The data suggest that unless capture efficiency is increased at this and probably other similar hatchery operations relying on segregated stocks, the risks of genetic introgression and ecological interactions with wild steelhead populations will remain high. There was significant repeat spawning of hatchery fish in a segregated steelhead program where no fish should have repeat-spawned, indicating weir inefficiency or spawning elsewhere.

Small et al. (2009) investigates the impacts of supplementation on genetic diversity. In supplementation programs, hatcheries employ wild-origin fish as brood stock and their offspring are allowed into wild spawning areas. Resource managers use supplementation to support imperiled salmonid populations, seeking to increase census size and possibly effective population size (Ne), while minimizing risks of genetic diversity loss and domestication from hatchery intervention. Genetic effects from 5–10 years of supplementation on threatened summer-run chum salmon in Hood Canal (HC) and Strait of Juan de Fuca (SJF) in Washington State were compared with unsupplemented summer- and fall-run chum salmon from HC and South Puget Sound. Microsatellite allele frequencies identified four run-timing and geographic groups. HC and SJF summer chum salmon genetic relationships followed a metapopulation pattern of isolation by distance, similar to patterns prior to supplementation, suggesting that supplementation minimally impacted population structure. In most supplemented subpopulations, no effects were detected on diversity and Ne, but high variance in individual pairwise relatedness values indicated over-representation of family groups. In two subpopulations, hatchery impacts (decreased diversity and lower Ne) were confounded with extreme bottlenecks. Rebounds in census sizes in all subpopulations suggest that general survivorship has improved and that possible hatchery effects on genetic diversity will be overcome.

Tatara et al. (2009) propose that after hatchery-reared salmonids are released into the wild, their survival and performance are frequently lower than those of wild conspecifics. Additionally, negative effects of hatchery fish on wild fish are cited as factors affecting the recovery of salmonid populations. Alternative hatchery rearing environments and release practices have been proposed to mitigate both problems. Post release growth, survival, habitat use, and spatial distribution of hatchery steelhead fry reared in conventional and enriched environments were investigated and performance was compared with that of naturally reared steelhead fry from the same parent population in two streams. Average instantaneous growth rates differed between streams but not among the three rearing groups. The survival of naturally reared fry was significantly greater than that of both types of hatchery fry but did not differ between the conventional and enriched environments. Naturally reared fry grew and survived equally well regardless of the type of hatchery fry with which they were stocked. Supplementation increased fry population size in all stream sections but produced hatchery-biased populations. Steelhead fry preferred pool habitat within stream sections, but pool use was affected by an interaction between rearing environment and stream. Hatchery fry had more clumped spatial distributions than naturally reared fry, which were affected by a significant interaction between rearing type and stream. Hatchery rearing type and stream had no effect on the spatial distribution of naturally reared fry. Results indicate that 1) hatchery steelhead fry released in streams grow as well as naturally reared fry but do not survive as well, 2) enriched hatchery environments do not improve post release growth or survival, and 3) upon release, fry raised in enriched hatchery environments affect the growth and survival of naturally reared fry in much the same way as fry reared in conventional hatchery environments.

In the context of conservation hatcheries that seek to bolster wild populations by releasing captively-reared fishes into the wild, Lee and Berejikian (2008) used steelhead to test the hypothesis that naturalistic rearing environments promote adaptive behavior that might otherwise not develop in typical hatchery environments. When comparisons were made among fish reared in barren, structured or structurally variable environments (i.e. the location of the structure was repositioned every two to three days), structure in the rearing environment increased future exploratory behavior, but only if the structure was stable. Under conditions of high perceived predation risk, the fish no longer exhibited increased exploratory behavior, suggesting that it is expressed in an adaptive, context-dependant manner. Another concern with hatcheries is that relaxed selection over multiple generations in captivity can increase maladaptive behavioral variation. Compared to rearing in hatchery-typical barren environments, rearing in structured-stable environments decreased behavioral variation. This effect, which occurred during development and did not involve selection, demonstrates a different mechanism for change in behavioral variation in captivity. These experiments show that effects of structure and structural stability occur at the level of both average behavior and behavioral variation, and suggest that these effects should be considered when fishes are reared in hatcheries for later release into the wild.

2.3.2.3 Regional Independent Science Team Report

A Regional Independent Science Team (RIST 2009) was asked to investigate a number of significant issues for hatcheries including:

1. Is there evidence of different rates of domestication for different life history types?

RIST concludes that based on current information, hatchery programs that involve breeding, incubation and no or very brief rearing may be less likely to result in strong domestication selection than programs that involve longer periods of rearing. But because substantial selection may occur before the fry stage, there may not be that much difference in domestication between longer and shorter life-history types.

2. What information is there to inform systematic assessments of ecological impacts at the population level?

About half a dozen recent studies have examined correlations between hatchery fish abundance and wild salmon survival, abundance or productivity. All found significant negative associations. These estimated effects can be substantial – in some cases suggesting a >50% reduction in estimated wild population productivity. Reductions in hatchery production have also been found to be effective at increasing natural productivity: reductions in hatchery coho releases have been estimated to be responsible for a ~23% increase in the productivity of natural Oregon coast coho populations. Many of the scenario building tools currently available to recovery planners, such as AHA, SHIRAZ and SLAM, could be readily adapted to use existing information on ecological interactions between hatchery and wild salmon. Data show clear effects and tools can be developed to approach the problem.

3. Investigating the use of weirs for isolating wild and hatchery production.

Many factors need to be considered in developing and using weirs, 1) there may be other ways to accomplish what the managers intend, 2) weirs can be very expensive, 3) they can have unintended consequences non-target species, and 4) their efficiency can vary widely. If existing weirs are used or new weirs are installed their effectiveness needs to be monitored.

2.3.3 Relevance to the 2008 FCRPS BiOp Analysis and AMIP

More than 100 hatchery programs are funded by the Action Agencies to mitigate losses of salmon and steelhead attributable to the construction and continuing operation of the FCRPS. The continued funding of these programs was the subject of the 2008 consultation, but the effects of hatchery operations are being addressed in ongoing consultations on the operators' Hatchery Genetic Management Plans as described in RPA Action 39. Therefore, no prospective quantitative benefits were assigned to any listed salmon or steelhead population in the 2008 analysis, although hatchery programs that conserve genetic resources were singled-out for reducing short-term extinction risk.

In summary, the presence of genetically compatible hatchery fish can positively affect the overall status of a species by increasing the abundance and potentially the productivity of the natural populations, improving spatial distribution, serving as a source for repopulating unoccupied areas, and conserving genetic resources of depressed natural populations. Conversely, as reinforced by much of the new scientific information described above, a hatchery program can reduce the actual productivity of the species through competition with wild stocks, disease, maladaptive genetic traits, etc. NOAA Fisheries is giving these risks special consideration and in response, is defining site-specific best management practices in the Section 7(a)(2) consultations with the FCRPS funding agencies (RPA Action 39).

2.4 Harvest Rates

As described below, the prospective harvest rates that NOAA Fisheries assumed in the 2008 BiOp analysis for Interior species are still in effect. The harvest rate for early-run fall Chinook from the Lower Columbia River ESU is the only change and that has decreased by 3%. If the status of an Interior species declines to the point that an Early Warning or Significant Decline trigger is tripped, NOAA Fisheries will evaluate current harvest agreements to see if they are sufficiently protective. If it determines that additional protection is needed, NOAA Fisheries will use existing procedural provisions to seek consensus among the parties to modify the agreements.

2.4.1 New Information Relevant to 2008 FCPS BiOp and AMIP

The harvest rates currently in effect for Interior Columbia basin salmon and steelhead are the same as those described in Section 8 in the 2008 BiOp). The harvest rate for early-run fall Chinook from the Lower Columbia River ESU has decreased by 3%. Most individuals from this stock are caught in the ocean, but some are taken in the non-treaty fall season fisheries below Bonneville Dam as discussed in the 2008 BiOp. In the 2008 prospective analysis, NOAA Fisheries assumed that the total (ocean + river) exploitation rate would not exceed 41% during 2008. In fact, the actual rate was less than or equal to 38% in 2008. Based on NOAA Fisheries' guidance to the Pacific Fisheries Management Council (Council) (Thom and McInnis 2010; updated in NMFS 2010), it is not expected to exceed 38% in 2010 and 36% in 2011. NOAA Fisheries advised the Council that the limit could be increased to 37% in 2011 if defined tasks were completed to reduce uncertainties about the recovery strategy for this species (NMFS 2010).

In its 2009 guidance letter to the Council (Thom and McInnis 2009), NOAA Fisheries expressed its expectation that, with the co-managers cooperation, it would be able to layout a multi-year approach to harvest management of LCR Chinook beginning in 2010, instead of providing year-by-year guidance. The goal was to reduce the uncertainties associated with the role of harvest in the recovery strategy while adding predictability to recreational, commercial and tribal fisheries. However, time constraints prevented the co-managers, recovery planners and other interested parties from fully reviewing, considering, and reacting to the Northwest Fisheries Science Center's new life-cycle modeling analysis before the start of the 2010 fishing season. The guidance NOAA Fisheries has provided the Council at this time will therefore only apply to 2010 and 2011. NOAA Fisheries continues to work toward the goal of a long term biological opinion for these fisheries.

2.4.2 Relevance to 2008 FCRPS BiOp Analysis and AMIP

The prospective harvest rates that NOAA Fisheries assumed in the 2008 BiOp analysis for Interior basin species are still in effect. The RPA, as amended, includes Early Warning and Significant Decline triggers for those species, which if tripped, would cause NOAA Fisheries to evaluate existing harvest management agreements, among other measures. The purpose of the evaluation would be to assess whether the existing agreements provided adequate protection for the species given its decline in status. Under the U.S. v. Oregon agreement, if the performance measure of any indicator stock declines for three consecutive years when compared to the base period (1988 to 2007), any party may request that an analysis of the decline is conducted. The analysis must be completed within one year. If, after reviewing the analysis, NOAA Fisheries determines that additional protection is needed, existing procedural provisions will be used to seek consensus among the parties to modify the agreements.

2.5 Research, Monitoring, and Evaluation

NOAA Fisheries intends that an extensive program of RM&E will ensure that managers have the information needed to adaptively manage and determine the effectiveness the 2008 RPA. As described in the following sections, the new scientific information reviewed for this remand informs the design and implementation of the monitoring, but does not alter the analysis of effects of the RPA, as amended.

2.5.1 New Information Relevant to 2008 FCPS BiOp and AMIP

The 2008 BiOp and the AMIP are predicated on a robust adaptive management approach that responds to new research, monitoring and evaluation (RM&E) information concerning fish status and trends, habitat status and trends, action effectiveness, and critical uncertainties. Recent scientific publications and analyses continue to inform the design and implementation of RM&E activities under the 2008 BiOp and AMIP.

Since the release of the 2008 BiOp, the Action Agencies, NOAA, and the NPCC have been working together with States and tribes to include the 2008 BiOp RM&E actions into an integrated plan for the region. This framework and related recommendations have been included in a report and are now being reviewed by the ISAB.

2.5.1.1 Research and Monitoring on Marine Survival

Beamish et al. (2009a) presents an international strategic plan to coordinate research and monitoring among North Pacific countries and improve the understanding of factors affecting the marine survival of Pacific salmonids. The collaboratively developed research and monitoring plan outlines long-term research and monitoring needs for Canada, Japan, Korea, Alaska and the Oregon-Washington-California region. The research and monitoring priorities identified are focused on elucidating the ecological processes affecting marine mortality during the marine phase of the salmonid life-history. Priorities for the Oregon-Washington-California region include:

- Monitoring of the abundance and distribution of prey and predator species
- Monitoring of ocean growth rates and bioenergetic condition in juveniles and adults
- Advancing genetic methods of stock identification
- Evaluating the relative importance of marine habitats to stock distribution, growth and survival

The authors underscore that there is a critical information gap on the winter ecology of Pacific salmonids and the effects on survival. They also advocate for integrating freshwater and marine RM&E efforts to better understand the factors affecting the Pacific salmonid dynamics throughout their entire life cycle.

2.5.1.2 Protocols for Monitoring the Effectiveness of Estuary Restoration Actions

Roegner et al. (2009) describes a set of standardized protocols and an efficient suite of metrics for monitoring the effectiveness of actions to restore degraded wetland habitat in the lower Columbia River and estuary. The guidance was developed collaboratively by NOAA Fisheries, the Pacific Northwest National Laboratory, the Columbia River Estuary Study Taskforce, and the U.S. Army Corps of Engineers. The publication presents coordinated statistical design and specific protocols for monitoring the following:

- Hydrology (water surface elevation)
- Water quality (temperature and salinity, elevation (topography)
- Landscape features (remote sensing)
- Plant community (plant species composition and cover)
- Vegetation plantings (planting success)
- Fish communities (species composition, temporal presence, size, and age structure)

The protocols are intended to allow research and managers the information necessary to evaluate the results of individual restoration activities, compare the results among projects, and determine the long-term and cumulative effects of habitat restoration actions on the overall estuary ecosystem. The selected metrics represent a balance of the metrics that are necessary to detect the results of restoration actions, while remaining practical in terms of the financial and logistical requirements to implement monitoring of the metrics.

2.5.1.3 Monitoring Habitat Improvements—Statistical Design

Analyses of statistical power are an effective tool in designing effectiveness monitoring programs capable of detecting anticipated changes in salmon survival. A design often considered for effectiveness monitoring is the before-after-control-impact (BACI) design in which there is a “Before” period of no treatment followed by an “After” period where some populations are treated an others are not. Hinrichsen (2010b) provides an a priori analysis of the maximum in statistical power one could reasonably expect and over what time-frames from alternative BACI designs. The intent of the analysis was to evaluate whether small changes in fish survival (e.g., of 1-5% for some populations) are detectable. Hinrichsen’s analysis found that small survivorship changes of 1-5% are very unlikely to be detected even under the best of circumstances. Detecting a survival change in the range of 1-5% was impossible even when 20 populations were employed and monitored over 30 years. Survival changes of 30% or more were detectable with one treatment and one control population over 20 years or more. The results of the analysis suggest that restoration planners may need to revise their expectations of effectiveness monitoring programs, and the timeframes over which they expect benefits of restoration actions to be realized.

2.5.1.4 Hatchery Marking Strategies

Hinrichsen and Sharma (2010) present a sensitivity analysis to illustrate how varying marking rates of hatchery-origin fish might affect the overall accuracy of escapement estimates of hatchery-origin and natural-origin spawners. The sensitivity analysis evaluated the influence of 3 factors: the size of the sampled population; the sample rate; and the mark rate of the target hatchery group. The analysis assumed that there are only 2 groups of fish sampled (a natural and hatchery run) and the sole management objective of the marking is to estimate the escapement of these two groups.

From the analysis, the authors conclude that unbiased estimates are obtainable without marking 100% of the fish, but such results require perfect knowledge of the sampling rate of all spawners and the true marking rate of hatchery-origin fish. If strays are entering the spawning population with a different marking rate than the one assumed, then the escapement estimators will be biased. Standard error tends to be large when the marking rate or sampling rate is low. The marking rate can be just as influential as a sampling rate in determining the accuracy of the escapement estimates. The analysis suggests that very high – if not 100% marking rates – are necessary for obtaining reliable escapement estimates, particularly in area subject to hatchery straying.

2.5.1.5 Capture and Transport of Adult Sockeye Salmon: Effects Analysis

Losses of adult sockeye between Lower Granite Dam and the Sawtooth Valley lakes can be high (in the general range of 25-50%) in the mid- to late-summer; most likely due to relatively high temperatures in the Snake and Salmon Rivers. RPA 42 requires the Action Agencies to “work with appropriate parties to investigate feasibility and potentially develop a plan for ground transport of adult sockeye from LGR Dam to Sawtooth Valley lakes or artificial propagation facilities.” More detailed plans are now developed to evaluate the capture and transportation of adult sockeye at Lower Granite Dam. This action will assess whether survival rates are substantially increased, as expected, for adult sockeye transported between Lower Granite Dam and the Sawtooth Valley lakes (2008 BiOp, Sections 8.4.3.1 and 8.4.5.1) in the mid to late-summer period compared to those left to migrate inriver. Those adult sockeye that are transported will arrive at the Sawtooth Valley lakes earlier than they would if migrating through the river themselves.

Additional, incidental handling of several hundreds of adult Chinook and steelhead will likely occur as a result of the effort to collect sockeye salmon at Lower Granite Dam. However, only a relatively small proportion of spring/summer Chinook and steelhead adults are passing in July (the period in which most sockeye salmon are likely to be caught for transport) and only some of these individuals are likely to be affected by the sorting process (minor handling and delayed migration - they will not be transported). Mortalities are expected to be rare (< 10 adults of each species annually).

2.5.2 Relevance to 2008 FCRPS BiOp Analysis and AMIP

The new scientific information described above informs the design and implementation of the monitoring, but does not alter the analysis of effects under the BiOp. For example, the research priorities identified by Beamish et al. (2009a) are consistent with the critical uncertainties identified in RPA Action 61. Roegner et al. (2009) informs the design and implementation of estuary action effectiveness studies, assisting in the implementation of RPA Action 60. Hinrichsen (2010b) pertains to the detectability of the habitat quality improvements predicted by the Expert Panels to be achievable if the appropriate restoration actions are implemented (see RPA Action 35, Table 5). The study does not question the survival improvements expected from habitat restoration that are listed in Table 5, but rather revises expectations that the these changes will be detectable during the term of the 2008 BiOp; The analysis of Hinrichsen (2010b) suggests that for some populations survival improvements may not be detectable for decades. Hinrichsen & Sharma (2010) pertains to the effectiveness monitoring associated with implementing the hatchery-related RPA Actions 39 – 42, as well as the reporting of population status and trend information as part of the comprehensive progress reports (RPA Action 3). The report does not cause NOAA Fisheries to question the requirements under RPA Actions 39-42, but would inform the marking rates and monitoring design implemented.

Additional adult telemetry studies are required (as part of adaptive management) to assess where adult losses are occurring and the factors responsible for these losses. This information would allow the Action Agencies, NOAA Fisheries, and co-managing states and tribes to implement actions to address or minimize these impacts. Mortalities associated with these studies should not exceed 5% of the tagged fish (600-1200 adults of the target species) or 0.5% of other adults handled incidentally.

The capture and transport of adult SR sockeye salmon (related to implementation of RPA Action 42) is required to assess the effectiveness of transporting these fish to avoid losses caused by high summer temperatures in the Snake and Salmon rivers. This action should substantially improve adult survival rates to Sawtooth Valley lakes or artificial propagation facilities. Mortalities associated with this action should not exceed 2% of the adult sockeye captured and transported (up to 50% of the run) or 10 adults Chinook salmon are steelhead handled incidentally as a result of this action.

In summary, the new scientific information described above supports the monitoring requirements of the RPA, as amended.

2.6 Habitat Conditions & Ecological Interactions Affecting the Southern Resident Killer Whale

In the following paragraphs, NOAA Fisheries describes the new scientific information on Southern Resident killer whale prey requirements, quality and quantity. There is additional data to support the Southern Residents preference for Chinook salmon in inland waters, the assumption that Southern Residents prefer Chinook salmon in coastal waters, and to demonstrate the link between Chinook abundance and whale survival and fecundity. The conclusions of this analysis provide more refined information on areas and times of year when the whales may be more vulnerable to reductions in their prey base. However, 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.

2.6.1 New Scientific Information Related to the 2008 FCRPS Biological Opinion

2.6.1.2 Habitat Use

Distribution in coastal waters

There have been some new sightings of Southern Resident killer whales in coastal waters. In March 2005, L pod was sighted working a circuit across the Columbia River plume from the North Jetty across to the South Jetty during the spring Chinook run in the Columbia River (Zamon et al. 2007). K and L pods were also encountered off the Columbia River in March of 2006 (Hanson et al. 2008). L pod was again seen feeding off Westport, Washington in March 2009, and genetic analysis of prey remains collected from two predation events identified both fish as spring Chinook from Columbia River stocks (Hanson et al. 2010a).

The NWFSC also deploys and collects data from remote autonomous acoustic recorders in coastal waters of Washington State and in 2009 documented 52 Southern Resident killer whale detections from this acoustic system (Emmons et al. 2009). As these data become analyzed, more information will be available about the seasonal distribution, movements and habitat use of Southern Resident killer whales, specifically in Washington coastal waters of their coastal range.

The NWFSC conducted an analysis of the number of days Southern Residents spend time in inland waters, on average (Hanson and Emmons 2008), and by extrapolation, the number of days that Southern Residents may spend in coastal waters (i.e., when not confirmed to be in inland waters) is added in the table below (Table 11). This analysis provides more detailed information on Southern Resident killer whale distribution than previously presented in Figure 9.1-2 of the 2008 BiOp.

Table 11. Average number of days spent by Southern Resident killer whales in inland and coastal waters by month, 2003-2007.

Months	Jpod		Kpod		Lpod	
	Days Inland	Days Coastal	Days Inland	Days Coastal	Days Inland	Days Coastal
Jan	3	29	8	23	5	26
Feb	4	24	0	28	0	28
March	7	24	2	29	2	29
April	13	17	0	30	0	30
May	26	5	0	31	2	29
June	26	5	12	18	14	16
July	24	7	17	14	18	13
Aug	17	15	17	14	17	15
Sep	19	11	17	13	20	10
Oct	14	17	8	24	12	19
Nov	13	17	7	23	5	25
Dec	8	23	10	21	1	30

2.6.1.3 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. Results to date were recently published by Hanson et al. (2010b), which constitute the best available scientific information on diet composition of Southern Residents in inland waters (specifically surrounding the San Juan Islands, Washington and in the western Strait of Juan de Fuca, British Columbia) during summer months. In these inland waters, an average of 82% of the identified prey in the Southern Residents' diet consisted of Chinook from May to September. Chinook comprised 96% of identified prey during July and 91% during August (Table 2 in Hanson et al. 2010b). Genetic analysis of these samples indicate that they represented stocks from the Fraser River (e.g., Upper, Mid, and Lower Fraser; North, South, and Lower Thompson); Puget Sound (North and South Puget Sound); the Central British Columbia Coast; West and East Vancouver Island; and California's Central Valley (Hanson et al. 2010b). The samples from predation events in the San Juan Islands indicated that the whales consume a high proportion of Fraser River Chinook stocks. Ongoing studies (Ford et al. 2010) also show a shift from Chinook to more abundant chum salmon in the fall in inland waters.

Size selectivity

In the 2008 SCA and Ward et al.(2008b) scientists from the NWFSC evaluated the age of Chinook prey relative to the age distribution produced by FRAM, a fisheries management model. Their findings agreed with those of Ford and Ellis (2006): Southern Residents consumed older (larger) fish in far greater proportion than their presence (Table 12).

Table 12. Mean abundance by age class (%) and kills by age class

Age	NWFSC (n = 75)		Ford & 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

To date, there have been direct observations of two predation events in coastal waters of Washington State where the prey were identified to species and stock by genetic analyses. Both were identified as Columbia River spring Chinook stocks (Hanson et al. 2010a). Prey preference in coastal waters is a subject of ongoing research.

Metabolic needs

The NWFSC updated their model to estimate the potential range of daily energy expenditure for Southern Resident killer whales for all ages and both sexes (Noren in press). Although the model provides a range in daily energy expenditure, the range is meant to represent uncertainty in the calculations. Until additional information on Southern Resident killer whale body size and energetic costs of growth in young animals and adolescent males and lactation in females are better known, Noren (in press) suggest that it is probably best to estimate population needs based on the upper bound equation, which is the high end of the range in daily energy expenditure estimated.

2.6.1.4 Prey Quantity

Ford et al. (2009) correlated coastwide reductions in Chinook abundance (Alaska, British Columbia, and Washington) with decreased survival of resident whales from the Northern and Southern Resident DPSs, but 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. Ward et al. (2009) correlated Chinook abundance trends with changes in fecundity of Southern Resident killer whales, and reported that the probability of calving increased by 50% between

low and high Chinook abundance years. Results of this study indicate the Chinook abundance indices from the West Coast of Vancouver Island are an important predictor of fecundity.
In recent consultations subsequent to 2008 BiOp, NOAA Fisheries has continued to compare the food energy of prey available to the whales' estimated metabolic needs using estimates of Chinook available and prey requirements of Southern Residents (i.e., NMFS 2009b). In light of new data on the Southern Resident population size, habitat use, prey preferences, and metabolic needs, NOAA Fisheries updated these metrics to reflect the new science (Agness 2010). Similar to past estimates (NMFS 2009b), the update identifies areas and times of year when the ratio of prey available compared to needs is low. Although we do not currently have information on the foraging efficiency of the whales to assist in a more quantitative analysis, these low ratios may indicate seasonal conditions when the whales may not be able to obtain sufficient prey to meet their daily needs. Low ratios reinforce the need for a better understanding of the whales' prey requirements and preferences temporally and spatially across their coastal range. NOAA Fisheries is currently engaged in research to improve the available scientific data in these areas.

2.6.1.5 Prey Quality

Contaminants

Studies continue to document high concentrations of PCBs, DDTs, and PBDEs in killer whale tissues (Krahn et al. 2009, Mongillo 2009). Studies also continue to document PCB and PBDE levels in Chinook (Cullon et al. 2009). The mobilized contaminants can reduce the whales' resistance to disease and can affect reproduction (Krahn et al. 2009, Mongillo 2009). Recent studies suggest that certain pharmaceuticals and personal care products (PPCPs) may also accumulate in marine mammals. Synthetic musks and antibacterial chemicals (e.g. Triclosan) have been detected in dolphins and porpoises in coastal waters off Japan and the southeastern United States and in harbor seals off the California Coast (Nakata 2005, Kannan et al. 2005; Nakata et al. 2007; Fair et al. 2009). A wider range of PPCPs, including anti-depressants, cholesterol-lowering drugs, antihistamines, and drugs affecting blood pressure and cholesterol levels have been detected in tissues of fish from urban areas and sites near wastewater treatment plans (Brooks et al. 2005; Ramirez et al. 2009), suggesting possible contamination of prey. As yet no data are available on concentrations of PPCPs in either killer whales or their prey species, but these are a concern because of their widespread occurrence, potential for biomagnifications, and biological activity in other species.

Prey origin

Southern Resident killer whales likely consume both natural- and hatchery-origin salmon (Hanson et al. 2010b). 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 SCA), which are differences that could affect Southern Residents. Potential run-specific differences in the quality of natural and hatchery salmon are evaluated where data are available. In recent consultations where information on size or run timing differences between hatchery- and natural-origin Chinook from specific river systems or runs has been available, we have incorporated the information in our assessment of the equivalency of natural and hatchery Chinook as prey for the whales (e.g., size and run-timing differences in Upper Willamette River Chinook; NMFS 2008b). Specific information on differences in natural and hatchery origin fish in the Columbia and Snake River basins is currently not available. Krasnow (2010) recently reviewed size at age data for Chinook at Bonneville Dam and found that the potential for bias in these data is severe enough that it does not support a conclusion about differences in size between hatchery- and natural-origin Chinook, even regarding spring Chinook.

2.6.2 Relevance to the 2008 FCRPS Biological Opinion Analysis & RPA

The new science on Southern Resident killer whale prey requirements, quality and quantity reinforce the assumptions from the 2008 BiOp. There is additional data to support the Southern Residents preference for Chinook salmon in inland waters, the assumption that Southern Residents prefer Chinook salmon in coastal waters, and to demonstrate the link between Chinook abundance and whale survival and fecundity. The analysis in the 2008 BiOp analysis focused on Chinook to provide a conservative estimate of potential effects on Southern Residents, which is supported by the new science.

Updated information on the number of whales in the population, habitat use, metabolic needs, and prey selectivity informed a new review of the prey available to the whales compared to their needs. The conclusions of this analysis provide more refined information on areas and times of year when the whales may be more vulnerable to reductions in their prey base. As discussed in the 2008 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 determined that the hatchery production contained in the 2008 RPA more than offsets losses to the killer whale prey base. The updated information provides a better context for considering changes in prey availability, however, it does 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 information about emerging contaminants of concern and PCB and PBDE contaminant levels in Chinook informs our baseline assessment of prey quality, but does not change our analysis of prey effects. In addition, there is no new science to indicate that hatchery origin Chinook are not sufficient to offset the losses of natural and hatchery origin fish in the short-term.

2.7 Habitat Conditions & Ecological Interactions Affecting the Southern DPS of North American Green Sturgeon

In the 2008 FCRPS Biological Opinion, NOAA determined that "By changing flow, sediment transport (turbidity), and the characteristics of the Columbia River estuary, the FCRPS RPA may affect green sturgeon." Other than adding uncertainty to the analysis of green sturgeon habitat requirements in the Columbia River, there is no evidence that changes in the spring hydrograph and/or in sediment delivery to the estuary, both effects of the hydrosystem, are adversely affecting the biological requirements of this species.

2.7.1 New Information Relevant to 2008 FCPS BiOp and AMIP

Subadult and adult green sturgeon reside in the lower Columbia River and other estuaries in the Pacific Northwest May through September each year. Commercial gillnet data from 1981–2004 (Washington Department of Fish and Wildlife (WDFW) 2007) show that catch was largest below RM 52 although some fish were caught in zone 5, close to the tailrace of Bonneville Dam. Telemetry data show greater numbers of detections in the lower portion of the estuary (Moser et al. 2007). However, the telemetry data do not describe how frequently green sturgeon move upstream past RM 46 because the farthest upstream acoustic tag monitor is at that point. Individuals that move into the Bonneville tailrace during May could be vulnerable to predation by California or Steller sea lions that gather to feed on returning salmon and steelhead.

Telemetry data show that tagged green sturgeon dispersed widely throughout the Columbia River estuary, most likely for foraging although there is little information on preferred prey the Columbia River and none on the use of the deep channel versus shallow areas. 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 (*Cancer magister*), crangonid shrimp, and small amounts polychaetes, clams, and amphipods (Dumbauld et al. 2008). Burrowing shrimp were less important in green sturgeon guts from the Columbia River than in those from Willapa Bay; of the two green sturgeon landed in the Columbia in 2004 and 2005 with identifiable items in their guts, contents were mostly crangonid shrimp.

Given the paucity of information on either preferred prey or relative use of the deep channel versus shallow areas in the Columbia River, it is difficult to determine whether FCRPS flow management or changes in sediment delivery to the estuary have negatively affected prey availability. 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 (*C. magister*) were also prominent at the entrance of the estuary and in the channel bottom in the seaward region of the estuarine mixing zone.

2.7.2 Relevance to 2008 FCRPS BiOp Analysis and AMIP

Recently published tagging and genetic studies indicate that the size of the spawning population in the Sacramento River could be smaller than NOAA Fisheries assumed in its 2008 analysis (Section 2.1.5). However, the issues of concern in the Columbia River pertain to prey availability and habitat use below Bonneville Dam by subadults and non-spawning adults. These fish are assumed to be foraging, although little data are currently available on foraging areas and preferred prey.

In the 2008 BiOp, NOAA Fisheries determined that "By changing flow, sediment transport (turbidity), and the characteristics of the Columbia River estuary, the FCRPS RPA may affect green sturgeon." However, "Because 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 this remand indicate that some of the assumptions made in the 2008 analysis may no longer be valid: 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 assumes that green sturgeon use the deep channel in preference to shallow margin areas. However, as stated above, other than adding uncertainty to the analysis of green sturgeon habitat requirements in the Columbia River, there is no evidence that changes in the spring hydrograph and/or in sediment delivery to the estuary, both effects of the hydrosystem, are adversely affecting the biological requirements of this species.

Section 3 Additional Actions

3.1 Reasonable and Prudent Alternative

The 2008 BiOp recommended a reasonable and prudent alternative (RPA) in Chapter 4 to comply with the standards of Section 7(a)(2) of the ESA. An RPA Action Table, Appendix 1 to the 2008 BiOp, describes the RPA NOAA recommended and which the Action Agencies formally adopted for implementation through records of decision. NOAA's RPA was based on the Action Agencies' proposed RPA that was developed with substantial advice from regional sovereigns during the collaboration of the 2005 – 2008 remand. Acknowledging this development, NOAA incorporated Section 2 and Appendix B of the Action Agencies' Biological Assessment into the 2008 BiOp to provide additional information about the RPA and its expected implementation.

3.2 Adaptive Management Implementation Plan

In 2009, the Obama Administration engaged in a review of the 2008 FCRPS BiOp and its RPA and scientific underpinnings. Administration officials heard from agency scientists and technical staff, regional technical experts, resource managers and from independent scientists. With this input NOAA and the Action Agencies developed the Adaptive Management Implementation Plan (AMIP) to address various issues raised during this review through a more precautionary implementation of the RPA. In an exchange of letters, the Action Agencies and NOAA concluded that the 2008 RPA, as implemented through the AMIP, is biologically and legally sound, is based on the best science available and satisfies the jeopardy standard as articulated by the Ninth Circuit Court of Appeals: "its effects are not likely to jeopardize the continued existence of the listed species (i.e. combined with the effects of the environmental baseline and cumulative effects, the species are expected to survive with an adequate potential for recovery), nor likely destroy or adversely modify designated critical habitat."

At the Action Agencies' request, NOAA has now conducted a reinitiation of consultation for the FCRPS during this limited, voluntary remand. With help from the parties and the region's scientific community, NOAA has evaluated the currently available scientific and commercial data as discussed in this supplemental biological opinion. In response to that new information, and consistent with the RPA and AMIP, the agencies have developed additional implementation actions to amend and further enhance the AMIP. NOAA has determined that the AMIP should be amended to include the following actions for the reasons explained in Sections 2 and 4 of this supplemental biological opinion:

Amendment 1:

Under RPA Action 55 the Action Agencies will undertake selected hydrosystem research to resolve critical uncertainties. As part of this action, by June 2012, the Corps will complete a report to identify the use and location of adult salmon thermal refugia in the lower Columbia and lower Snake Rivers using existing information on adult migration, temperature monitoring data, and modeling efforts. Additional investigation or action may be warranted based on the results of this report.

Amendment 2:

Under RPA Action 52, the Action Agencies will enhance fish population monitoring. As part of this action, in February 2011 the Corps will initiate a study at The Dalles and John Day Dams to determine a cost effective adult PIT tag detection system design and whether installation of PIT tag detectors will improve inter-dam adult survival estimates. The study will be completed by December 2012. Following the results of the study, by April 2013, the Action Agencies will determine in coordination with NOAA if one or both of these PIT tag detectors substantially improve inter-dam adult loss estimates. If warranted, the Action Agencies will proceed to construction. Funding will be scheduled consistent with the RPA requirement and priorities for performance standard testing and achievement of these performance standards at the projects.

Amendment 3:

Under RPA Action 15, the Action Agencies are providing water quality information and implement water quality measures to enhance fish survival and protect habitat. As part of this action, the Action Agencies will contribute to regional climate change impact evaluations by providing NOAA past and future water temperature data from their existing monitoring stations, to be used as part of a regional temperature database. The Action Agencies will begin to provide data to NOAA within 6 months following the establishment of a regional database and annually thereafter. NOAA anticipates having a regional database established no later than 2012.

Amendment 4:

Under RPA Action 35, the Action Agencies are identifying tributary habitat projects for implementation and consider potential effects of climate change on limiting factors. As part of this action, the Action Agencies will continue to coordinate with NOAA in its efforts to use existing tributary habitat effectiveness studies, IMWs, and the NOAA enhanced lifecycle modeling to track climate change impacts. Starting in September 2011, the Action Agencies will annually provide NOAA with study data to be used as part of a regional climate change database. After 2011, new climate change findings will be provided to the tributary habitat expert panels to apply and use to help identify and prioritize habitat improvement actions.

Amendment 5:

Under RPA Action 35, the Action Agencies are identifying tributary habitat projects for implementation based on the population specific overall habitat quality improvement identified in the RPA Action. As part of this action, after 2011, the Action Agencies will include as a consideration in the expert panel project evaluation process 1) the presence of invasive species and 2) site-specific toxicology issues, based on information made available by the appropriate state and Federal agencies.

Amendment 6:

Under RPA Action 64 and under the AMIP Hatchery Effects p. 22, the Action Agencies are supporting efforts to resolve hatchery critical uncertainties. As part of this effort, beginning in December 2010, the Action Agencies will assist NOAA to further develop or modify existing studies that address the Ad Hoc Supplementation Workgroup Recommendations Report and that additionally address potential density-dependent impacts of FCRPS hatchery releases on listed species. These studies would provide support for future hatchery management actions to reduce potential adverse hatchery effects. By December 2010, the Action Agencies will work with NOAA to convene a technical workgroup with fishery managers to discuss potential studies and potential management tools. The goal for the workgroup will be to complete its work by December 2011.

3.3 Integration of AMIP as Amended into 2008 FCRPS Biological Opinion

NOAA has further determined that the AMIP as amended should be integrated into the 2008 BiOp by including in the 2008 RPA the following New RPA Action 1A:

New RPA Action 1A:

The Adaptive Management Implementation Plan (AMIP), as adopted by NOAA on September 14, 2009, and as further amended on May 19, 2010, is hereby integrated into the 2008 BiOp's RPA. The AMIP, as amended, is integrated into the implementation of the 2008 RPA as more fully described in the AMIP, Chapter 1.C at page 14.

Integration of 2008 BiOp and its RPA, as amended, into the 2010 Supplemental Biological Opinion

NOAA hereby integrates into this supplemental biological opinion the 2008 BiOp and its RPA, as amended to include new RPA Action 1A.

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Section 4 Conclusions

NOAA Fisheries concluded in its 2008 BiOp for the FCRPS, that through implementation of the recommended Reasonable and Prudent Alternative (RPA) the operation of the FCRPS would not likely jeopardize thirteen ESA-listed species of salmon or steelhead affected by the system. Further it concluded there that the operation of the FCRPS pursuant to the RPA would not likely destroy or adversely modify affected critical habitat designated for twelve of those species. Also, NOAA Fisheries concurred with the FCRPS Action Agencies that the system was not likely to adversely affect listed discrete population segments of green sturgeon and killer whales. NOAA's May 5, 2008, biological opinion, and its administrative record, identifies the best science and commercial data available and used by NOAA in reaching its 2008 determinations. That biological opinion and its administrative record are incorporated in full by this reference for the analyses of this supplemental biological opinion.

In Section 2, NOAA reviewed the new pertinent scientific information available since reaching its 2008 determinations. In Section 3, NOAA amended the AMIP to include six additional actions in light of that new information. NOAA then integrated the AMIP as amended into the 2008 RPA as a new RPA Action 1A and integrated the 2008 BiOp and the entire RPA, as amended, into this Supplemental BiOp.

In this Section, NOAA Fisheries reconsiders its 2008 determinations based on the entire RPA, as amended, using the best scientific and commercial data currently available. For each affected listed species and designated critical habitat, the Service reaches new determinations pursuant to ESA § 7(a)(2) and the consultation regulations at 50 C.F.R. Part 402.

4.1 Interior Columbia River Basin Salmon and Steelhead Conclusions

In reaching determinations for Columbia River salmon and steelhead, NOAA Fisheries first considers new information that has become available since issuance of the 2008 BiOp. Sections 4.1.1 through 4.1.3 summarize the key findings of Section 2, reviewing the three most relevant areas of new information (updated adult returns, new climate information, and new information regarding cormorant predation). Section 4.1.4 reviews the AMIP, which is expected to reduce the overall risk of unforeseen, rapid significant declines to the species posed by the uncertainty of climate change. Additionally, the AMIP's accelerated RM&E program will aid in assessing the effectiveness of RPA actions on species survival and recovery and will also help to better target and prioritize actions for maximum effectiveness. Based on the review of new information, NOAA Fisheries proposed, with Action Agency concurrence, new amendments to the AMIP to further reduce uncertainty associated with climate change and other factors. These amendments are reviewed in Section 4.1.5. Section 4.1.6 considers factors related to critical habitat. New details relevant to the Incidental Take Statement are reviewed in the context of the 2008 BiOp's effects analysis in Section 4.1.7. In Section 4.1.8, NOAA Fisheries considers all of this information, as well as all of the information in the 2008 BiOp, and concludes that the combination of all new information is within the range of expectations from the 2008 BiOp and therefore the 2008 BiOp conclusions are confirmed to comply with ESA § 7(a)(2) and the consultation regulations at 50 C.F.R. Part 402.

As described in Section 2, the main sources of new information that are relevant to the 2008 BiOp are:

- New adult return data
- New information on biological effects of climate change
- New information on cormorant predation
- Information regarding six new actions to reduce uncertainty associated implementation of the RPA, including four that are related to climate change

Other information reviewed in Section 2 (mainstem conditions, tributary habitat restoration, estuary and plume, predation by other species and other ecological interactions, chemical contaminants, introduced species, hatchery programs and ecological interactions, harvest rates, and research, monitoring, and evaluation) was clearly within the expectations of the 2008 BiOp, so these reviews are not re-stated in this section. A summary of the other new information follows.

4.1.1 New Adult Return Data

As described in Section 2.1.1.1.2, in 2009 NOAA Fisheries' Northwest Fisheries Science Center (NWFSC) analyzed recent trends in abundance for listed salmonid species in the Columbia River basin. This review was done pursuant to the requirements of the Government Performance and Results Act (GPRA). These estimates were based on population-level spawner abundance data for most interior Columbia River Basin populations, but where this information was not available, dam counts were applied. The population-level results were combined in a manner that yielded results for the entire species. In its analysis, the NWFSC concluded that abundance trends were stable or increasing over the most recent ten years for all but one of the listed salmonid species in the Columbia and Willamette River basins. The exception was Snake River sockeye salmon, which was considered "mixed" in spite of recent abundance increases, in part because of the degree of artificial propagation necessary to maintain the species. An analysis of aggregate population estimates for each species based on dam counts reached similar conclusions (Section 2.1.1.1.1).

While not directly informing the 2008 BiOp's quantitative estimates, the new information in Sections 2.1.1.1.1 and 2.1.1.1.2 is important because it shows that at the aggregate population level, species have been stable or increasing over the last decade rather than declining. This suggests that the actions in the RPA, which are expected to improve survival in various life-history stages, should continue to improve the species' status such that they will generally trend upwards when the RPA is implemented, as anticipated in the 2008 BiOp.[1]

Section 2.1.1.1.3 describes two to five new years of adult return data for a subset of populations in the Interior Columbia River basin. As described in Section 2.1.1.2.1, these data indicate higher 10-year average abundance for all but one population, compared to estimates in the 2008 FCRPS BiOp, and stable or increasing base period abundance trends for most populations. Other metrics, including base period natural productivity expressed as R/S and lambda (HF=1), declined for most populations with addition of the new adult return data. Base period extinction risk estimates generally decreased or remained unchanged for two species, but generally increased for three species.

When viewed in terms of potential impacts on the 2008 BiOp's prospective estimates (i.e., estimates that assess how base period information likely will change under current management actions and expected effects of the RPA), a few populations with trends greater than 1.0 or extinction risk less than 5% in the 2008 BiOp would be likely to shift to trends less than 1.0 or extinction risk greater than 5% when the new base period information is considered. Prospective estimates for the UCR spring Chinook ESU, the Middle Fork Salmon MPG of the SR spring/summer Chinook ESU, and the UCR steelhead DPS are those most affected by the new data.

The updated base period metrics resulting from addition of the new return data, while resulting in updated point estimates that differ from estimates in the 2008 BiOp for some populations, are all within the range of statistical variation reported in the 2008 BiOp and are consistent with the patterns of returns based on dam counts that were described in both the AMIP and the Action Agencies' 2008 Progress Report. Variations in annual abundance and productivity were anticipated in the 2008 BiOp – in particular, Chapter 7.1 described the expectation that productivity would decline as abundance increased based, in part, on density dependence. These variations are expected to continue in the future and to fluctuate both positively and negatively. For example, the dam counts and new population data described in this section indicate high adult returns in the early 2000s, lower returns in the mid-2000s, and an upturn in adult abundance beginning in 2008 for most species. Not reflected in the updated metrics, preliminary data from 2009 indicate above-average returns for some species and predictions based on ocean conditions and jack counts lead to an expectation of above-average adult returns for some species in 2010 and possibly 2011 (see Section 2.2.1.3.2.7). These anticipated higher returns represent progeny from the mid-2000 spawning years, which had lower abundance, so they will likely result in increasing productivity estimates for one or more brood cycles. This is because, if more naturally-spawning adults return than the adults that produced them, the R/S estimate will be

[1] This is subject to the cautions in the 2008 BiOp Section 7.1.1.2, which states that the estimates in the BiOp analysis represent the initial productivity that would be expected following an instantaneous survival rate change. That initial change in productivity would lead to greater abundance of spawners, which in turn would lead to density-dependent interactions that would reduce the productivity rate over time.

greater than 1.0. However, low river flows and waning El Niño conditions during spring 2010 (Section 2.2.1.3.1.6) are predicted to result in reduced survival of outmigrating juveniles during 2010, which could lead to a downturn in 2012 adult returns and productivity.

As described in Section 2.1.1.4, inferences about the effect of the new data on the BiOp's prospective estimates made in Chapter 2.1.1.2 do not account for factors other than the base period estimates have changed since completion of the BiOp. Other factors that are necessary component of the 2008 BiOp's estimates of base-to-current survival changes and survival changes associated with the RPA are discussed in the following subsections. The overall impact of the new adult return data on 2008 BiOp conclusions is then considered along with other factors in Section 4.1.8.

4.1.2 New Climate Change Information

As described in Section 2.2.1, new observations and predictions regarding physical effects of climate change are 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 provide additional details on effects previously considered more generally. In particular, several new studies document effects of higher temperatures that can modify adult migration timing and reduce 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. The new studies suggest that the adult life stage may need particular attention through monitoring and proactive actions such as those included as amendments in Section 3.

4.1.3 New Information Regarding Cormorant Predation

As described in Section 2.2.5.1, the increase in cormorant predation on steelhead and subyearling Chinook since the early part of the base period was not considered in the 2008 BiOp. This information would likely reduce estimates of "base-to-current" survival improvements included in the 2008 BiOp for SR, UCR, and MCR steelhead and for SR fall Chinook. Between 2001 and 2009, cormorant predation rates declined slightly for steelhead and yearling Chinook and increased for subyearling Chinook (especially those from the LCR Chinook salmon ESU).

4.1.4 New AMIP Information, Actions and Contingent Actions

As described in the AMIP, several RPA mitigation actions and RM&E activities have been accelerated and enhanced. The AMIP established biological triggers that, if tripped, will activate a suite of short and long-term contingent 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. Additionally, the AMIP's accelerated RM&E program will aid in assessing the effectiveness of RPA actions on species survival and recovery and will also help to better target and prioritize actions for maximum effectiveness.

4.1.5 New Climate Change Actions

As described in (Section 3), and summarized below NOAA has amended the AMIP to include four new actions to further reduce uncertainties associated with climate change. These actions augment climate change monitoring and evaluation in the RPA and AMIP by improving monitoring and identification of potential problems associated with increasing river temperatures and other expected impacts of climate change. These actions will be added to the 2010-2013 Implementation Plan.

- During summer months, new studies have shown that adult salmon and steelhead seek and utilize cooler areas of the mainstem for significant periods of time as they migrate upriver to spawn. It is assumed that adults use these areas to rest and lessen the level of stress caused by higher water temperatures. As mainstem Columbia and Snake rivers temperatures may rise as a result of climate change, it is important to identify these thermal fish refugia and determine whether protective measures are necessary. Under Amendment 1 to the AMIP, the Corps will identify the use and location of adult salmon refugia in the lower Columbia and lower Snake rivers.

- Adult detectors at The Dalles and John Day dams could provide better adult survival estimates for each project reach. They could also provide refined information on the timing and distribution of adult migrants and allow a better assessment of how environmental factors such as temperature affect migration behavior and adult survival. The adult detectors, along with PIT tag detectors in tributaries or other areas, could be used to assess the survival of fish that enter potential cool-water refugia from those that do not. This information would aid future management decisions regarding the use and importance of cool-water refugia to listed species. Under Amendment 2 of the AMIP, the Corps will initiate a study at The Dalles and John Day dams to investigate whether PIT tag detection systems will improve adult survival estimates. If warranted (per the criteria in Amendment 2), the Action Agencies will install PIT tag detectors at one or both dams.

- To help track possible temperature effects of climate change, a comprehensive data system that compiles and summarizes Columbia Basin water temperatures would be very useful. Later this year, NOAA will initiate discussions with other parties to determine how to organize a regional temperature data system and how best to move toward that goal. After this system has been established, the entities collecting temperature data could provide information on a regular basis to give a comprehensive look at temperatures in the basin. Under Amendment 3 of the AMIP, the Action Agencies will provide NOAA with water temperature data from their monitoring sites on a regular basis once a regional temperature data system has been established.

- Changes in climate could impact salmon and steelhead habitat in ways that range from gravel scouring high flow events in winter to creating elevated summer temperatures in tributaries. It is important to consider potential climate change impacts on habitat limiting factors when selecting and implementing habitat projects to ensure their effectiveness in protecting listed species. An approach to apply new climate change information to help identify and prioritize habitat improvement projects is needed. Under Amendment 4 of the AMIP, the Action Agencies will incorporate new climate change findings into the tributary expert panel process to help identify and prioritize habitat improvement projects.

4.1.6 Primary Constituent Elements of Designated Critical Habitat

NOAA Fisheries' analysis of effects on designated critical habitat examines the functioning of primary constituent elements (PCE) of the habitat that are important to the listed salmonid species. The new information indicates the potential, as climate changes occur, for the functioning of PCEs in spawning and rearing areas, juvenile and adult migration corridors, and areas for growth and development to adulthood (i.e., the estuary) to change over time due to increased temperatures (water quality) and altered seasonal flows related to shifts in the timing of precipitation (water quantity). As described in the 2008 BiOp a number of actions in the mainstem migration corridor and in tributary and estuarine areas will proactively address the effects of climate change. Some of these improvements have already been implemented and others are scheduled for implementation over the term of the RPA (Appendices E and F).

NOAA Fisheries expects that reductions in Caspian tern nesting habitat and management of cormorant predation on East Sand Island, continued implementation of the Northern Pikeminnow Management Program with increased rewards in the sport-reward fishery, and continued implementation and improvement of avian deterrence at mainstem dams will improve the conservation value of critical habitat by increasing the survival of migrating juvenile salmonids within the migration corridor (safe passage PCE). The Action Agencies' Tribal Accords will improve water quality, water quantity, cover/shelter, food, riparian vegetation, space and safe passage/access in Interior basin tributaries used for spawning, incubation, and rearing by spring and summer Chinook salmon and steelhead.

These factors, when considered together and in the context of the original analysis in the 2008 BiOp, indicate no change from NOAA Fisheries' overall conclusions.

4.1.7 Effect of New Estimates of Incidental Take on the 2008 BiOp Effects Analysis

Evaluation of transport as a means of improving adult Snake River sockeye survival from Lower Granite Dam to Sawtooth Valley lakes (or artificial production facilities) is likely to substantially benefit this species. Current losses - especially for adult sockeye migrating in the Snake and Salmon Rivers in the late summer - are high. While some incidental mortalities (from capturing, handling, and transport) are expected (up to 5%) from implementing this action, overall it should result in a substantial net benefit to the productivity and abundance of the ESU as a whole.

Individual Snake River steelhead, spring/summer Chinook, and fall Chinook will be handled incidentally as a result of transport operations for adult sockeye at Lower Granite Dam. A relatively small proportion (hundreds of individuals) of these adult salmon and steelhead are likely to be affected. A few of these individuals could die (< 10 of each species annually) as a result of this handling; the effects on the remaining fish are likely to be minor (short-term stress and slightly delayed migration) and of short duration. Overall, this action should have no measurable long-term effect on the ESUs/DPSs for these species.

4.1.8 Consideration of All New Information

The new information represents a combination of some factors that are better than anticipated in the 2008 BiOp and some that are more negative. The purpose of this section is to determine if, on balance, the new information falls within the expectations of the 2008 BiOp when coupled with all of the factors that remain unchanged in the 2008 BiOp's analysis, and the 2008 RPA, as amended, continues to comply with ESA Section 7(a)(2). Factors that indicate improvements from the description in the 2008 BiOp include:

- Increased 10-year average abundance of all populations for which new data are available (Section 2.1.1.2.1)
- Stable or increasing abundance trends for all interior Columbia Basin species except SR sockeye salmon, which are "mixed," per the NOAA Fisheries report to Congress. Species-level aggregate dam counts also indicate that interior Columbia Basin species have been stable or increasing in recent years (Sections 2.1.1.1.1, 2.1.1.1.2)
- Increasing abundance trends for most individual populations for which new data are available (Section 2.1.1.2.5)
- New implementation actions that help to reduce uncertainties associated with climate change (Section 3)

New information that indicates factors that are more negative than anticipated in the 2008 BiOp are:

- Reduced average natural productivity and increased extinction risk during the base period, which may reduce prospective estimates of average natural productivity and increase prospective estimates of extinction risk for some populations of UCR Chinook, UCR steelhead, and SR spring/summer Chinook (Sections 2.1.1.2.2, 2.1.1.2.3 and 2.1.1.2.4)
- Reduced survival of SR, UCR, and MCR steelhead and SR fall Chinook due to cormorant predation during the base-to-current period, although predation rates appear to have fallen slightly in recent years for yearling Chinook and steelhead. (Section 2.2.5.1.1)

These factors, when considered together and in the context of the original analyses in the 2008 BiOp do not represent a significant deviation from the conditions analyzed and anticipated in the 2008 BiOp. The 2008 BiOp anticipated annual variations in performance as evidenced by large confidence intervals around estimates. The updated metrics are within the 2008 BiOp's confidence limits and the new scientific information is consistent with the information considered in the 2008 BiOp.

With respect to the new status information, NOAA Fisheries notes that 10-year average abundance has increased overall since the 2008 BiOp's analysis. Trends in abundance are stable or increasing over the last ten years for all listed salmonid species in the Columbia River basin. The recent downturn in natural productivity, if it continued over many years, would be a cause for concern, since it would eventually lead to declines in abundance. However, annual variations in productivity are to be expected, based on the historical record. The reduction in productivity for the high-abundance brood years from the early 2000s is also consistent with the expectations of stock recruitment, in which productivity generally declines following years of higher abundance, in part due to density dependence (2008 BiOp Chapter 7.1). That is, stock-recruit functions predict interference or competition for resources at high abundance, which reduces the number of recruits produced per spawner, compared to the productivity at low abundance and density. Similarly, the extinction risk estimated must be viewed in the context of the analytical assumptions. The extinction risk estimates for UCR steelhead and UCR spring Chinook assume that all hatchery production ceases immediately. This overstates the actual short-term extinction risk, as shown by modeling of continued hatchery supplementation in the 2008 BiOp (chapters 7.1, 8.6, 8.7 and the 2008 SCA Appendix B). Additionally, analysis of a quasi-extinction threshold of 50 fish may overstate the extinction risk of some smaller populations, such as some in the Middle Fork Salmon as described in chapter 7.1.1.1 of the 2008 BiOp.

Even considering the potential changes in prospective extinction risk and natural productivity at face value, they would have little influence on the 2008 BiOp's jeopardy analysis for SR spring/summer Chinook and UCR steelhead as described in Section 2.1.1.4. For UCR Chinook, NOAA Fisheries and the Action Agencies will continue to monitor population performance closely with respect to AMIP triggers and ensure that all RPA and Accord actions are implemented as planned. As described in Section 2.2.3.2, the combination of the 2008 BiOp habitat actions and the Columbia Basin Fish Accords adds to NOAA Fisheries' confidence that habitat improvements over the term of the BiOp will meet or exceed expectations for these UCR Chinook populations.

While these variations are within the ranges anticipated in the 2008 BiOp, the AMIP responds to the advice of independent scientists who were concerned about the levels of uncertainty inherent in any analysis of future salmonid population trends. Accordingly, the AMIP established biological triggers that represent significant and unexpected deviations from the expectations of the BiOp. The AMIP requires the development of detailed short- and long-term contingency plans that would be implemented in the event any of these triggers are tripped. The Action

Agencies and NOAA are on track to complete the development of these plans as called for in the AMIP.

Evaluation of transport as a means of improving adult Snake River sockeye survival from Lower Granite Dam to Sawtooth Valley lakes (or artificial production facilities) is likely to substantially benefit this species. Individual Snake River steelhead, spring/summer Chinook, and fall Chinook will be handled incidentally as a result of transport operations for adult sockeye at Lower Granite Dam. Overall, this action should have no measurable long-term adverse effect on the ESUs/DPSs for these species.

Climate change is a particular concern raised by many of the independent scientific reviewers and commenters on the 2008 BiOp and AMIP. After a thorough review of new climate science, NOAA Fisheries concludes that the physical effects of climate change are likely to be within the range of effects considered in the 2008 BiOp. However, new information suggests that seasonally elevated temperatures in the mainstem Columbia and Snake Rivers may be having an increased effect on adult survival and spawning success. A number of the new actions proposed in this document are intended to respond to this information. In addition, the 2008 BiOp's adult survival standards provide assurance that this phenomenon will be adequately monitored and mitigated, if necessary.

The 2008 BiOp set a schedule for re-analyzing and re-evaluating implementation progress and species status, including an assessment of whether the 2008 BiOp's biological expectations are likely to be realized. The first check-in is scheduled for 2013. This date was chosen in order to allow some of the 2008 BiOp's RPA actions to be reflected in updated data expected to be available at that time. For the 2013 check-in, recent data for more populations will be available, as well as the results of NMFS' Five Year Status Reviews. Currently, preliminary information from only a subset of populations is available. Also, because salmonid survival is so variable, it is more appropriate to rely on population performance over a 5-year period than a 3-year period.

In summary, NOAA Fisheries continues to find that the RPA, as amended through this remand, 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 or destroy or adversely modify their designated critical habitat.

4.2 Conclusions for Lower Columbia Basin Salmon and Steelhead

The following new information applies to the analysis of effects for the lower Columbia River species:

4.2.1 New Climate Change Information

New observations and predictions regarding physical effects of climate change are 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 provide additional details on effects previously considered and suggest that adult migration conditions in the mainstem lower Columbia may need particular attention through monitoring and proactive actions. A number of new actions proposed in this document are intended to respond to this information.

4.2.2 New Information Regarding Cormorant Predation

Between 2001 and 2009, cormorant predation rates declined slightly for steelhead and yearling Chinook and increased for sub-yearling Chinook (especially those from the LCR Chinook ESU).

4.2.3 New Information Regarding Harvest Rates

Harvest rates are the same as those considered in the 2008 BiOp except for tule populations of the LCR fall Chinook ESU. Harvest rates for this species have decreased approximately 6% from those assumed in the Opinion (to 38%) and are expected to decrease another 1 to 2% during 2011 (Section 2.4.1).

4.2.4 Consideration of All New Information

The new information represents a combination of some factors that are better than anticipated in the 2008 BiOp and some that are more negative. Factors that indicate improvements from the descriptions in the 2008 BiOp include:

- New implementation actions that help to reduce uncertainties associated with climate change
- Slightly reduced rates of cormorant predation on yearling Chinook and steelhead in the estuary in recent years

New information that indicates factors related to the RPA actions that are more negative than anticipated in the 2008 BiOp are:

- Increased rates of cormorant predation on subyearling Chinook from the Lower Columbia River ESU in the estuary in recent years

In summary, these factors, when considered together and in the context of the original analyses in the 2008 BiOp do not represent a significant deviation from the conditions analyzed and anticipated.

4.2.5 Primary Constituent Elements of Designated Critical Habitat

The new information concerning climate change indicates the potential for the functioning of PCEs in spawning and rearing areas, juvenile and adult migration corridors, and areas for growth and development to adulthood (i.e., the estuary) to change over time due to increased temperatures (water quality) and altered seasonal flows related to shifts in the timing of precipitation (water quantity). However, after a thorough review of new climate science, NOAA concludes that the physical effects are likely to be within the range considered in the 2008 BiOp, and actions in estuarine areas will proactively address the effects of climate change. NOAA Fisheries expects that ongoing reductions in Caspian tern nesting habitat and management of cormorant predation on East Sand Island will improve the conservation value of critical habitat by increasing the survival of migrating juvenile salmonids within the migration corridor (safe passage PCE).

These factors, when considered together and in the context of the original analyses in the 2008 BiOp, indicate no change from NOAA Fisheries' overall conclusions.

4.2.6 Conclusions for Lower Columbia Basin Salmon and Steelhead

NOAA Fisheries continues to find that the RPA, as amended through this remand, is not likely to jeopardize the continued existence of listed CR chum, LCR Chinook, or UWR Chinook salmon or of LCR or UWR steelhead or destroy or adversely modify their designated critical habitat. The modified RPA is also not likely to jeopardize the continued existence of LCR coho salmon (critical habitat has not yet been designated for this species).

4.3 Conclusions for Southern Resident Killer Whale DPS

The new science 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 FCRPS RPA more than offsets losses to the killer whale prey base. There is no new science 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 the method to evaluate effects to the prey base of 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 FCRPS 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 Agency determination that the FCRPS RPA may affect, but is not likely to adversely affect this listed DPS of killer whales.

4. 4 Conclusions for Southern Resident DPS of North American Green Sturgeon

Based on recently published tagging and genetic studies, the size of the spawning population in the Sacramento River could be smaller than NOAA assumed in its 2008 analysis. The issues of concern in the Columbia River pertain to prey availability and habitat use below Bonneville Dam by subadults and non-spawning adults, which are thought to use this habitat for foraging, not spawning.

The new scientific information reviewed for this remand indicates that some of the information used in the 2008 analysis has changed but the overall conclusions remain valid (Section 2.7.2). There is no evidence that changes in the spring hydrograph and/or in sediment delivery to the estuary (both effects of the hydrosystem) are adversely affecting the biological requirements of this species. NOAA Fisheries finds that the new scientific information does not change its determination regarding the nature and significance of effects of the RPA actions on the listed green sturgeon. Therefore, NOAA Fisheries concludes that the RPA may affect, but is not likely to adversely affect green sturgeon.

Section 5 Supplemental Incidental Take Statement

5.1 Introduction

This section supplements the Incidental Take Statement (ITS) of the 2008 BiOp (Section 14.2.6 - Amount of Incidental Take from RM&E Actions). It documents NOAA Fisheries' conclusion that additional take of ESA-listed adult salmon and steelhead is necessary for research to assess transport of adult sockeye salmon as a method of increasing late summer survival from Lower Granite Dam to Sawtooth Valley lakes (or artificial production facilities). Estimates of take provided in this section are in addition to those already specified in the 2008 BiOp (Section 14.2) and the reasonable and prudent measures (and related terms and conditions) to reduce take associated with these activities, as specified here, are also in addition to those already specified in the 2008 BiOp (Sections 14.4 and 14.5). As explained in Section 4, NOAA Fisheries concludes that the incidental taking of threatened or endangered species specified in the 2008 BiOp's ITS as supplemented here will not violate ESA Section 7(a)(2).

5.2 Capture and Transport of Adult Sockeye

5.2.1 Amount or Extent of Anticipated Take

Implementation of RPA 42 is intended to evaluate the benefits of transporting up to half of adult listed Snake River sockeye salmon arriving at Lower Granite Dam. Incidental take will occur for the capture and handling of these adults that is necessary to implement this RPA action. Mortalities associated with this measure will result in losses of no more than 5% of the number of adults captured (or one fish – whichever is greater).[1] Adult listed Chinook salmon and steelhead will also likely be handled incidentally to the capture of sockeye for transport. However, effects (minor handling and delayed passage) on these species, considering that only a small proportion of spring-summer Chinook and steelhead pass Lower Granite Dam in July when the majority of sockeye are passing, should be minimal. Mortalities for these non-targeted species, collectively, shall not exceed 10 individuals per species as a result of this action.

5.2.2 Reasonable and Prudent Measures

The FCRPS Action Agencies (or their designated contractors conducting research) shall conduct research and handle fish at the adult trapping facilities in accordance with existing NOAA Fisheries-approved protocols (use of anesthetics, handling criteria, trap operation criteria,

[1] Losses of sockeye salmon between Lower Granite Dam and the Sawtooth Valley lakes can be high (in the general range of 25 to 50%) in the mid- to late-summer; most likely due to the relatively high temperatures in the snake and Salmon rivers. If effective, adult transport (to Sawtooth Valley Lakes or artificial production facilities) could substantially improve adult survival rates.

temperature criteria, etc.) to ensure that lethal take resulting from the handling of adults salmon and steelhead is minimized to the extent practicable.

5.2.3 Terms and Conditions

No additional terms and conditions are needed beyond those prescribed in the 2008 BiOp, Sections 14.5.3.

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Appendix A

Excerpts From: Endangered Species Act Federal Columbia River Power System 2008 Progress Report. (U.S. Army Corps of Engineers et al. 2009)

The following figures are from the 2008 Progress Report. These are based primarily on dam counts and represent the aggregate of most or all populations within each ESU or DPS.

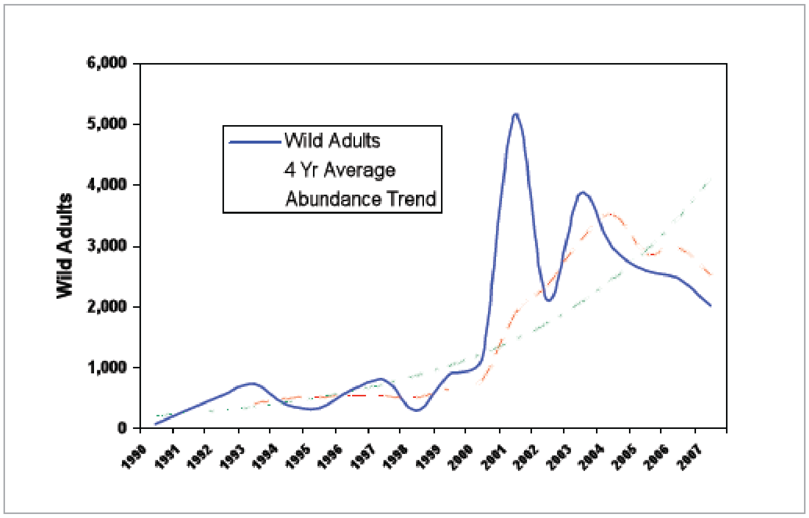

Figure 19. Returns of Naturally Produced Adult Snake River Fall Chinook Salmon.[9]

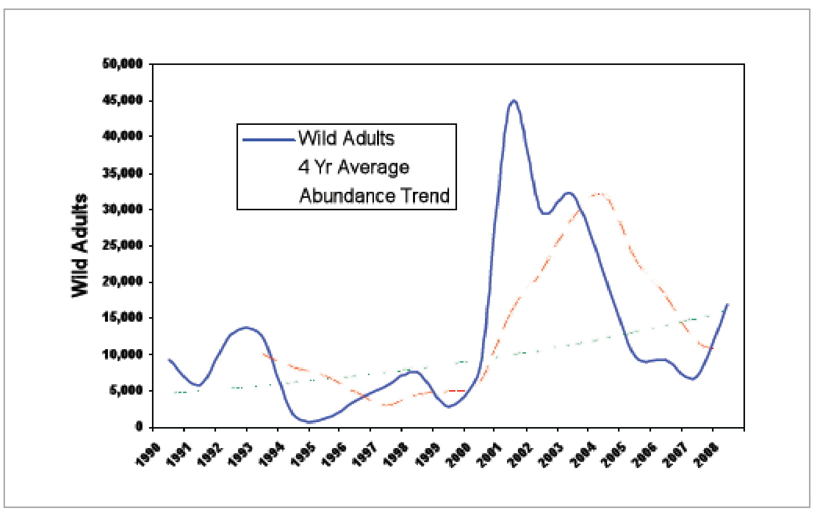

Figure 20. Returns of Naturally Produced Adult Snake River Spring/Summer Chinook Salmon.

[9] *Abundance charts in this report show ESU-level abundance from 1990 until the most recent available observation, consistent with the 2008 BiOp's "short-term" trend estimation period. Estimates are of naturally produced adult returns provided by NOAA Fisheries for all ESUs except Middle Columbia River steelhead.*

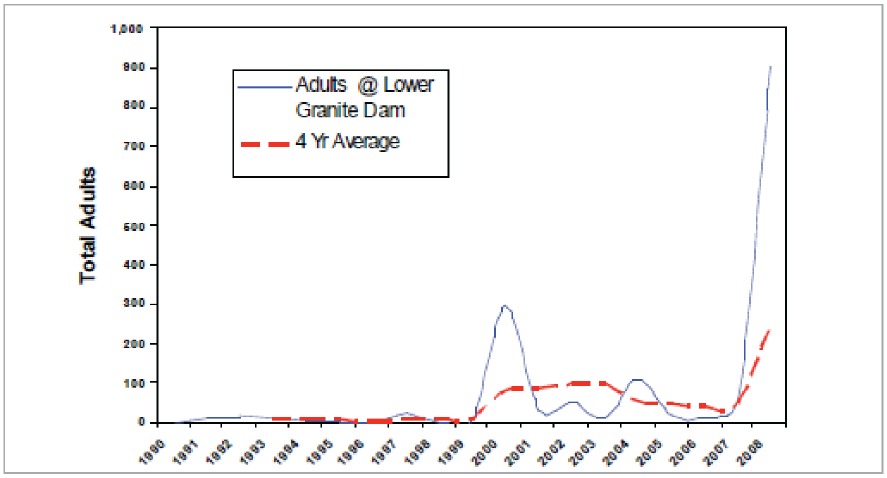

Figure 21. Returns of All Snake River Sockeye Salmon.

Data from Columbia River DART (Data Access in Real Time): http://www.cbr.washington.edu/ dart/Snake River Steelhead DPS. Snake River sockeye salmon survival benefited in 2008 from hydro, habitat, predator control, hatchery, and harvest actions.

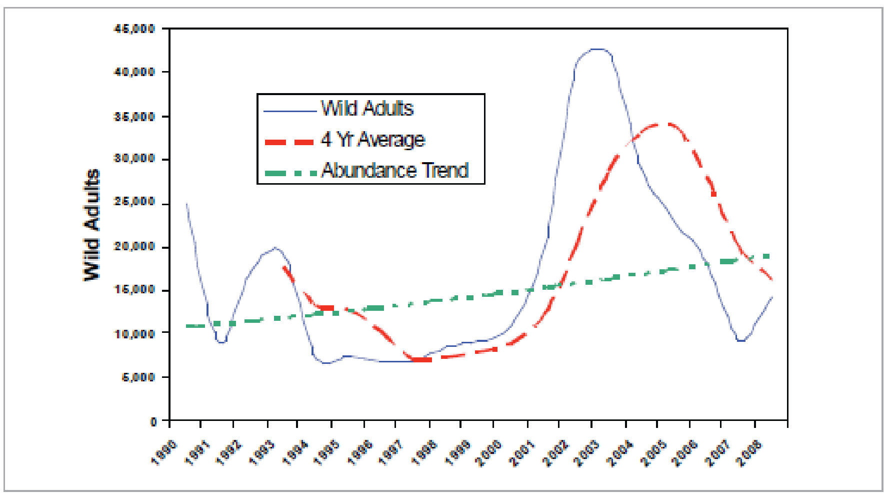

Figure 22. Returns of Naturally Produced Adult Snake River Steelhead.

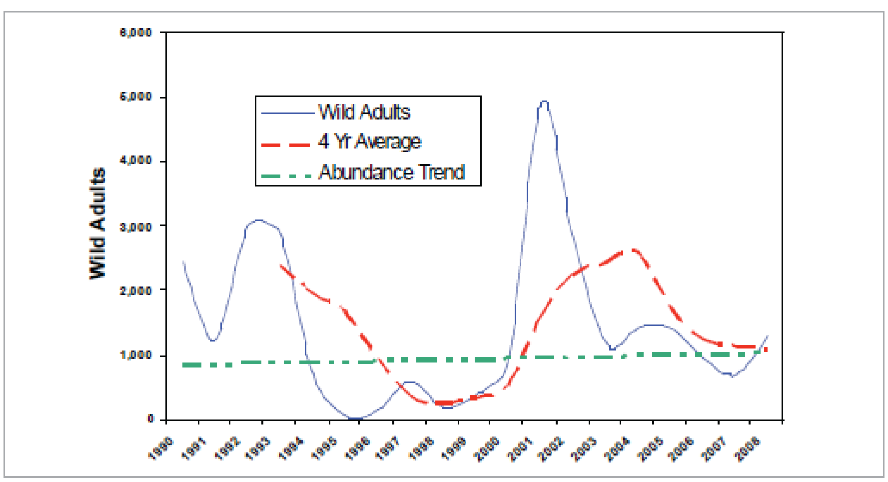

Figure 23. Returns of Naturally Produced Adult Upper Columbia River Spring Chinook Salmon.

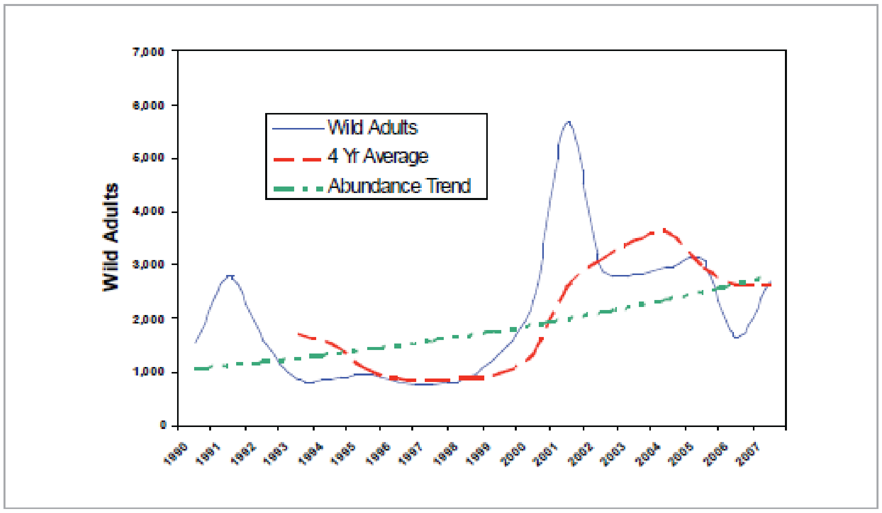

Figure 24. Returns of Naturally Produced Adult Upper Columbia River Steelhead.

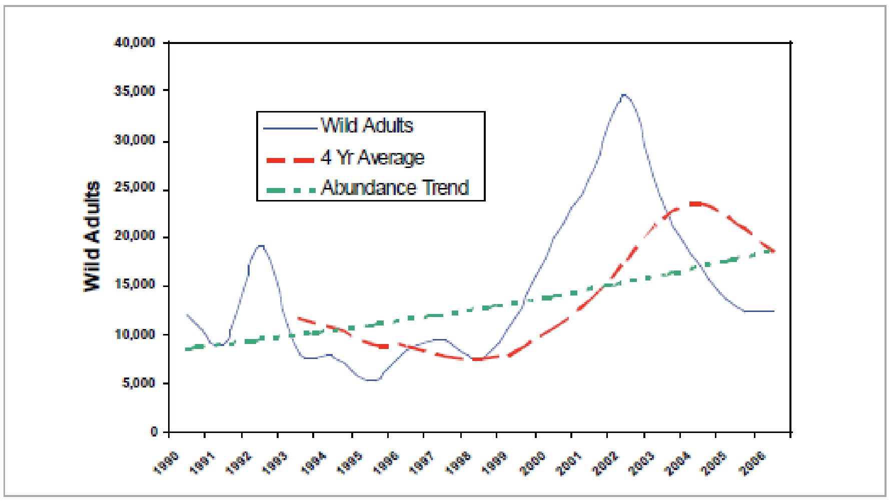

Figure 25. Returns of Naturally Produced Adult Middle Columbia River Steelhead (DPS Composite). [11]

[11] *The DPS estimate is based on a composite of multiple data sources compiled by Fisher Fisheries.*

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Appendix B

Hinrichsen (2010) Extinction Risk Analysis - Detailed Results

B.1 Steelhead Results

Table. (**OLD RESULTS**) Confidence limits on extinction probabilities (Prob) for steelhead (updated with "**Sthd datasets 1_22_08 for dist.xls**") . The lower confidence bound represents the 0.025 quantile of the 1000 extinction probability replications, while the upper limit represents the 0.975 quantile of the the 1000 extinction probability replications. Extinction probabilities were calculated over a time window of **24 years** with various levels of quasi-extinction threshold (QET) and reproductive failure threshold (RFT). Note that less that 1000 replications were actually generated for each of the populations because some bootstrap samples resulted in invalid maximum likelihood estimates of the Ricker model. The column "ngood" represents the number of valid replicates of the parameter estimates. "nbadb" represents the number of replicates with b less than zero, and "nbadalpha" represents the number of replicates with alpha greater than 1.0. Whenever a replication of alpha was greater than one, it was set equal to one. Extinction probabilities were based on 4000 population trajectories. The time period used was 1978-present ("present" at the time of the biological opinion). The population projections were initialized with the most recent six spawner observations.

Population	Prob	Lower95	Upper95	QET	RFT	nbadb	nbadalpha	ngood
Upper Columbia Steelhead -- Wenatchee Riv	0.01	0.00	0.38	1	2	0	23	996
Upper Columbia Steelhead -- Wenatchee Riv	0.06	0.00	0.59	10	10	0	23	996
Upper Columbia Steelhead -- Wenatchee Riv	0.19	0.00	0.84	30	10	0	23	996
Upper Columbia Steelhead -- Wenatchee Riv	0.27	0.00	0.92	50	10	0	23	996
Upper Columbia Steelhead -- Entiat River	0.53	0.00	0.67	1	2	0	263	988
Upper Columbia Steelhead -- Entiat River	0.80	0.00	0.95	10	10	0	263	988
Upper Columbia Steelhead -- Entiat River	0.95	0.01	1.00	30	10	0	263	988
Upper Columbia Steelhead -- Entiat River	0.99	0.10	1.00	50	10	0	263	988
Upper Columbia Steelhead -- Methow River	0.00	0.00	0.82	1	2	0	36	996
Upper Columbia Steelhead -- Methow River	0.07	0.00	0.99	10	10	0	36	996
Upper Columbia Steelhead -- Methow River	0.28	0.00	1.00	30	10	0	36	996
Upper Columbia Steelhead -- Methow River	0.47	0.02	1.00	50	10	0	36	996
Upper Columbia Steelhead -- Okanogan Rive	0.93	0.18	1.00	1	2	0	50	990
Upper Columbia Steelhead -- Okanogan Rive	1.00	0.56	1.00	10	10	0	50	990
Upper Columbia Steelhead -- Okanogan Rive	1.00	0.71	1.00	30	10	0	50	990
Upper Columbia Steelhead -- Okanogan Rive	1.00	0.77	1.00	50	10	0	50	990
Satus Creek Steelhead	0.00	0.00	0.04	1	2	0	40	978
Satus Creek Steelhead	0.00	0.00	0.13	10	10	0	40	978
Satus Creek Steelhead	0.00	0.00	0.22	30	10	0	40	978
Satus Creek Steelhead	0.00	0.00	0.30	50	10	0	40	978
Toppenish Creek Steelhead	0.48	0.00	0.58	1	2	1	611	778
Toppenish Creek Steelhead	0.61	0.00	0.73	10	10	1	611	778
Toppenish Creek Steelhead	0.73	0.00	0.92	30	10	1	611	778
Toppenish Creek Steelhead	0.79	0.00	0.97	50	10	1	611	778
Naches River Steelhead	0.06	0.00	0.58	1	2	1	200	933
Naches River Steelhead	0.18	0.00	0.77	10	10	1	200	933
Naches River Steelhead	0.27	0.00	0.83	30	10	1	200	933
Naches River Steelhead	0.34	0.00	0.87	50	10	1	200	933
Upper Yakima River Steelhead	0.37	0.00	1.00	1	2	1	612	837
Upper Yakima River Steelhead	0.50	0.00	1.00	10	10	1	612	837
Upper Yakima River Steelhead	0.60	0.00	1.00	30	10	1	612	837
Upper Yakima River Steelhead	0.68	0.08	1.00	50	10	1	612	837

Table. (**UPDATED BASE PERIOD**) Confidence limits on extinction probabilities (Prob) for steelhead (updated w ith ""**Prelim Sthd_release format_021610.xlsx**") . The low er confidence bound represents the 0.025 quantile of the 1000 extinction probability replications, w hile the upper limit represents the 0.975 quantile of the the 1000 extinction probability replications. Extinction probabilities w ere calculated over a time w indow of **24 years** w ith various levels of quasi-extinction threshold (QET) and reproductive failure threshold (RFT). Note that less that 1000 replications w ere actually generated for each of the populations because some bootstrap samples resulted in invalid maximum likelihood estimates of the Ricker model. The column "ngood" represents the number of valid replicates of the parameter estimates. "nbadb" represents the number of replicates w ith b less than zero, and "nbadalpha" represents the number of replicates w ith alpha greater than 1.0. Whenever a replication of alpha w as greater than one, it w as set equal to one. Extinction probabilities w ere based on 4000 population trajectories. **The time period used was the base period employed in the Biological Opinion**. The population projections w ere initialized w ith the most recent six spaw ner observations.

Population	Prob	Low er95	Upper95	QET	RFT	nbadb	nbadalpha	ngood
Upper Columbia Steelhead -- Wenatchee River	0.00	0	0.36	1	2	0	37	986
Upper Columbia Steelhead -- Wenatchee River	0.06	0	0.56	10	10	0	37	986
Upper Columbia Steelhead -- Wenatchee River	0.18	0	0.79	30	10	0	37	986
Upper Columbia Steelhead -- Wenatchee River	0.28	0	0.89	50	10	0	37	986
Upper Columbia Steelhead -- Entiat River	0.02	0	0.72	1	2	1	70	989
Upper Columbia Steelhead -- Entiat River	0.38	0.03	0.99	10	10	1	70	989
Upper Columbia Steelhead -- Entiat River	0.77	0.19	1	30	10	1	70	989
Upper Columbia Steelhead -- Entiat River	0.92	0.37	1	50	10	1	70	989
Upper Columbia Steelhead -- Methow River	0.01	0	0.82	1	2	9	14	988
Upper Columbia Steelhead -- Methow River	0.39	0	1	10	10	9	14	988
Upper Columbia Steelhead -- Methow River	0.77	0.08	1	30	10	9	14	988
Upper Columbia Steelhead -- Methow River	0.90	0.21	1	50	10	9	14	988
Upper Columbia Steelhead -- Okanogan River	0.99	0.37	1	1	2	0	21	994
Upper Columbia Steelhead -- Okanogan River	1.00	0.76	1	10	10	0	21	994
Upper Columbia Steelhead -- Okanogan River	1.00	0.89	1	30	10	0	21	994
Upper Columbia Steelhead -- Okanogan River	1.00	0.92	1	50	10	0	21	994
Satus Creek Steelhead	0.00	0	0.04	1	2	0	36	974
Satus Creek Steelhead	0.00	0	0.17	10	10	0	36	974
Satus Creek Steelhead	0.00	0	0.27	30	10	0	36	974
Satus Creek Steelhead	0.00	0	0.36	50	10	0	36	974
Toppenish Creek Steelhead	0.48	0	0.58	1	2	3	581	764
Toppenish Creek Steelhead	0.61	0	0.79	10	10	3	581	764
Toppenish Creek Steelhead	0.70	0	0.96	30	10	3	581	764
Toppenish Creek Steelhead	0.78	0	0.99	50	10	3	581	764
Naches River Steelhead	0.06	0	0.46	1	2	0	240	956
Naches River Steelhead	0.18	0	0.7	10	10	0	240	956
Naches River Steelhead	0.29	0	0.8	30	10	0	240	956
Naches River Steelhead	0.34	0	0.86	50	10	0	240	956
Upper Yakima River Steelhead	0.38	0	1	1	2	3	621	836
Upper Yakima River Steelhead	0.49	0	1	10	10	3	621	836
Upper Yakima River Steelhead	0.61	0	1	30	10	3	621	836
Upper Yakima River Steelhead	0.68	0.06	1	50	10	3	621	836

B.2 Spring/Summer Chinook Results

Table. (**OLD RESULTS**) Confidence limits on extinction probabilities (Prob) (updated w ith "Chinook datasets 11_14_07 for dist.xls"). The low er confidence bound represents the 0.025 quantile of the 1000 extinction probability replications, w hile the upper limit represents the 0.975 quantile of the the 1000 extinction probability replications. Extinction probabilities w ere calculated over a time w indow of **24 years** w ith various levels of quasi-extinction threshold (QET) and reproductive failure threshold (RFT). Note that less that 1000 replications w ere actually generated for each of the populations because some bootstrap samples resulted in invalid maximum likelihood estimates of the Beverton-Holt model. The column "ngood" represents the number of valid replicates of the parameter estimates. "nbadb" represents the number of replicates w ith b less than zero, and "nbadalpha" represents the number of replicates w ith alpha greater than 1.0. Whenever a replication of alpha w as greater than one, it w as set equal to one. Extinction probabilities w ere based on 4000 population trajectories. The time period used w as 1978-present ("present" at the time of the Biological Opinion). The population projections w ere initialized w ith the most recent five years of spaw ner observations. Spaw ner numbers do not include jacks.

Population	Prob	Low er95	Upper95	QET	RFT	nbadb	nbadalpha	ngood
Tucannon Spring Chinook	0.00	0.00	0.13	1	2	9	33	905
Tucannon Spring Chinook	0.00	0.00	0.30	10	10	9	33	905
Tucannon Spring Chinook	0.02	0.00	0.55	30	10	9	33	905
Tucannon Spring Chinook	0.07	0.00	0.71	50	10	9	33	905
Secesh River Chinook	0.00	0.00	0.17	1	2	195	40	776
Secesh River Chinook	0.00	0.00	0.26	10	10	195	40	776
Secesh River Chinook	0.01	0.00	0.35	30	10	195	40	776
Secesh River Chinook	0.02	0.00	0.42	50	10	195	40	776
South Fork Salmon East Fork (inc Johnson Cr.)	0.00	0.00	0.02	1	2	353	15	623
South Fork Salmon East Fork (inc Johnson Cr.)	0.00	0.00	0.14	10	10	353	15	623
South Fork Salmon East Fork (inc Johnson Cr.)	0.01	0.00	0.33	30	10	353	15	623
South Fork Salmon East Fork (inc Johnson Cr.)	0.04	0.00	0.48	50	10	353	15	623
Big Creek Chinook	0.00	0.00	0.60	1	2	22	36	868
Big Creek Chinook	0.04	0.00	0.80	10	10	22	36	868
Big Creek Chinook	0.20	0.00	0.89	30	10	22	36	868
Big Creek Chinook	0.37	0.00	0.93	50	10	22	36	868
Sulphur Creek	0.00	0.00	0.65	1	2	8	43	797
Sulphur Creek	0.03	0.00	0.79	10	10	8	43	797
Sulphur Creek	0.27	0.00	0.88	30	10	8	43	797
Sulphur Creek	0.50	0.00	0.92	50	10	8	43	797
Bear Valley Creek	0.00	0.00	0.40	1	2	1	53	982
Bear Valley Creek	0.00	0.00	0.53	10	10	1	53	982
Bear Valley Creek	0.03	0.00	0.63	30	10	1	53	982
Bear Valley Creek	0.09	0.00	0.71	50	10	1	53	982
Marsh Creek Chinook	0.03	0.00	0.64	1	2	92	33	814
Marsh Creek Chinook	0.21	0.00	0.82	10	10	92	33	814
Marsh Creek Chinook	0.43	0.00	0.92	30	10	92	33	814
Marsh Creek Chinook	0.56	0.00	0.95	50	10	92	33	814
Low er Mainstem Salmon River (SRLMA)	0.00	0.00	0.41	1	2	1	116	865
Low er Mainstem Salmon River (SRLMA)	0.00	0.00	0.80	10	10	1	116	865
Low er Mainstem Salmon River (SRLMA)	0.13	0.00	0.97	30	10	1	116	865
Low er Mainstem Salmon River (SRLMA)	0.37	0.00	0.99	50	10	1	116	865
Valley Creek Chinook	0.00	0.00	0.32	1	2	1	58	720
Valley Creek Chinook	0.12	0.00	0.76	10	10	1	58	720
Valley Creek Chinook	0.50	0.01	0.96	30	10	1	58	720
Valley Creek Chinook	0.75	0.07	0.99	50	10	1	58	720
Wenatchee River Chinook	0.00	0.00	0.42	1	2	7	191	919
Wenatchee River Chinook	0.00	0.00	0.64	10	10	7	191	919
Wenatchee River Chinook	0.01	0.00	0.78	30	10	7	191	919
Wenatchee River Chinook	0.02	0.00	0.82	50	10	7	191	919
Entiat River Chinook	0.00	0.00	0.18	1	2	11	35	942
Entiat River Chinook	0.01	0.00	0.42	10	10	11	35	942
Entiat River Chinook	0.07	0.00	0.69	30	10	11	35	942
Entiat River Chinook	0.19	0.00	0.82	50	10	11	35	942

Table. (**Updated base period results**) Confidence limits on extinction probabilities (Prob) (updated with "**Prelim Chinook_release format_021210.xlsx**"). The lower confidence bound represents the 0.025 quantile of the 1000 extinction probability replications, while the upper limit represents the 0.975 quantile of the the 1000 extinction probability replications. Extinction probabilities were calculated over a time window of **24 years** with various levels of quasi-extinction threshold (QET) and reproductive failure threshold (RFT). Note that less that 1000 replications were actually generated for each of the populations because some bootstrap samples resulted in invalid maximum likelihood estimates of the Beverton-Holt model. The column "ngood" represents the number of valid replicates of the parameter estimates. "nbadb" represents the number of replicates with b less than zero, and "nbadalpha" represents the number of replicates with alpha greater than 1.0. Whenever a replication of alpha was greater than one, it was set equal to one. Extinction probabilities were based on 4000 population trajectories. **The time period used was the base period employed in the Biological Opinion.** The population projections were initialized with the most recent five years of spawner observations. Spawner numbers do not include jacks.

Population	Prob	Lower95	Upper95	QET	RFT	nbadb	nbadalpha	ngood
Tucannon Spring Chinook	0.00	0.00	0.11	1	2	7	36	904
Tucannon Spring Chinook	0.00	0.00	0.28	10	10	7	36	904
Tucannon Spring Chinook	0.02	0.00	0.53	30	10	7	36	904
Tucannon Spring Chinook	0.07	0.00	0.71	50	10	7	36	904
Secesh River Chinook	0.00	0.00	0.22	1	2	204	44	774
Secesh River Chinook	0.00	0.00	0.34	10	10	204	44	774
Secesh River Chinook	0.01	0.00	0.49	30	10	204	44	774
Secesh River Chinook	0.02	0.00	0.56	50	10	204	44	774
South Fork Salmon East Fork	0.00	0.00	0.17	1	2	372	21	621
South Fork Salmon East Fork	0.01	0.00	0.36	10	10	372	21	621
South Fork Salmon East Fork	0.03	0.00	0.48	30	10	372	21	621
South Fork Salmon East Fork	0.08	0.00	0.57	50	10	372	21	621
Big Creek Chinook	0.00	0.00	0.56	1	2	22	30	886
Big Creek Chinook	0.04	0.00	0.79	10	10	22	30	886
Big Creek Chinook	0.20	0.00	0.91	30	10	22	30	886
Big Creek Chinook	0.39	0.00	0.96	50	10	22	30	886
Sulphur Creek	0.00	0.00	0.58	1	2	8	40	708
Sulphur Creek	0.01	0.00	0.78	10	10	8	40	708
Sulphur Creek	0.26	0.00	0.89	30	10	8	40	708
Sulphur Creek	0.58	0.00	0.95	50	10	8	40	708
Bear Valley Creek	0.00	0.00	0.44	1	2	2	56	977
Bear Valley Creek	0.00	0.00	0.55	10	10	2	56	977
Bear Valley Creek	0.03	0.00	0.64	30	10	2	56	977
Bear Valley Creek	0.09	0.00	0.71	50	10	2	56	977
Marsh Creek Chinook	0.03	0.00	0.69	1	2	110	27	793
Marsh Creek Chinook	0.19	0.00	0.86	10	10	110	27	793
Marsh Creek Chinook	0.37	0.00	0.93	30	10	110	27	793
Marsh Creek Chinook	0.52	0.00	0.95	50	10	110	27	793
Lower Mainstem Salmon River	0.00	0.00	0.32	1	2	0	114	839
Lower Mainstem Salmon River	0.01	0.00	0.69	10	10	0	114	839
Lower Mainstem Salmon River	0.12	0.00	0.93	30	10	0	114	839
Lower Mainstem Salmon River	0.34	0.00	0.98	50	10	0	114	839
Valley Creek Chinook	0.00	0.00	0.30	1	2	0	52	720
Valley Creek Chinook	0.01	0.00	0.68	10	10	0	52	720
Valley Creek Chinook	0.36	0.01	0.93	30	10	0	52	720
Valley Creek Chinook	0.74	0.04	0.98	50	10	0	52	720
Wenatchee River Chinook	0.00	0.00	0.57	1	2	24	145	873
Wenatchee River Chinook	0.01	0.00	0.72	10	10	24	145	873
Wenatchee River Chinook	0.03	0.00	0.82	30	10	24	145	873
Wenatchee River Chinook	0.04	0.00	0.87	50	10	24	145	873
Entiat River Chinook	0.00	0.00	0.16	1	2	10	19	962
Entiat River Chinook	0.00	0.00	0.44	10	10	10	19	962
Entiat River Chinook	0.06	0.00	0.77	30	10	10	19	962
Entiat River Chinook	0.19	0.00	0.91	50	10	10	19	962

B.3 Fall Chinook Results

Table 3a. (**OLD RESULTS**) Snake River Fall chinook confidence limits on extinction probabilities (Prob) (updated with "**Chinook datasets 11_14_07 for dist.xls**"). The lower confidence bound represents the 0.025 quantile of the 1000 extinction probability replications, while the upper limit represents the 0.975 quantile of the the 1000 extinction probability replications. Extinction probabilities were calculated over a time window of **24 years** with various levels of quasi-extinction threshold (QET) and reproductive failure threshold (RFT). Note that less that 1000 replications were actually generated for each of the populations because some bootstrap samples resulted in invalid maximum likelihood estimates of the Ricker model. The column "ngood" represents the number of valid replicates of the parameter estimates. "nbadb" represents the number of replications with b less than zero, and "nbadalpha" represents the number of replications with alpha greater than 1.0. Whenever a replication of alpha was greater than one, it was set equal to one. Extinction probabilities were based on 4000 population trajectories. The time period used was 1978-present ("present" at the time of the Biological Opinion). The population projections were initialized with the most recent five years of spawner observations. Spawner numbers do not include jacks.

Population	Prob	Lower95	Upper95	QET	RFT	nbadb	nbadalpha	ngood
Snake River Fall Chinook	0	0	1	1	2	0	30	987
Snake River Fall Chinook	0	0	1	10	10	0	30	987
Snake River Fall Chinook	0	0	1	30	10	0	30	987
Snake River Fall Chinook	0.01	0	1	50	10	0	30	987

Table 3a. (**Updated base period**) Snake River Fall chinook confidence limits on extinction probabilities (Prob) (updated with "**Prelim Chinook_release format_021210.xlsx**"). The lower confidence bound represents the 0.025 quantile of the 1000 extinction probability replications, while the upper limit represents the 0.975 quantile of the the 1000 extinction probability replications. Extinction probabilities were calculated over a time window of **24 years** with various levels of quasi-extinction threshold (QET) and reproductive failure threshold (RFT). Note that less that 1000 replications were actually generated for each of the populations because some bootstrap samples resulted in invalid maximum likelihood estimates of the Ricker model. The column "ngood" represents the number of valid replicates of the parameter estimates. "nbadb" represents the number of replications with b less than zero, and "nbadalpha" represents the number of replications with alpha greater than 1.0. Whenever a replication of alpha was greater than one, it was set equal to one. Extinction probabilities were based on 4000 population trajectories. **The time period was the period used in the 2008 BIOP**. The population projections were initialized with the most recent five years of spawner observations. Spawner numbers do not include jacks.

Population	Prob	Lower95	Upper95	QET	RFT	nbadb	nbadalpha	ngood
Snake River	0	0	1	1	2	0	272	970
Snake River	0.01	0	1	10	10	0	272	970
Snake River	0.04	0	1	30	10	0	272	970
Snake River	0.07	0	1	50	10	0	272	970

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Appendix C

Lambda Estimates - Detailed Results

Table C1. Chinook lambda with HF=1, 1980-2003 with new data.

Population	Relative success of hatchery fish	Start Year	End Year	lambda	Lambda with confidence interval	Probability lambda greater than one	Variance (Holmes method)	mu	Non-missing spawner counts in original data	Number of outliers	Long-term mean (not median!) growth rate
Valley Creek - SR	1	1980	2003	1.069	1.069 (0.727 - 1.572)	0.6895	0.294	0.0666	24	1	1.2382
Lemhi - SR	1	1980	2003	1.026	1.026 (0.664 - 1.586)	0.5691	0.3745	0.0259	24	3	1.2376
Lower Mainstem Salmon - SR	1	1980	2003	1.037	1.037 (0.721 - 1.491)	0.6142	0.2603	0.0362	24	2	1.181
Big Creek - SR	1	1980	2003	1.093	1.093 (0.747 - 1.6)	0.7445	0.2864	0.089	24	2	1.2614
Sulphur Creek - SR	1	1980	2003	1.07	1.07 (0.724 - 1.582)	0.6907	0.3013	0.0679	24	1	1.2443
Loon Creek - SR	1	1980	2003	1.119	1.119 (0.77 - 1.627)	0.7956	0.2764	0.1126	24	2	1.285
Bear Valley/Elk - SR	1	1980	2003	1.107	1.107 (0.797 - 1.536)	0.8011	0.212	0.1013	24	2	1.2303
Marsh Creek - SR	1	1980	2003	1.085	1.085 (0.78 - 1.509)	0.7559	0.2145	0.0816	24	3	1.2078
Secesh - SR	1	1980	2003	1.073	1.073 (0.832 - 1.384)	0.7783	0.1279	0.0704	24	1	1.1439
Entiat - UCR	1	1980	2003	0.924	0.924 (0.708 - 1.205)	0.2072	0.1395	-0.0789	24	2	0.9909
Methow - UCR	1	1980	2003	0.915	0.915 (0.598 - 1.399)	0.2759	0.3565	-0.0892	24	2	1.0931
Wenatchee - UCR	1	1980	2003	0.896	0.896 (0.629 - 1.275)	0.1974	0.2461	-0.1099	24	3	1.0132
Tucannon - UCR	1	1980	2003	0.871	0.871 (0.623 - 1.219)	0.1413	0.222	-0.1376	24	1	0.9738
Snake Fall Chinook	1	1980	2003	0.966	0.966 (0.763 - 1.222)	0.3343	0.1097	-0.035	24	2	1.02

Table C2. Chinook lambda with HF=0, 1980-2003 with new data.

Population	Relative success of hatchery fish	Start Year	End Year	lambda	Lambda with confidence interval	Probability lambda greater than one	Variance (Holmes method)	mu	Non-missing spawner counts in original data	Number of outliers	Long-term mean (not median!) growth rate
Valley Creek - SR	0	1980	2003	1.069	1.069 (0.727 - 1.572)	0.6895	0.294	0.0666	24	1	1.2382
Lemhi - SR	0	1980	2003	1.026	1.026 (0.664 - 1.586)	0.5691	0.3745	0.0259	24	3	1.2376
Lower Mainstem Salmon - SR	0	1980	2003	1.037	1.037 (0.721 - 1.491)	0.6142	0.2603	0.0362	24	2	1.181
Big Creek - SR	0	1980	2003	1.093	1.093 (0.747 - 1.6)	0.7445	0.2864	0.089	24	2	1.2614
Sulphur Creek - SR	0	1980	2003	1.07	1.07 (0.724 - 1.582)	0.6907	0.3013	0.0679	24	1	1.2443
Loon Creek - SR	0	1980	2003	1.119	1.119 (0.77 - 1.627)	0.7956	0.2764	0.1126	24	2	1.285
Bear Valley/Elk - SR	0	1980	2003	1.107	1.107 (0.797 - 1.536)	0.8011	0.212	0.1013	24	2	1.2303
Marsh Creek - SR	0	1980	2003	1.085	1.085 (0.78 - 1.509)	0.756	0.2145	0.0816	24	3	1.2079
Secesh - SR	0	1980	2003	1.079	1.079 (0.836 - 1.393)	0.794	0.1284	0.0762	24	1	1.1507
Entiat - UCR	0	1980	2003	0.973	0.973 (0.722 - 1.311)	0.3951	0.1754	-0.0272	24	2	1.0623
Methow - UCR	0	1980	2003	0.987	0.987 (0.613 - 1.589)	0.4675	0.4479	-0.0133	24	2	1.2345
Wenatchee - UCR	0	1980	2003	0.947	0.947 (0.645 - 1.392)	0.3425	0.2926	-0.0541	24	3	1.0966
Tucannon - UCR	0	1980	2003	0.944	0.944 (0.677 - 1.315)	0.308	0.2175	-0.0582	24	1	1.0519
Snake Fall Chinook	0	1980	2003	1.108	1.108 (0.879 - 1.397)	0.8728	0.1061	0.1024	24	2	1.1682

Table C3. Chinook lambda with HF=1, 1980 through most recent year (new data).

Population	Relative success of hatchery fish	Start Year	End Year	lambda	Lambda with confidence interval	Probability lambda greater than one	Variance (Holmes method)	mu	Non-missing spawner counts in original data	Number of outliers	Long-term mean (not median!) growth rate
Valley Creek - SR	1	1980	2008	1.023	1.023 (0.757 - 1.381)	0.5774	0.2926	0.0225	29	1	1.1839
Lemhi - SR	1	1980	2008	0.955	0.955 (0.673 - 1.354)	0.3654	0.3967	-0.0465	29	2	1.164
Lower Mainstem Salmon - SR	1	1980	2008	0.991	0.991 (0.751 - 1.308)	0.4653	0.25	-0.0093	29	2	1.1227
Big Creek - SR	1	1980	2008	1.014	1.014 (0.738 - 1.393)	0.5451	0.3269	0.0138	29	1	1.194
Sulphur Creek - SR	1	1980	2008	1.032	1.032 (0.773 - 1.378)	0.6111	0.2718	0.0315	29	1	1.1822
Loon Creek - SR	1	1980	2008	0.986	0.986 (0.674 - 1.442)	0.4614	0.468	-0.0141	29	3	1.2459
Bear Valley/Elk - SR	1	1980	2008	1.039	1.039 (0.797 - 1.354)	0.6446	0.2277	0.038	29	2	1.164
Marsh Creek - SR	1	1980	2008	1.011	1.011 (0.766 - 1.334)	0.5405	0.2494	0.0108	29	2	1.1451
Secesh - SR	1	1980	2008	1.016	1.016 (0.816 - 1.265)	0.5741	0.1562	0.0157	29	2	1.0984
Entiat - UCR	1	1980	2008	0.9	0.9 (0.729 - 1.11)	0.1175	0.1431	-0.1057	29	2	0.9665
Methow - UCR	1	1980	2008	0.849	0.849 (0.598 - 1.205)	0.1323	0.3974	-0.1635	29	2	1.0359
Wenatchee - UCR	1	1980	2008	0.86	0.86 (0.666 - 1.112)	0.0898	0.2139	-0.1503	29	3	0.9576
Tucannon - UCR	1	1980	2008	0.864	0.864 (0.655 - 1.14)	0.1082	0.2489	-0.1463	29	1	0.9784
Snake Fall Chinook	1	1980	2007	0.914	0.914 (0.745 - 1.121)	0.1442	0.1302	-0.0901	28	2	0.9753

Table C4. Chinook lambda with HF=0, 1980 through most recent year (new data).

Population	Relative success of hatchery fish	Start Year	End Year	lambda	Lambda with confidence interval	Probability lambda greater than one	Variance (Holmes method)	mu	Non-missing spawner counts in original data	Number of outliers	Long-term mean (not median!) growth rate
Valley Creek - SR	0	1980	2008	1.023	1.023 (0.757 - 1.381)	0.5774	0.2926	0.0225	29	1	1.1839
Lemhi - SR	0	1980	2008	0.955	0.955 (0.673 - 1.354)	0.3654	0.3967	-0.0465	29	2	1.164
Lower Mainstem Salmon - SR	0	1980	2008	0.991	0.991 (0.751 - 1.308)	0.4653	0.25	-0.0093	29	2	1.1227
Big Creek - SR	0	1980	2008	1.014	1.014 (0.738 - 1.393)	0.5451	0.3269	0.0138	29	1	1.194
Sulphur Creek - SR	0	1980	2008	1.032	1.032 (0.773 - 1.378)	0.6111	0.2718	0.0315	29	1	1.1822
Loon Creek - SR	0	1980	2008	0.986	0.986 (0.674 - 1.442)	0.4614	0.468	-0.0141	29	3	1.2459
Bear Valley/Elk - SR	0	1980	2008	1.039	1.039 (0.797 - 1.354)	0.6446	0.2277	0.038	29	2	1.164
Marsh Creek - SR	0	1980	2008	1.011	1.011 (0.766 - 1.334)	0.5411	0.2493	0.011	29	2	1.1452
Secesh - SR	0	1980	2008	1.023	1.023 (0.822 - 1.274)	0.6067	0.1559	0.0228	29	2	1.106
Entiat - UCR	0	1980	2008	0.963	0.963 (0.762 - 1.217)	0.3396	0.1781	-0.0376	29	2	1.0528
Methow - UCR	0	1980	2008	0.97	0.97 (0.684 - 1.375)	0.409	0.3951	-0.0309	29	2	1.1814
Wenatchee - UCR	0	1980	2008	0.939	0.939 (0.705 - 1.249)	0.2857	0.2654	-0.0634	29	3	1.0717
Tucannon - UCR	0	1980	2008	0.943	0.943 (0.709 - 1.253)	0.298	0.2625	-0.0589	29	1	1.075
Snake Fall Chinook	0	1980	2007	1.078	1.078 (0.9 - 1.292)	0.8445	0.1014	0.0753	28	2	1.1343

Table C5. Chinook lambda with HF=1, 1990-2003 with new data.

Population	Relative success of hatchery fish	Start Year	End Year	lambda	Lambda with confidence interval	Probability lambda greater than one	Variance (Holmes method)	mu	Non-missing spawner counts in original data	Number of outliers	Long-term mean (not median!) growth rate
Valley Creek - SR	1	1990	2003	1.193	1.193 (0.224 - 6.343)	0.7962	0.1729	0.1765	14	1	1.3008
Lemhi - SR	1	1990	2003	1.128	1.128 (0.231 - 5.503)	0.7438	0.1557	0.12	14	2	1.2188
Lower Mainstem Salmon - SR	1	1990	2003	1.11	1.11 (0.163 - 7.561)	0.693	0.2279	0.1047	14	1	1.2444
Big Creek - SR	1	1990	2003	1.124	1.124 (0.081 - 15.634)	0.6631	0.4294	0.1166	14	1	1.3927
Sulphur Creek - SR	1	1990	2003	1.037	1.037 (0.175 - 6.154)	0.5817	0.1963	0.0368	14	2	1.1445
Loon Creek - SR	1	1990	2003	1.252	1.252 (0.077 - 20.41)	0.7535	0.4826	0.2246	14	1	1.5935
Bear Valley/Elk - SR	1	1990	2003	1.105	1.105 (0.112 - 10.899)	0.661	0.3245	0.0998	14	1	1.2996
Marsh Creek - SR	1	1990	2003	1.102	1.102 (0.126 - 9.645)	0.6648	0.2914	0.0972	14	0	1.275
Secesh - SR	1	1990	2003	1.129	1.129 (0.158 - 8.042)	0.7115	0.2388	0.1211	14	1	1.2719
Entiat - UCR	1	1990	2003	0.938	0.938 (0.082 - 10.683)	0.3972	0.3666	-0.0641	14	2	1.1266
Methow - UCR	1	1990	2003	0.816	0.816 (0.025 - 26.683)	0.2971	0.7533	-0.2033	14	1	1.1893
Wenatchee - UCR	1	1990	2003	0.861	0.861 (0.044 - 16.743)	0.3184	0.5456	-0.1499	14	1	1.1308
Tucannon - UCR	1	1990	2003	0.871	0.871 (0.058 - 13.119)	0.3174	0.4555	-0.1379	14	1	1.094
Snake Fall Chinook	1	1990	2003	1.067	1.067 (0.573 - 1.985)	0.7934	0.0239	0.0644	14	1	1.0794

Table C6. Chinook lambda with HF=0, 1990-2003 with new data.

Population	Relative success of hatchery fish	Start Year	End Year	lambda	Lambda with confidence interval	Probability lambda greater than one	Variance (Holmes method)	mu	Non-missing spawner counts in original data	Number of outliers	Long-term mean (not median!) growth rate
Valley Creek - SR	0	1990	2003	1.193	1.193 (0.224 - 6.343)	0.7962	0.1729	0.1765	14	1	1.3008
Lemhi - SR	0	1990	2003	1.128	1.128 (0.231 - 5.503)	0.7438	0.1557	0.12	14	2	1.2188
Lower Mainstem Salmon - SR	0	1990	2003	1.11	1.11 (0.163 - 7.561)	0.693	0.2279	0.1047	14	1	1.2444
Big Creek - SR	0	1990	2003	1.124	1.124 (0.081 - 15.634)	0.6631	0.4294	0.1166	14	1	1.3927
Sulphur Creek - SR	0	1990	2003	1.037	1.037 (0.175 - 6.154)	0.5817	0.1963	0.0368	14	2	1.1445
Loon Creek - SR	0	1990	2003	1.252	1.252 (0.077 - 20.41)	0.7535	0.4826	0.2246	14	1	1.5935
Bear Valley/Elk - SR	0	1990	2003	1.105	1.105 (0.112 - 10.899)	0.661	0.3245	0.0998	14	1	1.2996
Marsh Creek - SR	0	1990	2003	1.102	1.102 (0.126 - 9.648)	0.6649	0.2915	0.0973	14	0	1.2751
Secesh - SR	0	1990	2003	1.138	1.138 (0.159 - 8.148)	0.7217	0.24	0.1296	14	1	1.2834
Entiat - UCR	0	1990	2003	1.003	1.003 (0.066 - 15.186)	0.5046	0.4573	0.0031	14	2	1.2608
Methow - UCR	0	1990	2003	0.946	0.946 (0.014 - 62.826)	0.4474	1.0903	-0.0551	14	1	1.6324
Wenatchee - UCR	0	1990	2003	0.962	0.962 (0.038 - 24.509)	0.4519	0.6494	-0.0388	14	0	1.3309
Tucannon - UCR	0	1990	2003	0.999	0.999 (0.063 - 15.711)	0.4979	0.4704	-0.0015	14	1	1.2633
Snake Fall Chinook	0	1990	2003	1.221	1.221 (0.462 - 3.229)	0.8834	0.0586	0.1995	14	1	1.2571

Table C7. Chinook lambda with HF=1, 1990 through most recent year (new data).

Population	Relative success of hatchery fish	Start Year	End Year	lambda	Lambda with confidence interval	Probability lambda greater than one	Variance (Holmes method)	mu	Non-missing spawner counts in original data	Number of outliers	Long-term mean (not median!) growth rate
Valley Creek - SR	1	1990	2008	1.069	1.069 (0.613 - 1.863)	0.6708	0.2503	0.0664	19	2	1.2111
Lemhi - SR	1	1990	2008	0.968	0.968 (0.451 - 2.078)	0.4366	0.4724	-0.0321	19	1	1.2265
Lower Mainstem Salmon - SR	1	1990	2008	1.006	1.006 (0.576 - 1.758)	0.5164	0.2525	0.006	19	2	1.1414
Big Creek - SR	1	1990	2008	0.982	0.982 (0.458 - 2.106)	0.4643	0.4715	-0.0179	19	1	1.2433
Sulphur Creek - SR	1	1990	2008	0.987	0.987 (0.609 - 1.597)	0.4573	0.1881	-0.0136	19	2	1.0838
Loon Creek - SR	1	1990	2008	0.976	0.976 (0.349 - 2.733)	0.4648	0.8584	-0.0239	19	2	1.4998
Bear Valley/Elk - SR	1	1990	2008	0.995	0.995 (0.538 - 1.841)	0.4873	0.307	-0.0051	19	2	1.1599
Marsh Creek - SR	1	1990	2008	0.974	0.974 (0.511 - 1.859)	0.4393	0.3382	-0.026	19	2	1.1539
Secesh - SR	1	1990	2008	1.013	1.013 (0.571 - 1.798)	0.5344	0.2668	0.013	19	1	1.1577
Entiat - UCR	1	1990	2008	0.893	0.893 (0.503 - 1.583)	0.2417	0.2662	-0.1137	19	2	1.0196
Methow - UCR	1	1990	2008	0.749	0.749 (0.327 - 1.714)	0.1359	0.5554	-0.2891	19	1	0.9886
Wenatchee - UCR	1	1990	2008	0.815	0.815 (0.424 - 1.569)	0.1558	0.3471	-0.2042	19	1	0.9699
Tucannon - UCR	1	1990	2008	0.858	0.858 (0.434 - 1.699)	0.2188	0.3778	-0.1527	19	1	1.0369
Snake Fall Chinook	1	1990	2007	0.943	0.943 (0.605 - 1.471)	0.3143	0.1494	-0.0585	18	2	1.0164

Table C8. Chinook lambda with HF=0, 1990 through most recent year (new data).

Population	Relative success of hatchery fish	Start Year	End Year	lambda	Lambda with confidence interval	Probability lambda greater than one	Variance (Holmes method)	mu	Non-missing spawner counts in original data	Number of outliers	Long-term mean (not median!) growth rate
Valley Creek - SR	0	1990	2008	1.069	1.069 (0.613 - 1.863)	0.6708	0.2503	0.0664	19	2	1.2111
Lemhi - SR	0	1990	2008	0.968	0.968 (0.451 - 2.078)	0.4366	0.4724	-0.0321	19	1	1.2265
Lower Mainstem Salmon - SR	0	1990	2008	1.006	1.006 (0.576 - 1.758)	0.5164	0.2525	0.006	19	2	1.1414
Big Creek - SR	0	1990	2008	0.982	0.982 (0.458 - 2.106)	0.4643	0.4715	-0.0179	19	1	1.2433
Sulphur Creek - SR	0	1990	2008	0.987	0.987 (0.609 - 1.597)	0.4573	0.1881	-0.0136	19	2	1.0838
Loon Creek - SR	0	1990	2008	0.976	0.976 (0.349 - 2.733)	0.4648	0.8584	-0.0239	19	2	1.4998
Bear Valley/Elk - SR	0	1990	2008	0.995	0.995 (0.538 - 1.841)	0.4873	0.307	-0.0051	19	2	1.1599
Marsh Creek - SR	0	1990	2008	0.975	0.975 (0.511 - 1.859)	0.4399	0.3379	-0.0257	19	2	1.154
Secesh - SR	0	1990	2008	1.023	1.023 (0.577 - 1.813)	0.5604	0.2653	0.0229	19	1	1.1683
Entiat - UCR	0	1990	2008	0.976	0.976 (0.521 - 1.827)	0.4415	0.3186	-0.0243	19	2	1.1446
Methow - UCR	0	1990	2008	0.932	0.932 (0.369 - 2.35)	0.387	0.6935	-0.0705	19	1	1.3181
Wenatchee - UCR	0	1990	2008	0.942	0.942 (0.463 - 1.919)	0.3767	0.4097	-0.0595	19	2	1.1565
Tucannon - UCR	0	1990	2008	0.979	0.979 (0.489 - 1.958)	0.4528	0.39	-0.0216	19	1	1.1893
Snake Fall Chinook	0	1990	2007	1.134	1.134 (0.807 - 1.591)	0.8736	0.087	0.1253	18	2	1.1839

Table C9. Steelhead lambda with HF=1, 1980-2003 with new data.

Population	Relative success of hatchery fish	Start Year	End Year	lambda	Lambda with confidence interval	Probability lambda greater than one	Variance (Holmes method)	mu	Non-missing spawner counts in original data	Number of outliers	Long-term mean (not median!) growth rate
Satus - MCR	1	1980	2003	0.953	0.953 (0.69 - 1.317)	0.2952	0.0844	-0.0476	19	2	0.9946
Toppenish - MCR	1	1980	2003	1.068	1.068 (0.647 - 1.764)	0.6856	0.2039	0.0659	19	2	1.1828
Naches - MCR	1	1980	2003	0.995	0.995 (0.644 - 1.538)	0.4841	0.1534	-0.0045	19	1	1.0748
Upper Yakima - MCR	1	1980	2003	0.997	0.997 (0.675 - 1.472)	0.4867	0.1232	-0.0034	19	2	1.0599
Entiat - UCR	1	1980	2003	0.825	0.825 (0.658 - 1.036)	0.0372	0.1017	-0.1918	24	2	0.8685
Methow - UCR	1	1980	2003	0.675	0.675 (0.539 - 0.845)	0.0057	0.0996	-0.3935	24	2	0.7091
Okanogan - UCR	1	1980	2003	0.561	0.561 (0.444 - 0.709)	0.0021	0.1081	-0.5785	24	2	0.5919
Wenatchee - UCR	1	1980	2003	0.803	0.803 (0.606 - 1.065)	0.0449	0.1572	-0.2193	24	1	0.8687

Table C10. Steelhead lambda with HF=0, 1980-2003 with new data.

Population	Relative success of hatchery fish	Start Year	End Year	lambda	Lambda with confidence interval	Probability lambda greater than one	Variance (Holmes method)	mu	Non-missing spawner counts in original data	Number of outliers	Long-term mean (not median!) growth rate
Satus - MCR	0	1980	2003	0.973	0.973 (0.702 - 1.348)	0.375	0.0862	-0.0277	19	2	1.0155
Toppenish - MCR	0	1980	2003	1.087	1.087 (0.657 - 1.798)	0.7253	0.2052	0.0835	19	2	1.2045
Naches - MCR	0	1980	2003	1.014	1.014 (0.654 - 1.571)	0.5465	0.1554	0.0134	19	1	1.0954
Upper Yakima - MCR	0	1980	2003	1.002	1.002 (0.681 - 1.473)	0.5062	0.1204	0.0016	19	2	1.0637
Entiat - UCR	0	1980	2003	1.068	1.068 (0.78 - 1.464)	0.7238	0.1959	0.066	24	2	1.1782
Methow - UCR	0	1980	2003	1.089	1.089 (0.773 - 1.533)	0.7572	0.2313	0.0853	24	2	1.2226
Okanogan - UCR	0	1980	2003	1.038	1.038 (0.776 - 1.388)	0.6438	0.1667	0.037	24	2	1.1279
Wenatchee - UCR	0	1980	2003	1.087	1.087 (0.796 - 1.485)	0.7716	0.1921	0.0835	24	1	1.1967

Table C11. Steelhead lambda (HF=1) from 1980 (or earliest available year) through 2009 (new data).

Population	Relative success of hatchery fish	Start Year	End Year	lambda	Lambda with confidence interval	Probability lambda greater than one	Variance (Holmes method)	mu	Non-missing spawner counts in original data	Number of outliers	Long-term mean (not median!) growth rate
Satus - MCR	1	1985	2009	0.979	0.979 (0.822 - 1.168)	0.3797	0.0841	-0.0208	25	2	1.0215
Toppenish - MCR	1	1985	2009	1.017	1.017 (0.778 - 1.329)	0.5648	0.1948	0.0167	25	1	1.1209
Naches - MCR	1	1985	2009	0.99	0.99 (0.797 - 1.23)	0.4526	0.1281	-0.0099	25	2	1.0556
Upper Yakima - MCR	1	1985	2009	0.996	0.996 (0.801 - 1.238)	0.4793	0.1289	-0.0043	25	2	1.0619
Entiat - UCR	1	1980	2009	0.796	0.796 (0.662 - 0.957)	0.0131	0.11	-0.2284	29	2	0.8408
Methow - UCR	1	1980	2009	0.666	0.666 (0.574 - 0.772)	0.0004	0.0867	-0.4066	30	2	0.6954
Okanogan - UCR	1	1980	2009	0.559	0.559 (0.476 - 0.657)	0.0001	0.1019	-0.5807	30	3	0.5887
Wenatchee - UCR	1	1980	2009	0.794	0.794 (0.643 - 0.979)	0.0184	0.1742	-0.2312	30	1	0.8658

Table C12. Steelhead lambda (HF=0) from 1980 (or earliest available year) through 2009 (new data).

Population	Relative success of hatchery fish	Start Year	End Year	lambda	Lambda with confidence interval	Probability lambda greater than one	Variance (Holmes method)	mu	Non-missing spawner counts in original data	Number of outliers	Long-term mean (not median!) growth rate
Satus - MCR	0	1985	2009	0.995	0.995 (0.838 - 1.181)	0.468	0.0805	-0.0053	25	2	1.0356
Toppenish - MCR	0	1985	2009	1.031	1.031 (0.786 - 1.352)	0.6147	0.1998	0.0304	25	1	1.1392
Naches - MCR	0	1985	2009	1.004	1.004 (0.808 - 1.248)	0.5196	0.1285	0.0041	25	2	1.0707
Upper Yakima - MCR	0	1985	2009	1	1.0 (0.806 - 1.241)	0.5019	0.127	0.0004	25	2	1.066
Entiat - UCR	0	1980	2009	1.05	1.05 (0.83 - 1.329)	0.7023	0.1803	0.0489	29	2	1.1492
Methow - UCR	0	1980	2009	1.078	1.078 (0.864 - 1.345)	0.7892	0.1922	0.0753	30	2	1.1869
Okanogan - UCR	0	1980	2009	1.034	1.034 (0.848 - 1.262)	0.66	0.1551	0.0338	30	2	1.1178
Wenatchee - UCR	0	1980	2009	1.06	1.06 (0.858 - 1.31)	0.7451	0.1759	0.0583	30	1	1.1575

Table C13. Steelhead lambda with HF=1, 1990-2003 with new data.

Population	Relative success of hatchery fish	Start Year	End Year	lambda	Lower confidence interval on lambda	Upper confidence interval on lambda	Probability lambda greater than one	Variance (Holmes method)	mu	Non-missing spawner counts in original data	Number of outliers	Long-term mean (not median!) growth rate
Satus - MCR	1	1990	2003	1.004	0.258	3.906	0.5118	0.1143	0.004	14	1	1.063
Toppenish - MCR	1	1990	2003	1.178	0.191	7.267	0.7709	0.2052	0.1634	14	2	1.3047
Naches - MCR	1	1990	2003	1.085	0.244	4.819	0.6933	0.1377	0.0815	14	2	1.1623
Upper Yakima - MCR	1	1990	2003	1.085	0.322	3.655	0.7246	0.0914	0.0815	14	2	1.1356
Entiat - UCR	1	1990	2003	0.801	0.306	2.096	0.1045	0.0573	-0.2223	14	1	0.824
Methow - UCR	1	1990	2003	0.652	0.118	3.611	0.0972	0.1814	-0.4272	14	1	0.7143
Okanogan - UCR	1	1990	2003	0.574	0.104	3.185	0.0759	0.1817	-0.5545	14	2	0.629
Wenatchee - UCR	1	1990	2003	0.808	0.084	7.74	0.2216	0.3161	-0.2128	14	1	0.9467

Table C14. Steelhead lambda with HF=0, 1990-2003 with new data.

Population	Relative success of hatchery fish	Start Year	End Year	lambda	Lower confidence interval on lambda	Upper confidence interval on lambda	Probability lambda greater than one	Variance (Holmes method)	mu	Non-missing spawner counts in original data	Number of outliers	Long-term mean (not median!) growth rate
Satus - MCR	0	1990	2003	1.026	0.264	3.996	0.5758	0.1144	0.026	14	1	1.0867
Toppenish - MCR	0	1990	2003	1.2	0.197	7.325	0.7891	0.2027	0.1824	14	2	1.3281
Naches - MCR	0	1990	2003	1.106	0.25	4.893	0.7269	0.1369	0.1011	14	1	1.1848
Upper Yakima - MCR	0	1990	2003	1.09	0.329	3.61	0.7361	0.0888	0.0863	14	2	1.1396
Entiat - UCR	0	1990	2003	1.048	0.181	6.064	0.6039	0.1909	0.0468	14	1	1.1529
Methow - UCR	0	1990	2003	1.016	0.095	10.901	0.5264	0.3489	0.0155	14	1	1.2092
Okanogan - UCR	0	1990	2003	1.013	0.094	10.867	0.5224	0.3487	0.0132	14	1	1.2062
Wenatchee - UCR	0	1990	2003	1.041	0.175	0	0.5887	0.1964	0.0401	14	1	1.1484

Table C15. Steelhead lambda (HF=1) from 1990 through 2009 (new data).

Population	Relative success of hatchery fish	Start Year	End Year	lambda	Lambda with confidence interval	Probability lambda greater than one	Variance (Holmes method)	mu	Non-missing spawner counts in original data	Number of outliers	Long-term mean (not median!) growth rate
Satus - MCR	1	1990	2009	1.02	1.02 (0.819 - 1.27)	0.6042	0.0759	0.0199	20	2	1.0596
Toppenish - MCR	1	1990	2009	1.064	1.064 (0.729 - 1.554)	0.6816	0.2263	0.0623	20	2	1.1918
Naches - MCR	1	1990	2009	1.043	1.043 (0.805 - 1.352)	0.6799	0.1063	0.0422	20	3	1.1001
Upper Yakima - MCR	1	1990	2009	1.05	1.05 (0.819 - 1.345)	0.711	0.097	0.0484	20	2	1.1018
Entiat - UCR	1	1990	2009	0.761	0.761 (0.544 - 1.065)	0.0364	0.0914	-0.2733	19	1	0.7965
Methow - UCR	1	1990	2009	0.647	0.647 (0.491 - 0.852)	0.0075	0.1195	-0.4355	20	2	0.6867
Okanogan - UCR	1	1990	2009	0.567	0.567 (0.429 - 0.75)	0.0038	0.1232	-0.5666	20	2	0.6035
Wenatchee - UCR	1	1990	2009	0.791	0.791 (0.531 - 1.18)	0.0797	0.2524	-0.234	20	1	0.8978

Table C16. Steelhead lambda (HF=0) from 1990 through 2009 (new data).

Population	Relative success of hatchery fish	Start Year	End Year	lambda	Lambda with confidence interval	Probability lambda greater than one	Variance (Holmes method)	mu	Non-missing spawner counts in original data	Number of outliers	Long-term mean (not median!) growth rate
Satus - MCR	0	1990	2009	1.036	1.036 (0.836 - 1.284)	0.6813	0.0727	0.0352	20	2	1.0742
Toppenish - MCR	0	1990	2009	1.079	1.079 (0.733 - 1.586)	0.7117	0.2351	0.0757	20	2	1.2132
Naches - MCR	0	1990	2009	1.058	1.058 (0.813 - 1.376)	0.7264	0.1095	0.056	20	3	1.1171
Upper Yakima - MCR	0	1990	2009	1.054	1.054 (0.824 - 1.349)	0.7285	0.096	0.053	20	2	1.1062
Entiat - UCR	0	1990	2009	1.025	1.025 (0.653 - 1.609)	0.5822	0.1645	0.0247	19	1	1.1129
Methow - UCR	0	1990	2009	1.026	1.026 (0.701 - 1.502)	0.5771	0.2296	0.0254	20	2	1.1505
Okanogan - UCR	0	1990	2009	1.017	1.017 (0.692 - 1.494)	0.5512	0.2338	0.0169	20	2	1.1432
Wenatchee - UCR	0	1990	2009	1.016	1.016 (0.735 - 1.404)	0.5556	0.1657	0.0155	20	1	1.1033

Appendix D

Trend of ln(Natural Abundance+1) ("BRT Trend") - Detailed Results

Table D1. Chinook BRT trend, 1980-2003 with new data.

Population	Time Series Period	Years of Spawner Data	Mean hatchery fraction	Exp Trend	Exp Trend in Ln (NatSpawners) With CI	Probability Trend in Ln Nat Spawners > 0
Valley Creek - SR	1980 - 2003	24	0	1.02	1.016 (0.934 - 1.105)	0.652
Lemhi - SR	1980 - 2003	24	0	0.98	0.983 (0.923 - 1.046)	0.2863
Lower Mainstem Salmon - SR	1980 - 2003	24	0	1.00	0.996 (0.939 - 1.057)	0.4472
Yankee Fork - SR	1980 - 2003	24	0	1.03	1.026 (0.944 - 1.116)	0.7371
Big Creek - SR	1980 - 2003	24	0	1.01	1.014 (0.935 - 1.101)	0.6419
Sulphur Creek - SR	1980 - 2003	24	0	1.01	1.009 (0.905 - 1.126)	0.5692
Loon Creek - SR	1980 - 2003	24	0	1.06	1.058 (0.953 - 1.174)	0.8623
Bear Valley/Elk - SR	1980 - 2003	24	0	1.05	1.051 (0.982 - 1.125)	0.9297
Marsh Creek - SR	1980 - 2003	24	0.0004	0.99	0.989 (0.888 - 1.103)	0.42
Secesh - SR	1980 - 2003	24	0.0251	1.05	1.045 (0.999 - 1.093)	0.9722
Entiat - UCR	1980 - 2003	24	0.2115	0.93	0.932 (0.887 - 0.979)	0.0037
Methow - UCR	1980 - 2003	24	0.2358	0.89	0.887 (0.825 - 0.953)	0.0011
Wenatchee - UCR	1980 - 2003	24	0.1891	0.89	0.893 (0.843 - 0.946)	0.0003
Tucannon - SR	1980 - 2003	24	0.3075	0.85	0.847 (0.76 - 0.944)	0.0021
Snake Fall Chinook	1980 - 2003	24	0.4117	1.10	1.102 (1.058 - 1.148)	1

Table D2. Chinook BRT trend, 1990-2003 with new data.

Population	Time Series Period	Years of Spawner Data	Mean hatchery fraction	Exp Trend	Exp Trend in Ln (NatSpawners) With CI	Probability Trend in Ln Nat Spawners > 0
Valley Creek - SR	1990 - 2003	14	0	1.20	1.203 (0.991 - 1.461)	0.9702
Lemhi - SR	1990 - 2003	14	0	1.13	1.126 (0.974 - 1.302)	0.95
Lower Mainstem Salmon - SR	1990 - 2003	14	0	1.12	1.122 (0.982 - 1.28)	0.9578
Yankee Fork - SR	1990 - 2003	14	0	1.12	1.123 (0.912 - 1.383)	0.8754
Big Creek - SR	1990 - 2003	14	0	1.15	1.154 (0.943 - 1.413)	0.9248
Sulphur Creek - SR	1990 - 2003	14	0	1.07	1.066 (0.81 - 1.402)	0.6874
Loon Creek - SR	1990 - 2003	14	0	1.38	1.384 (1.069 - 1.79)	0.9913
Bear Valley/Elk - SR	1990 - 2003	14	0	1.16	1.157 (0.973 - 1.376)	0.9547
Marsh Creek - SR	1990 - 2003	14	0.0007	1.11	1.106 (0.809 - 1.513)	0.7516
Secesh - SR	1990 - 2003	14	0.0378	1.14	1.143 (1.021 - 1.281)	0.9879
Entiat - UCR	1990 - 2003	14	0.2671	1.01	1.005 (0.87 - 1.162)	0.5308
Methow - UCR	1990 - 2003	14	0.4029	0.87	0.868 (0.703 - 1.071)	0.0849
Wenatchee - UCR	1990 - 2003	14	0.3227	0.97	0.969 (0.824 - 1.139)	0.3401
Tucannon - SR	1990 - 2003	14	0.5071	0.90	0.901 (0.644 - 1.261)	0.2583
Snake Fall Chinook	1990 - 2003	14	0.4757	1.25	1.254 (1.16 - 1.354)	1

Table D3. Chinook BRT trend, 1980 through most recent year (new data).

Population	Time Series Period	Years of Spawner Data	Mean hatchery fraction	Exp Trend	Exp Trend in Ln (NatSpawners) With CI	Probability Trend in Ln Nat Spawners > 0
Valley Creek - SR	1980 - 2008	29	0	1.03	1.03 (0.973 - 1.091)	0.8525
Lemhi - SR	1980 - 2008	29	0	0.97	0.97 (0.93 - 1.012)	0.0779
Lower Mainstem Salmon - SR	1980 - 2008	29	0	1.00	1.001 (0.962 - 1.042)	0.5233
Yankee Fork - SR	1980 - 2008	29	0	1.03	1.028 (0.962 - 1.1)	0.8015
Big Creek - SR	1980 - 2008	29	0	1.01	1.009 (0.954 - 1.068)	0.6329
Sulphur Creek - SR	1980 - 2008	29	0	1.02	1.019 (0.946 - 1.099)	0.6935
Loon Creek - SR	1980 - 2008	29	0	1.04	1.036 (0.965 - 1.113)	0.8402
Bear Valley/Elk - SR	1980 - 2008	29	0	1.04	1.04 (0.993 - 1.09)	0.953
Marsh Creek - SR	1980 - 2008	29	0.0008	1.00	0.997 (0.927 - 1.074)	0.4705
Secesh - SR	1980 - 2008	29	0.032	1.04	1.038 (1.004 - 1.073)	0.9848
Entiat - UCR	1980 - 2008	29	0.2683	0.96	0.96 (0.926 - 0.995)	0.013
Methow - UCR	1980 - 2008	29	0.3167	0.93	0.931 (0.882 - 0.981)	0.0048
Wenatchee - UCR	1980 - 2008	29	0.276	0.93	0.926 (0.887 - 0.967)	0.0005
Tucannon - SR	1980 - 2008	29	0.3245	0.92	0.915 (0.844 - 0.992)	0.0159
Snake Fall Chinook	1980 - 2007	28	0.4593	1.11	1.105 (1.073 - 1.139)	1

Table D4. Chinook BRT trend, 1990 through most recent year (new data).

Population	Time Series Period	Years of Spawner Data	Mean hatchery fraction	Exp Trend	Exp Trend in Ln (NatSpawners) With CI	Probability Trend in Ln Nat Spawners > 0
Valley Creek - SR	1990 - 2008	19	0	1.14	1.141 (1.028 - 1.265)	0.9923
Lemhi - SR	1990 - 2008	19	0	1.02	1.023 (0.939 - 1.114)	0.7083
Lower Mainstem Salmon - SR	1990 - 2008	19	0	1.07	1.07 (0.994 - 1.151)	0.9658
Yankee Fork - SR	1990 - 2008	19	0	1.09	1.088 (0.947 - 1.249)	0.8906
Big Creek - SR	1990 - 2008	19	0	1.08	1.076 (0.961 - 1.204)	0.904
Sulphur Creek - SR	1990 - 2008	19	0	1.07	1.067 (0.923 - 1.232)	0.82
Loon Creek - SR	1990 - 2008	19	0	1.15	1.148 (0.982 - 1.342)	0.9599
Bear Valley/Elk - SR	1990 - 2008	19	0	1.08	1.081 (0.983 - 1.189)	0.9496
Marsh Creek - SR	1990 - 2008	19	0.0012	1.07	1.07 (0.909 - 1.26)	0.8037
Secesh - SR	1990 - 2008	19	0.0451	1.08	1.077 (1.003 - 1.155)	0.9789
Entiat - UCR	1990 - 2008	19	0.3391	1.03	1.025 (0.95 - 1.106)	0.7527
Methow - UCR	1990 - 2008	19	0.4824	0.98	0.975 (0.864 - 1.1)	0.3312
Wenatchee - UCR	1990 - 2008	19	0.4201	1.00	1.004 (0.92 - 1.096)	0.5383
Tucannon - SR	1990 - 2008	19	0.4805	1.03	1.026 (0.854 - 1.234)	0.6156
Snake Fall Chinook	1990 - 2007	18	0.5356	1.18	1.183 (1.121 - 1.25)	1

Table D5. Steelhead BRT trend, earliest year to 2003 (using new data).					
Population	Time Series Period	Years of Spawner Data	Exp Trend	Exp Trend in Ln (NatSpawners) With CI	Probability Trend in Ln Nat Spawners > 0
Satus - MCR	1985 - 2003	19	0.97	0.969 (0.919 - 1.023)	0.1227
Toppenish - MCR	1985 - 2003	19	1.08	1.076 (1.001 - 1.156)	0.9769
Naches - MCR	1985 - 2003	19	1.01	1.006 (0.951 - 1.063)	0.5829
Upper Yakima - MCR	1985 - 2003	19	0.99	0.991 (0.938 - 1.047)	0.3684
Entiat - UCR	1980 - 2003	24	1.04	1.036 (0.994 - 1.08)	0.9535
Methow - UCR	1980 - 2003	24	1.06	1.058 (1.014 - 1.103)	0.9943
Wenatchee - UCR	1980 - 2003	24	1.03	1.034 (0.99 - 1.08)	0.9354
Okanogan - UCR	1980 - 2003	24	1.01	1.009 (0.971 - 1.048)	0.6894

Table D6. Steelhead BRT trend, 1980 or earliest year to most recent year (using new data).					
Population	Time Series Period	Years of Spawner Data	Exp Trend	Exp Trend in Ln (NatSpawners) With CI	Probability Trend in Ln Nat Spawners > 0
Satus - MCR	1985 - 2009	25	1.01	1.011 (0.976 - 1.047)	0.7408
Toppenish - MCR	1985 - 2009	25	1.08	1.076 (1.03 - 1.123)	0.9991
Naches - MCR	1985 - 2009	25	1.03	1.033 (0.998 - 1.067)	0.9671
Upper Yakima - MCR	1985 - 2009	25	1.03	1.026 (0.991 - 1.064)	0.9296
Entiat - UCR	1980 - 2008	29	1.04	1.042 (1.012 - 1.071)	0.9968
Methow - UCR	1980 - 2009	30	1.07	1.069 (1.04 - 1.099)	1
Wenatchee - UCR	1980 - 2009	30	1.04	1.037 (1.008 - 1.065)	0.9935
Okanogan - UCR	1980 - 2009	30	1.03	1.033 (1.006 - 1.06)	0.991

Table D7. Steelhead BRT trend, 1990-2003 (using new data).

Population	Time Series Period	Years of Spawner Data	Exp Trend	Exp Trend in Ln (NatSpawners) With CI	Probability Trend in Ln Nat Spawners > 0
Satus - MCR	1990 - 2003	14	1.05	1.049 (0.97 - 1.135)	0.898
Toppenish - MCR	1990 - 2003	14	1.21	1.212 (1.101 - 1.335)	0.9996
Naches - MCR	1990 - 2003	14	1.11	1.105 (1.028 - 1.188)	0.995
Upper Yakima - MCR	1990 - 2003	14	1.08	1.084 (1.006 - 1.168)	0.9822
Entiat - UCR	1990 - 2003	14	1.04	1.036 (0.946 - 1.133)	0.7928
Methow - UCR	1990 - 2003	14	1.02	1.017 (0.914 - 1.132)	0.631
Wenatchee - UCR	1990 - 2003	14	1.03	1.026 (0.935 - 1.125)	0.7211
Okanogan - UCR	1990 - 2003	14	1.01	1.014 (0.911 - 1.13)	0.6123

Table D8. Steelhead BRT trend, 1990 to most recent year (using new data).

Population	Time Series Period	Years of Spawner Data	Exp Trend	Exp Trend in Ln (NatSpawners) With CI	Probability Trend in Ln Nat Spawners > 0
Satus - MCR	1990 - 2009	20	1.07	1.067 (1.027 - 1.11)	0.999
Toppenish - MCR	1990 - 2009	20	1.13	1.133 (1.07 - 1.2)	0.9999
Naches - MCR	1990 - 2009	20	1.09	1.089 (1.049 - 1.13)	0.9999
Upper Yakima - MCR	1990 - 2009	20	1.09	1.085 (1.043 - 1.129)	0.9998
Entiat - UCR	1990 - 2008	19	1.05	1.052 (1.004 - 1.103)	0.9822
Methow - UCR	1990 - 2009	20	1.07	1.066 (1.01 - 1.125)	0.9891
Wenatchee - UCR	1990 - 2009	20	1.04	1.043 (0.999 - 1.09)	0.9713
Okanogan - UCR	1990 - 2009	20	1.06	1.059 (1.004 - 1.117)	0.9813

Appendix E

Water Temperature Actions and Climate Change

U.S. Army Corps of Engineers

Bureau of Reclamation

Bonneville Power administration

The FCRPS Action Agencies have considered the respective ecological objectives of the ESA and the CWA and consequently have examined impacts of the FCRPS project operations on river temperatures through ESA consultations with NOAA Fisheries. The following is a synopsis of activities the Action Agencies are undertaking pursuant to these responsibilities, which also address uncertainties concerning long-term climate change.

I. Monitoring and Modeling

The following describes the Action Agencies' efforts to monitor river temperatures in the mainstem Columbia and Snake rivers and associated tributaries; water quality annual reporting; and, water temperature modeling efforts for the mainstem rivers.

A. Monitoring

Since 1994, hourly temperature values have been measured at the total dissolved gas (TDG) fixed monitoring stations identified in Figure E-1. The monitoring information is coupled with operational data and reported in real time and can be viewed online[1]. In general, monitoring stations in the project forebays are intended to be indicative of total river conditions and the stations located downstream of the project within the tailwater channel, are intended to monitor spillway releases.

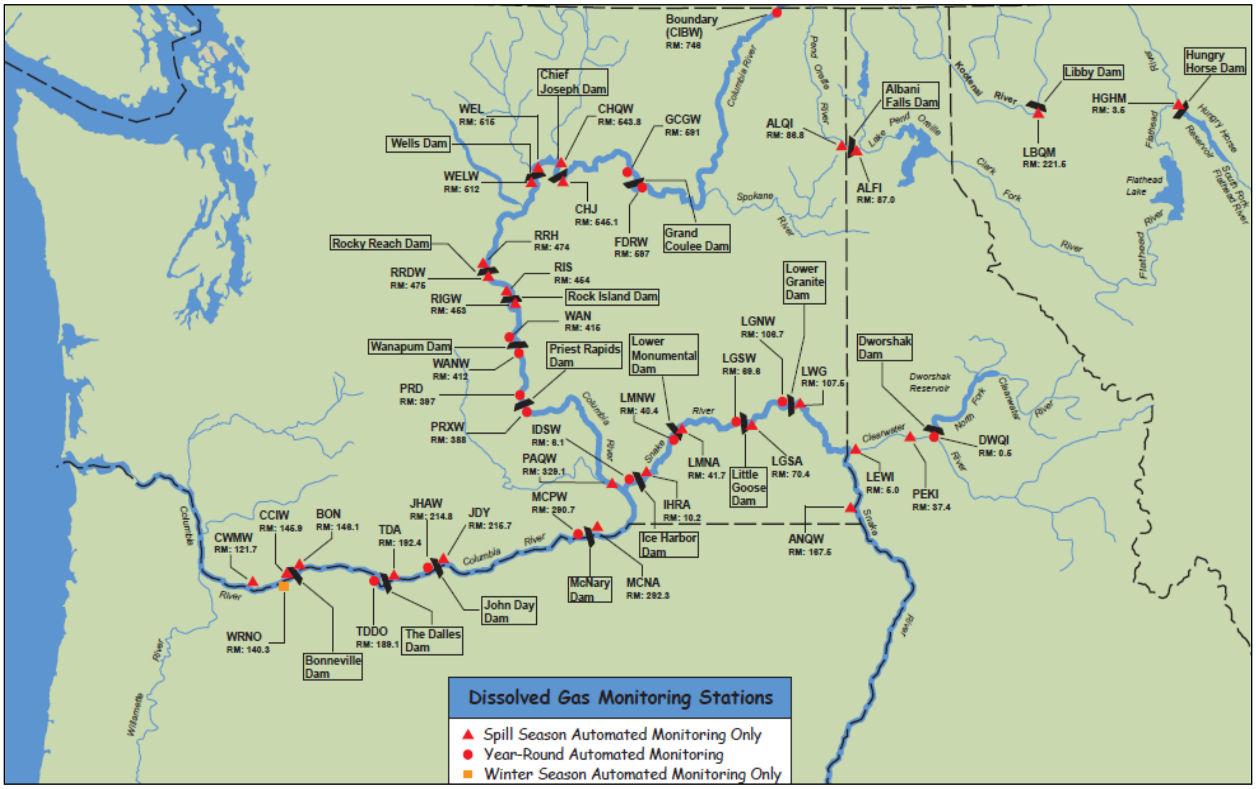
In addition to the monitoring stations identified in Figure 1, there also are fixed hourly temperature monitoring stations located at the following tributaries:

- N. Fork Clearwater River near Canyon Ranger Station
- Yakima River near Kiona
- Clearwater River at Orofino
- Clearwater River at Spalding
- Walla Walla River near Touchet

[1] http://www.nwd-wc.usace.army.mil/tmt/documents/ops/temp/

- Umatilla River near Umatilla
- Salmon River at Whitebird

Figure E-1: TDG and Temperature Monitoring Network



Several of the FCRPS projects also include thermistor strings in the forebay that measure water temperature at varying depths. These monitoring strings are typically located near the edge of the boat restricted zone and collect data that is used for temperature modeling. Data from these gages is available is available for viewing online[2].

Thermistor strings are located at, Lower Granite, Little Goose, Lower Monumental, Ice Harbor and McNary dams. In addition to these mainstem project locations, there are thermistor strings at Libby, Dworshak, and Grand Coulee dams.

The Corps annually reports on water quality information gathered during the year. The report, *Annual Dissolved Gas and Water Temperature Monitoring*[3], includes graphs that summarize hourly water temperature in the forebays and the tailwaters of the Corps' projects from April 1 to September 30 for each year (Appendix H). Appendix H Table H-1, displays water temperature information providing the number of days that temperatures were above 68 ºF on a daily average,

[2] http://www.nwd-wc.usace.army.mil/tmt/documents/ops/temp/string_by_project.html
[3] http://www.nwd-wc.usace.army.mil/tmt/wqnew/

the date this condition began, when it ended and other general information. In addition, Table 11 provides a five year comparison of the number of days that a gauge recorded temperatures above 68ºF on a daily average for the past five years.

In addition to these annual water quality reports, as described in the 2008 FCRPS BiOp, the Action Agencies prepare periodic implementation plans, annual progress reports and more comprehensive reports scheduled for 2013 and 2016. The implementation plans take into account pertinent new information on climate change and effects of that information on limiting factors and project prioritization (RPA Action 1).

The annual progress reports include a summary of the annual forecast review and also summarize any new, pertinent climate change information or research (RPA Action 2). As part of the annual progress report, NOAA Fisheries annually provides the Action Agencies with a scientific literature review regarding habitat and ocean conditions, habitat project priorities and forecasting and modeling results to ensure that the latest scientific information on climate change is considered throughout implementation of the RPA (AMIP p 12).

The 2013 and 2016 Comprehensive RPA Evaluation Reports will summarize information pertaining to temperatures and climate change from the annual progress reports and the implementation plans. (RPA Action 3).

B. Modeling and Temperature Studies

The Action Agencies have conducted studies to evaluate temperature conditions in several river reaches and have developed models that are used to assist in project operations. The following describes these activities:

i. The Corps currently uses the CE-QUAL-W2 model to simulate and project water temperature releases from Dworshak Dam on the Clearwater River downstream through the lower Snake River projects. This model is used to evaluate alternative release volumes and temperatures from Dworshak with the objective of maintaining temperatures below 68ºF as measured at the Lower Granite forebay.

   In response to RPA Action 15 of the 2008 FCRPS BiOp, the Corps and Bureau of Reclamation are working with U.S. Army Engineer Research and Development Center (ERDC) to define the scope, plan and costs to expand the CE-QUAL-W2 temperature modeling capability to include the Columbia River from Grand Coulee Dam to Bonneville Dam. This will allow evaluation of alternative release patterns and strategies that may provide more favorable temperature conditions throughout the Columbia and Snake rivers. The Corps' initial scoping effort is being funded through FY 10. The Corps is positioned to seek appropriations and accomplish model development beginning in FY 2012.

ii. In response to a newly developed temperature TMDL for the Pend Oreille River, from Lake Pend Oreille in Idaho to the Canadian border, the Corps conducted a three year temperature study of the Pend Oreille River and Lake Pend Oreille to provide temperature information for the development of a CE-QUAL-W2 temperature model. The Idaho portion of the model for the Pend Oreille River was developed by Portland State University, working together with the Idaho Department of Environmental Quality (IDEQ), the Washington Department of Ecology (WDOE), and the Environmental Protection Agency (EPA).

iii. The Corps conducted a surface water temperature study in the Columbia River above and below Chief Joseph Dam during 2003. The purpose of the study was to collect baseline temperature data to determine the temporal and spatial gradients in water temperature in the Columbia River upstream and downstream of Chief Joseph Dam. Baseline temperature data will allow the Corps to share data and work together with other state and federal agencies to develop a more comprehensive Columbia River temperature TMDL. In addition, baseline temperature data will help the Corps better define the relationship between Chief Joseph Dam operations and the water temperatures in the Columbia River.

iv. The Corps also conducted a forebay water temperature profile study at Libby Dam from 2002 to 2004. The purpose of the study was to collect baseline temperature data to determine the temporal and spatial gradients in water temperature in the forebay at Libby Dam. Accurate water temperature profile data are important for Libby Dam operations to improve downstream river temperatures that are suitable for aquatic biota and to aid in the successful recruitment of sturgeon.

II. FCRPS Project Operations and Water Temperature Management Activities

The Action Agencies implement a variety of measures to address temperature conditions in day-to-day operations, many of which are included in the 2008 BiOp. These include fish passage actions such as spill for fish passage, use of spillway weirs, juvenile bypass systems, and juvenile transportation - all of which reduce juvenile migration time and reduce exposure to warmer river temperatures.

In addition to fish passage at the dams, storage reservoirs are operated to enhance fish survival by augmenting river flows to help juvenile migration and adult spawning, and to cool water temperatures. Also, mainstem projects in the lower Snake River are operated at “minimum operating pool” (MOP), and John Day Dam is operated between elevation 262.5 and 265 in order to reduce juvenile travel time and help reduce water temperatures by reducing the cross-section of the reservoir (RPA Action 5).

The Corps prepares the annual Fish Passage Plan[4], which includes criteria and describes operational procedures and methods to reduce fish exposure to high temperatures when present in the river.

Examples of established operational procedures to address temperature are listed below:

A. In-Season Management

Throughout the migration season, conditions are monitored and adjustments are made to project operations to address temperature issues. This process occurs in the regional sovereigns' Technical Management Team (TMT). The TMT assesses current river and migration conditions and recommends operations in response to these conditions. For instance, annually the TMT recommends the timing of releases from Dworshak to assist in moderating temperatures in the lower Snake River. Another example, in response to an increase in the temperature gradient at McNary Dam resulting in fish mortalities, using temperature monitoring capability, the TMT developed an alternative spill operation that improved fish survival conditions until the temperature gradient weakened to acceptable levels.

B. Flow Augmentation

Flow augmentation assists with temperature management through the addition of cool water in the river and by increasing flows, which reduces travel time. Federal storage projects such as Dworshak, Libby, Albeni Falls, Grand Coulee, Hungry Horse, Banks Lake, and Reclamations' upper Snake River projects all are operated for flow augmentation. Flow augmentation release strategies for several of these projects consider water temperature conditions. (e.g. Dworshak, Libby, Albeni Falls, and the Upper Snake projects). In addition to the flow augmentation provided by the projects noted above, an agreement with Canada for 1 MAF of non-treaty storage for flow augmentation is sought annually (RPA Action 10).

Dworshak Operations - The 2008 BiOp calls for cold-water releases from Dworshak reservoir in July and August with the objective of maintaining Lower Granite tailwater temperatures at or below 68 ºF (RPA Action 4). These releases serve to increase flows and reduce travel time through the lower Snake River projects; and, enhance migration conditions by reducing the risk of disease for juvenile migrants. Dworshak Dam is equipped with selector gates, which can move vertically and draw water from varying elevations in the reservoir allowing operators to manage the temperatures of the project releases.

One of the purposes for releasing stored cool water from Dworshak Dam during the summer is to reduce water temperatures in the lower Snake River for returning adults. Complex mixing of Clearwater and warmer Snake River water masses results in vertical and lateral temperature gradients below the confluence of these two rivers and persists into the Lower Granite reservoir. These gradients represent variation in the thermal environment from which adult salmonids may

[4] 2010 Fish Passage Plan: http://www.nwd-wc.usace.army.mil/tmt/documents/fpp/2010/

potentially select to regulate body temperature during upstream migration (behavioral thermoregulation). Studies in 2001, 2002, and 2004 using Chinook and steelhead tagged with acoustic Multiple Array Processor (MAP) tags which indicated fish position and transmitted temperatures and depths of fish, supported the hypothesis that upstream migrating adults use the cool water released from Dworshak Reservoir and that these releases reduce thermal stress during warm summer months.

The management of the flows and water temperatures from Dworshak reservoir is coordinated with the Nez Perce Tribe and TMT. The Corps' objective is to ensure that a sufficient quantity of water is maintained through mid-September and provide information on what outflow water temperatures will be expected from various proposed operations. The Corps provides TMT with water temperature stratification data from the Dworshak reservoir, data concerning the amount of storage of cool water in the reservoir, temperatures of released water derived from the Dworshak tailwater fixed monitoring station (DWQI), and CE-QUAL-W2 temperature modeling results.

C. Project Operations: McNary Dam

During the summer, when all collected fish are transported, turbine operating priority at McNary changes to the north powerhouse loading to improve juvenile egress conditions, when recorded forebay temperatures reach 70° F. During times of elevated forebay temperatures (>70 ° F measured in the forebay) the project biologist, may recommend designating up to 5 turbine units to a higher priority of operation to even out water temperature differences within the juvenile collection channel and to spread out the tailrace flow to reduce back eddies for safer smolt egress and safer fish barge docking conditions.

D. Forecasting and Climate Change/Variability

The Action Agencies hold annual forecast performance reviews looking at in-place tools for seasonal volume forecasts and to report on the effectiveness of experimental or developing/emerging technologies and procedures. As new procedures and techniques become available and are identified to have significant potential for reducing forecast error and improve forecast reliability, the Action Agencies will discuss the implementation possibilities with regional interests. The purpose is to achieve upper rule curve elevations by reducing forecasts errors and thereby providing for improved spring flows.

The Action Agencies are working collaboratively with other agencies and research institutions to investigate the impacts of possible climate change scenarios to the Pacific Northwest and listed salmon and steelhead. Focus areas are: (1) modeling the hydrology and operations of the Columbia River system using possible future climate change scenarios; (2) investigating possible adaptation strategies for the system; (3) monitoring the hydrologic system for trends, cycles, and changes; and, (4) staying abreast of research and studies that address climate cycles, trends, and modeling. (RPA Action 7)

III. Temperature Effects on Adult Passage

The Corps has evaluated adult passage through the hydrosystem for several decades. In the last 15 years, improved research techniques and technology have provided a better understanding of the hydrosystem operational effects on adult salmonid dam passage timing, distribution, behavior, and physiology. Reports are available to be downloaded from the Corps Portland District[5], the Corps Walla Walla District[6] and from the University of Idaho[7].

The relationship of water temperature exposure to survival, passage times, and spawning success has been one of the focus areas of this research. Systemwide tracking of fish tagged with temperature archiving tags have helped us determine the use and location of thermal refugia in the FCRPS. Overall, adult passage survival at the mainstem dams on the Lower Snake and Columbia rivers remains high with system survival through the FCRPS near or surpassing the 2008 FCRPS BIOP standards since 2002.

From 1996 to 2002, upstream migration rates were determined for more than 12,000 radio-tagged adult spring–summer and fall Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*) past Columbia and Snake River dams, reservoirs, and longer hydrosystem reaches that included multiple dams and reservoirs. Passage rates were also calculated for 1,800 spring–summer Chinook salmon as they passed through 12 unimpounded reaches and tributaries. Most radio-tagged fish (90% or more) from all runs passed individual mainstem Columbia and Snake River dams in 24 to 48 hours. Migration behavior in reservoirs and through multiple dam/reservoir reaches varied substantially within and between years and between species. Within years, spring–summer Chinook salmon migrated more rapidly as water temperature increased; between years, spring–summer Chinook salmon migrated quickly in low-discharge years and slowly in high-discharge years. Steelhead migrations slowed dramatically when summer water temperatures peaked within each year, then increased as rivers cooled in fall. Mean summer temperatures explained more between-year variation in steelhead passage rates than did differences in discharge. Fall Chinook salmon also slowed migration through the mainstem Columbia River during warm water periods.

Adult salmonids migrating through the Columbia-Snake River hydrosystem, as well as the historic free running river, experience some amount of time with body temperatures widely considered to be physiologically stressful, even in years with moderate river temperatures. Researchers found evidence that some Chinook salmon (*O. tshawytscha*) and steelhead (*O. mykiss*) will slow migration and postpone entry into the Snake River during warm water conditions and will pass dams later, on average, in years when mean summer-time water temperatures are high. Prior to impoundment, water temperatures in the Snake River were also high in mid to late summer, often exceeding 20 ºC. Currently, similar or slightly higher

[5] http://www.nwp.usace.army.mil/pm/e/afep_docs.asp
[6] http://www.nww.usace.army.mil/planning/ep/fishres/research-reports.htm
[7] http://www.cnr.uidaho.edu/uiferl/Reports.htm#Technical_Reports

maximum temperatures occur during the summer and persist somewhat longer into the fall than historically on the lower Snake River.

Higher temperature exposure of migrating adults varies greatly by species. In a study using data storage tags in 2000 and 2002, spring Chinook had only a mean 2% percentage exposure time to temperatures above 20 ºC while summer Chinook and steelhead exposure time was 20-22% and 45% for fall Chinook. Three years of evaluations in the South Fork Salmon River in Idaho found the lowest spawning success in summer Chinook (29-36%) during years with high temperatures in the spawning areas (9-12 days of exposure to temperature > 20 ºC) and higher spawner density. No relationship between spawning success and the number of high temperature days at LGR was found but sample sizes were limited.

During the summer months, primarily July and August, fish ladders have been identified as areas where adult migrants encounter warm temperatures. Body temperatures of salmon and steelhead outfitted with archival temperature sensors were warmest during fish ladder passage compared to tailrace and reservoir passage at lower Columbia and Snake River dams. As water temperatures exceed 20°C fish tended to have longer passage times through ladders, backed out of ladders into the tailrace more often, and increased passage during the early morning hours. In addition to the effects of warm temperatures per se, thermal gradients in fish ladders have been associated with slowed migration. These differential temperatures can exceed 1-2°C during fish passage events at most FCRPS but the majority of each run for all species pass when temperature differences between the top and bottom of the ladders are from 0-1°C. At Lower Granite Dam temperature differentials have reached as high as 4°C during which time few fish pass.

Current studies of adult passage are focused primarily on evaluating the effects on adult passage from specific modifications to structures or operations. These vary from evaluating how a new spill pattern or spillway structure, such as The Dalles Dam spillwall, affect passage time and distribution of passage to evaluating how overwintering steelhead and steelhead kelts use surface passage routes in December and March.

Starting in 2010, pilot studies of adult transportation of Snake River Sockeye salmon from Lower Granite Dam to Idaho, are being undertaken to determine the feasibility of transport as a means of ensuring spawning stock reaches hatcheries during years of low returns. Long term reconditioning of wild female steelhead kelts is one of the options and areas of evaluation in development of the kelt management plan. Such programs would ensure that some level of high quality reproductive female steelhead would reach spawning grounds even if river conditions were challenging for migrating fish.

The Corps' existing adult passage monitoring program includes window counting at all ladders at all dams, PIT tag detection systems, and regular inspections of fishways. These actions are used to keep track of any problems that may arise with adult passage in relationship to changes in river conditions, dam operations, or emergencies situations. Any unexpected changes in passage patterns are immediately brought to the regional forums (FPOM, TMT) and appropriate actions are taken.

IV. Climate Change Long-term Planning

One of the most important climate related actions that the Action Agencies are currently implementing is the climate and hydrology dataset development study. This effort will help incorporate climate change considerations into the long term Columbia Basin hydrology planning studies.

A. Columbia-Snake River Basin

In 2008 the Corps, BPA, and Reclamation recognized the need to incorporate climate change into long-term planning studies. The Action Agencies have initiated a collaborative study to develop a climate change and hydrology dataset for their longer-term planning activities in the Columbia-Snake River Basin (CSRB). The agencies agreed on common data sets and a common approach to doing studies. In addition to these data, the Action Agencies also worked together to adopt a set of methods for incorporating these data into long-term planning activities. As part of this overall project, the three agencies have met with outside agencies, including NOAA Fisheries, NW Power and Conservation Council, USFWS, and CRITFC, at periodic workshops to discuss and coordinate work, provide status reports, share results, and discuss issues and decisions throughout the entire process. The Study will:

- Leverage the ongoing University of Washington Climate Impacts Group (UW CIG) effort to develop regional climate and hydrologic datasets reflective of the latest Intergovernmental Panel on Climate Change (IPCC) modeling at all key points in the FCRPS.
- Utilize limited sections of two information types (Hybrid-Delta and Transient climate projection data) from the larger ensemble of scenarios and projections being issued by UW CIG. Hybrid-Delta data includes information that reflects step-change in climate and hydrology from historical to future periods and the Transient data includes information that reflects time-developing climate and hydrology conditions through historical and future periods. The purpose of considering both types is to gain understanding on which type is more appropriate for a given type of longer-term planning effort.
- Verify the data received from UW CIG through an independent hydrologic modeling performed by USBR staff, and thereby enable agencies technical staff to develop a firmer understanding on UW CIG data development procedures and information limitations.
- Demonstrate the ability to model climate change through various reservoir regulation models and tools.

Seven deliverables from the study include:

1. Select monthly climate change scenarios (Hybrid-Delta data type; 12 scenarios) and time-developing climate projections (Transient data type; 6 scenarios).
2. Selection and verification of daily weather inputs for hydrologic modeling (both data types)
3. Verification of hydrologic modeling results (natural streamflow, snowpack)
4. Adjusted streamflows for reservoir systems modeling
5. Adjusted seasonal runoff volume forecasts for reservoir systems modeling
6. Adjusted reservoir storage targets for flood control and operating rule curves consistent with adjusted inflows and seasonal runoff volume forecasts
7. Demonstration study on reservoir systems analysis using inputs associated with Hybrid-Delta and/or Transient style approaches

It is anticipated that the Action Agencies will incorporate the datasets from this effort into other planning studies such as the Columbia River Treaty 2014/2024 Review, ESA consultations, and NEPA analyses. The datasets and analysis will also be available for use by other agencies throughout the region. A joint report documenting the project is to be completed by late September.

B. West-wide Risk Assessment of Climate Change Impacts on Water Resources

Reclamation is embarking on a multi-year risk assessment of climate change impacts to water supply and demand to meet Secure Water Act requirements; the Columbia Basin is included in this effort. The West-wide risk assessment consists of five main activities:

- Development of a consistent set of downscaled climate projections
- Projections of water supplies
- Projections of water demands
- Operational risk assessments
- Assessments of aquatic ecosystem response

Although this effort is just beginning it should produce useful information for the region that can be used to track the impact of climate change on water resources.

Appendix F

Climate Change – RPA and Other Program Habitat Implementation

U.S. Army Corps of Engineers

Bureau of Reclamation

Bonneville Power administration

Chapter 8.1.3 of the 2008 FCRPS Biological Opinion provides a review of the ISAB's recommendations for mitigating the effects of climate change (ISAB 2007a). The BiOp's RPA incorporates many of the ISAB's recommendations, including its recommendations for mitigating climate change impacts in the tributaries and estuary of the Columbia River. Indeed, the ISAB recognized that there is considerable overlap between their habitat recommendations and projects implemented through the Northwest Power and Conservation Council's and BPA's Fish and Wildlife Program, which includes RPA and Fish Accord actions implemented by BPA.

The ISAB's recommendations for mitigating climate change impacts in the tributaries and estuary included the following actions:

- Temperature increases in some tributaries may be minimized by implementing measures to retain shade along stream channels and augment summer flow. Adequate protection or restoration of riparian buffers along streams is the most effective method of providing summer shade. This action will be most effective in headwater tributaries where shading is crucial for maintaining cool water temperatures. Expanding efforts to protect riparian areas from grazing, logging, development, or other activities that could impact riparian vegetation will help reduce water temperature increases.
- Removing barriers to fish passage into thermal refugia also should be a high priority.
- Managing water withdrawals to maintain as high a summer flow as possible could help alleviate both elevated temperatures and low stream flows during summer and autumn.
- Protecting and restoring wetlands, floodplains, or other landscape features that store water also will provide some mitigation for declining summer flow as the climate warms.
- Removal of dikes to open backwater, slough and other off-channel habitats along mainstem reservoirs and the estuary can increase flow through these areas and may encourage increased hyporheic flow. Increasing the proportion of flow that is

transported below the surface of the river bed or riparian area can substantially cool the water and has been shown to be an important mechanism for the formation of cool water refugia.

The Action Agencies are implementing an array of projects in the tributaries and estuary that are consistent with these recommendations and could mitigate for future climate change impacts. Included among these actions are projects under RPA Action 34 to acquire or protect instream water flows, enhance riparian habitat, remove barriers to fish passage into areas that may provide refuge from higher water temperatures, and restore wetlands and floodplains. There are also significant efforts underway that remove or set back dikes along some tributaries and connect side channels; these actions are likely to improve riparian condition in some areas. Actions under RPAs 36 and 37 will improve and protect estuary habitat by removing dikes to open backwater, slough and other off-channel habitats, acquire and restore mainstem and side-channel habitat, and protect and restore riparian and wetland areas.

RPA 35 requires the Action Agencies to prioritize their tributary habitat efforts based on the biological needs of listed fish populations. Specific populations are identified for needed habitat and survival improvements. Table F-1 shows categories of projects implemented through 2009 benefitting the priority population identified in the RPA. Project categories such as “protect instream flows,” which includes acquisition and enhancement of summer flows in critical tributaries, “riparian acres improved and protected” are entirely consistent with ISAB recommendations. In addition to actions implemented under the RPA, BPA funds an extensive number of habitat protection and restoration projects under the Fish and Wildlife Program and the Fish Accords.

In 2008, the Action Agencies completed eight on-the-ground habitat projects in the estuary, with another three projects in the planning and development phase. One of the estuary habitat projects implemented by the Action Agencies in 2008 is the Willow Grove Acquisition and Restoration Project, which permanently protects 304 acres of intertidal wetland habitat adjacent to the Columbia River just downstream of Longview, Washington. The Willow Grove property has been altered by past land uses but represents an example of critical intertidal wetlands within this reach of the Columbia River. The wetlands provide important rearing habitat for juvenile salmon and will help to mitigate the future effects of climate change in the estuary.

In 2009 the Action Agencies implemented a number of projects in the estuary, including acquiring critical salmon habitat, the Elochoman acquisition, consisting of 182 acres which is composed of intertidal forest, tidal channels and a forested riparian shoreline. Restoration actions for this property are currently being designed and will be implemented in 2010-11. Another on-the-ground implementation project is the Grays River Restoration Project. This project increased instream salmon habitat quality and complexity to over a mile of the Grays River by increasing instream habitat diversity, channel stability and riparian integrity in the critical response reach upstream and adjacent to salmon spawning areas utilized by listed salmon.

Under the BiOp's RPA, the Action Agencies are using an expert panel process to evaluate tributary and estuary habitat projects and estimate the associated survival improvements. The expert panel process for 2010-2012 tributary habitat projects has been completed and projects for that period have been selected. The estuary expert panel has reviewed and assessed projects for 2010 and is in the process of reviewing projects for 2011. Unfortunately, there is little information presently available on likely climate change-induced biological impacts at a watershed or sub-basin scale in the Interior Columbia River basin. However, as noted in this chapter, aggressive efforts are underway to model these impacts for the listed ESUs in the Interior Columbia. For example, USGS is using a decision analysis model to work with stakeholders in the Yakima and Methow Basins as a demonstration project to identify resource management options under climate change scenarios. This decision analysis model will incorporate data from the Methow habitat effectiveness RME/IMW work and will help inform future habitat project selection, especially with respect to climate impacts. It is anticipated that results from this and other work will be available for consideration during the 2012 expert panel process and enable the Action Agencies to refine and better target their efforts at future climate impacts.

The full effects of climate change are unlikely to be realized during the period covered by this BiOp (the term of this BiOp expires in 2018). As those effects become more evident, the periodic updates and assessments under the BiOp's expert panel process will be able to respond to changing conditions and mitigate for new or more extreme climate-induced limiting factors. It will also be able to incorporate updated information from NOAA's recovery planning process as that becomes available. This flexibility in project selection will allow the Action Agencies to address specific, localized climate impacts. This is one important aspect of the BiOp's adaptive management framework.

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Table F-1: 2009 Action Agencies' Climate Change RPA and Other Program Habitat Implementation										
2009 Completed Metrics			Water Quantity	Entrainment	Passage		Channel Complexity	Water Quality Riparian Protection and Enhancement		
ESU-listed ESU/DPS	MPG	Population	CFS acquired or enhanced	# of screens addressed	# of barriers addressed	Stream miles opened	Stream miles improved	Stream miles protected	Riparian acres improved	Riparian acres protected
Snake River Spring/Summer-run Chinook Salmon ESU	Grande Ronde / Imnaha	Grande Ronde River upper mainstem			1	2.8	1		39	
		Lostine River	15				1.2		37.1	
	Lower Snake	Asotin Creek							11	
		Tucannon River						11.67		221.2
	South Fork Salmon River	East Fork South Fork Salmon River			3	15.63				
		Little Salmon River			1	5.3				
	Upper Salmon River	Lemhi River	31.4							
		Pahsimeroi River		2	1	1				
		Salmon River lower mainstem below Redfish Lake	3.23							
		Salmon River upper mainstem above Redfish Lake	7.97						2	
		Valley Creek		1	1	3				
Snake River Spring/Summer-run Chinook Salmon ESU Total			**57.6**	**3**	**12**	**36.73**	**4.22**	**11.67**	**248.4**	**221.2**

Upper Columbia River Spring-run Chinook Salmon ESU	Upper Columbia / East Slope Cascades	Entiat River	0.3						2	
		Methow River	34.64				0.75	0.54	32.3	42
		Wenatchee River			2				2.1	
Upper Columbia River Spring-run Chinook Salmon ESU Total			**34.94**		**2**		**0.75**	**0.54**	**36.4**	**42**
Middle Columbia River Steelhead DPS	Cascades Eastern Slope Tributaries	Deschutes River - eastside	2.28					3.76	156	57.8
		Deschutes River - westside							20	
		Fifteenmile Creek (winter run)	3.76					4.74		172.9
		Klickitat River			3	3.81				
	John Day River	John Day River lower mainstem tributaries			4	22.5		4.37	5	85.1
		John Day River upper mainstem	7.14		3	8.1		0.75	12	50
		Middle Fork John Day River			1	2.5	0.52	8	11.5	195
		North Fork John Day River						8.3	22	270
		South Fork John Day River			1	2.5		13.74	6	185
	Umatilla and Walla Walla River	Umatilla River	0.81				0.5		296.6	
		Walla Walla River	1.16		1					
	Yakima River Group	Naches River	3.58	1	1	0.5				
		Satus Creek			1	93		56		8062
		Toppenish						1.5		1
		Yakima River upper mainstem	10.5		4	14.5	0.08			
Middle Columbia River Steelhead DPS Total			**29.23**	**1**	**19**	**147.41**	**1.1**	**101.16**	**529.1**	**9078.8**

Snake River Basin Steelhead DPS	Clearwater River	Clearwater River lower mainstem					0.02		143.3	
		Lochsa River			1	1				
		Lolo Creek			3	6.5				
		South Fork Clearwater River			1	1.5	2		16	
	Grande Ronde River	Grande Ronde River upper mainstem			1	2.8	1		39	
		Joseph Creek			1	9.1			11	
		Wallowa River	15				1.2		37.1	
	Grande Ronde River Total				5	9	2.02		159.3	
	Lower Snake	Asotin Creek							119	
		Tucannon River						11.67		221.2
	Salmon River	East Fork Salmon River	2							
		Lemhi River	31.4							
		Little Salmon and Rapid River			1	5.3				
		Pahsimeroi River	1.23	2	1	1				
		Salmon River upper mainstem	7.97	1	1	3			2	
		South Fork Salmon River			3	15.63				
Snake River Basin Steelhead DPS Total			**57.6**	**3**	**13**	**45.83**	**4.22**	**11.67**	**367.4**	**221.2**
Upper Columbia River Steelhead DPS	Upper Columbia / East Slope Cascades	Entiat River	0.3						2	
		Methow River	34.64				0.75	0.54	32.3	42
		Okanogan River	30.1		4	14	0.15	0.55	13	3.5
		Wenatchee River			2				2.1	
Upper Columbia River Steelhead DPS Total			**65.04**		**6**	**14**	**0.9**	**1.09**	**49.4**	**45.5**

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Appendix G

The Columbia Basin Fish Accords

U.S. Army Corps of Engineers

Bureau of Reclamation

Bonneville Power Administration

The FCRPS Action Agencies entered into agreements with four Columbia Basin Tribes and the states of Idaho and Montana on May 2, 2008 for 10-year commitments to benefit fish, particularly Columbia River Basin salmon and steelhead stocks. These original "Fish Accords" were added to by an agreement between the Action Agencies and the Shoshone-Bannock Tribes on November 7, 2008 focused on salmon and steelhead stocks in the Snake River Basin. Then on September 16, 2009, the Action Agencies and the State of Washington entered into an agreement to enhance and accelerate habitat protection and restoration for salmon and steelhead in the Columbia River estuary. All of these agreements support and enhance implementation of the 2008 FCRPS BiOp by increasing the number of habitat projects specifically identified with their associated benefits, by securing funding, and by indentifying the entities that will implement projects.

The Fish Accords directly address certainty of implementation to achieve biological benefits. The habitat projects supported by the Accords represent a near doubling of the previous habitat program. The agreements (with the exception of the agreement with Montana) specify an expansive list of projects for implementation and funding for a 10 year period to help meet performance requirements of the BiOp. Some agreements (e.g. State of Idaho, 3 Treaty Tribe, Colville, etc.) also specify a number of projects to benefit listed salmon and steelhead that are above and beyond the population-specific biological benefits called for in RPA Action 35, Table 5, of the BiOp and evaluated in the Supplemental Comprehensive Analysis. The Parties to the Fish Accords believed that in negotiating the agreements it was important to specify biological benefits for actions being taken to improve salmon and steelhead habitat. The Parties made these assessments using the methodology developed in the remand collaboration based on the best available science information and based on their professional knowledge of the habitat in their respective implementation areas. As noted in the AMIP, all Accord habitat projects that occur in areas where the RPA Action 35 expert panels are convened will be reviewed by the panels to confirm habitat improvements and survival estimates. In addition, all Accord habitat projects will undergo scientific review by the Independent Scientific Review Panel.

The following populations are expected to benefit from Accord tributary habitat actions that exceed those called for in RPA Action 35 Table 5 of the BiOp.

Mid-Columbia River Steelhead DPS

All populations in this DPS with the exception of Touchet River steelhead

Snake River Steelhead DPS

The Upper Grande Ronde River steelhead population

Snake River Spring/Summer Chinook Salmon ESU

The Upper Grande Ronde River and Lemhi River spring Chinook salmon populations

Upper Columbia River Spring Chinook Salmon ESU

The Wenatchee spring Chinook salmon population

Upper Columbia River Steelhead DPS

The Entiat River, Wenatchee River and Okanogan River steelhead populations

The focus of habitat project selection and implementation in the Accords is treatment of limiting factors that demonstrably improve salmon and steelhead survival and are based on recovery plans. This approach is supported by extensive research, monitoring and evaluation to confirm estimates of biological benefit and allow mid-course adjustments through the adaptive management process resulting in a disciplined process of informed and accountable implementation.

The Action Agencies have recently completed the expert panel process to select habitat projects for the upcoming implementation period under the BiOp. Accord projects proposed for implementation in these areas were presented by the Accord party and reviewed by the expert panel[8]. Projects were reviewed for their treatment of limiting factors and biological benefits and estimates were confirmed. In addition, implementation that occurred in the ’07 to ’09 period was reviewed to confirm whether actions were implemented as planned and projected benefits were being realized. Research, monitoring and evaluation results were considered in this process to ensure that projects implemented in the next period could be informed by the results of relevant RM&E. The 2010 – 2012 portfolio of projects are identified in the Action Agencies’ draft Implementation Plan recently released to the RIOG for review.

[8] Those that were not ready for review but will be implemented during the 2010-2012 period were noted and will receive review in the next expert panel process scheduled for 2012.