Supplemental Comprehensive Analysis of the Federal Columbia River Power System and Mainstem Effects of the Upper Snake and other Tributary Actions

NOAA Fisheries

May 5, 2008

Table of Contents

1 SUPPLEMENTAL COMPREHENSIVE ANALYSIS - PURPOSE & USE 1-3

2 PROSPECTIVE ACTIONS.....2-3

3 COMPREHENSIVE ACTION AREA.....3-3

4 SPECIES & CRITICAL HABITAT AFFECTED.....4-3
4.1 Species Affected by the Prospective Actions 4-3
4.2 Rangewide Status of Designated Critical Habitat.....4-5
4.2.1 Designated Critical Habitat for Columbia Basin Salmon and Steelhead.....4-5
4.2.2 Designated Critical Habitat for Southern Resident Killer Whales 4-8
4.2.3 Designated Critical Habitat for Green Sturgeon.....4-8
4.3 Endangered Species Act Recovery Planning.....4-8

5 ENVIRONMENTAL BASELINE.....5-3
5.1 Hydro Effects.....5-4
5.1.1 Blocked Habitat 5-4
5.1.2 Mainstem Habitats & the Migratory Corridor 5-6
5.1.3 Mainstem Hydrologic Conditions.....5-13
5.1.4 Mainstem Water Quality.....5-19
5.2 Tributary Habitat Effects 5-26
5.2.1 Indirect Effects of Hydrosystem Mortality on Nutrients in Tributaries 5-27
5.3 Estuary & Plume Habitat Effects.....5-28
5.3.1 Columbia River Estuary.....5-28
5.3.2 Columbia River Plume.....5-29
5.4 Predation & Disease Effects 5-29
5.4.1 Predation 5-29
5.4.2 Disease 5-34
5.5 Hatchery Effects.....5-37
5.6 Harvest Effects.....5-40
5.6.1 Species Effects of Harvest under the Environmental Baseline.....5-42
5.7 Large-scale Environmental Variation.....5-59
5.7.1 The Southern Oscillation Index, El Niño & La Niña.....5-60
5.7.2 PDO.....5-62
5.7.3 Global Climate Change.....5-63

6 CUMULATIVE EFFECTS 6-3

7 ANALYTICAL METHODS FOR SALMONIDS 7-3
7.1 Life-cycle analyses to evaluate whether populations are likely to have a sufficiently low short-term extinction risk and are likely to trend toward recovery 7-6
7.1.1 Population-level quantitative analytical methods for six interior Columbia Basin species 7-6

7.1.2 Population-Level Qualitative Analytical Methods for all Thirteen Interior Columbia Basin Species 7-33
7.2 Life-stage & Action-Specific Analyses to Support the Life-Cycle Analysis and to Estimate Incidental Take 7-38
7.2.1 Hydro Methods 7-38
7.2.2 Tributary Habitat Analysis Methods 7-44
7.2.3 Estuary Habitat Analysis Methods 7-47
7.2.4 Hatchery Methods 7-47
7.2.5 Predation Methods 7-49
7.2.6 Methods for Evaluating the Effect of RM&E Actions 7-50
7.3 Methods for Considering Population Level Analysis at ESU/DPS level 7-50
7.4 Critical habitat analysis methods 7-52

8 EFFECTS ANALYSIS FOR SALMONIDS 8-3
8.1 General Considerations for Multiple ESUs 8-3
8.1.1 Juvenile Migrant Survival Improvement Strategies 8-3
8.1.2 Adult Migrant Survival Effects 8-15
8.1.3 Climate Change Considerations 8-17
8.1.3 Effects of Prospective Research and Monitoring Actions 8-23
8.1.4 Effect of Hatchery Programs 8-35

8.2 SNAKE RIVER FALL CHINOOK SALMON 8.2-3
8.2.2 Current Rangewide Status 8.2-5
8.2.3 Environmental Baseline 8.2-9
8.2.4 Cumulative Effects 8.2-17
8.2.5 Effects of the Prospective Actions 8.2-17
8.2.6 Aggregate Effect of the Environmental Baseline, Prospective Actions & Cumulative Effects, Summarized By Major Population Group 8.2-26
8.2.7 Aggregate Effect of the Environmental Baseline, Prospective Actions & Cumulative Effects on the Snake River Fall Chinook ESU 8.2-26

8.3 SNAKE RIVER SPRING/SUMMER CHINOOK SALMON 8.3-3
8.3.2 Current Rangewide Status 8.3-5
8.3.3 Environmental Baseline 8.3-9
8.3.4 Cumulative Effects 8.3-17
8.3.5 Effects of the Prospective Actions 8.3-18
8.3.6 Aggregate Effect of the Environmental Baseline, Prospective Actions & Cumulative Effects, Summarized By Major Population Group 8.3-28
8.3.7 Aggregate Effect of the Environmental Baseline, Prospective Actions & Cumulative Effects on the Snake River Spring/Summer Chinook Salmon ESU 8.3-40

8.4 SNAKE RIVER SOCKEYE SALMON 8.4-3
8.4.2 Current Rangewide Status 8.4-5
8.4.3 Environmental Baseline 8.4-9
8.4.4 Cumulative Effects 8.4-15

8.4.5 Effects of the Prospective Actions 8.4-16
8.4.6 Aggregate Effect of the Environmental Baseline, Prospective Actions, and Cumulative Effects on Snake River Sockeye 8.4-20

8.5 SNAKE RIVER STEELHEAD 8.5-3
8.5.2 Current Rangewide Status 8.5-5
8.5.3 Environmental Baseline 8.5-8
8.5.4 Cumulative Effects 8.5-18
8.5.5 Effects of the Prospective Actions 8.5-19
8.5.6 Aggregate Effect of the Environmental Baseline, Prospective Actions & Cumulative Effects, Summarized by Major Population Group 8.5-32
8.5.7 Aggregate Effect of the Environmental Baseline, Prospective Actions & Cumulative Effects on the Snake River Steelhead DPS 8.5-43

8.6 UPPER COLUMBIA RIVER SPRING CHINOOK SALMON 8.6-3
8.6.2 Current Rangewide Status 8.6-4
8.6.3 Environmental Baseline 8.6-7
8.6.4 Cumulative Effects 8.6-16
8.6.5 Effects of the Prospective Actions 8.6-18
8.6.6 Aggregate Effect of the Environmental Baseline, Prospective Actions & Cumulative Effects, Summarized by Major Population Group 8.6-26
8.6.7 Aggregate Effect of the Environmental Baseline, Prospective Actions & Cumulative Effects on the Upper Columbia River Spring Chinook ESU 8.6-27

8.7 UPPER COLUMBIA RIVER STEELHEAD 8.7-3
8.7.2 Current Rangewide Status 8.7-5
8.7.3 Environmental Baseline 8.7-9
8.7.4 Cumulative Effects 8.7-21
8.7.5 Effects of the Prospective Actions 8.7-22
8.7.6 Aggregate Effect of the Environmental Baseline, Prospective Actions, & Cumulative Effects, Summarized By Major Population Group 8.7-35
8.7.7 Aggregate Effect of the Environmental Baseline, Prospective Actions, & Cumulative Effects on the Upper Columbia River Steelhead DPS 8.7-36

8.8 MIDDLE COLUMBIA RIVER STEELHEAD 8.8-3
8.8.2 Current Rangewide Status 8.8-5
8.8.3 Environmental Baseline 8.8-8
8.8.4 Cumulative Effects 8.8-18
8.8.5 Effects of the Prospective Actions 8.8-19
8.8.6 Aggregate Effect of the Environmental Baseline, Prospective Actions & Cumulative Effects, Summarized By Major Population Group 8.8-32
8.8.7 Aggregate Effect of the Environmental Baseline, Prospective Actions & Cumulative Effects on the Middle Columbia River Steelhead DPS 8.8-41

8.9 COLUMBIA RIVER CHUM SALMON 8.9-3
8.9.2 Current Rangewide Status 8.9-4

8.9.3 Environmental Baseline 8.9-10
8.9.4 Cumulative Effects 8.9-17
8.9.5 Effects of the Prospective Actions 8.9-18
8.9.6 Aggregate Effect of the Environmental Baseline, Prospective Actions & Cumulative Effects on Columbia River Chum Salmon 8.9-22

8.10 LOWER COLUMBIA RIVER CHINOOK SALMON 8.10-5
8.10.2 Current Rangewide Status 8.10-7
8.10.3 Environmental Baseline 8.10-28
8.10.4 Cumulative Effects 8.10-42
8.10.5 Effects of the Prospective Actions 8.10-43
8.10.6 Aggregate Effect of the Environmental Baseline, Prospective Actions & Cumulative Effects on Lower Columbia River Chinook Salmon & Critical Habitat 8.10-49

8.11 LOWER COLUMBIA RIVER COHO SALMON 8.11-3
8.11.2 Current Rangewide Status 8.11-5
8.11.3 Environmental Baseline 8.11-28
8.11.4 Cumulative Effects 8.11-36
8.11.5 Effects of the Prospective Actions 8.11-37
8.11.6 Aggregate Effect of the Environmental Baseline, Prospective Actions & Cumulative Effects on Lower Columbia River Coho Salmon 8.11-43

8.12 LOWER COLUMBIA RIVER STEELHEAD 8.12-5
8.12.2 Current Rangewide Status 8.12-7
8.12.3 Environmental Baseline 8.12-15
8.12.4 Cumulative Effects 8.12-24
8.12.5 Effects of the Prospective Actions 8.12-25
8.12.6 Aggregate Effects of the Environmental Baseline, Prospective Actions & Cumulative Effects on Lower Columbia River Steelhead DPS 8.12-30

8.13 UPPER WILLAMETTE RIVER CHINOOK SALMON 8.13-3
8.13.2 Current Rangewide Status 8.13-5
8.13.3 Environmental Baseline 8.13-13
8.13.4 Cumulative Effects 8.13-17
8.13.5 Effects of the Prospective Actions 8.13-18
8.13.6 Aggregate Effect of the Environmental Baseline, Prospective Actions & Cumulative Effects on Upper Willamette River Chinook Salmon 8.13-21

8.14 UPPER WILLAMETTE RIVER STEELHEAD 8.14-3
8.14.2 Current Rangewide Status 8.14-5
8.14.3 Environmental Baseline 8.14-11
8.14.4 Cumulative Effects 8.14-17

8.14.5 Effects of the Prospective Actions 8.14-18
8.14.6 Aggregate Effect of the Environmental Baseline, Prospective Actions, and Cumulative Effects on Upper Willamette River Steelhead 8.14-20

9 SOUTHERN RESIDENT KILLER WHALES 9-3
9.1 Current Rangewide Status 9-3
9.1.2 Listing status 9-4
9.1.3 Range and Distribution 9-5
9.1.4 Life history 9-7
9.2 Environmental Baseline 9-9
9.3 Effects of the Prospective Actions on Southern Resident Killer Whales 9-14
9.3.1 Effects of Hydro and Associated Actions on Southern Resident Killer Whales 9-15
9.3.2 Effects of Harvest Actions on Southern Resident Killer Whales 9-19
9.4 Cumulative Effects 9-21

10 GREEN STURGEON OF THE SOUTHERN DPS 10-3
10.1 Status of the Species 10-3
10.1.1 Listing 10-3
10.1.2 Life history 10-3
10.1.3 Status/Population Trend 10-4
10.1.4 Key Limiting Factors for Green Sturgeon 10-4
10.1.5 Harvest Effects 10-4
10.2 Effects of the Prospective Actions 10-7
10.2.1 Effect of Prospective Harvest 10-7
10.2.2 Hydrosystem Effects 10-7

11 MEMORANDA OF AGREEMENT 11-3

11.1 Effects of the Memoranda of Agreement with Tribes and States 11-3

12 LITERATURE CITED 12-3

Appendices

Appendix A Adult Survival Estimates

Appendix B Aggregate Analysis

Appendix C Artificial Propagation for Pacific Salmon

Appendix D Hatchery Effects Report.

Appendix E Hydro Modeling

Appendix F Inriver Juvenile Survival

Appendix G Marine Mammals

Appendix H Quantitative Analysis of Harvest Actions

Appendix I Quantitative Analysis of Hatchery Actions

Appendix J Snake River Steelhead Kelt

Appendix K West Coast River Survival

Table of Tables

Table 4.2.1-1 PCEs identified for SR Sockeye, spring/summer Chinook, and fall Chinook Salmon 4-5

Table 4.2-2 Factors considered by Columbia Basin CHARTs to determine the conservation value of occupied HUC-5s. 4-7

Table 4.3-2. Status of Columbia Basin Recovery Plans 4-16

Table 5.1.2-1 Migration rates (km/day) of juvenile SR spring-summer Chinook salmon and steelhead through free flowing and impounded sections of the Snake and Columbia Rivers under low, medium, and high flow conditions. 5-7

Table 5.1-1 Estimated combined annual percentage of the non-tagged yearling Chinook salmon and steelhead populations transported from Lower Granite, Little Goose, Lower Monumental, and McNary dams. 5-12

Table 5.1-2 Snake and Columbia River flow objectives for operating the FCRPS since 1995. 5-15

Table 5.1-3 Average flow reduction effects of Reclamation's irrigation projects in the Columbia basin (in cfs) 5-17

Table 5.1-4 Summary of Potential Thermal Effects to Salmonids in the Columbia Basin. (Source: EPA 2003) 5-22

Table 5.1-5. Summary of the EPA Water Temperature Guidelines and Potential Effects to Salmon. 5-23

Table 5.4-1. Fish diseases known from the Columbia Basin showing increases in infectivity and virulence with increasing water temperature. 5-35

Table 5.6-1 Incidental take limits and expected incidental take (as proportion of total run size) of listed salmonids for non-Indian and treaty Indian fisheries under the 2005-07 Interim Management Agreement (table and associated footnotes taken from the Biological Opinion on the Interim Agreement. 5-41

Table 5.6.1-1 Harvest rates of A-run steelhead in spring, summer, and fall season fisheries expressed as a proportion of the Skamania and A-run steelhead run size. 5-49

Table 5.6.1-2 Harvest rates of B-run steelhead in treaty Indian fisheries and non-Treaty fisheries expressed as a proportion of the B-run index steelhead run size. 5-50

Table 5.6.1-3 Non-Indian harvest rates of winter-run steelhead expressed as a proportion of the total winter-run steelhead run size (TAC 2008). 5-51

Table 5.6.1-4. Treaty Indian harvest rates of winter-run steelhead expressed as a proportion of the unmarked winter-run steelhead counts at Bonneville Dam in the winter season. 5-52

Table 5.6.1-5 Non-Indian harvest rates for summer-run populations of the LCR steelhead DPS. 5-52

Table 5.6.1-6 Expected average incidental take of natural-origin steelhead associated with prospective tribal tributary fisheries. 5-53

Table 5.6.1-7. Total adult equivalent exploitation rates for the Cowlitz spring Chinook population (as an example of exploitation rates for LCR spring Chinook). 5-54

Table 5.6.1-8. Total adult equivalent exploitation rate for the North Fork Lewis bright Chinook population 5-55

Table 5.6.1-9. Total adult equivalent exploitation rates for LCR tule populations. 5-57

Table 5.6.1-10 Estimated Ocean (all marine area fisheries) and In-river Exploitation Rates on Lower Columbia River Natural Coho, 1970-2006. 5-58

Table 7.4-1 Key analytical assumptions for the life-cycle analysis, characterized by their effect on conclusions. 7-31

Table 7.1.2.1-1 Measures recommended by ISAB to mitigate the anticipated adverse effects of climate change on Columbia basin salmon and steelhead. 7-34

Table 8.2.5.5-1 Abundance-based harvest rate schedule for SR fall Chinook. 8.2-23

Table 8.2.5.5-2 Observed harvest rate on SR fall Chinook compared to the maximum allowable harvest rate limit. 8.2-24

Table 8.2.2-1 Status of SR fall Chinook salmon with respect to abundance and productivity VSP factors. Productivity is estimated using two base time periods, as described in Section 8.2.3. 8.2-33

Table 8.2.2-2 Status of SR fall Chinook salmon with respect to spatial structure and diversity VSP factors. 8.2-34

Table 8.2.2-3 Status of SR fall Chinook salmon with respect to extinction risk. Short-term (24-year) extinction risk is estimated from performance during the

"base period" of the 20 most recent brood years (approximately 1980 BY – 1999 BY).. ..... 8.2-34

Table 8.2.2-4 Changes in density-independent survival ("gaps") necessary for indices of productivity to equal 1.0 and estimates of extinction risk no higher than 5% for SR fall Chinook salmon. Survival changes would need to be greater than these estimates for trend or productivity to be greater than 1.0. Estimated "gaps" are based on population performance during the "base period" of approximately the last 20 brood years or spawning years. Factors greater than 1.0 indicate a need for higher survival (e.g., 1.225 indicates that a 22.5% proportional increase in survival is necessary for productivity or trend to equal 1.0); 1.0 indicates no change; and numbers less than 1.0 indicate that additional changes in survival are not necessary for productivity or trend equal to 1.0 and extinction risk to be less than or equal to 5%..... 8.2-35

Table 8.2.3-1 Proportional changes in average base period survival expected from completed actions and current human activities that are likely to continue into the future. Factors greater than one result in higher survival (e.g., 1.225 indicates a 22.5% increase in survival, compared to the base period average); 1.0 indicates no change; and numbers less than 1.0 result in lower survival (e.g., 0.996 indicates a 0.4% reduction in survival, compared to the base period average). The 1990-present estimate, which likely includes recent harvest and hydro survival, is not adjusted. 8.2-36

Table 8.2.5-1 Proportional changes in survival expected from the Prospective Actions. Factors greater than 1.0 result in higher survival (e.g., 1.225 indicates a 22.5% increase in survival, compared to average current survival); 1.0 indicates no change; and numbers less than 1.0 result in lower survival (e.g., 0.996 indicates a 0.4% reduction in survival, compared to current average survival)..... 8.2-37

Table 8.2.6.1-1 Summary of prospective estimates relevant to the recovery prong of the jeopardy standard for SR fall Chinook. The 1977-present time series was adjusted for base-to-current survival changes other than hydro, which could not be estimated quantitatively. The 1990-present time series was not adjusted for base-to-current changes. Estimates of productivity expected under the Prospective Actions do not include future hydro survival improvements, which could not be quantified for this species. 8.2-38

Table 8.3.5.5-1 Abundance-based harvest rate schedule for upriver spring Chinook and Snake River spring/summer Chinook in spring management period fisheries (TAC 2008)..... 8.3-25

Table 8.3.5.5-2 Actual harvest rate on SR spring/summer Chinook, & those allowed under the applicable abundance based harvest rate schedule (Observed HR from TAC 2008). 8.3-26

Table 8.3.2-1 Status of SR spring/summer Chinook salmon with respect to abundance and productivity VSP factors. Productivity is estimated from performance during the "base period" of the 20 most recent brood years (approximately 1980 BY – 1999 BY). 8.3-48

Table 8.3.2-2 Status of SR spring/summer Chinook salmon with respect to spatial structure and diversity VSP factors. 8.3-49

Table 8.3.2-3 Status of SR spring/summer Chinook salmon with respect to extinction risk. Extinction risk is estimated from performance during the "base period" of the 20 most recent brood years (approximately 1980 BY – 1999 BY). 8.3-50

Table 8.3.2-4 Changes in density-independent survival ("gaps") necessary for indices of productivity equal to 1.0 and estimates of extinction risk no higher than 5% for SR spring/summer Chinook salmon. Survival changes would need to be greater than these estimates for trend or productivity to be greater than 1.0. Estimated "gaps" are based on population performance during the "base period" of approximately the last 20 brood years. Factors greater than 1.0 indicate a need for higher survival (e.g., 1.225 indicates that a 22.5% proportional increase in survival is necessary for productivity or trend to equal 1.0); 1.0 indicates no change; and numbers less than 1.0 indicate that additional changes in survival are not necessary for productivity or trend equal to 1.0 and extinction risk to be less than or equal to 5%. 8.3-51

Table 8.3.3-1 Proportional changes in average base period survival of SR spring/summer Chinook salmon expected from completed actions and current human activities that are likely to continue into the future. Factors greater than 1.0 result in higher survival (e.g., 1.225 indicates a 22.5% increase in survival, compared to the base period average); 1.0 indicates no change; and numbers less than 1.0 result in lower survival (e.g., 0.996 indicates a 0.4% reduction in survival, compared to the base period average). 8.2-53

Table 8.3.5-1 Proportional changes in survival of SR spring/summer Chinook salmon expected from the Prospective Actions. Factors greater than 1.0 result in higher survival (e.g., 1.225 indicates a 22.5% increase in survival, compared to average current survival); 1.0 indicates no change; and numbers less than 1.0 result in lower survival (e.g., 0.996 indicates a 0.4% reduction in survival, compared to current average survival). 8.2-55

Table 8.3.6.1-1 Summary of prospective estimates relevant to the recovery prong of the jeopardy standard for SR spring/summer Chinook salmon. 8.3-57

Table 8.3.6.1-2 Summary of prospective estimates relevant to the survival prong of the jeopardy standard for SR spring/summer Chinook salmon. Numbers represent additional survival improvements (remaining "gaps") to reduce 24-year extinction risk to 5% or less. Numbers less than 1.0 indicate that no additional survival changes are necessary. 8.3-59

Table 8.4.2.1-1 Snake River sockeye ESU description. (Sources: NMFS 2005a ; ICTRT 2003; McClure et al. 2005; and Flagg 2007) 8.4-6

Table 8.4.5.6-1 Sockeye Harvest Rate Schedule. 8.4-20

Table 8.5.5.5-1 Harvest rates of A-run steelhead in spring, summer, and fall season fisheries expressed as a proportion of the Skamania and A-run steelhead run size (TAC 2008). 8.5-26

Table 8.5.5.5-2 Abundance Based Harvest Rate Schedule for B-run Steelhead (TAC 2008). 8.5-27

Table 8.5.5.5-3 Retrospective analysis of allowable harvest rates for B-run steelhead in the tribal fall season fisheries. 8.5-28

Table 8.5.2-1 Status of SR steelhead with respect to abundance and productivity VSP factors. Productivity is estimated from performance during the "base period" of the 20 most recent brood years (approximately 1980 BY – 1999 BY). Italicized estimates represent application of average A-run and B-run estimates to individual A-run and B-run populations lacking population-specific estimates. 8.5-50

Table 8.5.2-2 Status of SR steelhead with respect to spatial structure and diversity VSP factors. 8.5-51

Table 8.5.2-3 Status of SR steelhead with respect to extinction risk. Extinction risk is estimated from performance during the "base period" of the approximately 20 most recent brood years. Italicized estimates represent application of average A-run and B-run estimates to individual A-run and B-run populations lacking population-specific estimates. 8.5-52

Table 8.5.2-4 Changes in density-independent survival of SR steelhead ("gaps") necessary for indices of productivity equal to 1.0 and estimates of extinction risk no higher than 5% for SR steelhead. Survival changes would need to be greater than these estimates for trend or productivity to be greater than 1.0. Estimated "gaps" are based on population

performance during the "base period" of approximately the last 20 brood years or spawning years. Factors greater than 1.0 indicate a need for higher survival (e.g., 1.225 indicates that a 22.5% proportional increase in survival is necessary for productivity or trend to equal 1.0); 1.0 indicates no change; and numbers less than 1.0 indicate that additional changes in survival are not necessary for productivity or trend equal to 1.0 and extinction risk to be less than or equal to 5%. Italicized estimates represent application of average A-run and B-run estimates to individual A-run and B-run populations lacking population-specific estimates. 8.5-53

Table 8.5.3-1 Proportional changes in SR steelhead average base period survival expected from completed actions and current human activities that are likely to continue into the future. Factors greater than one result in higher survival (e.g., 1.225 indicates a 22.5% increase in survival, compared to the base period average); 1.0 indicates no change; and numbers less than 1.0 result in lower survival (e.g., 0.996 indicates a 0.4% reduction in survival, compared to the base period average). 8.5-54

Table 8.5.5-1 Proportional changes in SR steelhead survival expected from the Prospective Actions. Factors greater than 1.0 result in higher survival (e.g., 1.225 indicates a 22.5% increase in survival, compared to average current survival); 1.0 indicates no change; and numbers less than 1.0 result in lower survival (e.g., 0.996 indicates a 0.4% reduction in survival, compared to current average survival). 8.5-56

Table 8.5.6.1-1 Summary of prospective estimates relevant to the recovery prong of the jeopardy standard for SR steelhead. 8.5-59

Table 8.6.5.1-1 Abundance-based harvest rate schedule for upriver spring Chinook and Snake River spring/summer Chinook in spring management period fisheries. 8.6-23

Table 8.6.5.5-2 Actual harvest rate on UCR spring Chinook, and those allowed under the applicable abundance based harvest rate schedule. 8.6-24

Table 8.6.2-1 Status of UCR spring Chinook salmon with respect to abundance and productivity VSP factors. Productivity is estimated from performance during the "base period" of the 20 most recent brood years (approximately 1980 BY – 1999 BY). 8.6-34

Table 8.6.2-2 Status of UCR spring Chinook salmon with respect to spatial structure and diversity VSP factors. 8.6-35

Table 8.6.2-3. Status of UCR spring Chinook salmon with respect to extinction risk. Extinction risk is estimated from performance during the "base period"

of the 20 most recent brood years (approximately 1980 BY – 1999 BY). 8.6-36

Table 8.6.2-4 Changes in density-independent survival ("gaps") necessary for indices of productivity equal to 1.0 and estimates of extinction risk no higher than 5% for UCR spring Chinook salmon. Survival changes would need to be greater than these estimates for trend or productivity to be greater than 1.0. Estimated "gaps" are based on population performance during the "base period" of approximately the last 20 brood years. Factors greater than 1.0 indicate a need for higher survival (e.g., 1.225 indicates that a 22.5% proportional increase in survival is necessary for productivity or trend to equal 1.0); 1.0 indicates no change; and numbers less than 1.0 indicate that additional changes in survival are not necessary for productivity or trend equal to 1.0 and extinction risk to be less than or equal to 5%. 8.6-37

Table 8.6.3-1 Proportional changes in average base period survival of UCR Chinook salmon expected from completed actions and current human activities that are likely to continue into the future. Factors greater than one result in higher survival (e.g., 1.225 indicates a 22.5% increase in survival, compared to the base period average); 1.0 indicates no change; and numbers less than 1.0 result in lower survival (e.g., 0.996 indicates a 0.4% reduction in survival, compared to the base period average). 8.6-38

Table 8.6.5-1 Proportional changes in survival of UCR spring Chinook salmon expected from the Prospective Actions. Factors greater than 1.0 result in higher survival (e.g., 1.225 indicates a 22.5% increase in survival, compared to average current survival); 1.0 indicates no change; and numbers less than 1.0 result in lower survival (e.g., 0.996 indicates a 0.4% reduction in survival, compared to current average survival). 8.6-39

Table 8.6.6.1-1 Summary of prospective estimates relevant to the recovery prong of the jeopardy standard for UCR spring Chinook. 8.6-40

Table 8.6.6.1-2 Summary of prospective estimates relevant to the survival prong of the jeopardy standard for UCR spring Chinook. Numbers represent additional survival improvements (remaining "gaps") to reduce 24-year extinction risk to 5% or less. Numbers less than 1.0 indicate that no additional survival changes are necessary. 8.6-41

Table 8.7.5.5-1 Harvest rates of A-run steelhead in spring, summer, and fall season fisheries expressed as a proportion of the Skamania and A-run steelhead run size. 8.7-30

Table 8.7.5.5-2 Abundance Based Harvest Rate Schedule for B-run Steelhead. 8.7-31

Table 8.7.5.5-3 Retrospective analysis of allowable harvest rates for B-run steelhead in the tribal fall season fisheries 8.7-32

Table 8.7.2-1 Status of UCR steelhead with respect to abundance and productivity VSP factors. Productivity is estimated from performance during the "base period" of the 20 most recent brood years (approximately 1980 BY – 1999 BY)..... 8.7-44

Table 8.7.2-2 Status of UCR steelhead with respect to spatial structure and diversity VSP factors..... 8.7-44

Table 8.7.2-3 Status of UCR steelhead with respect to extinction risk. Extinction risk is estimated from performance during the "base period" of the 20 most recent brood years (approximately 1980 BY – 1999 BY)..... 8.7-45

Table 8.7.2-4 Changes in density-independent survival of UCR steelhead ("gaps") necessary for indices of productivity equal to 1.0 and estimates of extinction risk no higher than 5% for UCR steelhead. Survival changes would need to be greater than these estimates for trend or productivity to be greater than 1.0. Estimated "gaps" are based on population performance during the "base period" of approximately the last 20 brood years or spawning years. Factors greater than 1.0 indicate a need for higher survival (e.g., 1.225 indicates that a 22.5% proportional increase in survival is necessary for productivity or trend to equal 1.0); 1.0 indicates no change; and numbers less than 1.0 indicate that additional changes in survival are not necessary for productivity or trend equal to 1.0 and extinction risk to be less than or equal to 5%..... 8.7-45

Table 8.7.3-1 Proportional changes in average base period survival of UCR steelhead expected from completed actions and current human activities that are likely to continue into the future. Factors greater than 1.0 result in higher survival (e.g., 1.225 indicates a 22.5% increase in survival, compared to the base period average); 1.0 indicates no change; and numbers less than 1.0 result in lower survival (e.g., 0.996 indicates a 0.4% reduction in survival, compared to the base period average)..... 8.7-46

Table 8.7.5-1 Proportional changes in survival of UCR steelhead expected from the Prospective Actions. Factors greater than 1.0 result in higher survival (e.g., 1.225 indicates a 22.5% increase in survival, compared to average current survival); 1.0 indicates no change; and numbers less than 1.0 result in lower survival (e.g., 0.996 indicates a 0.4% reduction in survival, compared to current average survival)..... 8.7-47

Table 8.7.6.1-1 Summary of prospective estimates relevant to the recovery prong of the jeopardy standard for UCR steelhead. Low and high productivity

estimates are a result of the range of changes in hatchery-origin spawner effectiveness from the base to the current conditions.....8.7-48

Table 8.8.5.5-1 Harvest rates of A-run steelhead in spring, summer, and fall season fisheries expressed as a proportion of the Skamania and A-run steelhead run size.....8.8-24

Table 8.8.5.5-2 Treaty Indian harvest rates of winter-run steelhead expressed as a proportion of the unmarked winter-run steelhead counts at Bonneville Dam in the winter season. 8.8-25

Table 8.8.5.5-3 Abundance Based Harvest Rate Schedule for B-run Steelhead 8.8-27

Table 8.8.5.5-4 Retrospective analysis of allowable harvest rates for B-run steelhead in the tribal fall season fisheries 8.8-28

Table 8.8.2-1 Status of MCR steelhead with respect to abundance and productivity VSP factors. Productivity is estimated from performance during the "base period" of the 15-20 most recent brood years (approximately 1980-1985 BY through 1998-1999 BY, depending on population).....8.8-47

Table 8.8.2-2 Status of MCR steelhead with respect to spatial structure and diversity VSP factors.....8.8-48

Table 8.8.2-3 Status of MCR steelhead with respect to extinction risk. Extinction risk is estimated from performance during the "base period" of the 15-20 most recent brood years (approximately 1980-1985 BY through 1998-1999 BY, depending upon population). 8.8-49

Table 8.8.2-4 Changes in density-independent survival of MCR steelhead ("gaps") necessary for indices of productivity equal to 1.0 and estimates of extinction risk no higher than 5% for MCR steelhead. Survival changes would need to be greater than these estimates for trend or productivity to be greater than 1.0. Estimated "gaps" are based on population performance during the "base period" of approximately the last 20 brood years or spawning years. Factors greater than 1.0 indicate a need for higher survival (e.g., 1.225 indicates that a 22.5% proportional increase in survival is necessary for productivity or trend to equal 1.0); 1.0 indicates no change; and numbers less than 1.0 indicate that additional changes in survival are not necessary for productivity or trend equal to 1.0 and extinction risk to be less than or equal to 5%. 8.8-50

Table 8.8.3-1 Proportional changes in average base period survival of MCR steelhead expected from completed actions and current human activities that are likely to continue into the future. Factors greater than one result in higher survival (e.g., 1.225 indicates a 22.5% increase in survival,

compared to the base period average); 1.0 indicates no change; and numbers less than 1.0 result in lower survival (e.g., 0.996 indicates a 0.4% reduction in survival, compared to the base period average). 8.8-51

Table 8.8.5-1 Estimates of percent juvenile steelhead in-river survival rates through the lower Columbia River under the Prospective Actions and in a hypothetical free-flowing reach of equal length. 8.8-52

Table 8.8.5-2 Proportional changes in survival of MCR steelhead expected from the Prospective Actions. Factors greater than one result in higher survival (e.g., 1.225 indicates a 22.5% increase in survival, compared to average current survival); 1.0 indicates no change; and numbers less than 1.0 result in lower survival (e.g., 0.996 indicates a 0.4% reduction in survival, compared to current average survival). 8.8-53

Table 8.8.6.1-1 Summary of prospective estimates relevant to the recovery prong of the jeopardy standard for MCR steelhead. 8.8-55

Table 8.9.2.1-1 Columbia River chum ESU description and major population groups (MPGs). (Sources: NMFS 2005a; Myers et al. 2006). The designations "-C" and "-G" identify Core and Genetic legacy populations, respectively. 8.9-4

Table 8.9.2.1-2 Key limiting factors for Columbia River chum. 8.9-5

Table 8.9.2.1-3 Abundance, productivity, and trends of Columbia River chum populations.. ..... 8.9-7

Table 8.9.2.1-4 Risk of extinction in 100 years; categories for populations of Columbia River chum 8.9-8

Table 8.10.2.1-1 Life history and population characteristics of Chinook salmon originating in Washington portions of the lower Columbia River. 8.10-7

Table 8.10.2.1-2 LCR Chinook salmon ESU description and major population groups (MPGs) (Sources: NMFS 2005a; Myers et al. 2006). The designations "(C)" and "(G)" identify Core and Genetic Legacy populations, respectively. 8.10-9

Table 8.10.2.1-2 Key limiting factors for LCR Chinook salmon. 8.10-10

Table 8.10.2.1-3 Abundance, productivity, and trends of LCR Chinook salmon populations. 8.10-13

Table 8.10.2.1-4 The ecological zones and populations for the Lower Columbia River Chinook salmon ESU. Primary populations identified for greater than high viability objectives are denoted with an asterisk. 8.10-14

Table 8.10.2.1-5 Current and historically available habitat located below barriers in the Lower Columbia River Chinook salmon ESU. 8.10-16

Table 8.10.2.1-6 Total annual escapement of Lower Columbia River spring Chinook populations. 8.10-18

Table 8.10.2.1-7 Annual escapement of Lower Columbia River bright fall Chinook populations 8.10-19

Table 8.10.2.1-8 Annual escapement for several Lower Columbia River tule Chinook populations 8.10-21

Table 8.10.2.1-9 Risk of extinction (in 100 years) categories for populations of LCR Chinook salmon (sources: Washington's Lower Columbia Fish Recovery Board plan 8.10-23

Table 8.10.2.1-10 LCFRB status summaries for Lower Columbia River tule Chinook populations 8.10-24

Table 8.10.3.6-1 Total adult equivalent exploitation rates for the Cowlitz spring Chinook population (as an example of exploitation rates for LCR spring Chinook). 8.10-34

Table 8.10.3.6-2 Total adult equivalent exploitation rate for the North Fork Lewis bright Chinook population 8.10-35

Table 8.10.3.6-3 Total adult equivalent exploitation rates for LCR tule populations. 8.10-36

Table 8.10.5.5-1 Expected exploitation rates on Lower Columbia River tule Chinook in 2008 marine area fisheries 8.10-48

Table 8.11.2.1-1 Lower Columbia River coho ESU description and major population groups (MPGs). 8.11-5

Table 8.11.2.1-2 Key limiting factors for Lower Columbia River coho. 8.11-6

Table 8.11.2.1-3 Abundance, productivity, and trends of LCR coho populations. 8.11-8

Table 8.11.2.1-4 Current and historically available habitat located below barriers in the Lower Columbia River coho salmon ESU. 8.11-10

Table 8.11.2.1-5 Abundance of wild Clackamas coho, 1957-2007. ..... 8.11-12

Table 8.11.2.1-6 Abundance of wild Sandy coho, 1957-2006. ..... 8.11-16

Table 8.11.2.1-7 Recent abundance of wild coho in other Oregon population areas. 8.11-19

Table 8.11.2.1-8 RFT/QET and Minimum Viability Abundance Thresholds for Oregon population of the Lower Columbia River coho salmon ESU. 8.11-21

Table 8.11.2.1-9 Estimates of natural coho salmon juvenile outmigrants from Washington Lower Columbia River streams. 8.11-23

Table 8.11.2.1-10 Estimated smolt production from streams with hatcheries, streams without hatcheries, minimum abundance from monitored streams, and predicted smolt abundance for the Washington-side of the LCR ESU (Volkhardt et al. 2008). 8.11-24

Table 8.11.2.1-11 The ecological zones (strata) and populations for the Lower Columbia River coho salmon ESU(LCFRB 2004). Primary (P), contributing (C), and stabilizing (S) population designations for the recovery scenario. Respective target viabilities are high or better, medium, and no lower than current levels. Primary populations identified for greater than high viability objectives are denoted with an '*'. 8.11-25

Table 8.11.2.1-12 Risk of extinction in 100 years categories for populations of LCR coho (sources: Washington's Lower Columbia Fish Recovery Board plan 8.11-26

Table 8.11.3.6-1 Estimated Ocean (all marine area fisheries) and Inriver Exploitation Rates on Lower Columbia River Natural Coho, 1970-2007 ..... 8.11-32

Table 8.11.5.5-1 Harvest management matrix for Lower Columbia River coho salmon showing maximum allowable Ocean fishery mortality rate. 8.11-40

Table 8.11.5.5-2 Lower Columbia River coho hatchery programs, escapement goals and escapement, by program for the last 10 years. Shaded areas/Italic type highlights programs that are used, at least in part, to support supplementation or reintroduction activities. Numbers in bold indicate years in which the escapement goal was not met for that program. 8.11-41

Table 8.12.2.1-1 Lower Columbia River steelhead DPS description and major population groups (MPGs). The designations "(C)" and "(G)" identify Core and Genetic Legacy populations, respectively. 8.12-7

Table 8.12.2.1-2 Key limiting factors for LCR steelhead.....8.12-8

Table 8.12.2.1-3 Abundance, productivity, and trends of LCR steelhead populations 8.12-11

Table 8.12.2.1-4 Risk of extinction categories for populations of LCR steelhead 8.12-12

Table 8.12.3.6-1 Non-Indian harvest rates for winter-run steelhead expressed as a proportion of the total winter-run steelhead run size.....8.12-17

Table 8.12.3.6-2 Treaty Indian harvest rates for winter-run steelhead expressed as a proportion of the unmarked winter-run steelhead counts at Bonneville Dam in the winter season. 8.12-17

Table 8.12.3.6-3 Treaty Indian and non-Indian harvest rates for summer-run populations of the LCR steelhead DPS (Treaty and non-Indian harvest rates are not additive because these are calculated using a different denominator). 8.12u-18

Table 8.13.2.1-1 Upper Willamette River ESU description. The designations "(C)" and "(G)" identify Core and Genetic Legacy populations, respectively 8.12-5

Table 8.13.2.1-2 Key Limiting Factors for Upper Willamette River Chinoon.....8.13-6

Table 8.13.2.1-3 Abundance, productivity, and trends of UWR Chinook populations.....8.13-9

Table 8.13.2.1-4 Risk of extinction categories for populations of UWR Chinook 8.1310

Table 8.14.2.1-1 Upper Willamette River steelhead DPS description. 8.142-5

Table 8.14.2.1-2 Key limiting factors for Upper Willamette River steelhead.....8.14-6

Table 8.14.2.1-3 Abundance, productivity, and trends of UWR Steelhead populations.....8.14-8

Table 8.14.2.1-4 Risk of extinction categories for populations of UWR Steelhead.....8.14-9

Table of Figures

Figure 5.1-1 Cross-section view of a removable spillway weir in its operating position..... 5-10

Figure 5.1-2 Simulated mean monthly Columbia River flows at Bonneville Dam under current conditions and flows that would have occurred without water development (water years 1929 – 1978)..... 5-14

Figure 5.1-3 Median daily Snake River water temperatures (°C) at Ice Harbor Dam before and after development of the four lower Snake River projects. 5-20

Figure 5.1-4 Compensatory effects of depth (hyperbaric pressure) on fish exposed to supersaturated water..... 5-25

Figure 5.6.1-1 Ocean and In-river Exploitation Rates for Snake River fall Chinook 5-43

Figure 5.6.1-2 Harvest rates for all commercial, recreational, and C&S fisheries in the mainstem. 5-44

Figure 5.7.1-1 Time-series of MEI conditions from 1950 through November 2007. 5-62

Figure 5.7.2-1 Monthly Values for the PDO Index: 1900-January 2008. 5-63

Figure 7.1-1 Schematic showing the method of applying survival changes that have occurred during the base period to a "base-to-current" productivity adjustment factor and method of applying expected prospective survival changes to a "current-to-future" productivity adjustment factor. Detailed methodology is described in the accompanying text. This example uses average returns-per spawner (R/S) as the productivity estimate, applied to the Marsh Creek population of SR Spring/ Summer Chinook salmon..... 7-9

Figure 7.1-2 Schematic showing the method of applying survival changes that have occurred during the base period to a "base-to-current" adjustment factor for an extinction risk survival gap and method of applying expected prospective survival changes to a "current-to-future" adjustment factor. 7-10

Figure 7.1-3 Adult spawners in the Sulphur Creek population of SR spring/summer Chinook salmon. Circles indicate four consecutive return years that are below 50 spawners..... 7-18

Figure 7.1-4 Graphic comparison of methods used to calculate average returns-per-spawner (R/S), mean population growth rate (lambda), and the BRT abundance trend (regression of log-transformed abundance). All calculations are based on 1979- 2003 spawner abundance estimates for the Marsh Creek SR spring/summer Chinook population. The estimates

in this figure match those in Table 8.2.2-1 for the "base case" Marsh Creek population. The Marsh Creek population has no hatchery-origin spawners; this simplifies the methods compared to populations with both hatchery-origin and natural-origin spawners. 7-22

Figure 7.1-5 Abundance and productivity (R/S) of the Catherine Creek population of SR spring/summer Chinook salmon predicted in ICTRT and Zabel (2007, their Table 7) using a matrix simulation model. A 6.5% survival improvement is applied to the model at simulation year 1. The matrix model estimates represent means of 100,000 model runs. Matrix model results are compared to an estimate of the initial R/S productivity following instantaneous achievement of a 6.5% survival improvement using the proportional increase method in the SCA. 7-29

Figure 7.1-6 Same as Figure 7.1-5 for the South Fork Salmon River population of SR spring/summer Chinook salmon 7-30

Figure 7.1-7 Same as Figure 7.1-5 for the Marsh Creek population of SR spring/summer Chinook salmon. 7-30

Figure 8.1-1 Mean monthly Snake River discharge (cfs) at Brownlee Dam under the current operations and under the Prospective Action. 8.1-10

Figure 8.1-2 Mean monthly Snake River discharge (cfs) at Lower Granite Dam under the current operations and under the prospective operations. 8.1-11

Figure 8.1-3 Mean monthly Snake River discharge (cfs) at McNary Dam under the current operations and under the prospective operations. 8.1-12

Figure 8.1-4 Mean monthly Snake River discharge (cfs) at Bonneville Dam under the current operations and under the prospective operations. 8.1-13

Figure 8.2.2.1-1 Snake River Fall Chinook Salmon Abundance Trends..... 8.2-6

Figure 8.3.2-1 Snake River Spring Summer Chinook Abundance Trends 8.3-6

Figure 8.3.6-1 Summary of prospective mean R/S estimates for SR spring/summer Chinook salmon under the “recent” climate assumption, including 95% confidence limits..... 8.3-61

Figure 8.3.6-2 Summary of prospective mean R/S estimates for SR spring/summer Chinook salmon under three climate assumptions. 8.3-62

Figure 8.3.6-3 Summary of prospective 5% 24-year extinction risk gap estimates for SR spring/summer Chinook salmon under the “recent” climate

assumption, showing effects of three alternative quasi-extinction thresholds (QET). 8.3-63

Figure 8.3.6-4 Summary of prospective 5% 24-year extinction risk gap estimates for SR spring/summer Chinook salmon under three climate assumptions. . 8.3-64

Figure 8.5.2.1-1 Snake River Steelhead DPS Abundance and 5-Year Geometric Mean . 8.5-6

Figure 8.5.6-1 Summary of prospective mean R/S estimates for SR steelhead under the "recent" climate assumption, including 95% confidence limits. 8.5-62

Figure 8.5.6-2 Summary of prospective mean R/S estimates for SR steelhead under three climate assumptions. 8.5-64

Figure 8.6.1.1-1 Upper Columbia River Spring Chinook Abundance Trends 8.6-5

Figure 8.6.6-1 Summary of prospective mean R/S estimates for UCR spring Chinook salmon under the "recent" climate assumption, including 95% confidence limits..... 8.6-42

Figure 8.6.6-2 Summary of prospective mean R/S estimates for UCR Spring Chinook salmon under three climate assumptions. 8.6-43

Figure 8.6.6-3 Summary of prospective 5% 24-year extinction risk gap estimates for UCR spring Chinook salmon under the "recent" climate assumption, showing effects of three alternative quasi-extinction thresholds 8.6-44

Figure 8.6.6-4 Summary of prospective 5% 24-year extinction risk gap estimates for UCR spring Chinook salmon under three climate assumptions. 8.6-45

Figure 8.7.2.1-1 Upper Columbia River Steelhead Abundance Trends, 1978 to 2004 .... 8.7-6

Figure 8.7.6-1 Summary of prospective mean R/S estimates for UCR steelhead under the "recent" climate assumption, including 95% confidence limits. 8.7-49

Figure 8.7.6-2 Summary of prospective mean R/S estimates for UCR steelhead under three climate assumptions. 8.7-50

Figure 8.8.2-1 Middle Columbia River Steelhead Abundance Trends..... 8.8-6

Figure 8.8.6-1 Summary of prospective mean R/S estimates for MCR steelhead under the "recent" climate assumption, including 95% confidence limits. 8.8-56

Figure 8.8.6-2 Summary of prospective mean R/S estimates for MCR steelhead under three climate assumptions. 8.8-58

Figure 8.11.2.1-1 Clackamas North Fork Dam counts of adult (3-year-old) coho salmon, 1957–2007. ..... 8.11-12

Figure 8.11.2.1-2 Clackamas North Fork Dam counts of adult (3-year-old) coho salmon by cohort, 1957-2002. Cohort A, cohort B and cohort C 8.11-15

Figure 8.11.2.1-3 Total outmigrating juvenile coho passing Clackamas North Fork Dam 8.11-16

Figure 8.11.2.1-4 Count of adult coho salmon at the Marmot Dam on the Sandy River. Almost all spawners above Marmot Dam are natural origin. 8.11-18

Figures 8.11.2.1-4a Youngs Bay coho salmon spawners per mile, 1949–2001. ..... 8.11-19

Figures 8.11.2.1-4b Big Creek coho salmon spawners per mile, 1949–2001. ..... 8.11-20

Figures 8.11.2.1-4c Clatskanie River coho salmon spawners per mile, 1949–2001. ... 8.11-20

Figures 8.11.2.1-4d Scappoose River spawners per mile, 1949–2001. ..... 8.11-21

Figure 8.11.2.1-5 Overall summary of population status for Oregon LCR coho populations. 8.11-22

Figure 9.1-1. Population size and trend of Southern Resident killer whales, 1960-2007. Data from 1960-1973 (open circles, gray line) are number projections from the matrix model of Olesiuk et al. (1990). Data from 1974-2007 (diamonds, black line) were obtained through photo-identification surveys of the three pods (J, K, and L) in this community and were provided by the Center for Whale Research (unpubl. data). Data for these years represent the number of whales present at the end of each calendar year except for 2007, when data extend only through October. 9-4

Figure 9.1-2 Geographic Range (light shading) of the Southern Resident Killer Whale Population. Reprinted from Wiles (2004). 9-5

Figure 9.1-3. Monthly occurrence of the three Southern Resident killer whale pods (J, K, and L) in the inland waters of Washington and British Columbia, 1976-2005. This geographic area is defined as the region east of Race Rocks at the southern end of Vancouver Island and Port Angeles on the Olympic Peninsula. Pods were recorded as present during a month if they were sighted on at least one day 9-6

Terms and Definitions

Abundance	In the context of salmon recovery, abundance refers to the number of adult fish returning to spawn.
Acre-feet	A common measure of the volume of water in the river system. It is the amount of water it takes to cover one acre (43,560 square feet) to a depth of one foot.
Adaptive Management	The process of adjusting management actions and/or directions based on new information.
Anadromous Fish	Species that are hatched in freshwater, migrate to and mature in salt water, and return to freshwater to spawn.
Baseline Monitoring	In the context of recovery planning, baseline monitoring is done before implementation, in order to establish historical and/or current conditions against which progress (or lack of progress) can be measured.
Beverton-Holt Function	This function predicts the number of progeny that will return to spawn from a given number of parental spawners.
Biogeographical Region	An area defined in terms of physical and habitat features, including topography and ecological variations, where groups of organisms have evolved in common.
Broad-Sense Recovery Goals	Goals defined in the recovery planning process, generally by local recovery planning groups, that go beyond the requirements for delisting, to address, for example, other legislative mandates or social, economic, and ecological values.
Compensatory Mortality	Refers to mortality that would have occurred for another reason.
Compliance Monitoring	Monitoring to determine whether a specific performance standard, environmental standard, regulation, or law is met.
Delisting Criteria	Criteria incorporated into ESA recovery plans that define both biological viability (biological criteria) and alleviation of the causes for decline (threats criteria based on the five listing factors in ESA section 4[a][1]), and that, when met, would result in a determination that a species is no longer threatened or endangered and can be proposed for removal from the Federal list of threatened and endangered species.
Demand	The amount of power being used at any given time. Demand in the Northwest is seasonal; with the highest use in the winter for heating and the lowest in the summer.
Density-Independent Survival	A change in survival that is not influenced by the number of fish in the population. Generally speaking, most factors influencing survival after the smolt stage are assumed to be density independent. During the egg-to-smolt stage, the density of adults

	and juveniles can influence survival as a result of competition for limited habitat or other factors. For evaluation of survival gaps, estimates of survival changes resulting from actions affecting early life stages of salmon and steelhead are made under the assumption of low density.
Dissolved Gas Level	As falling water hits the river surface, it drags in air as it plunges. With increasing water pressure, the air dissolves into the water and increases the levels of pre-existing dissolved gases.
Distinct population segment (DPS)	A listable entity under the ESA that meets tests of discreteness and significance according to USFWS and NOAA Fisheries policy. A population is considered distinct (and hence a "species" for purposes of conservation under the ESA) if it is discrete from and significant to the remainder of its species based on factors such as physical, behavioral, or genetic characteristics, it occupies an unusual or unique ecological setting, or its loss would represent a significant gap in the species' range.
Diversion	Refers to taking water out of the river channel for municipal, industrial, or agricultural use. Water is diverted by pumping directly from the river or by filling canals.
Diversity	All the genetic and phenotypic (life history, behavioral, and morphological) variation within a population. Variations could include anadromy vs. lifelong residence in freshwater, fecundity, run timing, spawn timing, juvenile behavior, age at smolting, age at maturity, egg size, developmental rate, ocean distribution patterns, male and female spawning behavior, physiology, molecular genetic characteristics, etc.
Draft Limit	The lowest level to which a reservoir can be drawn down. The limit is based on rule curves that are calculated on both historic and current streamflow data.
Drafting	The process of releasing water from storage in a reservoir. Operators begin drafting reservoirs—through turbines or over the spillway of a dam—to lower the level for a number of resasons, including flood control or downstream flows for fish or power generation.
Dredging	The act of removing sediment from the river bottom to keep the channel at the proper depth for navigation. The continual moving and shifting of sediment makes dredging an ongoing activity.
Effectiveness Monitoring	Monitoring set up to test cause-and-effect hypotheses about recovery actions: Did the management actions achieve their direct effect or goal? For example, did fencing a riparian area to exclude livestock result in recovery of riparian vegetation?
ESA Recovery Plan	A plan to recover a species listed as threatened or endangered under the U.S. Endangered Species Act (ESA). The ESA requires

	that recovery plans, to the extent practicable, incorporate (1) objective, measurable criteria that, when met, would result in a determination that the species is no longer threatened or endangered; (2) site-specific management actions that may be necessary to achieve the plan's goals; and (3) estimates of the time required and costs to implement recovery actions.
Evolutionarily significant unit (ESU)	A group of Pacific salmon or steelhead trout that is (1) substantially reproductively isolated from other conspecific units and (2) represents an important component of the evolutionary legacy of the species.
Factors For Decline	Five general categories of causes for decline of a species, listed in the Endangered Species Act section 4(a)(1)(b): (A) the present or threatened destruction, modification, or curtailment of its habitat or range; (B) overutilization for commercial, recreational, scientific, or educational purposes; (C) disease or predation; (D) the inadequacy of existing regulatory mechanisms; or (E) other natural or manmade factors affecting its continued existence.
Fall Chinook Salmon	This salmon stock returns from the ocean in late summer and early fall to head upriver to its spawning grounds, distinguishing it from other stocks which migrate in different seasons.
Fish Guidance Efficiency	Number of fish guided into the bypass system divided by total number passing via the powerhouse (i.e., the combined total for bypass system and turbine passage).
Fish Ladder	A series of stair-step pools that enables salmon to get past the dams. Swimming from pool to pool, salmon work their way up the ladder to the top where they continue upriver.
Fish Passage Efficiency	Number of fish passing the dam via non-turbine routes divided by total number passing the dam by all routes.
Flip Lips	A structural device that redirects water as it comes over the spillway of a dam. Flip lips reduce deep plunging of water into the pool below; keeping the water from becoming supersaturated with nitrogen. Fish are naturally attracted to the rapidly moving water at the base of the dam but can suffer from gas bubble disease when the water is supersaturated with gas.
Flood Control	Streamflows in the Columbia River Basin can be managed to keep water below damaging flood levels in most years. This level of flood control is possible because storage reservoirs on the river can capture and store heavy runoff as it occurs.
Flood Control Rule Curve	The curve is also called the upper rule curve. It establishes the amount of storage space that must be maintained in a reservoir to reduce damaging flood conditions downriver.
Flood Control Storage Space	The space that is provided in a storage reservoir to allow for the capture of runoff that could otherwise cause flood damage.

Flow Augmentation	Water released from system storage at targeted times and places to increase streamflows to benefit migrating salmon and steelhead
Freshet	The heavy runoff that occurs in the river when streams are at their peak flows with spring snowmelt. Before the dams were built, these freshets moved spring juvenile salmon quickly downriver
Functionally Extirpated	Describes a species that has been extirpated from an area; although a few individuals may occasionally be found, they are not thought to constitute a population.
Hyporheic Zone	Area of saturated sediment and gravel beneath and beside streams and rivers where groundwater and surface water mix.
Implementation monitoring	Monitoring to determine whether an activity was performed and/or completed as planned.
Independent population	Any collection of one or more local breeding units whose population dynamics or extinction risk over a 100-year time period is not substantially altered by exchanges of individuals with other populations.
Indicator	A variable used to forecast the value or change in the value of another variable.
Interim regional Recovery plan	A recovery plan that is intended to lead to an ESA recovery plan but that is not yet complete. These plans might address only a portion of an ESU or lack other key components of an ESA recovery plan.
International Joint Commission	Six-person Canada-U.S. board created by the 1909 Boundary Water Treaty to resolve disputes on waters shared by the two nations.
Intrinsic Productivity	The average of adjusted recruits per spawner estimates for only those brood years with the lowest spawner abundance levels.
Kelts	Steelhead that have spawned but may survive to spawn again, unlike most other anadromous fish.
Lambda	Also known as Population growth rate, or the rate at which the number of fish in a population increases or decreases.
Large woody debris (LWD)	A general term for wood naturally occurring or artificially placed in streams, including branches, stumps, logs, and logjams. Streams with adequate LWD tend to have greater habitat diversity, a natural meandering shape, and greater resistance to flooding.
Legacy Effects	Impacts from past activities (usually a land use) that continue to affect a stream or watershed in the present day.

Levees, Flood Walls, & Bank Protection	A levee is a raised embankment built to keep out flood waters. Flood walls, such as the concrete seawall along the Willamette River in downtown Portland, are barriers constructed to hold out high water. The soil on river banks is protected from erosion in a variety of ways. River grasses and trees are cultivated in some areas, and fine mesh screens are laid on banks in other areas to keep soil in place. Rip-rap is also used to protect against fast moving streams or vigorous wave action.
Limiting Factor	Physical, biological, or chemical features (e.g., inadequate spawning habitat, high water temperature, insufficient prey resources) experienced by the fish at the population, intermediate (e.g., stratum or major population grouping), or ESU levels that result in reductions in viable salmonid population (VSP) parameters (abundance, productivity, spatial structure, and diversity). Key limiting factors are those with the greatest impacts on a population's ability to reach its desired status.
Locally developed recovery plan	A plan developed by state, tribal, regional, or local planning entities to address recovery of a species. These plans are being developed by a number of entities throughout the region to address ESA as well as state, tribal, and local mandates and recovery needs.
Locks	The key to inland navigation on the Columbia-Snake River Waterway, locks raise and lower ships between pools on the river, i.e., from below a dam to the pool above it. On the trip from the ocean to Lewiston, Idaho, vessels travel from sea level through eight locks to an elevation of over 700 feet.
Major dams	Large hydro-electric projects developed by Federal agencies within the Pacific Northwest. Twenty-nine major dams are in the Columbia River Basin. Two dams are in the Rogue River Basin. A total of 31 dams comprise the Federal Power System.
Management unit	A geographic area defined for recovery planning purposes on the basis of state, tribal or local jurisdictional boundaries that encompass all or a portion of the range of a listed species, ESU, or DPS.
Major population group (MPG)	A group of salmonid populations that are geographically and genetically cohesive. The MPG is a level of organization between demographically independent populations and the ESU.
Megawatts	A measure of electrical power equal to one million watts. Megawatts delivered over an hour are measured in megawatt-hours.
Morphology	The form and structure of an organism, with special emphasis on external features.

Multipurpose Facilities	The Columbia River and the reservoir system are used for many purposes or uses. Projects that were authorized to serve a variety of purposes are referred to as "multipurpose."
Northern Pikeminnow	A giant member of the minnow family, the Northern Pikeminnow (formerly known as Squawfish) is native to the Columbia River and its tributaries. Studies show a Northern Pikeminnow can eat up to 15 young salmon a day.
Quasi-Extinction Threshold (QET)	This is the point at which a population has become too small to reliably reproduce itself, even though there may be a few fish remaining. Since there is debate about the exact population level at which this condition occurs, several possible levels (50, 30, 10, 1) are considered. Results from short-term quasi-extinction probability modeling are used to help assess near-term (24-year) extinction risk.
Operating Requirements	These are the limits within which a reservoir or dam must be operated. Some requirements are established by Congress when a project is authorized; others evolve with operating experience.
Operating Year	Detailed operations planned over a 12-month period. The operating year begins on August 1 and ends on July 31.
Parr	The stage in anadromous salmonid development between absorption of the yolk sac and transformation to smolt before migration seaward.
Peak Flow	The maximum rate of flow occurring during a specified time period at a particular location on a stream or river.
Phenotype	The external appearance of an organism resulting from the interaction of its genetic makeup and the environment.
Piscivorous	Describes fish that prey on other fish for food.
Population bottlenecks	The most significant limiting factors currently impeding a population from reaching its desired status. Bottlenecks result in the greatest relative reductions in abundance, productivity, spatial distribution, or diversity and are defined by considering viability impairment across limiting life stages and limiting factors.
Productivity	A measure of a population's ability to sustain itself or its ability to rebound from low numbers. The terms "population growth rate" and "population productivity" are interchangeable when referring to measures of population production over an entire life cycle. Can be expressed as the number of recruits (adults) per spawner or the number of smolts per spawner.
Proposed Action	A proposed action or set of actions
Prospective Actions	Actions from both the FCRPS Biological Assessment and Upper Snake Biological Assessment, August 2007

Reasonable and Prudent Alternative (RPA)	Recommended alternative actions identified during formal consultation that can be implemented in a manner consistent with the purposes of the action, that can be implemented consistent with the scope of the Federal agency's legal authority and jurisdiction, that are economically and technologically feasible, and that the Service believes would avoid the likelihood of jeopardizing the continued existence of the listed species or the destruction or adverse modification of designated critical habitat.
Recovery domain	An administrative unit for recovery planning defined by NOAA Fisheries based on ESU boundaries, ecosystem boundaries, and existing local planning processes. Recovery domains may contain one or more listed ESUs.
Recovery goals	Goals incorporated into a locally developed recovery plan. These goals may go beyond the requirements of ESA de-listing by including other legislative mandates or social values.
Recovery plan supplement	A NOAA Fisheries supplement to a locally developed recovery plan that describes how the plan addresses ESA requirements for recovery plans. The supplement also proposes ESA de-listing criteria for the ESUs addressed by the plan, since a determination of these criteria is a NOAA Fisheries' decision.
Recovery scenarios	Scenarios that describe a target status for each population within an ESU, generally consistent with TRT recommendations for ESU viability.
Recovery strategy	A statement that identifies the assumptions and logic—the rationale—for the species' recovery program.
Recruits per spawner	Generally, a population would be deemed to be "trending toward recovery" if average population growth rates (or productivities) are expected to be greater than 1.0.
Redd	A nest constructed by female salmonids in streambed gravels where eggs are deposited and fertilization occurs.
Reservoir Drawdown	The water levels in a reservoir can be lowered, or drawn down, by releases from the dam. These drawdowns have the effect of speeding up the water through a reservoir by decreasing its cross-sectional area.
Resident Fish	Fish that are permanent inhabitants of a water body. Resident fish include trout, bass, and perch.
Riparian area	Area with distinctive soils and vegetation between a stream or other body of water and the adjacent upland. It includes wetlands and those portions of floodplains and valley bottoms that support riparian vegetation.
River Reach	A general term used to refer to lengths along the river from one point to another, as in the reach from the John Day Dam to the McNary Dam.

Rule Curve	Water levels, represented graphically as curves, that guide reservoir operations.
Runoff	Precipitation, snowmelt, or irrigation water that runs off the land into streams or other surface water.
Salmonid	Fish of the family *Salmonidae*, including salmon, trout, chars, grayling, and whitefish. In general usage, the term usually refers to salmon, trout, and chars.
Smolt	A juvenile salmon or steelhead migrating to the ocean and undergoing physiological changes to adapt from freshwater to a saltwater environment.
Snowpack	The accumulation of snow in the mountains that occurs during the late fall and winter.
Sound	In order to pass via the spillway of a dam, smolts must dive to locate spillway entrances.
Spatial structure	The geographic distribution of a population or the populations in an ESU.
Spill	Water released from a dam over the spillway instead of being directed through the turbines.
Spill Effectiveness	The proportion of fish passing the spillway divided by the proportion of water spilled.
Spill Efficiency	The total number of fish passing the spillway divided by the total number passing the dam.
Stakeholders	Agencies, groups, or private citizens with an interest in recovery planning, or who will be affected by recovery planning and actions
Stratum/major population group	An aggregate of independent populations within an ESU that share similar genetic and spatial characteristics.
Streamflow	Streamflow refers to the rate and volume of water flowing in various sections of the river. Streamflow records are compiled from measurements taken at particular points on the river, such as The Dalles, Oregon.
Streamflow Records	For over 100 years, water resource managers in the Northwest have maintained records on the seasonal volume and rate of flow in the Columbia River. These historical records are of profound importance to planning system operations each year.
Technical Recovery Team (TRT)	Teams convened by NOAA Fisheries to develop technical products related to recovery planning. TRTs are complemented by planning forums unique to specific states, tribes, or regions, which use TRT and other technical products to identify recovery actions. See SCA Section 7.3 for a discussion of how TRT information is considered in these Biological Opinions.
Temperature Control	By drawing water from different elevations within a reservoir, water temperature can be regulated. This temperature regulation

	results in the ability to control the water temperature released from the reservoirs, and the subsequent water temperature downstream.
Threats	Human activities or natural events (e.g., road building, floodplain development, fish harvest, hatchery influences, volcanoes) that cause or contribute to limiting factors. Threats may exist in the present or be likely to occur in the future.
Transmission Grid	The network of high-voltage transmission lines serving the region, carrying power from generating plant to cities.
Turbine	An enclosed rotary type of prime mover that drives an electric generator to produce power.
Viability criteria	Criteria defined by NOAA Fisheries-appointed Technical Recovery Teams based on the biological parameters of abundance, productivity, spatial structure, and diversity, which describe a viable salmonid population (VSP) (an independent population with a negligible risk of extinction over a 100-year time frame) and which describe a general framework for how many and which populations within an ESU should be at a particular status for the ESU to have an acceptably low risk of extinction. See SCA Section 7.3 for a discussion of how TRT information is considered in these Biological Opinions.
Viable salmonid population (VSP)	An independent population of Pacific salmon or steelhead trout that has a negligible risk of extinction over a 100-year time frame. Viability at the independent population scale is evaluated based on the parameters of abundance, productivity, spatial structure, and diversity.
VSP Parameters	Abundance, productivity, spatial structure, and diversity. These describe characteristics of salmonid populations that are useful in evaluating population viability. See NOAA Technical Memorandum NMFS-NWFSC-42, “Viable salmonid populations and the recovery of evolutionarily significant units,” McElhany et al., June 2000.

Acronyms and Abbreviations

Action Agencies	U.S. Bureau of Reclamation, U.S. Army Corps of Engineers, and the Bonneville Power Administration
AFF	anadromous fish evaluation program
amsl	above mean sea level
B.C.	British Columbia
BIA	Bureau of Indian Affairs
BiOp	Biological Opinion
BLM	Bureau of Land Management
BMPs	Best Management Practices
BON	Bonneville Dam
BPA	Bonneville Power Administration
BRT	Biological Review Team (NOAA Fisheries)
BY	brood years
CBFWA	Columbia Basin Fish and Wildlife Authority
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cfs	cubic feet per second
CHARTs	critical habitat analytical review teams
CI	confidence interval
Comanagers	States and Tribes of the Columbia River Basin
COMPASS	Comprehensive Fish Passage
Corps	U.S. Army Corps of Engineers
CR	Columbia River
CRB	Columbia River Basin
CREP	Conservation Reserve Enhancement Program
CRFMP	Columbia River Fishery Management Plan
CTUIR	Confederated Tribes of the Umatilla Indian Reservation
CTWSRO	Confederated Tribes of the Warm Springs Reservation of Oregon
CTWS	Confederated Tribes of the Warm Springs
CWA	Clean Water Act
CWMS	Corps Water Management System (database)
CWT	coded-wire tag
D	differential delayed survival of transported fish

DART	Data Access in Real Time (University of Washington Program)
DDT	dichlorodiphenyltrichloroethane
DIP	demographically independent population
DNR	see WA DNR
DPS	Distinct Population Segment
EDT	ecosystem diagnosis and treatment
EEZ	Exclusive Economic Zone
EF	east fork
EFH	essential fish habitat
EIP	Ecological Improvement Potential
EIS	environmental impact statement
ENSO	El Niño Southern Oscillation
ESA	Endangered Species Act
ESBS	extended-length submersible bar screen
EST	Columbia River estuary
ESU	evolutionary significant unit
FCRPS	Federal Columbia River Power System
FFDRWG	Fish Facility Design Review Work Group
FEIS	Final Environmental Impact Statement
FERC	Federal Energy Regulatory Commission
FHWA	Federal Highway Administration
FGE	fish guidance efficiency
FMEP	Fisheries Management and Evaluation Plan
FPE	fish passage efficiency
FPOM	Fish Passage Operations and Maintenance Coordination Team
FR	Federal Regulation
FRN	Federal Regulation Notice
FS	Forest Service
GBT	gas bubble trauma
GDU	genetic diversity unit
H	High
HCD	Habitat Conservation Diversion
HCP	Habitat Conservation Plan
HCY	Hell's Canyon
HGMP	hatchery and genetic management plan

HIP	Habitat Improvement Program
HOF	hatchery-origin fish
HSRG	Hatchery Scientific Review Group
HUC	Hydrological Unit Code
HYDROSIM	Hydro Simulation Program
I-205	Interstate Highway 205
I-5	Interstate Highway 5
ICB-TRT	Interior Columbia Basin Technical Recovery Team
ICTRT	Interior Columbia Basin Technical Recovery Team
IDFG	Idaho Department of Fish and Game
IDL	Idaho Department of Lands
IHR	Ice Harbor Dam
IPER	Implementation Plan Evaluation Report
ISAB	Independent Scientific Advisory Board
ISRP	Independent Scientific Review Panel
ISS	Idaho Supplementation Studies
JDA	John Day Dam
kcfs	thousand cubic feet per second
km^2	square kilometers
ksfd	Thousand cubic feet per second days
L	Low
LCFRB	Lower Columbia Fish Recovery Board of the NWPCC
LCR	Lower Columbia River
LGO	Little Goose Dam
LGR	Lower Granite Dam
L-M	Low to Medium
LMN	Lower Monumental Dam
LSRCP	Lower Snake River Compensation Plan
LWD	large woody debris
MAF	million acre-feet
MaSA	major spawning areas
MCN	McNary Dam
MCR	Mid-Columbia River
MFJD	Middle Fork John Day
MHHW	mean higher high water level

mi/mi^2	miles per square mile
MIP	minimum irrigation pool
MiSA	minor spawning areas
MMPA	Marine Mammal Protection Act
MOP	minimum operating pool
MPG	major population group
MSA	Magnuson-Stevens Fishery Conservation and Management Act
NF	north fork
NFH	National Fish Hatcheries
NFJDR	North Fork John Day River
ng/g	nanograms per gram
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NOF	natural-origin fish
NPMP	Northern Pikeminnow Management Program
NRC	National Research Council
NWF	National Wildlife Federation
NWPCC	Northwest Power and Conservation Council
NWPPC	Northwest Power Planning Council
ODEQ	Oregon Department of Environmental Quality
ODFW	Oregon Department of Fish and Wildlife
OWRD	Oregon Water Resources Department
PA	Proposed Action
PAH	polyaromatic hydrocarbons
PCBs	polychlorinated biphenyls
PCE	primary constituent element
PCSRF	Pacific Coast Salmon Recovery Fund
PCTS	Public Consultation Tracking System (database)
PDO	Pacific Decadal Oscillation
PECE	"Policy for Evaluation of Conservation Efforts When Making Listing Decisions"
PFMC	Pacific Fishery Management Council
PGE	Portland General Electric

PIT	passive integrated transponder
POD	point of diversion
ppt	Parts per thousand
PUD	Public Utility District
QET	quasi-extinction threshold
R/S	returns-per-spawner
RFT	reproductive failure threshold
RHCA	riparian habitat conservation area
Rkm	river kilometer
RM	river mile
RM&E	Research, Monitoring, and Evaluation
ROD	Record of Decision
RPA	Reasonable and Prudent Alternative
RPMs	reasonable and prudent measures
R/S	recruits per spawner
RSW	removable spillway weir
SAR	smolt-to-adult return rate
SASSI	Salmon and Steelhead Stock Inventory
SbyC	separated-by-code
SCA	Supplemental Comprehensive Analysis
SCT	System Configuration Team
SEF	East Fork Salmon River
SF	south fork
SFJD	South Fork John Day
SIMPAS	simulated passage (model)
SR	Snake River
SRPAH	Pahsimeroi River
SRS	sediment retention structure
SRUMA	Salmon River-Upper Mainstem
SRWG	Studies Review Workgroup
SRYFS	Salmon River-Yankee Fork
STS	submersible traveling screen
SWHA	shallow water habitat area
SWCD	Soil and Water Conservation District
SYSTDG	System Total Dissolved Gas (TDG) Model

T&C	terms and conditions
TDA	The Dalles Dam
TDG	total dissolved gas
TERP	Tower Ecosystem Restoration Projects
TMDL	total maximum daily load
TMT	Technical Management Team
TRT	Technical Recovery Team
TSW	temporary spillway weir
UCM	Unit Characteristic Method
UCR	Upper Columbia River
UCUT	Upper Columbia United Tribes
UNF	Umatilla National Forest
UPA	Updated Proposed Action
URC	upper rule curve
USBR	U.S. Bureau of Reclamation
USDA	U.S. Department of Agriculture
USFS	U.S. Forest Service
USFWS	U.S. Fish and Wildlife Service
USGS	U.S. Geological Survey
USRC	Upper Salmon River at Challis Project
USRITAT	Upper Salmon River Interagency Technical Advisory Team
UWR	Upper Willamette River
VARQ	variable (VAR) outflow (Q)
VH	Very High
VL	Very Low
VSP	viable salmonid population
W/LC TRT	Willamette/Lower Columbia TRT
WA DNR	Washington Department of Natural Resources
WCS BRT	West Coast Salmon Biological Review Team
WDF	Washington Department of Fisheries
WDFW	Washington Department of Fish and Wildlife
WF	west fork
WNFH	Winthrop National Fish Hatchery
WQT	Water Quality Team

WRIA	water resource inventory area
YN	Yakima Nation

Chapter 1

Supplemental Comprehensive Analysis Purpose & Use

This Page Intentionally Left Blank

Chapter 1
Supplemental Comprehensive Analysis - Purpose & Use

NOAA Fisheries is conducting multiple ESA consultations for several Federal actions that are occurring simultaneously affecting the same listed species of Columbia River Salmon and Steelhead. The actions are listed in Chapter 2, Prospective Actions; they concern the operation of the Federal Columbia River Power System (FCRPS), various Bureau of Reclamation irrigation storage projects and certain fisheries in the Columbia and Snake River Basins. Litigation concerning consultations for these activities creates a situation that justifies simultaneous ESA conclusions about the effects of these projects.

NOAA Fisheries issued its previous Biological Opinion for the FCRPS and associated Reclamation irrigation projects on November 30, 2004. In *NWF v. NMFS*, CV01-640-RE, Judge James A. Redden, Federal District Court of Oregon, invalidated this Opinion by his decision of May 26, 2005. NOAA Fisheries issued its previous biological opinion for Reclamation's Upper Snake River projects on March 31, 2005. In *American Rivers v. NOAA Fisheries*, CV-04-0061-RE, Judge Redden also invalidated NOAA Fisheries' Biological Opinion for the Upper Snake projects on May 23, 2006. The Court remanded both Biological Opinions to NOAA Fisheries and the FCRPS Action Agencies to comply with the ESA, as interpreted by the Court. Although these are separate ESA consultations and court cases, they are on the same court-ordered schedule for completion.

NOAA Fisheries is also one of the federal agencies involved in the Indian treaty fishing rights case of *United States v. Oregon*, CV68-513-KI (D. Oregon). Columbia River treaty and non-treaty fisheries have most recently occurred pursuant to a settlement agreement approved by the *U.S. v. Oregon* court in 2005. That agreement will expire in May, 2008. The parties to *US v. Oregon* have negotiated a new ten year agreement which they must submit to the court for approval. The court requires that NOAA Fisheries first issue a biological opinion detailing whether the effects of this agreement on the same listed salmon and steelhead species that are affected by the FCRPS and various USBR projects are consistent with the ESA standards of Section 7(a)(2). The parties to *U.S. v. Oregon* are all also participants in the litigation and remand for the FCRPS. Several are also participants in the litigation and remand for the USBR Upper Snake projects. The fishing activities of the *U.S. v. Oregon* agreement have been integrated by the parties into the actions considered for the FCRPS and USBR projects.

The FCRPS Action Agencies and Reclamation for its Upper Snake projects founded their two biological assessments for their actions on a common comprehensive analysis entitled Comprehensive Analysis of the Federal Columbia River Power System and Mainstem Effects of Upper Snake and Other Tributary Actions (Corps et al. 2007a). NOAA Fisheries received these biological assessments and the supporting Comprehensive Analysis (CA) on August 29, 2007. NOAA Fisheries' development of biological opinions for these actions began with consideration of the FCRPS Action

Agencies' Comprehensive Analysis. NOAA Fisheries has prepared this Supplemental Comprehensive Analysis to capture the best available data and analysis contemporaneous with its issuance of these biological opinions.

NOAA Fisheries' Supplemental Comprehensive Analysis builds on the FCRPS Action Agencies' Comprehensive Analysis, incorporating by reference the information relevant to NOAA Fisheries' analysis. NOAA Fisheries augments or substitutes that information with additional or alternative data and analysis about the effects of these actions on the listed species. Where there are explicit or implicit differences between NOAA Fisheries' SCA and the FCRPS Action Agencies' Comprehensive Analysis, NOAA Fisheries determines that the information in the SCA represents the best science and data available. Further, NOAA Fisheries has integrated its consideration of the activities called for by the *U.S. v. Oregon* settlement agreement into this SCA, considering those activities to be part of the Prospective Actions for that analysis.

The SCA is a reference document. The Biological Opinion for the FCRPS and Reclamation Projects, the Biological Opinion for Reclamation's Upper Snake Projects and the Biological Opinion for the 2008-2017 *U.S. v. Oregon* Management Agreement are decision documents. NOAA Fisheries' ultimate determinations about jeopardy and destruction or adverse modification of critical habitat, pursuant to ESA § 7(a)(2), are found in the biological opinions. Incidental take statements for these actions, pursuant to ESA § 7(b)(4), are also in the respective biological opinions. NOAA Fisheries' consideration and evaluation of the relevant data and analysis on which these decisions are based, are found in the SCA. The biological opinions each explicitly incorporate information from the SCA necessary to support their respective determinations. In this way, the multiple biological opinions are tiered off of the common SCA.

At the same time, to ensure the relevance of its information, the SCA is based on the actions as detailed in their originating documents. The SCA incorporates for its analysis the Reasonable and Prudent Alternative (RPA) as described in the biological opinion for the FCRPS and associated Reclamation projects. Also, the SCA looks to the FCRPS Biological Opinion for the description of NOAA Fisheries' issuance of a research and enhancement permit, pursuant to ESA § 10(a)(1)(A), for the Corps' Juvenile Transport Program. Similarly, the SCA incorporates for its analysis the Proposed Action for Reclamation's Upper Snake Projects, from the Reclamation's biological assessment for those projects. Finally, the SCA looks to the 2008-2017 *U.S. v. Oregon* Management Agreement Biological Opinion for a full description of those activities for consultation. In this way the SCA is contemporaneous with NOAA Fisheries' Biological opinions for all of these actions.

Chapter 2

Prospective Actions

This Page Intentionally Left Blank

Chapter 2
Prospective Actions

The following Federal actions are aggregated in this Supplemental Comprehensive Analysis and are referenced hereinafter as the Prospective Actions:

- Operation and configuration of the FCRPS as described in the 2007 FCRPS Biological Assessment (Corps et al. 2007b) and the mainstem effects of 11 Reclamation irrigation projects (Corps et al. 2007b, Appendix B-1-7), as modified by;

    - NOAA Fisheries' RPA for the FCRPS (described in Chapter 4 of the FCRPS Biological Opinion (NMFS 2008a),

- NOAA Fisheries' § 10(a)(1)(A) Transportation Permit (described in Chapter 2 of the FCRPS Biological Opinion [NMFS 2008a]), and

- Reclamation's Upper Snake proposed action (described in Reclamation's 2007 Upper Snake Biological Assessment [USBR 2007]).

- NOAA Fisheries' participation in the 2008-2017 *United States v. Oregon* Management Agreement (hereafter, "2008 *U.S. v. Oregon* Agreement") concerning particular Columbia River fisheries related activities as described in Chapter 2 of NOAA Fisheries' Biological Opinion for that Agreement

This Page Intentionally Left Blank

Chapter 3

Comprehensive Action Area

This Page Intentionally Left Blank

Chapter 3
Comprehensive Action Area

The action area for this Comprehensive Analysis is the composite of the relevant action areas described in Chapters 4 of the FCRPS and USBR Upper Snake Biological Opinions and in Chapter 3 of the 2008-2017 *United States v. Oregon* Agreement Biological Opinion.

This Page Intentionally Left Blank

Chapter 4

Species & Critical Habitat Affected

4.1 Species Affected by the Prospective

4.2 Designated Critical habitat Affected by the Prospective Action

4.3 Endangered Species Act Recovery Planning

This Page Intentionally Left Blank

Chapter 4
Species & Critical Habitat Affected

4.1 Species Affected by the Prospective Actions

The following 13 species (and for 12, their designated critical habitat) are the subject of the FCRPS and Upper Snake consultations on remand.

Chinook Salmon (*Oncorhynchus tshawytscha*)

ESU	ESA Listing Status	ESA Critical Habitat
Snake River (SR) spring/summer Chinook salmon	Listed as threatened on June 28, 2005 [NMFS 2005a]	Critical habitat designated on October 25, 1999 [NMFS 1999a]
Snake River (SR) fall Chinook salmon	Listed as threatened on June 28, 2005 [NMFS 2005a]	Critical habitat designated on December 28, 1993 [NMFS 1993]
Upper Columbia River (UCR) spring Chinook salmon	Listed as endangered on June 28, 2005 [NMFS 2005a]	Critical habitat designated on September 2, 2005 [NMFS 2005b]
Upper Willamette River (UWR) Chinook salmon	Listed as threatened on June 28, 2005 [NMFS 2005a]	Critical habitat designated on September 2, 2005 [NMFS 2005b]
Lower Columbia River (LCR) Chinook salmon	Listed as threatened on June 28, 2005 [NMFS 2005a]	Critical habitat designated on September 2, 2005 [NMFS 2005b]

Steelhead (*Oncorhynchus mykiss*)

ESU	ESA Listing Status	ESA Critical Habitat
Snake River (SR) steelhead	Listed as threatened on January 5, 2006 [NMFS 2006a]	Critical habitat designated on September 2, 2005 [NMFS 2005b]
Upper Columbia River (UCR) steelhead	Listed as endangered on June 13, 2007 [Court decision]	Critical habitat designated on September 2, 2005 [NMFS 2005b]
Middle Columbia River (MCR) steelhead	Listed as threatened on January 5, 2006 [NMFS 2006a]	Critical habitat designated on September 2, 2005 [NMFS 2005b]

Steelhead (*Oncorhynchus mykiss*) Continued

ESU	ESA Listing Status	ESA Critical Habitat
Upper Willamette River (UWR) steelhead	Listed as threatened on January 5, 2006 [NMFS 2006 a]	Critical habitat designated on September 2, 2005 [NMFS 2005b]
Lower Columbia River (LCR) steelhead	Listed as threatened on January 5, 2006 [NMFS 2006 a]	Critical habitat designated on September 2, 2005 [NMFS 2005b]

Chum Salmon (*Oncorhynchus keta*)

ESU	ESA Listing Status	ESA Critical Habitat
Columbia River (CR) chum salmon	Listed as threatened on June 28, 2005 [NMFS 2005a]	Habitat designated on September 2, 2005 [NMFS 2005b]

Sockeye Salmon (*Oncorhynchus nerka*)

ESU	ESA Listing Status	ESA Critical Habitat
Snake River (SR) sockeye salmon	Listed as endangered on June 28, 2005 [NMFS 2005a]	Critical habitat designated on December 28, 1993 [NMFS 1993]

Coho Salmon (*Oncorhynchus kisutch*)

ESU	ESA Listing Status	ESA Critical Habitat
Lower Columbia River coho salmon	Listed as threatened on June 28, 2005 [NMFS 2005a]	Critical habitat designation under development

Killer Whales (*Orcinus orca*)

ESU	ESA Listing Status	ESA Critical Habitat
Southern Resident DPS Killer Whales	Listed as endangered on November 18, 2005 [NMFS 2005d]	Critical habitat designation on November 29, 2006 [NMFS 2006c]

Green Sturgeon (*A. medirostris*)

ESU	ESA Listing Status	ESA Critical Habitat
Southern DPS of Green Sturgeon	Listed as endangered on April 7, 2006 [NMFS 2006d]	Critical habitat designation under development

4.2 Designated Critical Habitat Affected by the Prospective Actions

4.2.1 Designated Critical Habitat for Columbia Basin Salmon and Steelhead

NOAA Fisheries has designated critical habitat for 12 of the 13 salmon and steelhead species that would be affected by the FCRPS and Upper Snake prospective actions.[1] Critical habitat includes the stream channel within each designated stream reach with the lateral extent defined by the ordinary high-water line. Within these areas, the primary constituent elements (PCEs) essential for the conservation of the listed species are those sites and habitat components that support one or more life stages. The PCEs for three species of SR salmon are shown in Table 4.2.1-1, below. The PCEs for nine other species of Columbia basin salmon and steelhead are described in the paragraphs following Table 4.2.1-1.

Table 4.2.1-1. PCEs identified for SR Sockeye, spring/summer Chinook, and fall Chinook Salmon (NMFS 1993)

Habitat Component	Sockeye	Spring/Summer Chinook	Fall Chinook
Spawning & juvenile rearing areas	1) spawning gravel 2) water quality 3) water quantity 4) water temp. 5) food 6) riparian veg. 7) access	1) spawning gravel 2) water quality 3) water quantity 4) cover/shelter 5) food 6) riparian veg. 7) space	Same as spr/sum Chinook
Juvenile migration corridors	1) substrate 2) water quality 3) water quantity 4) water temp. 5) water velocity 6) cover/shelter 7) food 8) riparian veg. 9) space 10) safe passage	Same as sockeye	Same as sockeye
Areas for growth & development to adulthood	Ocean areas – not identified	Same as sockeye	Same as sockeye
Adult migration corridors	1) substrate 2) water quality 3) water quantity 4) water temp. 5) water velocity 6) cover/shelter 7) riparian veg.	Same as sockeye	Same as sockeye

[1] NOAA has not yet developed a critical habitat designation for LCR coho salmon.

Habitat Component	Sockeye	Spring/Summer Chinook	Fall Chinook
	8) space 9) safe passage		

NOAA Fisheries (NMFS 2005b) has identified the following PCEs for the nine other species of Columbia basin salmonids.[2]

1. Freshwater spawning sites with water quantity and quality conditions and substrate supporting spawning, incubation and larval development. These features are essential to conservation because without them the species cannot successfully spawn and produce offspring.

2. Freshwater rearing sites with water quantity and floodplain connectivity to form and maintain physical habitat conditions and support juvenile growth and mobility; water quality and forage supporting juvenile development; and natural cover such as shade, submerged and overhanging large wood, log jams and beaver dams, aquatic vegetation, large rocks and boulders, side channels, and undercut banks. These features are essential to conservation because without them, juveniles cannot access and use the areas needed to forage, grow, and develop behaviors (e.g., predator avoidance, competition) that help ensure their survival.

3. Freshwater migration corridors free of obstruction with water quantity and quality conditions and natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, side channels, and undercut banks supporting juvenile and adult mobility and survival. These features are essential to conservation because without them juveniles cannot use the variety of habitats that allow them to avoid high flows, avoid predators, successfully compete, begin the behavioral and physiological changes needed for life in the ocean, and reach the ocean in a timely manner. Similarly, these features are essential for adults because they allow fish in a non-feeding condition to successfully swim upstream, avoid predators, and reach spawning areas on limited energy stores.

4. Estuarine areas free of obstruction with water quality, water quantity, and salinity conditions supporting juvenile and adult physiological transitions between fresh- and saltwater; natural cover such as submerged and overhanging large wood, aquatic vegetation, large rocks and boulders, and side channels; and juvenile and adult forage, including aquatic invertebrates and fishes, supporting growth and maturation. These features are essential to conservation because without them juveniles cannot reach the ocean in a timely manner and use the variety of habitats that allow them to avoid predators, compete successfully, and complete the behavioral and physiological changes needed for life in the ocean. Similarly, these features are essential to the conservation of adults because they provide a final source of abundant forage that will provide the energy stores needed

[2] A fifth category in NOAA Fisheries (NMFS 2005b), "nearshore marine areas," refers to areas designated in Puget Sound (i.e., is not applicable to Columbia basin salmonids).

to make the physiological transition to fresh water, migrate upstream, avoid predators, and develop to maturity upon reaching spawning areas.

At the time of the critical habitat designations that became final in September of 2005, NOAA Fisheries' Critical Habitat Analytical Review Teams (CHARTs) rated 525 occupied watersheds in the Columbia River basin. The CHARTs gave each of these occupied watersheds a high, medium, or low rating. High-value watersheds are those with a high likelihood of promoting conservation, while low value watersheds are expected to contribute relatively little. Conservation value was determined by considering the factors listed in Table 4.2-2 below.

Table 4.2-2. Factors considered by Columbia Basin CHARTs to determine the conservation value of occupied HUC-5s.[3]

Factors	Considerations
PCE quantity	Total stream area or number of reaches in the HUC-5 where PCEs are found; compares to both distribution in other HUC-5s and to probable historical quantity within the HUC-5
PCE quality – current condition	Existing condition of the quality of PCEs in the HUC-5
PCE quality - potential condition	Likelihood of achieving PCE potential in the HUC-5, either naturally or through active conservation/restoration, given known limiting factors, likely biophysical responses, and feasibility
PCE quality - support of rarity/importance	Support of rare genetic or life history characteristics or rare/important types in the HUC-5
PCE quantity - support of abundant populations	Support of variable-sized populations relative to other HUC-5s and the probably historical levels in the HUC-5
PCE quality - support of spawning/rearing	Support of spawning or rearing of varying numbers of populations (i.e., different run-timing or life history types within a single ESU and or different ESUs)

Of the 525 watersheds evaluated, 382 were assigned a high rating, 93 a medium rating, and 50 a low rating. The CHART ratings do not address SR spring/summer Chinook salmon, SR fall Chinook salmon, or SR sockeye salmon because critical habitat was designated for these ESUs in 1993. Ratings for the LCR coho salmon ESU are under development.

Many factors, both human-caused and natural, have contributed to the decline of salmon over the past century. Salmon habitat has been altered through activities such as urban development, logging, grazing, power generation, and agriculture. These habitat alterations have resulted in the

[3] A HUC is a Hydrologic Unit Code, developed by the U.S. Geological Survey as a standardized way of identifying drainage basins, subbasins, and watersheds throughout the country. A HUC-5 is a five unit (ten two-digit numbers) code. Examples of HUC-5s are "Salmon River-Redfish Lake Creek" (1706020102) in the upper Salmon River basin, Idaho; "Wenatchee River—Icicle Creek" (1709000501) in the upper Willamette basin, Oregon.

loss of important spawning and rearing habitat and the loss or degradation of migration corridors. Thus, critical habitat is not able to serve its conservation role in its current condition in many of the designated watersheds. Factors limiting the functioning of PCEs and thus the conservation value of critical habitat are discussed for each species in Chapter 8 of this document.

4.2.2 Designated Critical Habitat for Southern Resident Killer Whales

NOAA Fisheries published the final designation of critical habitat was published November 29, 2006 (NMFS 2006c). Critical habitat consists of three specific areas (1) the Summer Core Area in Haro Strait and waters around the San Juan Islands; (2) Puget Sound; and (3) the Strait of Juan de Fuca, which comprise approximately 2,560 square miles of marine habitat. Based on the natural history of the Southern Residents and their habitat needs, NOAA Fisheries identified the following physical or biological features (i.e., PCEs) essential to conservation: (1) water quality to support growth and development; (2) prey species of sufficient quantity, quality and availability to support individual growth, reproduction and development, as well as overall population growth; and (3) passage conditions to allow for migration, resting, and foraging.

Factors limiting the functioning of PCEs and thus the conservation value of critical habitat are water quality (Puget Sound); prey quantity, quality, and availability (throughout portions of the designated area used for foraging); and impediments to passage between areas used for foraging and other activities (e.g., the presence of vessels).

There is no designated critical habitat for Southern Resident Killer Whales in the action area for the Prospective Actions.

4.2.3 Designated Critical Habitat for Green Sturgeon

NOAA Fisheries has not yet designated critical habitat for this species.

4.3 Endangered Species Act Recovery Planning

This section describes current recovery planning activities for the listed salmonid species affected by the FCRPS.

The ESA requires NOAA Fisheries to develop and implement recovery plans for species listed under the Act. The purpose of recovery plans is to identify actions needed “for the conservation and survival” [ESA Section 4(f)(1)] of threatened and endangered species to the point that they no longer need the Act’s protection. ESA recovery plans organize, coordinate, and prioritize possible recovery actions to provide a road map for species’ recovery. NOAA Fisheries’ recovery plans articulate the goals and scientifically supported strategies needed to recover a listed species (NMFS 2007a).

The ESA mandates that a recovery plan must provide:

- A description of such site-specific management actions as may be necessary to achieve the plan's goal for the conservation and survival of the species;
- Objective, measurable criteria which, when met, would result in a determination that the species be removed from the list, and;
- Estimates of the time required and the cost to carry out those measures needed to achieve the plan's goal and to achieve intermediate steps toward that goal. See ESA Section 4(f)(1)(B).

ESA Section 4(a)(1) lists factors for listing, re-classification or delisting, and these are addressed in recovery plans:

- The present or threatened destruction, modification, or curtailment of [the species'] habitat or range
- Over-utilization for commercial, recreational, scientific or educational purposes
- Disease or predation
- The inadequacy of existing regulatory mechanisms, or
- Other natural or manmade factors affecting its continued existence.

ESA Recovery Planning: Overview

NOAA Fisheries is basing ESA recovery plans for Pacific salmon on the state, regional, Tribal, local, and private conservation efforts already underway throughout the region. To support recovery planning process in the Columbia Basin, NOAA Fisheries convened two Technical Recovery Teams (TRT) to develop recommendations on biological viability criteria for ESUs and their component populations, to provide scientific support to local and regional recovery planning efforts, and to provide scientific evaluations of recovery plans. These are the Willamette /Lower Columbia and the Interior Columbia TRTs.

Nominations for each TRT were solicited from the scientific community and candidates were evaluated by an independent panel before being appointed. These TRTs are scientific advisory committees. Although they are coordinated and chaired by NOAA Fisheries' Northwest Fisheries Science Center staff and their work includes significant contributions from NOAA Fisheries science staff, most of the members are not NOAA Fisheries scientists. TRT members include scientists from other federal agencies, state agencies, Tribes, states, universities, and consultants.

All TRTs used the same biological principles for developing their ESU and population viability criteria. These principles are described in a NOAA Fisheries technical memorandum, *Viable Salmonid*

Populations and the Recovery of Evolutionarily Significant Units (McElhany et al. 2000). A viable salmonid population (VSP) is defined as one that has a negligible extinction risk over a 100-year time frame. Viable salmonid populations are defined in terms of four parameters: abundance, productivity or growth rate, spatial structure, and diversity. Viable ESUs are defined by some combination of populations, at least some of which meet or exceed "viable" thresholds for abundance and productivity, and that have appropriate geographic distribution, protection from catastrophic events, and diversity of life histories and other genetic expression.

The TRTs identified the historical population structure of each ESU/DPS including independent populations and major population groups (MPGs), based on shared geography or ecosystems, genetic similarity, and other considerations, within each ESU/DPS (The Interior Columbia TRT called these groupings major population groups (MPGs); the Willamette/Lower Columbia TRT called them strata—in this discussion we use the term major population group to refer to both.).

Both TRTs then developed viability criteria at the population, MPG, and ESU/DPS scales (WLCTRT and ODFW 2006; ICTRT 2007a). Both TRTs concluded that for an ESU/DPS to be considered viable, all MPGs within that ESU/DPS should be at low risk. A low risk MPG was defined as one with some minimum number of viable populations and with other populations improved to or maintained at some other (generally higher) risk status so that they are nevertheless contributing to overall MPG or ESU/DPS viability.[4]

Given the hierarchical structure of salmonid biology, an overall assessment of extinction risk for an ESU or DPS begins at the population level and builds up to the MPG and ESU/DPS levels (See Figure 4.3-1). Moreover, the status of individual populations is evaluated to assess MPG risk status, and then the status of each MPG within an ESU/DPS is considered when evaluating overall ESU/DPS status. Both TRTs developed reports assessing the current status and extinction risk of individual populations, MPGs, and ESUs/DPSs based on their criteria.

[4] Technical Recovery Team "viability" recommendations are associated with recovery and delisting in recovery plans for salmon and steelhead. It therefore goes beyond the "potential for recovery" prong of the jeopardy standard as described in Section 7.1.

Hierarchy in Salmonid Population Structure

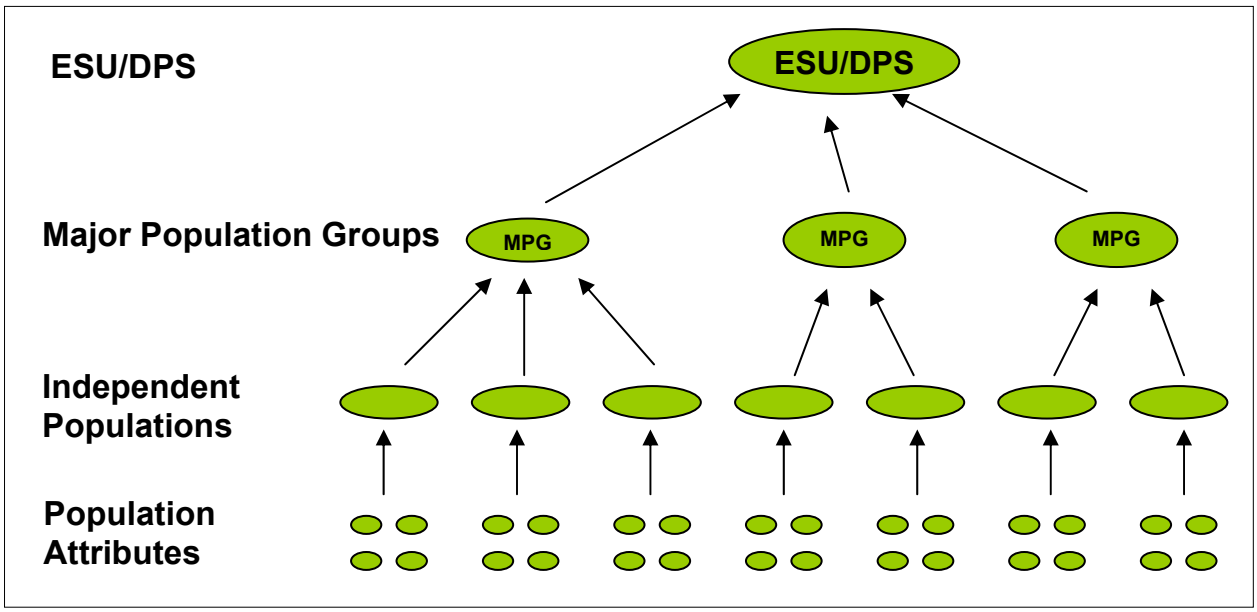


Figure 4.3-1 Hierarchical levels of salmonid species structure as defined by the TRTs for ESU/DPS recovery planning.

Adopting Plans as NOAA Fisheries' Recovery Plans

In some cases, NOAA Fisheries will adopt a local plan directly as the ESA recovery plan. In other cases, NOAA Fisheries may write a "supplement" summarizing a locally developed plan and noting any necessary additions or qualifications to make it adequate for ESA recovery. The supplement then becomes part of the ESA recovery plan for the ESU. To finalize and formally adopt a plan under the ESA, NOAA Fisheries issues a notice of availability of the proposed recovery plan in the Federal Register and requests public comment for at least 60 days. During this time, NOAA Fisheries also requests technical review of the certain aspects of the plan. NOAA Fisheries then considers all comments received and may amend the proposed plan in response. The record for the final plan includes NOAA Fisheries' written response to comments. NOAA Fisheries also publishes a notice in the Federal Register when the plan is final. The status of recovery plans in the domains, sub-domains, and management units are summarized in table 4.3-2.

Major Recovery Plan Elements

All recovery plans contain several common elements, described below.

Recovery goals, broad sense recovery goals and delisting criteria

The primary goal of ESA recovery plans is for the species to reach the point where they no longer need the protection of the Act – i.e., to be delisted. All locally developed recovery plans incorporate this primary goal. Some of the locally developed recovery plans in the Columbia Basin also contain "broad-sense recovery goals" that go beyond ESA requirements for delisting, to address other legislative mandates or social, economic, and ecological values. Recovery plans may, for instance,

address the impacts of regional human population growth on listed salmonids in the Columbia River basin.[5]

Delisting criteria define conditions that, when met, would result in a determination by NOAA Fisheries that the species are not likely to become endangered within the foreseeable future throughout all or a significant portion of its range. Where species are endangered, the recovery plans also provide criteria for determining that the species is no longer in danger of extinction throughout all, or a significant portion, of its range.

ESA delisting criteria are of two kinds: biological criteria – the population or demographic parameters for viability, and threats criteria - the conditions under which the listing factors, or threats detailed in the ESA Section 4(a)(1) can be considered to be addressed or mitigated. All of the Columbia basin recovery plans either have based or will base their biological recovery criteria on viability criteria from Interior Columbia and Willamette/Lower Columbia TRT reports. All of the plans' threats criteria have been or will be developed to address the specific conditions related to habitat, hydropower, harvest, hatcheries, and other limiting factors (such as predation, competition, and invasive species) as they affect the ESUs or DPSs in a particular domain. Together, the biological criteria and threats criteria make up the "objective, measurable criteria" required under Section 4(f)(1)(B).

Delisting criteria are a NOAA Fisheries' determination and may include both technical and policy considerations. The criteria that are in recovery plans could exceed the minimum necessary to delist the species. Delisting decisions will be made at some future time and will take into account information and conditions at that time.

In accordance with ESA Section 4(c)(2), NOAA Fisheries will conduct status reviews of the 13 listed Columbia Basin salmon and steelhead ESUs or DPSs every five years to evaluate their status and determine whether they should be proposed for de-listing or a change in status. Such evaluations will take into account the following:

- The biological recovery criteria (ICTRT 2007a; WLCTRT and ODFW 2006) and listing factor (threats) criteria (which attempt to provide measurable criteria for the Section 4(a)(1) listing factors).

- The management programs in place to address the threats.

- Principles presented in the Viable Salmonid Populations paper (McElhany et al. 2000).

[5] Regional population growth is projected to continue through 2030 in the Pacific Northwest (ISAB 2007a). The implications of this growth include increased demand for land, water, and hydroelectricity, all of which have the potential to limit listed salmonid viability. Recovery plans, under the premise of "broad-sense recovery goals," may account for the impacts of human population growth in local recovery efforts. In doing so, recovery planning would not only go beyond the ESA requirements for delisting, but would address, and potentially mitigate for, the impacts of regional growth on listed species.

- Best available information on population and ESU/DPS status and new advances in risk evaluation methodologies.

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

- Hatchery fish considerations and progress on hatchery reform.

- Conservation efforts evaluated according to NOAA Fisheries' Policy for Evaluating Conservation Efforts (NMFS 2003a).

Recovery Scenarios

Both the Willamette/Lower Columbia and Interior Columbia TRT recommended that for an ESU/DPS to be considered at low risk of extinction (and therefore viable), all MPGs in that ESU/DPS should be at low risk. A low risk MPG was defined as one with some minimum number of viable populations and with other populations improved to or maintained at some other (possibly higher) risk status so that they are contributing to overall MPG or ESU/DPS viability. Thus, the status of individual populations is evaluated to assess MPG risk status, and then the status of each MPG within an ESU/DPS is considered when evaluating overall ESU/MPG status (see Sections 7.1.1.1 and 7.3).

For Columbia Basin ESUs/DPS that are comprised of multiple populations and MPGs, it may not be necessary for all of the populations to attain low risk in order to provide sufficient viability for the ESU/DPS as a whole; the ESU/DPS-level viability criteria allow for some combination of risk status among the component populations. Furthermore, there is more than one combination of populations at various risk levels that constitute a viable ESU/DPS. NOAA Fisheries refers to the possible combinations of low-risk status populations in each MPG that would allow the ESU/DPS to meet the viability criteria as "recovery scenarios."

Status reviews conducted by the Biological Review Team (BRT)[6] provide precedence for determinations that not all populations that were historically present must be present in an ESU for the ESU to be viable (need status review cites for non-listed ESUs). The BRT reviewed ESUs and determined that they were not threatened or endangered, even though the ESUs contained some populations that clearly would not meet VSP criteria.[7]

In the analyses described in Sections 7.1 through 7.3, NOAA Fisheries applied two general considerations apply to determining the minimum number of populations that needed to be viable within an MPG for it to be sufficiently low risk for viability of the ESU/DPS. First, having multiple viable populations can provide a spatial distribution that maintains within MPG diversity while

[6] The BRT's findings are not recommendations regarding listing because they did not include consideration of the potential contribution of hatchery stocks to the viability of ESUs, or evaluate efforts being made to protect the species (NMFS 2005a).
[7] NMFS (2005a).

providing for dispersal at normative rates and second, having multiple viable populations reduces extinction risk due to local catastrophic events (VSP paper, WLCTRT and ODFW 2006). Also, a general objective for the combinations of viable and less than viable populations provided by the ICTRT (2007 a) is that the composite MPG productivity be at or above replacement, thus ensuring long-term persistence of the ESU/DPS. The ICTRT and WLCTRT also concluded that achieving viability goals for the minimum number of populations will likely require attempting to meet those targets in more than just those populations because the efficacy of recovery efforts is uncertain. Finally, both TRTs stated the importance of maintaining the status of the additional populations not meeting viability criteria within a particular recovery scenario at levels that contribute to the ecological and evolutionary function of the ESU as a whole. At the time of a status review and listing classification decision, all of these considerations will be applied in the context of the status and risks facing the populations.

Limiting Factors Analyses & Threats Assessments

Recovery plans describe the limiting factors and threats that are the reasons for the species' decline. The recovery plans define "limiting factors" as the biological and physical conditions limiting ESU/DPS and population status (e.g. elevated water temperature), and define "threats" as those human activities or naturally induced conditions that cause the limiting factors (e.g. removal of riparian vegetation, which causes loss of shade and, consequently, elevated water temperature). The limiting factors are evaluated based on their impacts on population viability parameters and risk status.

Most Columbia Basin salmon ESUs and steelhead DPSs contain multiple populations distributed across a wide region of varying ecology and multiple political and jurisdictional boundaries. Because populations are the building blocks for evaluating the status of ESUs/DPSs, limiting factors and threats analyses in recovery plans are based on assessments of population-level limiting factors and then rolled up to the MPG and ESU/DPS level. These limiting factors/threats analyses are based on available scientific information, including subbasin assessments and plans, watershed assessments, expert panels, published research, ongoing field studies, and the expert opinion of regional biologists.

Recovery Strategies and Actions

Recovery plans include, "a description of such site-specific management actions as may be necessary to achieve the plan's goal for the conservation and survival of the species" (ESA (f)(1)(B)(i). NOAA Fisheries has required Columbia Basin recovery actions to be derived from the limiting factors and threats assessments. Columbia Basin recovery plans generally describe strategies and actions for each population in an ESU/DPS.

Estimates of Time & Cost

All of the locally-developed recovery plans contain extensive lists of actions needed to recover the ESUs/DPSs. The estimate of total time for recovery may end up ranging from 5 to 50 years; however, there are many uncertainties involved in predicting the course of recovery and in estimating total costs. Such uncertainties include biological and ecosystem responses to recovery actions as well as long-term and future funding. Most of the recovery plans are focusing on immediate needs and NOAA Fisheries has supported an initial focus on the first 10 to 15 years of implementation, provided that, before the end of this first implementation period, specific actions and costs will be estimated for

subsequent years, to achieve long-term goals and to proceed until a determination is made that listing is no longer necessary.

Research, Monitoring & Evaluation

Recovery plans need monitoring and evaluation programs that answer these basic questions: How will we know we are making progress? How will we get the information we need? And how will we use the information in decision making? All of the recovery plans will have actions for research, monitoring and evaluation. The Upper Columbia Recovery Plan for salmon and steelhead contains the Columbia Basin's first such monitoring plan. It is designed and will be incorporated into an adaptive management framework based on the principles and concepts laid out in the NOAA Fisheries draft guidance document, Adaptive Management for Salmon Recovery: Evaluation Framework and Monitoring Guidance (NMFS 2007b) NOAA Fisheries will work with local planners to ensure that, taken together, the monitoring and evaluation programs for each management unit, combined with monitoring components of the modules incorporated into the plans, address the needs of the entire ESUs/DPSs.

Relationship between Recovery Planning and Section 7

Recovery plans provide important context for making section 7 determinations. When NOAA Fisheries conducts a consultation pursuant to section 7(a)(2), it assists Federal agencies in ensuring that their actions are not likely to jeopardize the continued existence of listed species or result in the destruction or adverse modification of critical habitat. The ESA regulations, define "jeopardize the continued existence of" as "engag[ing] in an action that would reasonably be expected, directly or indirectly to reduce appreciably the likelihood of both the survival and recovery of listed species in the wild by reducing the reproduction, numbers or distribution of that species." Recovery plans provide criteria that describe what "recovery" looks like. Recovery plans provide biological criteria for the abundance, productivity, spatial structure and diversity of a recovered species and also criteria for evaluating whether threats to the species have been addressed. The criteria describing the characteristics of recovered species also provide metrics that are useful for evaluating the effects of human actions on listed species. NOAA Fisheries' critical habitat analysis determines whether the proposed action will destroy or adversely modify designated or proposed critical habitat for ESA-listed species by examining any expected changes in the conservation value of the essential features of that critical habitat.

Table 4.3-2. Status of Columbia Basin Recovery Plans[8]

Domain Sub domain *Management Unit*	**Species Addressed**	**Final Recovery Plan**	**Interim Regional Recovery Plan Complete**[9]	**Target Draft Completion**	**Entity**
Interior Columbia					
Upper Columbia	Upper Col steelhead Upper Col. Chinook	X			U. Col Salmon Recovery Board
Snake *Idaho*	Snake River sockeye Snake River fall Chinook Snake River steelhead Snake River sp/su Chinook			January 2008	NOAA Fisheries in coordination with State of Idaho
Oregon	Snake River fall Chinook Snake River steelhead Snake River sp/su Chinook			January 2008	OR Snake Sounding Board
SE.Washington	Snake River fall Chinook Snake River steelhead Snake River sp/su Chinook		X		SE Wash. Salmon Recovery Board
Mid Columbia DPS	Mid Columbia steelhead			January, 2008	NOAA Fisheries in coordination with all Management Units
Oregon	Mid Columbia steelhead			October 2007	OR Snake Sounding Board
Yakima	Mid Columbia steelhead		X	Revision Oct. 2007	Yakima Salmon Recovery Board
SE.Washington	Mid Columbia steelhead		X		SE Wash. Salmon Recovery Board
Gorge	Mid Columbia Steelhead Lower Columbia steelhead			October 2007	NOAA Fisheries; Yakama Nation, with others

[8] Links to each individual plan are provided at: http://www.nwr.noaa.gov/Salmon-Recovery-Planning/ESA-Recovery-Plans/Draft-Plans.cfm
[9] These plans have been noticed in the Federal Register, received public comment and NOAA Fisheries has approved them as Interim Regional Recovery Plans until full ESU/DPS plans are complete.

Domain Sub domain *Management Unit*	**Species Addressed**	**Final Recovery Plan**	**Interim Regional Recovery Plan Complete**[9]	**Target Draft Completion**	**Entity**
Willamette/Lower Columbia					
Lower Columbia *Washington*	Columbia chum, Lower Columbia steelhead, L.Columbia Chinook L. Columbia coho		X		
Oregon	Columbia chum, Lower Columbia steelhead, L.Columbia Chinook L.Columbia coho				ODFW, NOAA Fisheries, L. Col. Sounding Board
U. Willamette	U.Willamette steelhead U.Willamette Chinook				ODFW, NOAA Fisheries, Willamette Sounding Board

This Page Intentionally Left Blank

Chapter 5

Environmental Baseline

5.1 Hydro Effects

5.2 Tributary Habitat Effects

5.3 Estuary & Plume Habitat Effects

5.4 Predation & Disease Effects

5.5 Hatchery Effects

5.6 Harvest Effects

5.7 Large-scale Environmental Variation

This Page Intentionally Left Blank

Chapter 5
Environmental Baseline

This chapter describes the effects of past and ongoing human and natural factors within the combined action area (Chapter 3), on the current status of the species, their habitats and ecosystems. The environmental baseline includes,

> "the past and present impacts of all Federal, state, or private actions and other human activities in the action area, including the anticipated impacts of all proposed Federal projects in the action area that have undergone Section 7 consultation and the impacts of state and private actions that are contemporaneous with the consultation in progress" (50 CFR 402.02, 'effects of the action').

To facilitate our analytical approach (see Section 7 of this document), this section is organized into hydro effects, tributary habitat effects, estuary and plume habitat effects, predation and disease effects, hatchery effects, harvest effects, and large-scale environmental factors. These are over-view discussions of environmental conditions affecting one or more ESUs in the action area and focused on past and ongoing effects related to the FCRPS, Upper Snake projects, and in-river harvest activities. In general, Columbia River salmon have been adversely affected by a broad number of human activities including habitat losses from all causes (population growth, urbanization, roads, etc.), fishing pressure, flood control, irrigation dams, pollution, municipal and industrial water use, introduced species, and hatchery production (NRC 1996). In addition, salmon populations have been strongly affected by ocean and climate conditions. Species-specific information that continues this discussion of the environmental baseline, including the current status of designated critical habitats, is presented in Chapter 8 of this document.

Killer whale (*Orcinus orca*) and green sturgeon (*Acipenser medirostris*) are included in this consultation. However, the Action Agencies have determined that while the Prospective Action may affect these species, they are not likely to be adversely affected and have requested NOAA Fisheries concurrence (Corps et al. 2008). For this reason, green sturgeon and killer whale are treated separately in Chapters 9 and 10. For details on the environmental baseline conditions for these species, please refer to Chapters 9 and 10.

The aggregated factors described below, taken together, have contributed to the current status of the species as quantified, to the best of NOAA Fisheries' abilities, in the environmental baseline section of Chapter 8, as well as in the Aggregate Analysis Appendix—including the mortality estimates for juvenile and adults migrating through the FCRPS mainstem projects (see SCA, Adult Survival Estimates and Hydro Modeling Appendices).

5.1 Hydro System Effects

This section identifies the past and continuing effects of dams and reservoirs located in the mainstem Columbia and Snake Rivers' migratory corridor on listed species of salmon and steelhead and their designated critical habitat. The mainstem migratory corridor extends from the base of Hells Canyon Dam, on the Snake River, and from Chief Joseph Dam, on the Columbia River, to the mouth of the Columbia River.

Columbia River Basin anadromous salmonids have been affected by the development and operation of dams. Dams, without adequate fish passage systems, have extirpated anadromous fish from their pre-development spawning and rearing habitats. Dams and reservoirs, within the currently accessible migratory corridor, have greatly altered the river environment and have affected fish passage. The operation of water storage projects has altered the natural hydrograph of the Snake and Columbia Rivers. Water impoundment and dam operations also affect downstream water quality characteristics, vital components to anadromous fish survival. Detailed descriptions of these effects are provided in Williams et al. 2005 and Ferguson et al. 2005 (NOAA Technical Memoranda NMFS-NWFSC-63 and 64). This information is summarized generally below. If any discrepancies are created as a result of this effort to summarize the more complex body of information into a more readable form, the information in the Technical Memoranda should be relied upon.

The effects of the operation, maintenance and structural modification of the FCRPS dams and reservoirs are one of the subjects of this SCA in support of multiple ESA consultations. The basic existence of the FCRPS dams is not the proposed action for ESA consultation, but is analyzed as part of the consultation consistent with the court decision in *NWF v. NMFS*, 481 F.3d 1224 (9th Cir. 2007). Rather that using a "reference operation," as in its 2004 FCRPS Biological Opinion (NMFS 2004a), NOAA Fisheries attempts to identify, and to the extent possible, quantify effects in the environmental baseline. However, because much of the effects in the environmental baseline would persist under the Prospective Action, NOAA Fisheries cannot draw a bright line for this consultation between hydro effects of the environmental baseline and those of the action for consultation. This section presents NOAA Fisheries' assessment of current dam effects on the listed species and critical habitat. This is the starting point for the species-specific analysis that continues in Chapter 8.

5.1.1 Blocked and Inundated Habitat

The construction of the FCRPS projects, Canadian flood control and hydropower projects, the Mid-Columbia Public Utility District dams, and (downstream of Shoshone Falls on the Snake River) Reclamation's Upper Snake projects and Idaho Power Company's mainstem dams have blocked access to salmon and steelhead from thousands of miles of habitat in the Columbia River basin, and inundated hundreds of miles more. Many smaller dams – even temporary dams - have had the same effects, though on much smaller scales.

Construction of Grand Coulee Dam in 1939 blocked access to historical production areas for upper Columbia River spring Chinook salmon and steelhead (NRC 1996; ICTRT 2003). Chief Joseph Dam, located downstream of Grand Coulee Dam, is also impassable. The Sanpoil, Spokane, Colville, Kettle, Pend Oreille, and Kootenai rivers each supported one or more populations of Chinook salmon and/or steelhead.

Before European contact, Snake River fall Chinook salmon occupied the mainstem Snake River up to Shoshone Falls (Gilbert and Evermann 1894; ICTRT 2003). In particular, the area downstream of Upper Salmon Falls, at river mile (RM) 578, was identified by Evermann (1895) as the "largest and most important salmon spawning ground of which we know in the Snake River." After loss of these upstream reaches with construction of Swan Falls Dam in 1901, the reach between Marsing, Idaho, and Swan Falls Dam (RM 349 to 424) was the primary spawning and rearing area for Snake River fall Chinook salmon (Irving and Bjornn 1981; Haas 1965, cited in ICTRT 2003). However, construction of the Hells Canyon Dam complex (1958–1967) cut off access to historical habitat upstream of RM 248. Additional fall Chinook habitat was lost through inundation as a result of the construction of the lower mainstem Snake River dams (Groves and Chandler 1999). In addition to the loss of fall Chinook salmon habitat on the mainstem Snake River, the Hells Canyon Dam complex cut off access to historical habitat in seven large tributaries for spring/summer Chinook salmon and steelhead. The seven tributaries are the Boise, Burnt, Malheur, Owyhee, Payette, Powder, and Weiser rivers (USBR 1997).[1] Each of these tributaries provided hundreds of miles of spawning and rearing habitat for spring/summer Chinook salmon and steelhead (and several lakes for sockeye salmon in the Payette River basin) (Fulton 1968; Fulton 1970; Gustafson 1997).

Similarly, dams constructed in tributary streams often were constructed without fish passage facilities, or fish passage that was provided functioned poorly. For example, Sunbeam Dam, built in 1910 about 20 miles downstream from Redfish Lake on the main Salmon River, was too high for salmon to surmount by leaping and was originally constructed without fish passage facilities. Though a poorly functioning concrete fish ladder was completed in 1920 and the dam was breached by blasting in 1934, the relatively short life of Sunbeam Dam is considered to be a major contributor to the decline of Snake River sockeye. In similar ways, many tributaries have been blocked by dams lacking adequate fish passage facilities.

In recent years, high quality fish passage is being restored where it did not previously exist, either through improvements to existing fish passage facilities or through dam removal (e.g., Marmot Dam on the Sandy River, Powerdale Dam on the Hood River, and Condit Dam on the White Salmon River). The anticipated effects of these actions on individual species are discussed in Sections 8.2 through 8.13 of this document.

---

[1] Many major projects were constructed between 1901 and 1958 in the tributaries upstream of the Hells Canyon Complex which prevented salmon and steelhead from reaching historical habitat. These include Barber (1906), Arrowrock (1915), Lucky Peak (1957) dams on the Boise River; Black Canyon Dam (1924) on the Payette River; Owyhee Dam (1932) on the Owyhee River; Thief Valley Dam (1931) on the Powder River; and Unity Dam (1940) on the Burnt River (USBR 1997).

Within the habitat currently accessible by salmon and steelhead, dams have negatively affected spawning and rearing habitat. Within the Columbia and Snake rivers where fish currently have access, short, relatively shallow and high velocity tailwater segments immediately downstream from each mainstem project provide small amounts of riverine habitat, some of which are used by spawning salmon. In addition, except for the Hanford and Hells Canyon Reaches (noted below) mainstem habitats in the Columbia and Snake Rivers have been reduced primarily to a single channel. Floodplains have been reduced, off-channel habitat features have been eliminated or disconnected from the main channel, and the amount of large woody debris in the mainstem has been greatly reduced. Remaining habitats often are affected by flow fluctuations associated with reservoir water management for power peaking, flood control, and other operations.

Upstream from Bonneville Dam, the 41-mile stretch (66 km) of the Columbia River known as the Hanford Reach between the head of Lake Wallula (McNary Dam pool) and the tailrace of Priest Rapids Dam, and the approximately 101-mile stretch (162 km) of the Snake River often referred to as the Hells Canyon Reach provide the longest remaining riverine ecosystems between Bonneville Dam and Chief Joseph dam on the Columbia River and Hells Canyon Dam on the Snake River (647 –miles or 1,042 km).

5.1.2 Mainstem Habitats & the Migratory Corridor

The Columbia and Snake Rivers (mainstem habitat) serve as migration corridors for migrating salmon and steelhead between the Pacific Ocean and their freshwater spawning and rearing habitats. Features of migration habitat important to these fish generally include: substrate, water quality, water quantity, water temperature, water velocity, cover/shelter, food (prey), riparian vegetation, space, and safe passage. For fall Chinook salmon and, to a lesser extent chum salmon, mainstem habitat also serves as important spawning and rearing habitat. Features of spawning and rearing habitat that are important to these fish generally include: spawning gravel, water quality, water quantity, water temperature, food, riparian vegetation, and access (to spawning and rearing areas).

Current conditions within much of the mainstem Columbia and Snake Rivers are altered compared to historic conditions. The development of hydropower and water storage projects within the Columbia River basin have resulted in the inundation of many mainstem spawning and shallow-water rearing areas (loss of spawning gravels and access to spawning and rearing areas); altered water quality (reduced spring turbidity levels), water quantity (seasonal changes in flows and consumptive losses resulting from use of stored water for agricultural, industrial, or municipal purposes), water temperature (including generally warmer minimum winter temperatures and cooler maximum summer temperatures), water velocity (reduced spring flows and increased cross-sectional areas of the river channel), food (alteration of food webs, including the type and availability of prey species), and safe passage (increased mortality rates of migrating juveniles) (Williams et. al 2005; Ferguson et. al 2005).

Table 5.1.2-1. Migration rates (km/day) of juvenile SR spring-summer Chinook salmon and steelhead through free flowing and impounded sections of the Snake and Columbia Rivers under low, medium, and high flow conditions. (Taken from Raymond 1979)

River Condition	Magnitude of Flow		
	Low[a]	Medium[b]	High[c]
Free-flowing	24	40	54
Impounded	8	13	24

a. Snake, 1,000 to 1,500 m^3/second; Columbia 4,000 to 5,000 m^3/second.
b. Snake, 2,000 to 3,000 m^3/second; Columbia 6,000 to 9,000 m^3/second.
c. Snake, 3,000 to 5,000 m^3/second; Columbia 10,000 to 14,000 m^3/second.

Within the migratory corridor, both dams and their associated reservoirs influence the current status of Columbia Basin salmon. To a greater or lesser extent specific to each dam, the dam present fish-passage hazards, causing passage delays and varying rates of injury and mortality. The altered habitats in project reservoirs reduce smolt migration rates and create more favorable habitat conditions for fish predators, including native northern pikeminnow (*Ptychocheilus oregonensis*), nonnative walleye (*Sander vitreus*), and smallmouth bass (*Micropterus dolomieu*).

5.1.2.1 Smolt Passage

Delay

Prior to the development of mainstem dams (c. 1938–1978), the mainstem migratory corridor was free-flowing with high velocities and a broad complex of habitats including rapids, short chutes, falls, riffles, and pools. It is not known how long it took juvenile salmon and steelhead to traverse the free-flowing river, but in 1966, when Snake River salmon encountered only four mainstem dams (Ice Harbor Dam on the Snake River and McNary, The Dalles, and Bonneville dams on the Columbia River), Raymond (1968; Raymond 1979), by comparing fish captured and marked in the Salmon River and recaptured at the four dams, estimated that migrating smolts traveled about one-third (in lower flow conditions) to one-half (in higher flow conditions) as fast through the impounded reaches as through the free-flowing reaches.

Dams within the migratory corridor converted much of the once free-flowing river into a stair-step series of slow pools. Today, median travel times for yearling Chinook from the Snake River to Bonneville Dam range from 14 days to 31 days depending on flow conditions, an increase of 40 to 50% over travel times measured in 1966 (see discussion above) when fish encountered only the four mainstem dams (Williams et al. 2005).

This increased travel time (migration delay) presents an array of potential survival hazards to migrating juvenile salmon and steelhead: increasing their exposure to potential mortality vectors in the reservoirs (e.g. predation, disease, thermals stress), disrupting arrival timing to the estuary

(which likely affects predator/prey relationships),[2] depleting energy reserves, potentially causing metabolic problems associated with smoltification (smoltification is the process of metabolic changes required to allow juvenile fish to convert from freshwater to saltwater environments), and for some steelhead and all Chinook salmon, contributing to residualism (a loss of migratory behavior).

A substantial fraction of the mortality experienced by juvenile outmigrants through the portion of the migratory corridor affected by the FCRPS occurs in the reservoirs (e.g., about half of the mortality of in-river migrating juvenile spring Chinook and steelhead) and reducing migration delays have therefore been a focus of recent actions to improve juvenile outmigrant survival through the FCRPS. For example, Federal storage reservoirs have, compared to historical operations, been operated to increase spring and summer flows to accelerate smolt migrations, voluntary spill (and most recently, the addition of surface passage routes) has been implemented to reduce forebay delay, and a large fraction of the annual outmigration has been collected and transported through the system, greatly accelerating passage.

Dam Passage

A substantial proportion of juvenile salmon and steelhead can be killed while migrating through dams, both directly through collisions with structures and abrupt pressure changes during passage through turbines and spillways, and indirectly, through non-fatal injury and disorientation which leave fish more susceptible to predation and disease, resulting in delayed mortality. Some juvenile mortality and injury is associated with all routes of dam passage, but turbines generally cause the highest direct mortality rates—generally ranging between 8 and 19 percent. Juveniles passing through project spillways, sluiceways and other surface routes generally suffer the lowest direct mortality rates, typically losses are 2% or less. However, substantially higher spillway mortalities have been measured through spillways at several mainstem projects (Ferguson et al. 2005, NOAA Technical Memoranda NMFS-NWFSC-64).[3] A significant rate of juvenile mortality (approximately 3-5%) can occur in project forebays, just upstream of the dams (Axel et al. 2003; Ferguson et al. 2005; Hockersmith 2007), where fish can be substantially delayed (median of 15-20 hours) before passing through the dam (Perry et al. 2007).[4] Forebay delay increases juvenile fish exposure to fish and avian predators, and increases their exposure time to adverse water quality conditions (e.g. elevated total dissolved gas levels and high water temperatures) (See discussion below regarding newly developed surface passage routes that are proving effective at reducing forebay delay).

---

[2] During the spring and summer a series of changes occur in the estuary and near-shore ocean environment. The assemblages of species change through time and disrupting arrival timing may increase the exposure of juvenile salmon to predators and/or diminish the availability of prey species.

[3] The route-specific mortality rate values given here are the averages of several investigations. Higher and lower moralities have been observed and measured route-specific mortality is influenced by an array of factors ranging from the health and species of the test fish, to the performance characteristics and working condition of the system being studied and environmental conditions.

[4] This study was conducted at McNary Dam; estimates of delay for individual fish ranged from 0 to 172 hours in this study.

In the 1980s and 1990s, seven of the eight FCRPS dams lying in the migratory path of Snake River juvenile salmon and steelhead were equipped with turbine intake screen systems that divert, depending on the species, 45-90% of the fish away from turbine entry and into bypass system channels. These bypass systems allow migrants to be collected for transport downstream to below Bonneville Dam or released back to the river. Contemporary mechanical screen bypass systems are vastly improved compared to the original systems that operated during the 1970s and early 1980s, based on recent low rates of descaling, injury, and system mortality. At present, estimates of mortality through these passage routes are usually low, typically less than 2 percent (Ferguson et al. 2005). As an example, Ferguson et al. (2007) summarized the impacts of the old juvenile bypass system in powerhouse two at Bonneville Dam (significant mortality, injury, and descaling as well as elevated stress indicators), and found that the new bypass system had high survival rates, virtually no injuries, little delay (compared to water particle travel times), and only mild indications of stress. However, outfall locations and dam configuration and operations remain important considerations for maximizing the survival of juvenile salmonids that are bypassed back to the river below dams. For instance, Perry et al. (2007) found that at McNary Dam in 2005, juvenile mortality associated with the bypass system occurred through predation downstream of the tailrace release outfall (where conditions allowed predators to exploit a point-source stream of bypassed migrants).

Sandford and Smith (2002) found that comparisons of SARs from in-river migrants with different juvenile migration histories showed that, for some stocks in some years, multiply bypassed fish returned at significantly lower rates than fish that were never detected in a bypass system. Most data from the 1995 through 1998 outmigrations indicated that multiple bypassed spring-summer Chinook salmon and hatchery steelhead had lower SAR than those not detected at collector dams. Budy et al. (2002) interpreted this as direct evidence that fish passing through bypass systems suffered “delayed” mortality. However, in more recent data, SARs did not differ for wild steelhead (2000 outmigration) or wild Chinook salmon (1999 and 2000 outmigrations) (Williams et al. 2005). Thus, “delayed” mortality resulting from juveniles passing through one or more bypass systems may occur in some, but not in all years (Williams et al. 2005). Although little empirical evidence exists at present to support or refute any mechanistic hypotheses that might explain these results, Williams et al. (2005) posited that differential size selection, possible inherent differences in the “quality” of fish using the bypass systems, and delayed passage (in each case, compared to fish using other passage routes) provided a mechanistic foundation for explaining the differences in return rates of fish multiply bypassed versus those that were not.

In recent years, operational improvements and passage route configuration changes at several of the dams have reduced juvenile mortality and injury rates. The proportion of water released through spillways has increased at most of the dams, resulting in a higher proportion of the migrants passing through these routes. Spilling water for fish (also termed voluntary spill) has been increasingly provided on a 24-hour basis during the juvenile migration at most FCRPS dams in the migratory corridor. (Water is also spilled when flows are higher than needed for turbine operation; an operation termed involuntary spill.)

All dams in the mainstem migratory corridor have multi-gated spillways that use either vertical lift or radial gates that open 15 to 18 meters below the usual reservoir surface. To pass via the spillway, smolts, which have a tendency to migrate within several meters of the water surface, must sound (dive) to locate spillway entrances. A reluctance to sound during daylight hours tends to increase juvenile delay in the forebays.

Surface passage routes increase spill effectiveness (spill effectiveness is the proportion of fish passing a project via spillways divided by the proportion of total project flow that is spilled). Surface bypass structures are currently used at five of the eight Corps dams on the lower Columbia and Snake Rivers. Three types of surface bypass structures are installed – removable spillway weirs (RSWs), temporary spillway weirs (TSWs), and surface bypass channels, including existing ice and trash sluiceways.

Figure 5.1-1. Cross-section view of a removable spillway weir in its operating position.

One spillway bay at both Lower Granite and Ice Harbor dams has been fitted with an RSW which converts the spill bay into an overflow weir. At McNary Dam two spill bays have been fitted with temporary spillway weirs. At The Dalles Dam, a trash sluiceway system at the powerhouse is operated throughout the migration season to attract fish away from the powerhouse via surface flow. At Bonneville Dam, the powerhouse 2 trash sluiceway was modified to serve as a corner collector to pass

juvenile salmon. Corner collectors, providing similar benefits have been installed at Rocky Reach Dam (owned by Douglas County Public Utility District). When properly configured, these surface passage routes are proving to be the safest and quickest passage routes for juveniles through the forebays and dams (Plumb et al. 2003 and 2004; Ferguson et al. 2005; Axel et al. 2007; Ogden et al. 2007).

Restoring and improving fish passage is one of NOAA Fisheries' primary recovery strategies and through hydropower licensing proceedings, NOAA Fisheries recently obtained new and improved passage at several facilities in Columbia Basin tributaries (e.g., Lewis River Project on the Lewis River, Cowlitz, Pelton Round Butte on the Deschutes, and others). Where appropriate, the effects of these new passage facilities are included in the analysis of anticipated effects of the environmental baseline (Chapter 8 of this document).

Transportation Program

Following a decade of research that led to the conclusion that in most cases, the average adult return rates of predominantly stream-type salmonids (spring/summer Chinook and steelhead) that were transported as juveniles exceeded the return rates of fish that migrated in-river, the Corps began large-scale juvenile transportation as a management measure in 1975 (Ebel 1980; Ebel et al. 1973; Mighetto and Ebel 1994). Currently, fish collection and transportation systems are operated seasonally at Lower Granite Dam, Little Goose Dam, Lower Monumental Dam, and McNary Dam. Most transported fish are barged to release points downstream from Bonneville Dam. When collection numbers become too small for barging to be cost-effective, collected fish are transported via truck. Approximately 60-90% of spring migrating smolts (spring/summer Chinook and steelhead) in the Snake River basin are transported annually (Table 5.1-1), although almost all fish (99%) were transported during the low water year conditions of 2001 (Williams et al. 2005). In 2007 transport rates were estimated to be much lower (about 25% for wild and hatchery yearling Chinook salmon and about 41% for wild and hatchery steelhead) (Smith 2008).

Recent data show that the effectiveness of transportation, in terms of the ratio of returning adults to transported juveniles (termed smolt-to-adult return ratio or SAR) from the Snake River, varies among species, season, and collection location (Williams et al. 2005; Scheuerell and Zabel 2007). In general, the SARs of both transported and in-river migrating Snake River spring Chinook and steelhead tend to decrease after early May (day of arrival below Bonneville Dam). For steelhead, SARs of transported fish are typically equal to or higher than those of the surviving in-river migrants arriving downstream of Bonneville Dam (transport-to-in-river SAR ratios > 1.0). For spring Chinook salmon, SARs of surviving inriver migrating fish are often substantially higher in early to mid May than those of transported migrants arriving downstream of Bonneville Dam (transport-to-in-river SAR ratios < 1.0). However, in late May and June, the differences are generally diminished such that SARs are nearly equal (transport-to-in-river ratios ≈1.0).

Table 5.1-1. Estimated combined annual percentage of the non-tagged yearling Chinook salmon and steelhead populations transported from Lower Granite, Little Goose, Lower Monumental, and McNary dams. (Williams et al. 2005)

	Chinook		Steelhead	
Year	Wild	Hatchery	Wild	Hatchery
1993	88.5	88.1	93.2	94.7
1994	87.7	84.0	91.3	82.2
1995	86.4	79.6	91.8	94.3
1996	71.0	68.7	79.8	82.9
1997	71.1	71.5	87.5	84.5
1998	82.5	81.4	88.2	87.3
1999	85.9	77.3	87.6	88.5
2000	70.4	61.9	83.9	81.5
2001	99.0	97.3	99.3	96.7
2002	72.1	64.2	75.2	70.4
2003	70.4	61.5	72.9	68.4

5.1.2.2 Adult Dam Passage

Unlike downstream migrating juveniles, there is no indication that reservoirs substantially delay adult upstream migration (Ferguson et al. 2005).

Adult fish passage, in the form of fish ladders, is provided at the eight mainstem FCRPS projects in the lower Snake and lower Columbia rivers and the five mainstem Federal Energy Regulatory Commission (FERC)-licensed projects in the mid-Columbia reach. In general, adult passage facilities are highly effective. Nonetheless, salmon may have difficulty finding ladder entrances, and fish also may fall back over the dam, either voluntarily (e.g., adults that "overshoot" their natal stream and migrate downstream through a dam of their own volition), or involuntarily, being entrained in spillways after exiting a fish ladder. Some adults that fall back or migrate downstream, pass through project turbines and juvenile bypass systems. Adult mortality rates have been estimates (or calculated using engineering principles) at between 22% and 59%, depending on the species and size of the individual fish (larger fish are more likely to contact a turbine blade, etc.) (Ferguson et al. 2005). The survival of adults through juvenile bypass systems is even less well known. It is logical to assume that survival rates would be much higher through these systems than through turbine units, and indeed, with the possible exception of passage through the 14" to 16" gatewell orifices, conditions within these systems should be easily navigable by adults.

Kelts

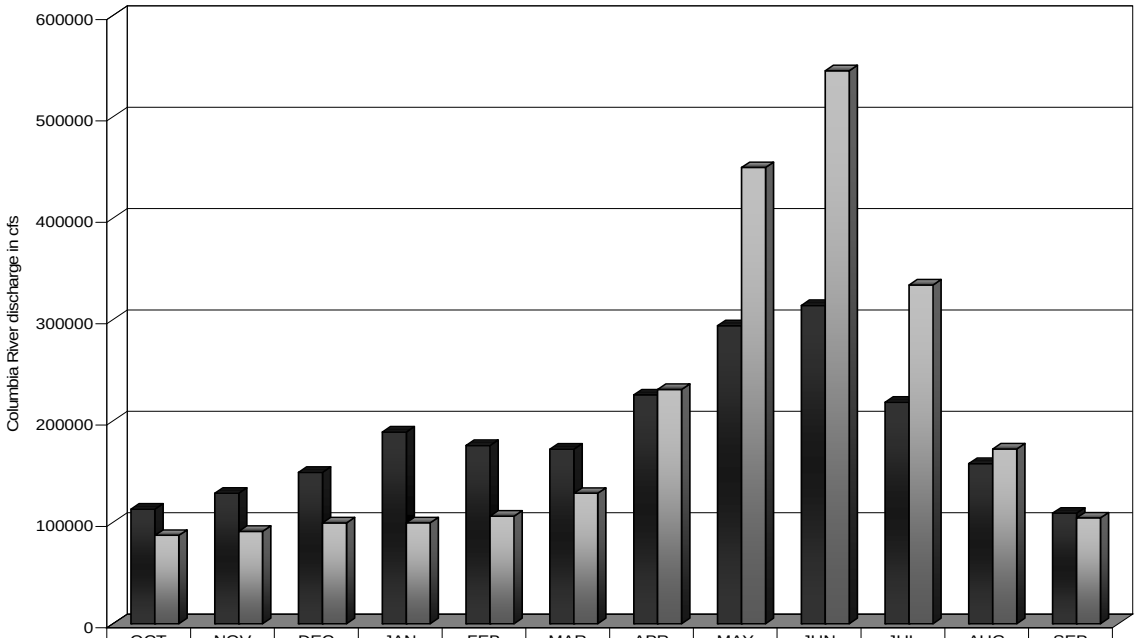
Unlike other Pacific salmonids, a large fraction of the adult steelhead do not die after spawning and instead attempts to migrate back to the Pacific Ocean. Termed kelts, very few of these post-spawn adult steelhead survive downstream passage through the hydrosystem to return and spawn again. Estimates of FCRPS passage survival ranged from 4.1-6.0% in the low flow year 2001 to 15.6% in 2002, and 34% in 2003 (Boggs and Peery 2004; Wertheimer and Evans 2005). Median forebay residence times for steelhead kelts at The Dalles and Bonneville dams during no spill were 9.6 and 8.0 hours, respectively. During spill, their times in the forebay at the same dams were 1.3 and 3.0 hours, respectively (Wertheimer and Evans 2005). Steelhead also reacted strongly to spill at John Day, and The Dalles with more than 90% of kelts passing via non-turbine routes during periods when spill was at or above 30% of total project discharge. Maximizing non-turbine passage of kelts is important because the survival of kelts passing via turbines, while not well known, is considered to be low because turbine passage survival tends to be lower for large fish than small fish (see discussion above). At present, juvenile collection and bypass systems are not designed to safely pass adult fish.

The importance of repeat spawning kelts to steelhead populations varies widely, with the fraction of repeat spawners in spawning steelhead populations ranging from 1 to 51% (Wertheimer and Evans 2005). Boggs and Peery (2004) cite an estimated 2% kelt rate for the Clearwater River in 1954. It is estimated that 17-25% of the steelhead run that pass Lower Granite Dam, return downstream as kelts (Boggs and Peery 2004; Wertheimer and Evans 2005). Thus, while there is a relatively large number of kelts present, their relatively poor survival through the FCRPS may limit the contribution that they can make to steelhead populations.

5.1.3 Mainstem Hydrologic Conditions

Flow regulation, water withdrawal, and climate change have reduced the Columbia River's average flow, altered its seasonality, and reduced sediment discharge and turbidity (NRC 1996; Sherwood et al. 1990; Simenstad et al. 1982 and 1990; Weitkamp 1994). Annual spring freshet flows through the Columbia River estuary are about one-half of the pre-development levels that flushed the estuary and carried smolts to sea (Figure 5.1-2). Total sediment discharge is about one-third of nineteenth-century levels. For example, large-scale U.S. and Canadian reservoir storage and flow regulation that began in the 1970s reduced the 2-year flood peak discharge, as measured at The Dalles, Oregon, from 580,000 cfs to 360,000 cfs (Corps 1999).

Figure 5.1-2. Simulated mean monthly Columbia River flows at Bonneville Dam under current conditions and flows that would have occurred without water development (water years 1929 – 1978. Source: Current Condition Flows – Bonneville Power Administration, HYDSIM model run FRIII_07rerun2004biop.xls; Pre-Development Flows – USBR (1999) Cumulative Hydrologic Effects of Water Use: An Estimate of the Hydrologic Impacts of Water Resource Development in the Columbia River Basin.



	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Current	113017	128641	149403	189076	175921	172150	225689	293948	313930	218523	157935	109020
Natural	87115	91029	99387	99496	106033	128580	231047	450040	545561	334238	172430	104310

Flow affects juvenile migrant travel time and the distribution of fish among the various routes of dam passage. In general, the lower the flow through the series of FCRPS reservoirs, the longer the travel time of outmigrating juveniles that migrate in-river.[5] The longer juveniles remain in project reservoirs, the greater their exposure to predation, elevated temperatures, disease, and other sources of mortality and injury.

Recognizing that the flow versus survival relationships for some ESUs displayed a plateau over a wide range of flows but declined markedly as flows dropped below some threshold (NMFS 1995b), NOAA Fisheries and the FCRPS Action Agencies have attempted to manage Columbia and Snake River water resources to maintain seasonal flows above those objectives (Table 5.1-2). This has been accomplished by avoiding excessive drafts going into the spring to minimize the flow reductions needed to refill the reservoirs and by drafting the storage reservoirs during the summer to augment flows. These flow objectives have guided preseason reservoir planning and in-season flow

[5] At lower river flows a higher proportion of some ESUs is collected and transported thereby avoiding the delay associated with in-river hydrosystem passage.

management with the understanding that their achievement depends on the water resources available in a given year.

Table 5.1-2. Snake and Columbia River flow objectives for operating the FCRPS since 1995. (Source: NMFS 1995a)

Location	Spring (in kcfs)	Summer (in kcfs)
Lower Granite	85-100 a	50-55 a
McNary	220-260 a	200
Priest Rapids	135	
a. flow objective varies with anticipated runoff volume		

The longer juveniles remain in the project reservoirs, the greater the potential that they will stop migrating.[6] Dam operating protocols designed to improve fish passage survival are often defined in terms of streamflow criteria. For example, under current operations, at spring flows of less than 85,000 cfs at Lower Granite Dam, the spill rate and duration are reduced. Spillways are usually the safest route of juvenile dam passage (Ferguson et al. 2005) and at lower total river flows, fewer migrants pass via project spillways.

Decreased spring flows and sediment discharges have also reduced the size, speed of movement, thickness, and turbidity of the plume that extended far out and south into the Pacific Ocean during the spring and summer (Cudaback and Jay 1996; Hickey et al. 1997). Changes in estuarine bathymetry and flow have altered the extent and pattern of salinity intrusion up the Columbia River and have increased stratification and reduced mixing (Sherwood et al. 1990).

In summary, combined with the influence of reservoirs behind the dams within the migratory corridor, reductions in spring and early summer flows slow juvenile fish emigration, increases their exposure to injury and mortality factors within the reservoirs (e.g. predation, temperature stress, disease, and others), and changes ocean-entry timing (see Section 5.1.3.1 for further detail). These flow reductions also reduce turbidity, which has also been shown to reduce juvenile survival (see Section 5.1.4.2). Flow-related changes in estuary bathymetry likely reduce juvenile rearing habitat, significant primarily to lower river populations and ESUs (e.g., LCR Chinook).

5.1.3.1 Mainstem Effects of Reclamation's Irrigation Projects in the Columbia Basin

In total, Reclamation's 23 irrigation projects in the Columbia basin reduce the annual runoff volume at Bonneville Dam by about 5.5 Maf (Table 5.1-3).[7] These depletions occur primarily during the spring and summer as the reservoirs are refilled and as water is diverted for irrigation and are incorporated

[6] The propensity to residualize varies between species. Steelhead are generally the most likely to residualize, followed by fall Chinook. Spring and summer Chinook seldom residualize. Residual sockeye are known in Sawtooth Valley lakes, but not the mechanisms (genetic and environmental) that lead to this form. In recent years some returning adult SR fall Chinook have displayed evidence of over-wintering in fresh water, indicating that some SR fall Chinook stop migrating during the summer and do not die or residualize, but complete their migrations the following spring (Section 5.1.4.1).

[7] Table 5.1-3 does not include the effects of all Reclamation reservoir operations. The hydrologic effects of Reclamation's multi-purpose FCRPS reservoir operations are not included.

into the juvenile passage modeling for the interior species. These hydrologic effects are included in the hydrologic analysis conducted for this consultation.

Spring flow reductions have both beneficial and adverse effects on fish survival. During above average water years, flow reduction during reservoir refill reduces involuntary spills. High rates of involuntary spill are known to cause undesirable TDG conditions in the migratory corridor. This beneficial effect is small as the amount of flow attenuation provided by Reclamation project operations is generally too small to greatly affect the magnitude and duration of involuntary spill events below Hells Canyon in Chief Joseph dams.

Flow depletions associated with Reclamation's projects contribute to juvenile migration delay and decrease juvenile migrant survival. These mainstem survival effects are captured in the juvenile migrant survival modeling (i.e., COMPASS modeling).

In addition to these mainstem flow effects, several of these projects below Hells Canyon and Chief Joseph dams may affect listed salmonids in the tributary streams where the project is located or where Reclamation's irrigation return flows occur. Supplemental consultations have been completed, are now underway, or are scheduled to begin for each of Reclamation's projects with tributary effects. For example, NOAA Fisheries completed a supplemental biological opinion for the Umatilla Irrigation Project dated April 23, 2004, in which these tributary effects are analyzed.

Table 5.1-3. Average flow reduction effects of Reclamation's irrigation projects in the Columbia basin (in cfs) [1/]

Project [2/]	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Upper Columbia River												
Columbia Basin Project (CBP)	-2,779	-293	-548	48	201	-1,404	-6,058	-6,971	-7,061	-7,464	-6,039	-6,129
Return Flows at Wanapum	64	53	47	41	38	33	48	43	45	51	60	70
Return Flows at Priest Rapids	278	126	108	94	73	122	244	202	231	245	269	307
Columbia Basin Project effects at Priest Rapids	-2,437	-114	-393	183	312	-1,249	-5,766	-6,726	-6,785	-7,168	-5,710	-5,752
Chief Joseph Dam Project	-2	0	0	0	0	0	-10	-64	-138	-190	-112	-22
Okanogan Project	-4	-6	-8	-7	-8	-11	-43	-87	-65	-15	10	10
Sum of effects at Priest Rapids	-2,443	-120	-401	176	304	-1,260	-5,819	-6,877	-6,988	-7,373	-5,812	-5,764
Yakima Project	-300	-800	-750	-650	-700	-1,100	-2,900	-4,300	-2,600	-200	1,550	1,600
Umatilla Phase II Pump Exchange	-62	0	0	0	0	0	-2	-8	-47	-137	-146	-96
Snake River												
Upper Snake River above Brownlee Reservoir	-329	-4,805	-5,174	-2,031	-2,910	-4,793	-5,794	-11,972	-9,523	1,922	3,822	3,352
Sum of effects at Lower Granite	-329	-4,805	-5,174	-2,031	-2,910	-4,793	-5,794	-11,972	-9,523	1,922	3,822	3,352
Lower Columbia River												
CBP Return Flows at McNary	534	386	312	236	228	309	432	432	475	470	512	550
CBP Blocks 2 and 3	-25	0	0	0	0	-9	-38	-50	-62	-70	-63	-25
Sum of effects at McNary	-2,625	-5,339	-6,013	-2,269	-3,078	-6,853	-14,121	-22,775	-18,745	-5,388	-137	-383
Percent of Columbia River Flows	<1	4.7	4.4	1.6	2.3	3.9	4.4	6	4	<1	3.3	4.7
Umatilla Phase I Pump Exchange	-32	0	0	0	0	5	10	2	-52	-19	-138	-50
Umatilla Project	196	-5	-186	-244	-314	91	-27	51	129	-26	36	135
Deschutes, Crooked River, and	-413	-450	-434	-410	-212	-757	-514	-166	-57	31	144	-53

Project [2/]	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Wapinitia Projects												
The Dalles Project	-4	0	0	0	0	0	-7	-27	-37	-47	-38	-22
Sum of effects at Bonneville	-2,878	-5,794	-6,633	-2,923	-3,604	-7,514	-14,659	-22,915	-18,762	-5,449	-133	-373
Tualatin Project	-24	-103	-58	-170	-178	-75	-40	-13	14	68	94	97
Sum of effects at Columbia River mouth	-2,902	-5,897	-6,691	-3,093	-3,782	-7,589	-14,699	-22,928	-18,748	-5,381	-39	-276

[1/] Negative values imply a flow reduction due to Reclamation activities. Natural flow diversions would still occur without Reclamation.
[2/] Sources: Corps et al. 2007a (Comprehensive Analysis, Appendix B, Tables B-5 and B-10),

5.1.4 Mainstem Water Quality

Water quality characteristics of the mainstem Snake and Columbia Rivers are affected by an array of land and water use developments. Water quality characteristics of particular concern are: water temperature, turbidity, total dissolved gas, and chemical pollutants.

5.1.4.1 Water Temperature

Water development influences water temperatures through storage, diversion, and irrigation return flows. Changes in water temperatures can have significant implications for anadromous fish survival.

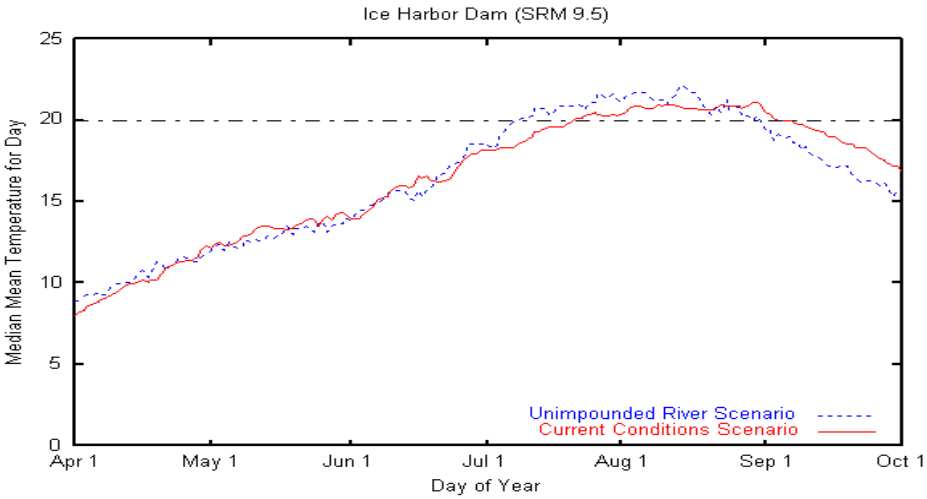
Comparisons of long term temperature monitoring in the migration corridor before and after impoundment reveal a fundamental change in the thermal regime of the Snake and Columbia rivers. Using historical flows and environmental records for the 35 years period from 1960 to 1995, one recent study compared water temperature records in the Lower Snake River with and without the lower Snake River dams (Perkins and Richmond 2001).[8] As shown in Figure 5.1-3, there are three notable differences between the current and the unimpounded river:

- the maximum summer water temperature has been slightly reduced,
- water temperature variability has decreased, and
- post-impoundment water temperatures stay cooler longer into the spring and warmer later into the fall. The latter phenomenon is termed thermal inertia.

Thermal inertia is of particular biological significance as it may, depending upon the specific species in question, affect adult migrations, spawn timing and juvenile emergence, rearing, and outmigration timing, as described below.

[8] NOTE: Significant land use practices, including the development of a large number of water storage and diversion projects had already occurred by the 1960s. This graphic does not attempt to imply that the unimpounded river scenario can be equated to pre-development.

Figure 5.1-3. Median daily Snake River water temperatures (°C) at Ice Harbor Dam before and after development of the four lower Snake River projects (20°C denotes Washington Department of Ecology standard).



Biological Effects

High water temperatures stress all life stages of anadromous fish, increase the risk of disease and mortality, affect toxicological responses to pollutants, and can cause migrating adult salmon to stop or delay their migrations. Warm water temperatures also increase the foraging rate of predatory fish thereby increasing the consumption of smolts. Though the duration and magnitude of high water temperatures in the migratory corridor is generally less under current, developed conditions than prior to water development, some juvenile fish are exposed to these conditions for a longer period of time due to the substantial increase in travel time.

In 2003, EPA collaborated with NOAA Fisheries and other regional resource managers in the preparation of guidance for developing water quality standards. With regard to water temperature, the EPA reviewed the scientific literature and established recommended thresholds for a variety of salmonid life stage reactions (Table 5.1-4). Comparison of the EPA guidelines (Table 5.1-5) with Tables 5.1-4 helps to identify the salmonid species, life stages and seasons for concern for listed stocks migrating and reproducing in the FCRPS affected segments of the Columbia River Basin (see Potential for Thermal Effects in Table 5.1-4).

To improve juvenile SR fall Chinook survival, Dworshak Dam on the North Fork Clearwater River has most recently been operated to cool the lower Snake River during July and August. Aimed at avoiding temperatures in the Lower Granite Dam tailrace in excess of 20 degrees C, this action reduces water temperatures in Lower Granite Reservoir by 2 to 5 degrees C. This beneficial effect gradually diminishes downstream.

The effects of thermal inertia on salmon depend on the coincidence of sensitive life stages with the time shifts in water temperature. Snake River fall Chinook may be the most vulnerable ESU as they spawn, incubate, and rear in mainstem habitats. In some years, adult arrival at spawning sites in the Snake system is delayed by high water temperatures (Bennett and Peery 2003). The migration is slowed or stopped when the fish take refuge in cooler areas (e.g. tributary mouths) and resumes when the general river temperature declines. Delayed adult migration, combined with delayed onset of water temperatures conducive to spawning, delays the onset of spawning. By reducing maximum late

summer water temperatures, the FCRPS may have allowed the expression of the SR fall Chinook yearling outmigration strategy (see Section 8.2).

In turn incubation, hatching, and rearing may occur under less than ideal thermal conditions, resulting in delayed juvenile emigration. Delayed downstream migration places juveniles in the migration corridor later in the spring, when water temperatures are rising, which in turn decreases the likelihood of survival.

The impacts of high summer water temperatures on juvenile salmon health may also be reduced by the availability of thermal refugia, areas where localized shade, springs or tributary inflows provide lower water temperatures. Researchers collecting juvenile fall Chinook in lower Granite Reservoir have noted higher concentrations of juveniles in such areas, suggesting that fish may be exploiting such opportunities (Kock et al. 2007).

Coincident and possible due to climate change, average annual Columbia Basin air temperatures have increased by about 1 degree C over the past century and water temperatures in the mainstem Snake and Columbia rivers have been affected similarly (ISAB 2007b). The influence of this and other large-scale environmental variations are discussed in Section 5.7 of this document.

Table 5.1-4. Summary of Potential Thermal Effects to Salmonids in the Columbia Basin. (Source: EPA 2003)

Species	Life Stage	Timing	Potential for Thermal Effects
Spring Chinook	Adult Migration	April – June	
	Spawning	August – October	X
	Egg Incubation/Alevin	Throughout Winter Season	
	Emergence	March – May	
	Juvenile Rearing	One Year in River	X
	Juvenile Outmigration	Spring	
Fall Chinook	Adult Migration	July – September	X
	Holding Period and Spawning	July – October	X
	Emergence	March – April	
	Juvenile Outmigration	March – April (season may extend through May - August)	Possible
Coho	Adult Migration	October	
	Spawning	November – January	
	Incubation	May – July	X
	Rearing	1-2 years	X
	Juvenile Outmigration	Spring	
Steelhead	Adult Migration	May – October	X
	Spawning	November – March	
	Incubation	May – July	X
	Emergence	May –July	X
	Rearing	1-2 Years in Freshwater	X
	Juvenile Outmigration	Spring	

Table 5.1-5. Summary of the EPA Water Temperature Guidelines and Potential Effects to Salmon. (Source: EPA 2003)

Life Stage	Life Stage Reaction		Threshold (˚C)
Adult	Lethal (1 week exposure)		21-22
	Migration Blockage		21-22
	Disease Risk	High	18-20
		Elevated	14-17
		Minimized	12-13
	Swim Performance	Reduced	>20
		Optimal	15-19
	Overall Reduction in Migration Fitness		>17-18
Spawning	Spawning Behavior Observed in the Field		4-14
Eggs & Incubation	Good Survival		4-12
	Optimal Incubation		6-10
	Reduced Viability of Gametes		>13
Emergence & Juvenile Rearing	Lethal (1 week exposure)		23-26
	Optimal Growth	Unlimited Food	13-20
		Limited Food	10-16
	Rearing Preference Temperature		10-17
	Impaired Smoltification		12-15
	Disease Risk	High	>18-20
		Elevated	14-17
		Minimized	12-13

5.1.4.2 Turbidity

Flow regulation and reservoir existence reduces turbidity in the Columbia and Snake Rivers. Reduced turbidity can increase predator success through improved prey detection, increasing the susceptibility smolts to predation. Predation is a substantial contributor to juvenile salmon mortality in reservoirs throughout the Columbia River and Snake River migratory corridors.

5.1.4.3 Total Dissolved Gas

Spill at mainstem dams can cause downstream waters to become supersaturated with dissolved atmospheric gasses. Supersaturated total dissolved gas (TDG) conditions can cause gas bubble trauma (GBT) in adult and juvenile salmonids resulting in injury or death. Biological monitoring shows that the incidence of GBT in both migrating smolts and adults remains between 1-2% when TDG concentrations in the upper water column do not exceed 120% of saturation in FCRPS project tailraces and 115% in project forebays. When those levels are exceeded, there is a corresponding increase in the incidence of signs of GBT symptoms.

Depth Compensation

The effects of total dissolved gas (TDG) supersaturation on aquatic organisms are moderated by depth due to hydrostatic pressure. Each meter of depth compensates for 10% of gas supersaturation as measured at the water surface. As illustrated by Figure 5.1-4, if the dissolved gas is recorded as 120% of supersaturation at the surface, then the saturation state at 0.5 m is reduced to 115%. A fish or an aquatic invertebrate at a depth of 0.5 m at equilibrium with the gas level of the surrounding water will benefit from depth compensation. That is, the organism's tissue will also be at 115% of saturation. If the fish is 2.0 m deep, its tissues will not be supersaturated. That is, a fish at 2.0 m of depth with the gas in its tissues in equilibrium with the surrounding water cannot develop gas bubble disease or trauma. In short, gas bubble trauma is the result of uncompensated hyperbaric pressure of TDG. Moreover, it is the same for all fish species, salmonid or resident, as well as for invertebrates (Weitkamp 2003).

TDG Control Efforts

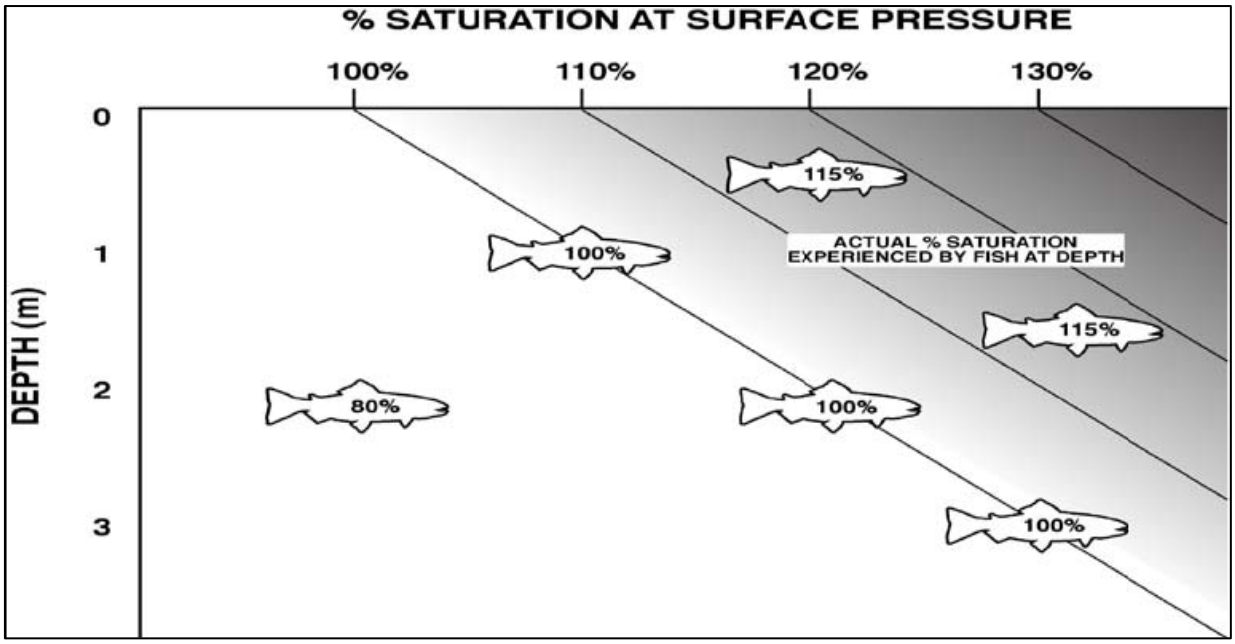
Current reservoir operations typically limit gas-generating, high-spill events to a few days or weeks during high-flow years. Historically, TDG supersaturation was a major contributor to juvenile salmon mortality, and TDG abatement is a focus of efforts to improve salmon survival. The 115-120% guideline is generally exceeded only with high rates of involuntary spill during the peak of the annual runoff hydrograph. The Corps has invested heavily in controlling TDG generation at its projects in the migratory corridor by:

- installing spillway improvements, typically flip-lips, at each mainstem dam (currently in progress at Chief Joseph Dam),

- managing spill operations to reduce gas entrainment, and

- TDG and GBT abatement monitoring and evaluation.

Figure 5.1-4. Compensatory effects of depth (hyperbaric pressure) on fish exposed to supersaturated water.



5.1.4.4 Pollutants

Background or ambient levels of pollutants in inflows carry cumulative loads from upstream areas in variable and generally unknown amounts. Growing population centers throughout the Columbia and Snake River basins and numerous smaller communities contribute municipal and industrial waste discharges to the rivers. Industrial and municipal wastes from the Portland-Vancouver metro areas affect the lower river and estuary. Mining areas scattered around the basin deliver higher background concentrations of metals. Highly developed agricultural areas of the basin also deliver fertilizer, herbicide, and pesticide residues to the river.

Current environmental conditions in the Columbia River estuary indicate the presence of contaminants in the food chain of juvenile salmonids including DDT, PCBs, and polyaromatic hydrocarbons (PAH) (NMFS 2001a). This data also indicates that juvenile salmonids in the Columbia River estuary have contaminant body burdens in the range where sublethal effects may occur. The sources of exposure are not clear but may be widespread. Several pesticides and heavy metal contaminants have been sampled in Columbia River sediments (ODEQ 2007). In field studies, juvenile salmon from sites in the Pacific Northwest have demonstrated immunosuppression, reduced disease resistance, and reduced growth rates due to contaminant exposure during their period of estuarine residence (Arkoosh et al. 1991, 1994, 1998; Varanasi et al. 1993; Casillas et al. 1995 a, 1995b, and 1998 a). Thus, some, currently unknown, level of impact in the Columbia River estuary is likely.

5.2 Tributary Habitat Effects

With the exception of fall Chinook, which generally spawn and rear in the mainstem, salmon and steelhead spawning and rearing habitat is found in tributaries to the Columbia and Snake Rivers. The quality and quantity of habitat in many Columbia River Basin watersheds have declined dramatically in the last 150 years. Forestry, farming, grazing, road construction, hydrosystem development, mining, and urbanization have changed the historical habitat conditions. Anadromous fish typically spend a few months to 3 years rearing in freshwater tributaries. Depending on the species, they spend from a few days to 1 or 2 years in the Columbia River estuary before migrating out to the ocean and another 1 to 4 years in the ocean before returning as adults to spawn in their natal streams. Thirty-two subbasins provide spawning and rearing habitat.

Many tributaries have been significantly depleted by water diversions. In 1993, Fish and Wildlife agency, Tribal, and conservation group experts estimated that 80% of 153 Oregon tributaries had low-flow problems (two-thirds caused at least in part by irrigation withdrawals) (OWRD 1993). The Northwest Power and Conservation Council showed similar problems in many Idaho, Oregon, and Washington tributaries (NPPC 1992). Depleted tributary streamflows have been identified a major limiting factors for most species in the Interior Columbia basin (PCSRF 2007).

In many watersheds, access to historical habitat areas is lost to land development, primarily due to road culverts that are not designed or installed to permit fish passage.

Water quality in many Columbia River Basin streams has been degraded to varying degrees by human activities such as dams and diversion structures, water withdrawals, farming and grazing, road construction, timber harvest activities, mining activities, and urbanization. Over 2,500 streams and river segments and lakes do not meet Federally-approved, state and Tribal water quality standards and are now listed as water-quality-limited under Section 303(d) of the Clean Water Act. Water quality problems in the upper tributaries contribute to poor water quality in mainstem reaches and the estuary where sediment and contaminants from the tributaries settle.

Most of the water bodies in Oregon, Washington, and Idaho that are on the 303(d) list do not meet water quality standards for temperature. Temperature alterations affect salmonid metabolism, growth rate, and disease resistance, as well as the timing of adult migrations, fry emergence, and smoltification. Many factors can cause high stream temperatures, but they are primarily related to land-use practices rather than point-source discharges. Some common actions that result in high stream temperatures are the removal of trees or shrubs that directly shade streams, excessive water withdrawals for irrigation or other purposes, and warm irrigation return flows. Loss of wetlands and increases in groundwater withdrawals have contributed to lower base-stream flows, which in turn contribute to water temperature increases. Channel widening and land uses that create shallower streams also increase water temperatures.

Pollutants also degrade tributary water quality. Salmon require clean gravel for successful spawning, egg incubation, and emergence of fry. Fine sediments clog the spaces between gravel and restrict the flow of oxygen-rich water to the incubating eggs. Excess nutrients, low levels of dissolved oxygen, heavy metals, and changes in pH also directly affect water quality for salmon and steelhead.

5.2.1 Indirect Effects of Hydrosystem Mortality on Nutrients in Tributaries

Mortality in the hydrosystem reduces the transport of marine-derived nutrients (MDN) to freshwater spawning and rearing areas. Gresh et al. (2000) estimated that only 6 to 7% of the marine-derived nitrogen and phosphorus that was delivered to the rivers of the Pacific Northwest by spawning salmon 140 years ago is currently returning to those streams. He attributed the loss to habitat changes due to beaver trapping, logging, irrigation, grazing, pollution, dams, urban and industrial development, and commercial and sport fishing. Marine-derived nutrients (MDN) have been shown to support the growth of coastal populations of coho salmon, which feed on salmon eggs and spawned-out carcasses. Bilby et al. (2001) observed an increase in the amount of marine-derived nitrogen in the muscle of coho parr with increasing abundance of carcass tissue up to about 0.01 kg/m^2 and 0.15 kg/m^2-wet weight. Salmon carcasses also appear to promote the growth of riparian forests, a source of large woody debris and stream shading. Helfield and Naiman (2001) hypothesized that there were several pathways for the transfer of MDN from streams to riparian vegetation, including the transfer of dissolved nutrients from decomposing carcasses into shallow subsurface flow paths and the dissemination in feces, urine, and partially-eaten carcasses by bears and other salmon-eating fauna. In studies with juvenile coho salmon, Quinn and Peterson (1996) correlated increased body size with higher rates of overwinter survival, although this study was not designed to determine whether the effect was related to carcass density. Bilby et al. (2002) found a positive linear relationship between the biomass of juvenile anadromous salmonids and the abundance of carcass material at sites in the Salmon and John Day rivers, suggesting that spawning salmon may be influencing aquatic productivity and the availability of food for rearing fishes, but mechanisms were not postulated. In summary, there is an increasing body of work suggesting that the biomass of carcasses affects the productivity of salmonid rearing habitat, but functional and quantitative relationships are poorly understood and difficult to generalize from the specific conditions studied. Limiting factors, and thus the ecological importance of marine-derived nutrients, differ among streams.

In summary, the best available scientific information indicates that reduced adult returns are likely to limit biogeochemical processes important to salmonid productivity in some watersheds by depriving rearing areas of some nutrient inputs. These nutrient limitations also result from habitat degradation, harvest, and adverse ocean conditions, all of which have reduced salmon survival and adult returns over time (Scheuerell and Williams 2005).

5.3 Estuary & Plume Habitat Effects

5.3.1 Columbia River Estuary

Historically, the downstream half of the Columbia River estuary was a dynamic environment with multiple channels, extensive wetlands, sandbars, and shallow areas. The mouth of the Columbia River was about 4 miles wide. Winter and spring floods, low flows in late summer, large woody debris floating downstream, and a shallow bar at the mouth of the Columbia River maintained a dynamic environment. Today, navigation channels have been dredged, deepened and maintained, jetties and pile-dike fields have been constructed to stabilize and concentrate flow in navigation channels, marsh and riparian habitats have been filled and diked, and causeways have been constructed across waterways. These actions have decreased the width of the mouth of the Columbia River to 2 miles and increased the depth of the Columbia River channel at the bar from less than 20 to more than 55 feet. Sand deposition at river mouths has extended the Oregon coastline approximately 4 miles seaward and the Washington coastline approximately 2 miles seaward (Thomas 1981).

More than 50% of the original marshes and spruce swamps in the estuary have been converted to industrial, transportation, recreational, agricultural, or urban uses. More than 3,000 acres of intertidal marsh and spruce swamps have been converted to other uses since 1948 (Lower Columbia River Estuary Program [LCREP] 1999). Many wetlands along the shore in the upper reaches of the estuary have been converted to industrial and agricultural lands after levees and dikes were constructed. Furthermore, water storage and release patterns from reservoirs upstream of the estuary have changed the seasonal pattern and volume of discharge. The peaks of spring/summer floods have been reduced, and the amount of water discharged during winter has increased.

In addition, model studies indicate that the hydrosystem and reduced river flows caused by climate change together have decreased the delivery of suspended particulate matter to the lower river and estuary by about 40% (as measured at Vancouver, Washington) and have reduced fine sediment transport by 50% or more (Bottom et al. 2000). Overbank flow events, important to habitat diversity, have become rare, in part because flow management and irrigation withdrawals prevent high flows and in part because diking and revetments have increased the "bankfull" flow level (from about 18,000 to 24,000 m^3/s). The dynamics of estuarine habitat have changed in other ways relative to flow. The availability of shallow (between 10 cm and 2 m depth), low-velocity (less than 30 cm/s) habitat now appears to decrease at a steeper rate with increasing flow than during the 1880s, and the absorption capacity of the estuary appears to have declined.

The significance of these changes for salmonids is unclear, although estuarine habitat is likely to provide services (food and refuge from predators) to subyearling migrants that reside in estuaries for up to two months or more (Fresh et al. 2005; Casillas 1999). Fresh et al. (2005) found that: "Estuarine habitats clearly contribute to the viability and persistence of salmon populations in a number of ways. The amount of estuarine habitat that is accessible affects the abundance and productivity of a population. The distribution, connectivity, number, sizes, and shapes of

estuarine habitats affect both the life history diversity and the spatial structure of a population." Historical data from Rich (1920) indicate that small juvenile salmon (< 50 mm), that entered the Columbia River estuary during May, grew 50 to 100 mm during June, July, and August. Contemporary data (Dawley et al.1986; CREDDP 1980) show little use of the Columbia River estuary by rearing salmon or steelhead.

5.3.2 Columbia River Plume

The Columbia River plume is that portion of the near-shore ocean environment sufficiently influenced by Columbia River energy, water quality, and biotic constituents to affect the local ecosystem. The plume is important juvenile salmonid habitat, particularly during the first month or two of ocean residence. The plume may represent an extension of the estuarine habitat, but more likely, it is a unique habitat created by interaction of the Columbia River freshwater flow with the California Current and local oceanographic conditions. Ongoing studies show that nutrient concentrations in the plume are similar to nutrient concentrations associated with upwelled waters. Upwelling is an oceanographic process that produces highly productive areas for marine species. Primary productivity, and more importantly, the abundance of zooplankton prey, is higher in the plume compared with adjacent non-plume waters. Further, salmon appear to prefer low surface salinity, as the abundance and distribution of juvenile salmon are higher and more concentrated in the Columbia River plume than in adjacent, more saline waters. These findings support the hypothesis that the plume is an important habitat for juvenile salmonids. What is not known is how Columbia River flows affect the structure of the plume during outmigration periods and whether critical threshold flows are needed. Research is ongoing to document important relationships between juvenile salmon growth and survival during this stage of their life history.

5.4 Predation & Disease Effects

5.4.1 Predation

Salmon and steelhead are exposed to high rates of natural predation during all life stages. Fish, birds, and marine mammals, including harbor seals, sea lions, and killer whales all prey on juvenile and adult salmon.

Dams and reservoirs are generally believed to have increased the incidence of predation over historical levels (Poe et al.1994). Impoundments in the Columbia River Basin:

- increase the availability of microhabitats in the range preferred by piscivorous fish (Faler et al. 1988; Beamesderfer 1992; Mesa and Olson 1993; Poe et al.1994);

- increase local water temperatures which increases piscivorous fish digestion and consumption rates (Falter 1969; Steigenberger and Larkin 1974; Beyer et al. 1988; Vigg and Burley1991; Vigg et al.1991);

- decrease turbidity, which increases predator capture efficiency (Gray and Rondorf 1986); and

- increase stress and subclinical disease of juvenile salmonids, which could increase susceptibility to predation (Rieman et al.1991; Gadomski et al.1994; Mesa 1994).

In addition, dam-related passage delay can affect the availability, distribution, timing, and aggregation of migrating salmonids, thereby increasing exposure time to predation (Raymond 1968, 1969, 1979, 1988; Park 1969; Van Hyning 1973; Bentley and Raymond 1976). In particular, passage delay increases exposure time later in the season, when predator consumption rates are higher (Beamesderfer et al. 1990; Rieman et al. 1991).

5.4.1.1 Piscivorous Predation

The Columbia River Basin has a diverse assemblage of native and introduced fish species, some of which prey on salmon and steelhead. The primary resident fish predators of salmonids in the reaches of the Columbia and Snake Rivers inhabited by anadromous salmon are northern pikeminnow (native), smallmouth bass (introduced), and walleye (introduced) (NMFS 2000a). Other predatory resident fish include channel catfish (introduced), Pacific lamprey (native), yellow perch (introduced), largemouth bass (introduced), and bull trout (native).

Northern Pikeminnow

Although northern pikeminnow (*Ptychocheilus oregonensis*) is a native species that always has preyed on juvenile salmonids, as noted above, development of the Columbia River hydropower system has likely increased the level of predation. Northern pikeminnow predation throughout the Columbia and Snake Rivers was indexed in 1990-1993 based on electrofishing catch rates of predators and the occurrence of salmonids in predator stomachs relative to estimates in John Day Reservoir (Ward et al. 1995). Northern pikeminnow abundance was estimated to total 1.8 million, and daily consumption rates averaged 0.06 salmonids per predator (Beamesderfer et al. 1996).

Beamesderfer et al. (1996) estimates that over 16 million total salmonids were consumed annually in the mainstem Columbia and Snake Rivers prior to initiation of the Northern Pikeminnow Management Program (NPMP see below). However, total system-wide impacts are not evenly distributed throughout the Columbia and Snake Rivers but are concentrated in the lower Columbia River from The Dalles Reservoir downstream, where approximately 13 million of the 16.4 million total salmonids are estimated to have been consumed by northern pikeminnow. This estimated predation loss is 8% of the approximately 200 million hatchery and wild juvenile salmonid migrants in the system.

Northern Pikeminnow Management Program (NPMP)

Predator control fisheries have been implemented in the Columbia Basin since 1990 to harvest northern pikeminnow with an annual exploitation rate goal of 10-20%, needed to obtain up to a 50% reduction in smolts consumed by pikeminnow (Rieman et al. 1991). The NPMP is a multi-year, ongoing effort funded by BPA to reduce piscivorous predation on juvenile salmon, primarily through

public, angler-driven, system-wide removals of predator-sized northern pikeminnow. From 1991 to 1996, three fisheries (sport-reward, dam angling, and gill net) harvested approximately 1.1 million northern pikeminnows greater than or equal to 250 mm fork length. Total exploitation averaged 12.0% (range, 8.1 to 15.5%) for 1991 to 1996 (Section 6.2.7.1 in NMFS 2000b).

Since the program's inception in 1990, the NPMP's monetary incentive to harvest northern pikeminnow has motivated sports fishermen to remove over two million northern pikeminnow throughout the system. This has reduced predation mortality by an estimated 25% (Friesen and Ward 1999), which is estimated to equate to approximately 4 million fewer juvenile salmonids consumed by pikeminnow each year. Currently, the annual harvest rate ranges approximately between 8 and 16% of the northern pikeminnow that qualify in size but has averaged approximately 12% in the last number of years. In 2001 and again in 2004, BPA increased the reward, which led to increases in both catch and exploitation.

Smallmouth Bass

Found in lakes, rivers, and streams, smallmouth bass (*Micropterus dolomieu*) have relatively large mouths that enable them to consume juvenile fish, including salmonids. According to Bennett and Naughton (1999), smallmouth bass and salmonid use many of the same habitat types. Smallmouth bass are the dominant predators in reservoirs of the lower Snake River and are co-dominant with northern pikeminnow and percids in certain reaches of the Snake River (NMFS 2000a). The highest densities of smallmouth bass in the Columbia and Snake Rivers occur in the Lower Granite forebay, tailrace, and reservoir, followed by the John Day Reservoir (NMFS 2000a). Throughout the John Day Reservoir study area, smallmouth bass consumed far fewer juvenile salmonids than did northern pikeminnow (Zimmerman 1999).

Zimmerman (1999) also found that smallmouth bass consumed smaller Chinook salmon in the spring than did northern pikeminnow, and they consumed far more subyearling Chinook salmon in the summer than yearling Chinook in the spring. Predator-prey size relationships may reflect the degree and timing of habitat overlap, as suggested by Tabor et al. (1993), who attributed high levels of smallmouth bass predation on subyearling Chinook salmon to overlap of rearing habitat for subyearling Chinook with the preferred habitats of smallmouth bass in summer.

There is also information to suggest that growth of smallmouth bass due to the availability of American shad prey in the late summer and fall could potentially result in a large increase in the number of juvenile salmonids consumed by this predator (Sauter et al. 2004).

Walleye

As the largest member of the perch family, walleye (*Sander vitreus*) can grow up to 20 pounds, are extremely piscivorous, and in the Columbia Basin are most abundant in dam tailraces, where the potential for impacts on juvenile salmonids is high (NMFS 2000a).

In the 1983-1986 John Day Reservoir study that forms the basis for the current predator management program, Rieman et al. (1991) found that walleye consumed 13% of the estimated annual 2.7 million

juvenile salmonids consumed by predatory fish. Northern pikeminnow accounted for 78% and smallmouth bass took 9%. Poe et al. (1991) stated that walleye are much less important predators than other fish species, and their salmon consumption appeared to consist mostly of subyearling Chinook during late summer in the John Day Reservoir. While the John Day Reservoir study found that smallmouth bass were the third most important predator of salmonids, more recent studies have indicated that there are smallmouth bass hotspots (e.g., The Dalles Dam tailrace) that may be worth further investigation for predator management options.

5.4.1.2 Avian Predation

Avian predation is another factor limiting salmonid recovery in the Columbia River Basin. Throughout the basin, piscivorous birds congregate near hydroelectric dams and in the estuary near man-made islands and structures and eat large numbers of migrating juvenile salmonids (Ruggerone 1986; Roby et al. 2003; Collis et al. 2002). Diet analyses indicate that juvenile salmonids are a major food source for avian predators in the Columbia River and its estuary and that basin-wide losses to avian predators are high enough that they constitute a substantial portion of several runs of salmon and steelhead (Roby et al. 2003).

Avian predation has been exacerbated by environmental changes associated with river developments. Water clarity caused by suspended sediments setting in impoundments increases the vulnerability of migrating smolts. Delay in project reservoirs, particularly immediately upstream from the dams increases smolt exposure to avian predators, and juvenile bypass systems concentrate smolts, creating potential feeding stations for birds. Dredge spoil islands, associated with maintaining the navigation channel, provide habitat for nesting Caspian terns and other piscivorous birds.

Caspian terns, double-crested cormorants, glaucous-winged/western gull hybrids, California gulls, and ring-billed gulls are the principal avian predators in the basin (NMFS 2000a). Populations of these birds have increased throughout the basin as a result of nesting and feeding habitats created by human activities, such as dredge spoil deposition in or near the estuary (creating nesting habitat) and reservoir impoundments and tailrace bypass outfalls associated with hydro projects (Roby et al. 2003). The breeding season for these birds coincides with the outmigration of yearling salmonids, which provides a ready prey source in the vicinity of large avian nesting colonies (Roby et al. 2003).

For many of the listed salmon species migrating through the Columbia River estuary, avian predation is considered one of the primary limiting factors affecting juvenile survival (Fresh et al. 2005. Since 1997, researchers have been studying the effect of piscivorous waterbirds on juvenile salmonid survival in the Lower Columbia River. In 1998, Collis et al. (2003) estimated that Caspian terns nesting on Rice Island consumed about 12.4 million juvenile salmonids, or approximately 13% of the estimated 97 million out-migrating smolts that reached the estuary during the 1998 migration year. This research prompted managers to relocate the tern colony to East Sand Island, approximately 15 miles downstream and near the ocean and a wider prey base, which resulted in a successful reduction in predation of juvenile salmonids by approximately five to six million fish annually. However,

annual predation rates of terns nesting on East Sand Island are still substantial. On average, terns consumed 5.9 million smolts annually from 2000 to 2003 (Collis et al. 2003).

The double-crested cormorant colony on East Sand Island in the Columbia River estuary is the largest along the Pacific coast (Collis et al. 2002). In 2003, approximately 10,646 breeding pairs were nesting on East Sand Island. Given the birds' feeding habits, it is difficult to determine the number of juvenile salmonids they consume. However, based on preliminary bioenergetics modeling, it appears that cormorants nesting on East Sand Island consumed about the same numbers of juvenile salmonids as Caspian terns in 2003.

Inland populations of avian predators also consume substantial numbers of juvenile salmon and steelhead. The primary avian predator colonies present on islands in the Columbia Plateau region include Caspian terns, double-crested cormorants, ring-billed and California gulls, and American white pelicans. The most significant populations of avian predators occur on Crescent Island (Caspian terns) and Foundation Island (cormorants) which are located in the Columbia River near the mouth of the Snake River. In 2000 and 2001, bioenergetics modeling was used to estimate the smolt consumption rate of the Crescent Island tern colony at 465,000 and 679,000 smolts, respectively (Antolos et al. 2005). Approximately 25% of this consumption consisted of steelhead from the Snake and upper Columbia rivers. Steelhead appear to be particularly vulnerable to avian predators. In 2001, the consumption rate of in-river migrating PIT tagged Snake River steelhead by the Crescent Island tern colony was estimated at 12.4%, much higher than the estimated yearling Chinook consumption rate of 3.9% (Antolos et al. 2005). From 2003 to 2005, the minimum combined avian consumption rates (Crescent and Foundation Island) of in-river migrating PIT tagged juvenile Snake River steelhead ranged from 4.1 to 18.3% (Ryan et al. 2006). The majority of these tag detections were from the tern colony on Crescent Island. While the population of Crescent Island tern colony has decreased in recent years (-6% between 2005 and 2006) the overall tern population in the Columbia Plateau region has remained about the same since 1997, at approximately 1000 pairs (Collis et al. 2007). In contrast, double-crested cormorant populations are increasing in the Columba Plateau region with a 14% increase in the breeding colony on Foundation Island between 2005 and 2006 (Collis et al. 2007). In 2006, salmonids comprised approximately 4% of the diet of the Foundation Island cormorant colony, which included 0.89% of the in-river PIT tagged Snake River smolts, suggesting that juvenile salmonids are not a primary cormorant food source during the breeding season (Collis et al. 2007). However, this 2006 study also indicates that a minimum of 2.8% and 1.4% of the hatchery and wild in-river migrating Snake River steelhead were consumed by this colony. Other piscivorous bird predator populations (primarily gulls and pelicans) are having little impact on the survival of juvenile salmonids from the Snake and upper Columbia rivers (Collis et al. 2007).

5.4.1.3 Pinniped Predation

Marine mammal predation has increased in recent years in the tailrace below Bonneville Dam. Aggregations of over 100 individual pinnipeds, primarily California sea lions with a few Stellar sea lions and Pacific harbor seals, have been observed feeding immediately below the dam, often near the powerhouse fishway entrances. Based on visual observations of adult fish consumption

downstream from Bonneville Dam and adult fish ladder counts, researchers have estimated that pinnipeds consumed 0.4, 1.2, and 2.0, 3.8, 2.7, and 5.1% of the total annual spring Chinook salmon runs during 2002, 2003, 2004, 2005, 2006, and 2007 respectively. Thus, based on actual observations, the average estimated predation rate (2004-2007) to spring-run Chinook salmon and winter-run steelhead is about 3.0% and 7.8%, respectively. However, these estimates are likely far less than actually occurs based on the limited amount of time and coverage of the observation period. Better estimates are likely provided by recent evaluations of radio telemetry study results, which suggest that the predation rate of California sea lions since 2004 is likely about 8.5% for spring-run Chinook and 21.8% for winter-run steelhead migrating past Bonneville Dam (Marine Mammal Appendix).

Recent attempts to reduce pinniped predation by hazing and by installing excluder devices at fishway entrances have met with limited success. However, NOAA Fisheries has completed Section 7 consultation on granting permits to the states of Oregon, Washington, and Idaho, under section 120 of the Marine Mammal Protections Act, for the lethal removal of certain individually identified California sea lions that prey on adult spring-run Chinook and winter-run steelhead in the tailrace of Bonneville Dam (NMFS 2008d). This action is expected to increase the absolute survival of migrating adult spring-run Chinook by 5.5% and of winter-run steelhead by 14.2%.

5.4.2 Disease

Columbia Basin salmonids co-exist with a range of viruses, bacteria, fungi, and parasites, collectively known as pathogens, that have significant effects on salmon populations through mortality or reduced fitness (morbidity). For salmonid and pathogen populations to persist, interactions between host and pathogen, like interactions between predator and prey, must maintain a dynamic balance where neither is wholly eliminated. Three major factors in this balance have been identified as host, environment, and pathogen. A change in one or more of these three factors will result in a change in the equilibrium, often resulting in large outbreaks of disease (epizootics) which may decimate salmonid populations.

Development of the Columbia Basin has created a number of factors that have the potential to cause shifts in the host-pathogen equilibria, increasing risks of epizootics. Impoundments increase summer water temperatures, creating conditions where some of the infectivity rates (rate of spread) and virulence (severity of effects on the host organism) of some pathogens are increased. Passage through the hydrosystem also delays and stresses salmonids, increasing their exposure and reducing their resistance to disease. Introduction of exotic species and between-basin transfer of native fishes create opportunities for the introduction of new pathogens, or for endemic pathogens to increase their range. Large-scale intensive hatchery culture provides conditions where pathogens could spread rapidly within the hatchery, and increases the risk of transfer of disease out of the hatchery through hatchery effluents and the release of infected fish. Changing environmental conditions altered relationships between parasites and their hosts, potentially increasing the severity of parasitic infection. Handling and transport of fish at dams has led to fish being held at much higher densities than observed in the wild, increasing chances of disease transmission. Thus, with changes in host, pathogen, and environment, a shift in host-pathogen relationships from pre-development conditions has occurred.

The effects of disease on wild salmonid populations are notoriously hard to enumerate, and the significance of a particular pathogen may also widely vary among different salmonid populations. Diseases which have been observed to cause significant losses to migrating fish (both hatchery and wild) in the Columbia River system are Columnaris (*Flexibacter columnaris*), bacterial kidney disease (*Renibacterium salmoninarum*), and ceratomyxosis (*Ceratomyxa shasta*). With the interruptions of natural disease control mechanisms through shifts in environmental conditions, introductions of new pathogens (or changes in distribution of endemic ones), or introduction of new potential sources of pathogens, such as hatcheries, this equilibrium has been substantially altered and the potential for large epizootics and high losses to salmonid populations has increased.

5.4.2.1 Effects of Temperature on Disease

In addition to the stress and direct physiological damage suffered by salmonids when exposed to elevated water temperatures, risks of mortality due to disease also increases. There appear to be two primary reasons for this increase. Temperature-related stress reduces the capacity of the fish to resist infection and eliminate pathogens. Pathogens also respond to changes in temperature. There is a particular range of optimum temperatures for each pathogen and in this range the reproduction, infectivity, and virulence of a pathogen are maximized. The combination of reduced resistance of fish and increased virulence and infectivity of a particular pathogen can result in epizootics and high rates of mortality due to disease. In a summary of issues related to temperature criteria for salmon, the EPA (2001) summarized the effects of water temperature on disease risk as follows:

Risk	Temperature range (˚C)
Minimized	<12-13
Elevated	14-17
Severe	18-20

There are a number of pathogens known in the Columbia Basin which show a direct increase in infectivity and virulence with increased water temperature. A brief summary of Columbia Basin pathogens with the potential for causing increased mortality among salmonids under elevated water temperature conditions is described in Table 5.4-1 below.

Table 5.4-1. Fish diseases known from the Columbia Basin showing increases in infectivity and virulence with increasing water temperature. (Source: WDOE 2002; EPA 1999; EPA 2001)

Organism	Disease	Temperature effects	Susceptible species	Severity of effects
Bacteria				
Flexibacter columnaris	Columnaris	Epizootics strongly related to high water temperature (>15)	All species	Has been observed to cause high levels of mortality among wild and hatchery populations, ^{o} C)
Renibacterium salmoninarum	Bacterial Kidney Disease (BKD)	Increased temperatures reduce	All salmonids, especially	Often causes high levels of mortality in

Organism	Disease	Temperature effects	Susceptible species	Severity of effects
		infectivity, but increase the severity of infections (time until death) in laboratory trials.	chinook and sockeye	hatcheries. High prevalence in some wild fish populations.
Aeromonas salmonicida	Furunculosis	Epizootics strongly correlated with temperature	All fishes	Has been observed to cause high levels of mortality in the wild and hatcheries
Myxobacter sp.	Bacterial Gill Disease (BGD)	Epizootics strongly correlated with water temperature and poor water quality	All fishes	
Parasites				
Ceratomyxa shasta	Ceratomyxosis	Increased temperatures reduced time from exposure to death in laboratory studies.	Salmonids, especially chinook	Has been observed to cause high levels of mortality in the wild and in hatcheries.
Icthyopthirius multifilis	Ich	Epizootics strongly associated with temps >15 ^{o} C	All fishes	Has been observed to cause high levels of mortality in the wild and in hatcheries

Juvenile salmon and steelhead mortalities from an array of disease have been observed at many fish collection and handling systems in the migratory corridor. Columnaris and BKD are two common diseases observed at FCRPS juvenile collection systems. In many cases, the proximate causes of fish mortality in the action area are largely unknown. While it is known that juvenile passage survival is lower under low-flow, high-temperature conditions, it is seldom known whether the direct cause of death is thermal stress, increased predation, increased susceptibility to disease, or a combination of these factors.

5.5 Hatchery Effects

The hatchery programs in the Proposed Action are funded by the Action Agencies to compensate for impacts to salmon and steelhead attributable to the FCRPS and continued funding is proposed. Benefits and risks from past and present hatchery operations are imbedded in the environmental baseline. For an overview of past and present hatchery programs see NMFS 2004b and NMFS 2006b.

Today, because nearly 90 percent of the Chinook salmon and steelhead habitat originally available in the Columbia Basin has been lost or degraded (Brannon et al. 2002), fish produced by hatcheries comprise the vast majority of the annual returns to the basin (CBFWA 1990). Annual returns of salmon and steelhead would be reduced by up to ninety percent and there would be little or no tribal, recreational, or commercial fishing opportunity without hatcheries.

Hatchery programs support tribal, recreational and commercial fisheries. The primary purpose of the nearly two hundred hatchery programs that operate in the Columbia Basin is to compensate for Federal and public and private utilities projects. Other hatchery programs are designed to conserve genetic resources, and in some cases, are used to help improve viability after the factors limiting viability are addressed.

As an unintended consequence of providing these benefits, there is the potential for hatchery programs to increase the extinction risk and threaten the long-term viability of natural populations. For example, because the progeny of hatchery fish that spawn in the wild are known to be less likely to survive and return as adults than the progeny of natural-origin spawners (Berejikian and Ford.2004), the fitness of a spawning aggregate or natural population is likely to decline (termed, outbreeding depression) if hatchery and natural-origin fish interbreed. For steelhead, outbreeding depression has been found to occur in the progeny of matings of hatchery and wild fish, even when the hatchery fish are the progeny of wild fish that were raised in a hatchery. Other potential risks posed by hatchery programs include disease transmission, competition with natural-origin fish, and increased predator and fishing pressure based mortality. The risks of several basin hatchery programs have been reduced through careful hatchery management and the implementation of hatchery reforms. When conducting ESA consultations on hatchery actions, NOAA Fisheries requires the submission of new Hatchery Genetic Management Plans and evaluates those plans to ensure such risks are minimized.

NMFS (2004b) evaluated the benefits and risks of hatchery programs at the population level and at the ESU or DPS level. For programs in the Interior Columbia (upstream from Bonneville Dam), NMFS (2006b), with input provided by members of the Hatchery and Harvest Workgroup of the FCRPS remand collaboration; (1) summarized the major factors limiting salmon and steelhead recovery at the population scale, (2) provided an inventory of existing hatchery programs including their funding source(s) and the status of their regulatory compliance under the ESA and under the National Environmental Policy Act, (3) summarized the effects on salmon and steelhead viability from current hatchery operations, and (4) identified new opportunities or changes in hatchery programs likely to

benefit population viability. As a follow-up to this report, NOAA Fisheries developed guidance for determining hatchery effects, including a general assessment of hatchery programs in the upper Columbia and Snake River Basin, and presented this paper to the Hatchery and Harvest Workgroup and to the Policy Workgroup in August of 2006. NOAA Fisheries received comments and made edits to this paper to provide updated guidance for assessing benefits and risks and operating hatchery programs (see Artificial Propagation for Pacific Salmon Appendix).

The history or evolution of hatcheries is an important factor in analyzing their past and present effects. From their origin more than one hundred years ago, hatchery programs have been tasked to compensate for factors that limit anadromous salmonid viability. The first hatcheries, beginning in the late 19th century, provided additional fish for harvest purposes on top of large relatively healthy salmon and steelhead populations. As development of the Columbia Basin proceeded (e.g., construction of the FCRPS between 1939 and 1975), the role of hatcheries shifted to replacing losses in fish production attributable to habitat degradation and reduced salmon and steelhead survival. Since that time, most hatchery programs have been tasked to maintain fishable returns of adult salmon, usually for cultural, social, recreational, or economic purposes as the capacity of natural habitat to produce salmon and steelhead has been reduced. National Fish Hatcheries in the upper Columbia, for example, produce salmon and steelhead for areas blocked by federal dams (about 50 percent of the production area for upper Columbia spring Chinook salmon and steelhead is blocked by dams and remains inaccessible) while federally funded hatchery programs in the Snake River are expected to replace losses of fall Chinook salmon from inundation of their spawning habitat and from reduced survival during their migration to and from the ocean because of the eight Lower Snake and Columbia River Federal projects. The scope and level of hatchery production increased greatly during this period as impacts from development and the requirement to compensate for those impacts increased.

A new role for hatcheries emerged during the 1980s and 1990s after populations declined to unprecedented low levels. Because tools were needed to help conserve salmon and steelhead genetic resources and reduce short-term extinction risk, some hatchery programs changed their goals and practices and whole new programs were implemented, including substantial new research to assess the efficacy of artificial propagation as a tool to promote conservation.

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 1991b; Hard et al. 1992). For a list of hatchery fish included in salmon ESUs and steelhead DPSs, see NMFS (2004b). Hatchery programs have also been used as a tool to conserve the genetic resources of depressed natural populations and to reduce extinction risk, at least in the short-term (e.g. Snake River Sockeye). Such programs are designed to preserve the genetic resources that salmon and steelhead conservation depends on and buy time until the factors limiting salmon and steelhead viability are addressed. In this role, hatchery programs reduce the risk of extinction (NMFS 2005b). Hatchery programs that only conserve genetic resources, however, "do not substantially reduce the extinction risk of the ESU in the foreseeable future" or long-term (NMFS 2005b). Furthermore, hatchery programs that conserve vital genetic resources are not without risk because the manner in which these programs are implemented

can affect the genetic structure and evolutionary trajectory of the target population by reducing genetic and phenotypic variability and patterns of local adaptation (ICTRT 2007b).

Population viability and reductions in threats are key measures of salmon and steelhead status relative to recovery. Beside their role in conserving genetic resources, hatchery programs also are a tool that can be used to help improve viability (i.e., hatchery supplementation). In general, these hatchery programs increase the number and spatial distribution of naturally spawning fish (i.e., F1 hatchery-origin fish). They are not, however, a proven technology for achieving sustained increases in adult production (NRC 1995), and the long-term benefits and risks of hatchery supplementation remain untested (Araki et al. 2007a). For an overview of the benefits and adverse implications from existing hatchery operations see NMFS (2004b and 2006b).

Hatchery actions designed to benefit salmon and steelhead viability sometimes produce only limited positive results. One potential reason for this is that other factors (i.e., limiting factors and threats) can offset or out-weigh the benefits from hatchery actions. Hatchery programs can serve an important conservation role when habitat conditions in freshwater depress juvenile survival or when access to spawning and rearing habitat is blocked. Under circumstances like these and in the short-term, the demographic risks of extinction of such populations likely exceed genetic and ecological risks to natural-origin fish that would result from hatchery supplementation. Benefits like this should be considered *transitory* or short-term and do not contribute to survival rate changes necessary to meet ICTRT abundance and productivity viability criteria. For example, in Puget Sound, eight Chinook salmon hatchery programs have been specifically implemented to preserve native populations in their natal watersheds "where habitat needed to sustain the populations naturally at viable levels has been lost or degraded" (NMFS 2005b). These hatchery programs help "to preserve remaining genetic diversity, and likely have prevented the loss of several populations" (NMFS 2005b). Until, however, the factors limiting Chinook salmon productivity are addressed, the full benefit (i.e., potential contributions to increased viability) of hatchery actions designed to benefit salmon viability may not be realized. Fixing the factors limiting viability is the key to long-term viability. "The fitness of the naturally spawning population, its productivity, and the numbers of adult salmon returning to the watershed, ultimately must depend on the natural habitat, not on the output of the hatchery" (HSRG 2004). Salmon and steelhead populations that rely on hatchery production are not viable (McElhany et al. 2000), and increased dependence on hatchery intervention results in decreasing benefits and increasing risk (ICTRT 2007a).

Increasing knowledge and experience is another important factor in the application of hatchery supplementation. Hatchery supplementation is an "experimental" technology. It is relatively new and there is little data on long-term benefits and risks – study results for a single generation of Pacific salmon take a minimum of three to five years. New information is emerging, however, from ongoing research and important new research will be implemented as a result of this Biological Opinion (see Chapter 2). The reproductive fitness of hatchery fish and the effects of hatchery supplementation on population viability will be investigated for steelhead in the Methow River and for fall Chinook salmon in the Snake River. NOAA Fisheries intends that the information emerging from ongoing and

new studies will shape future decisions over hatchery supplementation throughout the Interior Columbia Basin.

This Supplemental Comprehensive Analysis includes in the baseline the past effects of hatchery operations in the Columbia River Basin. As is acknowledged in Section 8.1.3, the past effects, and in some instances, continuing effects, of hatchery practices constitute significant factors which may increase risk to the recovery of the ESU. Such effects include those which result from the operation of hatcheries prior to this consultation, as well as the continued operation of hatcheries following this consultation to the extent hatcheries have undergone ESA section 7 consultation. Where hatchery consultations have expired or where hatchery operations have yet to undergo ESA section 7 consultation, the effects of future operations cannot be included in the baseline. In some instances, effects are ongoing (e.g., returning adults from past hatchery practices) and included in this analysis despite the fact that future operations are excluded from the baseline. See Hatchery Effects Appendix for the status of hatchery operations in the Columbia River Basin.

While hatchery effects are included in the baseline as described above, nevertheless the proposed action does not encompass hatchery operations per se, and therefore no incidental take coverage is offered through this biological opinion to hatcheries operating in the region. Instead, we expect the operators of each hatchery to address its obligations under the ESA in separate consultations, as required.

5.6 Harvest Effects

For thousands of years Native Americans have fished for salmon and steelhead, as well as other species, in the tributaries and mainstem of the Columbia River for ceremonial, subsistence, and economic purposes. A wide variety of gears and methods were used, including hoop and dip nets at cascades such as Celilo and Willamette Falls; to spears, weirs, and traps (usually in smaller streams and headwater areas). Commercial fishing developed rapidly with the arrival of European settlers and the advent of canning technologies in the late 1800s. The development of non-Indian fisheries began circa 1830, and by 1861 commercial fishing was an important economic activity. Fishing pressure, especially in the late nineteenth and early twentieth centuries, has long been recognized as a significant factor in the decline of Columbia River salmon runs (NRC 1996).

Treaty Indian fishing rights in the Columbia Basin are under the continuing jurisdiction of the U.S. District Court for the District of Oregon in the Case of *United States v. Oregon*, No. 68-513 (D. Oregon, continuing jurisdiction case filed in 1968). In U.S. v. Oregon, the court affirmed that the treaties reserved to the Tribes 50% of the harvestable surplus of fish destined to pass through their usual and accustomed fishing areas. In at least a half-dozen published opinions and several unpublished opinions in *U.S. v. Oregon*, as well as dozens of rulings in the parallel case in *U.S. v. Washington* (interpreting the same treaty language for Tribes in the Puget Sound area), the courts have established a large body of case law setting forth the fundamental principles of treaty rights and the permissible limits of conservation regulation of treaty fisheries. The parties to *U.S. v. Oregon* are the

United States acting through the Department of the Interior (U.S. Fish and Wildlife Service and Bureau of Indian Affairs) and the Department of Commerce (NOAA Fisheries), the Confederated Tribes of the Warm Springs Reservation of Oregon, the Confederated Tribes of the Umatilla Indian Reservation, the Nez Perce Tribe, the Confederated Tribes and Bands of the Yakama Nation, and the Shoshone-Bannock Tribes, and the states of Oregon, Washington, and Idaho.

Treaty Indian and non-Indian commercial and recreational fisheries in the Columbia River basin were managed subject to provisions of the Columbia River Fish Management Plan (CRFMP) from 1988 through 1998. The CRFMP was a stipulated agreement adopted by the Federal Court under the continuing jurisdiction of *U.S. v. Oregon*. NOAA Fisheries has consulted under section 7 of the ESA on proposed *U.S. v. Oregon* fisheries in the Columbia basin since 1992 when affected salmonids were fist listed. Table 5.6-1 displays the incidental take limits and expected incidental take (as a proportion of total run size) of listed salmonids for treaty Indian and non-Indian fisheries under the 2005-2007 Interim Management Agreement, which was scheduled to expire on December 31, 2007. The 2005 Interim Management Agreement was subsequently extended by the parties through May 8, 2008.

Table 5.6-1. Incidental take limits and expected incidental take (as proportion of total run size) of listed salmonids for non-Indian and treaty Indian fisheries under the 2005-07 Interim Management Agreement (table and associated footnotes taken from the Biological Opinion on the Interim Agreement (U.S. District Court 2005)).

ESU		Take Limits (%)	Treaty Indian (%)	Non-Indian (%)
Snake River Fall Chinook		31.29	11.6 – 23.04	5.9 – 8.25
Snake River Spring/Summer Chinook		5.5 – 17.07	5.0 – 15.0	0.5 – 2.0
Lower Columbia River Chinook	Spring Component	managed for escapement goal	0	0.2 – 2.0
	Tule Component (LRH stock)	49% exploitation rate	0	7.3 – 12.0 (49% exploitation rate
	Bright Component (LRW stock)	managed for escapement goal	0	9.5 – 18.8 (5.700 goal)
Upper Willamette River Chinook		15.0	0	5.0 – 11.0
Snake River Basin Steelhead	A-Run Component	4.03	3.5 – 8.2	1.0 – 1.8
	B-Run Component	17.04	3.4 – 15.04	1.5 – 2.0
Lower Columbia River Steelhead	Winter Component	6.05	0.6 – 10.76	0.8 – 6.0
	Sumer Component	4.03	3.5 – 8.27	0.6-1.6
Upper Willamette River Steelhead		6.04	0	0.8 – 6.02
Middle Columbia River Steelhead	Winter Component	6.05	0.6 – 10.7	0.8 – 6.0
	Summer Component	4.03	3.5 – 8.2	1.0 – 1.8

ESU		Take Limits (%)	Treaty Indian (%)	Non-Indian (%)
Upper Columbia River Spring Chinook		5.5 – 17.01	5.0 – 15.0	0.5 – 2.0
Columbia River Chum		5.0	0	1.6
Upper Columbia River Steelhead	Natural-origin Component	4.04	3.5 – 8.2	1.0 – 1.8
	Hatchery Component		3.5 – 8.2	8.6 – 15.0
Snake River Sockeye		6.0 – 8.08	2.8 – 7.0	0.0 – 1.0
Lower Columbia Coho		6.59	0	0 – 6.59

While the general principles for quantifying treaty Indian fishing rights are well established, their application to individual runs during the annual spring and fall fishing seasons is complicated. Annual calculations of allowable harvest rates depend (among other things) on estimated run sizes for the particular year, on the mix of stocks that is present, on application of the ESA to mixed-stock fisheries, on application of the tenets of the "conservation necessity principle" to regulation of treaty Indian fisheries, and on the effect of both the ESA and the conservation necessity principle on treaty and non-treaty allocations. While the precise quantification of treaty Indian fishing rights during a particular fishing season often cannot be established by a rigid formula, the treaty fishing right itself continues to exist and must be accounted for in the environmental baseline.

The sections that follow evaluate harvest mortality, under the environmental baseline, for individual ESUs and DPSs, as well as the estimated effects of all forms of harvest on those ESUs and/or DPSs that are subject to substantial harvest outside of the action area.

5.6.1 Species Effects of Harvest under the Environmental Baseline

Snake River Fall Chinook

Snake River (SR) fall Chinook are caught in ocean and in-river fisheries. Ocean fisheries occur outside the action area, but are nonetheless reviewed here to provide a more comprehensive overview of harvest affecting the status of this species.

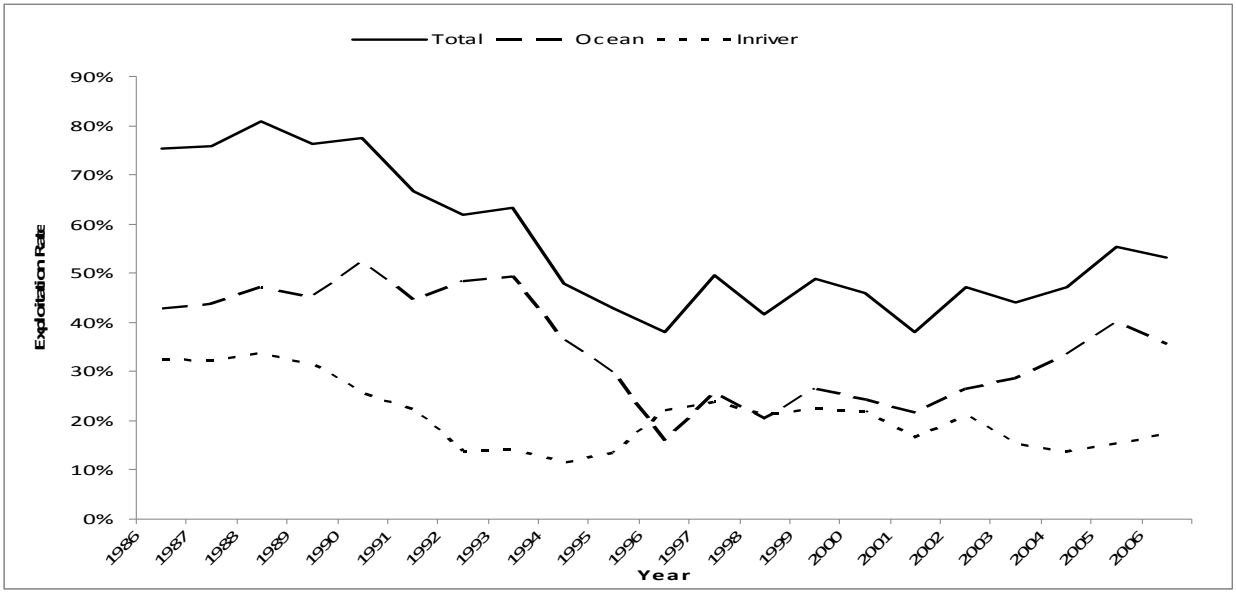
SR fall Chinook are broadly distributed and caught in fisheries from Alaska to California, but the center of their distribution and the majority of impacts occur in fisheries from the west Coast of Vancouver Island to central Oregon. The total ocean fishery exploitation rate averaged 46% from 1986 to 1991, and 31% from 1992 to 2006 (NMFS 2008e). Ocean fisheries have been required since 1996, through ESA consultation, to achieve a 30% reduction in the average exploitation rate observed during the 1988 to 1993 base period (NMFS 2008e).

SR fall Chinook area also caught in fall season fisheries in the Columbia River with most impacts occurring in Non-Indian and treaty Indian fisheries from the river mouth to McNary Dam. Fisheries affecting SR fall Chinook have been subject to ESA constraints since 1992. Since 1996, fisheries

have been subject to a total harvest rate limit of 31.29%. This represents a 30% reduction in the 1988 to 1993 base period harvest rate. Columbia River fisheries have a similar 30% base period reduction standard. But the ocean and inriver standards are separate, and the fisheries are managed independently subject to their respective own standard.

Total harvest mortality for the combined ocean and inriver fisheries can be expressed in terms of exploitation rates which provide a common currency for comparing ocean and inriver fishery impacts (Fisheries in the Columbia River are generally managed subject to harvest rate limits. Harvest rates are expressed as a proportion of the run returning to the river that is killed in river fisheries). The total exploitation rate has declined significantly since the ESA listing. Total exploitation rate averaged 75% from 1986 to 1991, and 45% from 1992 to 2006 (Figure 5.6.1-1).

Figure 5.6.1-1. Ocean and In-river Exploitation Rates for Snake River fall Chinook

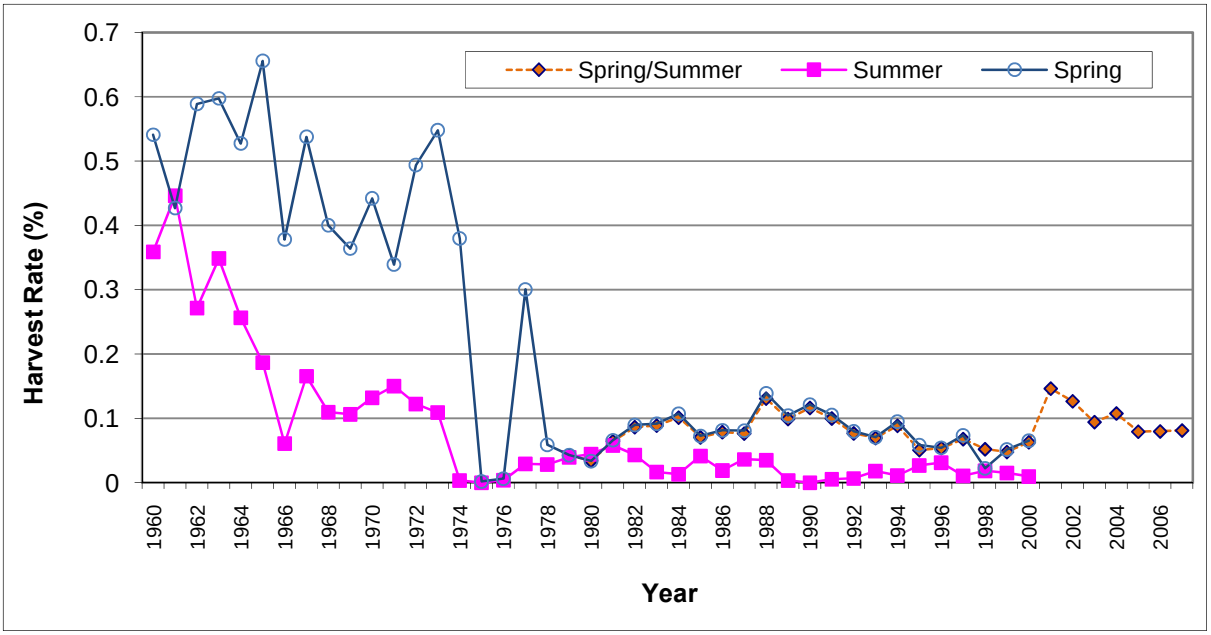


Upper Columbia River Spring Chinook & Snake River Spring/Summer Chinook

"Upriver" spring Chinook is a "management unit" and includes Upper Columbia River (UCR) Chinook ESU and Snake River (SR) spring and Summer Chinook ESUs. Recent analysis of PIT-tag information indicates that the timing of the SR summer Chinook populations is intermediate, and more similar to that of the SR spring Chinook populations than other summer Chinook populations that return to the Upper Columbia (that are not ESA listed). Until 2005, SR spring and summer Chinook were treated as different stocks and managed separately. Beginning in 2005, the end of the spring management period was shifted later by two weeks, to June 15, so that SR spring and summer Chinook populations could be managed, for harvest purposes, as a single stock, and separately from upper Columbia River summer populations. The harvest rate on the aggregate run of SR spring/summer Chinook has been recalculated back to 1979 (Figure 5.6.1-2). "Upriver" spring Chinook are caught in spring season fisheries in the mainstem Columbia River. Harvest mortality in ocean fisheries is assumed to be zero.

A review of the record of sequential harvest reductions over past years provides a pertinent perspective about harvest-related management actions that have been taken to protect upriver, natural-origin spring Chinook stocks, including SR spring/summer Chinook. A more detailed discussion of this record is provided in a biological opinion related to the 2001 harvest management agreement (NMFS 2001b).

Figure 5.6.1-2. Harvest rates for all commercial, recreational, and C&S fisheries in the mainstem (TAC 2008).



Upriver spring Chinook stocks were subject to substantial harvest through the early seventies. The average harvest rate on upriver spring Chinook from 1938-1973 was 55%. As the stocks declined it became apparent that these harvest rates were not sustainable. By the mid-1970s, the spring season fisheries that targeted upriver stocks were largely eliminated by the state and tribal managers. Harvest rates in all mainstem commercial, recreational, and ceremonial and subsistence (C&S) fisheries have averaged just over 8% since then (Figure 5.6.1-2).

The last mainstem fisheries targeting upriver summer Chinook stocks, including the summer component of the SR ESU, occurred in 1964. Harvest rates have not exceeded 10% since 1973 and have averaged less than 3% since 1974. As discussed above, in 2005 the management period separating upriver spring and summer Chinook stocks was adjusted. Snake River spring and summer Chinook are now managed as a unit and subject to similar harvest rates.

Beginning in 1988, the Columbia River Fish Management Plan (CRFMP or Plan), developed under the jurisdiction of *U.S. v. Oregon*, provided a framework for managing the mainstem fisheries that impact upriver spring and summer Chinook stocks. The purpose of the Plan was to define harvest

limits that would be sufficiently protective, in order to allow for the rebuilding of stocks of concern. The Plan was formally approved in 1988, but fisheries were managed subject to its provisions beginning in 1986. The Plan allowed for harvest rates of up to 4.1% on upriver spring stocks in non-Indian fisheries and 5% or 7% in treaty Indian C&S fisheries, depending on run size. There were provisions that allowed for higher harvest rates if run sizes increased, but such runs had not been seen for many years.

Despite the Plan's provisions, further constraints were implemented in 1992, through the Section 7 consultation process, when SR spring/summer Chinook were first listed. Management constraints were refined through a series of annual consultations that led to the development in 1996 of a three year Management Agreement that modified the Plan's original management framework. The Plan's provisions were modified by reducing allowable impacts in the non-Indian fisheries to 1-3%, depending on run size. The alternative target harvest rates in the treaty Indian fisheries (5-7%) were not changed as a result of the Agreement, largely in deference to treaty right considerations. However, the Agreement for the first time required that fisheries be managed in response to the status of listed natural-origin fish, rather than an aggregate runsize that was now composed primarily of hatchery-origin fish.

The CRFMP also limited harvest rates on upriver summer Chinook stocks in the non-Indian and treaty-Indian fisheries, which at that time included the SR summer Chinook populations, to 5% each. The three year Agreement reduced the harvest rate limit for upriver summer Chinook in the non-Indian fishery from 5-1% and clarified that all treaty Indian fisheries were subject to the 5% harvest rate limit.

The parties used provisions of the 1996 Agreement to direct fisheries through 1999. In 2000, and particularly 2001, the parties began to anticipate, as a result of preseason forecasts, the increased returns that occurred in the early part of the decade (NMFS 2001b). This lead to more detailed discussion among the *U.S. v. Oregon* parties regarding an abundance-based management system that would be responsive to the status of natural-origin spring Chinook stocks. In 2001, the parties concluded an agreement that allowed the harvest rates to vary between 5.5% and 17%, depending on the status of spring Chinook stocks (NMFS 2001b). That agreement was modified in 2005 to account for new information on the run timing of Snake River spring and summer Chinook populations (NMFS 2005c). The harvest rate schedule was adjusted so that it now accounted for the abundance of SR spring and summer Chinook populations, but the range of allowable harvest rates remained the same, – 5.5 to 17%. But for this technical adjustment made in 2005, the current abundance based harvest rate schedule has been in place since 2001.

Snake River, Upper Columbia, Middle Columbia & Lower Columbia River Steelhead

Steelhead returning to the Columbia Basin have both winter and summer-run return timing. Winter steelhead generally enter freshwater from November through May and spawn from March through June. The returns of wild winter steelhead generally peak in March and April, while hatchery fish dominate during the earlier portion of the run. Winter steelhead primarily return to rivers below Bonneville Dam, but there are a few winter-run populations that return to

rivers in the Bonneville pool. Most of the Lower Columbia River (LCR) steelhead populations have winter timing. Summer run steelhead returning to the Kalama, Lewis, and Washougal rivers from the Cascade Summer MPG, and Wind and Hood Rivers form the George summer MPG are part of the LCR steelhead DPS. Winter-run populations returning to the Klickitat and Fifteenmile Creek watersheds (Cascades Eastern Slope MPG) are part of the Middle Columbia River (MCR) steelhead DPS.

Summer steelhead enter the Columbia Basin from April through October and return to tributaries from the area below Bonneville Dam to the upper reaches of the SR and upper Columbia River. There are three identifiable stocks of summer steelhead that are used for management purposes. They include: Skamania, A-run, and B-run stocks. Skamania steelhead are a "lower river" summer stock.[9] A-run and B-run steelhead are "upriver" summer stocks, meaning they return to areas in the Upper Columbia River, Snake River, and Middle Columbia between Bonneville and McNary Dams. Most populations from MCR DPSs have summer timing. All SR and UCR populations are summer-run steelhead. Skamania steelhead have an earlier return timing than upriver steelhead with peak returns in May and June.

Hatchery fish of the Skamania stock return to tributaries in the Bonneville pool including the Big White Salmon, Hood River, and Klickitat. Summer steelhead caught in the lower Columbia River below Bonneville Dam from March through June are classified as Skamania steelhead. Summer steelhead that cross Bonneville Dam from April 1 through June 31 are also classified as Skamania stock. Steelhead crossing Bonneville Dam beginning July 1 are considered upriver summer steelhead.

Upriver steelhead are separated into A-run and B-run stocks. A-run steelhead typically return earlier than B-run steelhead, are smaller, and return primarily after one year in the ocean. Conversely, B-run steelhead return later, are larger, and return primarily after 2 years in the ocean. A-run and B-run steelhead are distinguished, for management purposes, based on fork length with A-run steelhead < 78 cm and B-run steelhead ≥ 78 cm. Hatchery fish are distinguished from wild fish primarily by the adipose fin clip used to mark hatchery reared steelhead. B-run steelhead generally are subject to higher harvest rates, particularly in fisheries above Bonneville Dam, because they are larger, and thus more susceptible to catch in gillnets, and because their run timing coincides with the timing of the fall season fisheries targeting Chinook.

All populations that are designated as B-run steelhead return to the Snake River, although some fish ≥ 78 cm return to other areas. This means that not all fish ≥ 78 cm are B-run steelhead. Some of the SR steelhead populations are also A-run steelhead. All of the populations in the Upper

[9] "Skamania" steelhead is a stock designation used by harvest managers that refers to summer steelhead populations in the LCR DPS. There is also Skamania hatchery stock that was derived from populations in the LCR and MCR DPSs, and used broadly for hatchery production throughout the basin. The Skamania hatchery stock is not listed as part of any DPS. In this biological opinion Skamania steelhead are used as an indicator for LCR summer steelhead populations

Columbia River DPS and most of the populations in the Middle Columbia River DPS are designated as A-run steelhead. Additionally, as indicated above, there are a few winter run populations in the MCR steelhead DPS.

Due to the complexity of the life history, as well as the fact that populations from the various DPSs intermingle, it is difficult to measure harvest impacts on mixed stock fisheries that are specific to each DPS or population. Instead, fisheries are managed using stocks, including: winter and summer; and among summer steelhead, lower river Skamania and upriver A-run and B-run stocks. As a result, it is assumed, for example, that all A-run populations are intermingled and subject to the same level of harvest in mixed stock fisheries. There may in fact be some differential impacts to components of the A-run stock complex or other stock complexes, but the information necessary to assess possible differences is not currently available.

Commercial harvest of steelhead in non-Treaty fisheries has been prohibited since 1975. From 1938 through the mid-1960s, the commercial catch of steelhead ranged from 100,000 to nearly 300,000 steelhead per year. From the mid-1960s until the non-Treaty commercial fisheries were closed, the catch of steelhead was approximately 50,000 fish per year (WDFW and ODFW 2002). These essentially were all wild fish since hatchery production of steelhead was still relatively limited at the time.

Since 1986, recreational anglers in the Columbia Basin have been required to release unmarked, wild steelhead. Wild steelhead are still subject to mortality associated with catch-and-release, but implementation of mark-selective fisheries has greatly reduced the impact to wild steelhead from recreational fisheries.

Beginning in 1988, the Columbia River Fish Management Plan (referred to as the CRFMP or Plan as stated above), developed under the jurisdiction of *U.S. v. Oregon*, provided a framework for managing the mainstem fisheries that impacted steelhead. The Plan limited tribal fishery impacts during the fall season management period to 15% for A-run steelhead, and 32% for B-run steelhead. Although the CRFMP was not formally completed until 1988, fisheries were managed subject to these harvest rate limits as of 1986.

After the ESA listing of SR fall Chinook in 1992, fall fisheries, where most of the steelhead impacts occur, were subject to further constraints in order to reduce the impacts to SR fall Chinook salmon. While the CRFMP limited tribal fishery impacts during the fall season management period to 15% for A-run and 32% for B-run steelhead, the constraints to reduce impacts to SR fall Chinook resulted in reductions in the incidental catch of steelhead.

Snake River Steelhead and Upper Columbia River Steelhead were ESA listed in August 1997. Fall fisheries managed under *U.S. v. Oregon* were reviewed first through ESA consultation in late 1997 and in more detail in 1998. These consultations addressed the incidental impacts on listed steelhead. Beginning in 1998, non-Treaty fall season fisheries were subject to a DPS-specific harvest rate limit of 2%, a provision that applied to the SR steelhead DPS and the MCR

steelhead DPS that were later listed in 1999. Similarly, beginning in 1998, treaty-Indian fall season fisheries were subject to a harvest rate limit of 15% for B-run steelhead; a reduction from the prior 32% limit in the CRFMP. This further limitation on B-run steelhead indirectly reduced the impacts to A-run steelhead as well. Additionally, non-Treaty winter, spring and summer season fisheries were subject to a harvest rate limit of 2% for all winter-run populations; a limit that applies to LCR steelhead, UWR steelhead, and the winter-run populations of the MCR steelhead DPSs.

Most of the take of A-run steelhead in *U.S. v. Oregon* fisheries occurs in the fall season. There are some impacts to A-run steelhead in treaty-Indian spring and summer season fisheries, which extend through July 31. The harvest rate for tribal spring and summer season fisheries has averaged 0.2% and 2.2%, respectively (Table 5.6.1-1) (TAC 2008). The yearly total incidental catch of A-run steelhead in tribal fisheries has averaged 6.4% and has ranged from 4.1-12.4% since 1998 (Table 5.6.1-1) (TAC 2008). The harvest rate for non-Indian spring and summer season fisheries has averaged 0.3% and 0.4%, respectively (Table 5.6.1-1). The total yearly incidental catch of A-run steelhead in non-Indian fisheries has averaged 1.6% and has ranged from 1.0 to 1.9% since 1999 (Table 5.6.1-1). The impacts to A-run steelhead from non-Indian fisheries are expected to be similar over the course of this Agreement (TAC 2008). A-run steelhead from the SR DPS have benefited from the protections provided to B-run steelhead.

It is assumed that the harvest rate estimated for A-run steelhead applies to the A-run populations of the SR steelhead DPS. There may in fact be some differential harvest impacts to various components of the A-run stock complex, but as indicated above, the information necessary to assess possible differences is not currently available.

The incidental take of B-run steelhead from non-Treaty fisheries has averaged 1.4% of the run since 1998, and has ranged from 1.1 to 2.0% (Table 5.6.1-2).The treaty-Indian fall season fisheries impacts for B-run Steelhead have averaged 17.9% from 1990 to 2003, and 12.2% from 1998 to 2006 (Table 5.6.1-2). This further limitation on B-run steelhead indirectly reduced the impacts to A-run steelhead from treaty-Indian fisheries as well.

The yearly incidental catch of winter-run steelhead populations in non-Indian fisheries has averaged 1.9% and has ranged from 0.2-9.3% since 2001 (Table 5.6.1-3). The high harvest rate observed in 2002 (i.e. 9.3%) was due to a lack of proper in-season management guidelines. These guidelines subsequently corrected in 2003 and have been in place since this time. The yearly incidental take of winter-run steelhead populations in tribal fisheries, which is limited to winter populations above Bonneville Dam, has averaged 2.2% and has ranged from 0.8-5.8% since 2001 (Table 5.6.1-4). Winter-run steelhead above Bonneville Dam can be part of the LCR and MCR steelhead DPSs. It is assumed that harvest impacts on winter populations above Bonneville Dam are proportioned equally among populations of the two affected DPSs.

Treaty Indian fisheries in some or all of the following tributaries also occur throughout the year: Wind, Little White Salmon (Drano Lake), Hood, White Salmon, Klickitat, Deschutes, Umatilla,

Walla Walla, and Yakima Rivers as well as in Icicle Creek (tributary to the Wenatchee). These fisheries target primarily non-ESA-listed spring Chinook, fall Chinook, and coho salmon, and well as hatchery-reared steelhead. Table 5.6.1-6 lists the fisheries by tributary, the average number of natural-origin steelhead harvested by fishery and the affected DPS (TAC 2008). Fisheries in Drano Lake and the Big White Salmon River may also incidentally harvest ESA-listed B-run steelhead, but these would be included in the overall impact limit of Table 5.5.1-2.

The yearly incidental catch of summer-run steelhead populations of the LCR steelhead ESU in non-Indian fisheries has averaged 0.3% and has ranged from 0.2-0.5% since 1999 (Table 5.6.1-5). The yearly incidental take of summer-run steelhead populations of the LCR steelhead ESU in tribal fisheries, which is limited to LCR summer-run populations above Bonneville Dam, is assumed to be the same than for A-run summer steelhead, and has ranged from 4.1 to 12.8 with an average of 6.4% (Table 5.6.1-1).

Table 5.6.1-1. Harvest rates of A-run steelhead in spring, summer, and fall season fisheries expressed as a proportion of the Skamania and A-run steelhead run size (TAC 2008).

Year	Treaty Indian				Non-Indian			
	Spring Season	Summer Season	Fall Season	Total	Spring Season	Summer Season	Fall Season	Total
1985	0.20%	NA	19.40%	19.50%				
1986	0.10%	NA	12.60%	12.70%				
1987	0.10%	NA	14.70%	14.80%				
1988	0.20%	NA	16.10%	16.20%				
1989	0.00%	4.00%	14.90%	18.90%				
1990	0.40%	3.50%	14.10%	18.00%				
1991	0.20%	1.90%	14.40%	16.40%				
1992	0.50%	2.00%	15.20%	17.60%				
1993	0.10%	1.40%	14.60%	16.20%				
1994	0.20%	1.10%	9.70%	10.90%				
1995	0.10%	2.20%	10.00%	12.20%				
1996	0.70%	2.30%	8.40%	11.40%				
1997	0.10%	2.70%	10.10%	12.80%				
1998	0.10%	3.80%	8.40%	12.40%				
1999	0.10%	2.10%	5.20%	7.40%	0.10%	0.30%	0.60%	1.00%
2000	0.10%	1.00%	4.00%	5.10%	0.10%	0.60%	1.00%	1.70%

Year	Treaty Indian				Non-Indian			
	Spring Season	Summer Season	Fall Season	Total	Spring Season	Summer Season	Fall Season	Total
2001	0.10%	2.10%	3.80%	6.00%	0.10%	0.40%	0.60%	1.10%
2002	0.10%	2.10%	2.40%	4.70%	0.40%	0.40%	0.80%	1.60%
2003	0.10%	2.80%	2.50%	5.40%	0.60%	0.30%	1.00%	1.90%
2004	0.10%	3.90%	3.00%	7.00%	0.40%	0.40%	1.00%	1.80%
2005	0.10%	2.30%	3.60%	5.90%	0.40%	0.40%	0.90%	1.70%
2006	0.20%	0.80%	5.00%	6.00%	0.30%	0.40%	1.20%	1.90%
2007	0.10%	0.50%	3.50%	4.10%	0.30%	0.30%	0.80%	1.40%
1985-07 average	0.2%	2.2%	9.4%	11.4%				
1989-07 average	0.2%	2.2%	8.0%	10.4%				
1998-07 average	0.1%	2.1%	4.1%	6.4%	0.3%	0.4%	0.9%	1.6%

Table 5.6.1-2. Harvest rates of B-run steelhead in treaty Indian fisheries and non-Treaty fisheries expressed as a proportion of the B-run index steelhead run size (TAC 2008).

Return Year	Non-Indian Harvest Rates (%)	Treaty-Indian Harvest Rates (%)	Total Harvest Rates (%)
1985	2.0%	30.4%	32.4%
1986	2.0%	26.2%	28.2%
1987	2.0%	36.5%	38.5%
1988	2.0%	23.0%	25.0%
1989	2.0%	34.3%	36.3%
1990	2.0%	21.1%	23.1%
1991	2.0%	29.4%	31.4%
1992	2.0%	25.8%	27.8%
1993	2.0%	18.7%	20.7%
1994	2.0%	18.2%	20.2%
1995	2.0%	18.3%	20.3%

Return Year	Non-Indian Harvest Rates (%)	Treaty-Indian Harvest Rates (%)	Total Harvest Rates (%)
1996	2.0%	33.9%	35.9%
1997	2.0%	14.0%	16.0%
1998	2.0%	15.3%	17.3%
1999	1.0%	12.4%	13.4%
2000	1.4%	14.1%	15.5%
2001	1.1%	11.3%	12.4%
2002	1.1%	3.3%	4.4%
2003	1.8%	14.6%	16.4%
2004	1.2%	11.1%	12.3%
2005	1.3%	12.0%	13.3%
2006	1.3%	15.6%	16.9%
Average 1885-2006	1.7%	20.0%	21.7%
Average 1990-2003	1.7%	17.9%	19.6%
Average 1998-2006	1.4%	12.2%	13.5%

Table 5.6.1-3. Non-Indian harvest rates of winter-run steelhead expressed as a proportion of the total winter-run steelhead run size (TAC 2008).

Year	Non-Indian
2001	0.6%
2002	9.3%
2003	1.0%
2004	0.9%
2005	0.6%
2006	0.2%
2007	0.6%
Average 2001-2007	1.91%

Table 5.6.1-4. Treaty Indian harvest rates of winter-run steelhead expressed as a proportion of the unmarked winter-run steelhead counts at Bonneville Dam in the winter season (TAC 2008).

Year	Treaty Indian
2001	3.40%
2002	0.30%
2003	5.80%
2004	0.80%
2005	0.80%
2006	1.80%
2007	2.30%
Average 2001-2007	2.17%

Table 5.6.1-5. Non-Indian harvest rates for summer-run populations of the LCR steelhead DPS (TAC 2008).

Year	Non-Indian
1998	
1999	0.5%
2000	0.4%
2001	0.3%
2002	0.4%
2003	0.4%
2004	0.2%
2005	0.3%
2006	0.3%
2007	0.3%

Table 5.6.1-6. Expected average incidental take of natural-origin steelhead associated with prospective tribal tributary fisheries (TAC 2008).

Fishery	Upper Columbia DPS	Snake River A-run	Snake River B-run	Mid-Columbia DPS	Lower Columbia DPS	Upper Willamette DPS	Total natural-origin
Tributary Total	46	19		285	31	0	355
Willamette River	0	0	0	0	0	0	0
Wind River Summer	0	0	0	0	4	0	4
Wind River Winter					1		
Drano/LWS Spring [1]	1	1	0	1	2	0	5
Drano/LWS Fall [2]	17	17	5	19	17	0	75
White Salmon River [1]	1	1	0	1	2	0	5
Hood River Summer	0	0	0	0	5	0	5
Hood River Winter				5			
Klickitat River Summer [3]	0	0	0	180	0	0	180
Klickitat River Winter				10			
Deschutes River [4]	0	0	0	40	0	0	30
John Day River	0	0	0	5	0	0	5
Umatilla River	0	0	0	10	0	0	10
Walla Walla River	0	0	0	5	0	0	0
Yakima River	0	0	0	9	0	0	9
Icicle River	27	0	0	0	0	0	27
Total by DPS	46	19	5	285	31	0	355
Total Summer By DPS	46	19	5	270	30		370
Total Winter By DPS				15	1		16

Notes:
[1] Based on CWT recoveries in Non-treaty fisheries steelhead caught in Drano and White Salmon may be from any DPS.
[2] Based on CWT recoveries in Non-treaty fisheries steelhead caught in Drano and White Salmon may be from any DPS. Impacts to B-Index steelhead in fall season Drano fisheries are counted with mainstem impacts.
[3] Based on 1986-2006 average from Klickitat Master Plan.
[4] May include some "dip-in" fish from other populations. Estimate for the Deschutes fishery is a maximum, a

Fishery	Upper Columbia DPS	Snake River A-run	Snake River B-run	Mid-Columbia DPS	Lower Columbia DPS	Upper Willamette DPS	Total natural-origin
release mortality of 0-40 wild fish is anticipated.							

Lower Columbia River Chinook

Tables 5.6.1-7, 5.6.1-8 and 5.6.1-9 provide estimates of historic harvest impacts and their distribution across fisheries for spring, bright, and tule populations in the Lower Columbia River Chinook ESU. Exploitation rates were for Cowlitz spring Chinook population (as a surrogate for all spring Chinook populations of the LCR Chinook ESU) generally higher prior to the mid 1990s, averaging 50% through 1994 (Table 5.6.1-7). Total exploitation rates have averaged approximately 27% since 1995 (Table 5.6.1-7). The average exploitation rates for non-Indian fisheries in the Columbia River for these same periods were 27% and 12% respectively (Table 5.6.1-7).

Table 5.6.1-7. Total adult equivalent exploitation rates for the Cowlitz spring Chinook population (as an example of exploitation rates for LCR spring Chinook) (Simmons 2008).

Year	Total Exploitation Rate	Ocean					Columbia River	
		Southeast Alaska	Canada		Southern US		Non-Indian	Indian
			WCVI	Other Canada	PFMC	PgtSd	Exp Rate	Exp Rate
1980	52%	2%	5%	4%	17%	0%	24%	0%
1981	48%	3%	5%	4%	17%	0%	20%	0%
1982	55%	2%	5%	3%	15%	0%	30%	0%
1983	57%	2%	9%	5%	9%	0%	32%	0%
1984	54%	2%	11%	5%	4%	0%	31%	0%
1985	43%	1%	5%	3%	8%	0%	25%	0%
1986	52%	1%	5%	3%	12%	0%	31%	0%
1987	45%	1%	5%	3%	11%	0%	25%	0%
1988	49%	1%	5%	2%	16%	0%	26%	0%
1989	50%	1%	3%	3%	19%	0%	25%	0%
1990	57%	1%	5%	2%	23%	0%	26%	0%
1991	54%	1%	4%	3%	14%	0%	32%	0%
1992	46%	1%	5%	3%	19%	0%	19%	0%
1993	48%	1%	5%	3%	15%	0%	25%	0%
1994	45%	1%	4%	3%	3%	0%	35%	0%
1995	10%	1%	2%	1%	4%	0%	1%	0%

Year	Total Exploitation Rate	Ocean					Columbia River	
		Southeast Alaska	Canada		Southern US		Non-Indian	Indian
			WCVI	Other Canada	PFMC	PgtSd	Exp Rate	Exp Rate
1996	11%	1%	0%	0%	7%	0%	2%	0%
1997	16%	1%	1%	2%	5%	0%	7%	0%
1998	12%	1%	0%	2%	9%	0%	0%	0%
1999	38%	1%	1%	1%	15%	0%	20%	0%
2000	38%	1%	3%	1%	9%	0%	25%	0%
2001	21%	1%	2%	1%	7%	0%	10%	0%
2002	43%	1%	2%	2%	13%	0%	24%	0%
2003	34%	1%	3%	2%	13%	0%	16%	0%
2004	31%	1%	3%	2%	13%	0%	11%	0%
2005	36%	1%	4%	2%	17%	0%	11%	0%
2006	34%	1%	4%	3%	16%	0%	11%	0%

Table 5.6.1-8 provides estimates of harvest estimates to the North Fork Lewis bright Chinook population (as a surrogate for all "bright" Chinook populations of the LCR Chinook ESU). Total exploitation rates were generally higher through 1989 (averaging 56%), declining during the decade of the 1990s (averaging 36%), and increased slightly since 2000 (averaging 38%) (Table 5.6.1-8). The average exploitation rates for non-Indian fisheries in the Columbia River for these same periods were 25%, 14% and 16% respectively (Table 5.6.1-8).

Table 5.6.1-8. Total adult equivalent exploitation rate for the North Fork Lewis bright Chinook population (Simmons 2008).

Year	Total exploitation rate	Ocean					Columbia River	
		Southeast Alaska	Canada		Southern US		Non-Indian Exp Rate	Indian Exp Rate
			WCVI	Other Canada	PFMC	PgtSd		
1979	64%	9%	8%	6%	9%	2%	29%	0%
1980	68%	11%	8%	7%	8%	2%	33%	0%
1981	39%	11%	6%	6%	6%	2%	7%	0%
1982	43%	9%	6%	6%	8%	2%	12%	0%
1983	42%	10%	11%	6%	4%	3%	8%	0%
1984	58%	10%	15%	7%	2%	2%	22%	0%
1985	54%	6%	7%	6%	5%	3%	27%	0%

Year	Total exploitation rate	Ocean					Columbia River	
		Southeast Alaska	Canada		Southern US		Non-Indian Exp Rate	Indian Exp Rate
			WCVI	Other Canada	PFMC	PgtSd		
1986	64%	5%	8%	6%	6%	4%	35%	0%
1987	65%	5%	8%	5%	5%	3%	39%	0%
1988	68%	6%	10%	5%	7%	3%	38%	0%
1989	44%	7%	3%	4%	4%	1%	24%	0%
1990	38%	8%	6%	4%	7%	2%	12%	0%
1991	57%	7%	5%	5%	5%	2%	33%	0%
1992	57%	7%	9%	6%	7%	3%	25%	0%
1993	51%	7%	6%	4%	7%	3%	25%	0%
1994	38%	7%	11%	9%	1%	3%	7%	0%
1995	36%	7%	3%	2%	1%	1%	22%	0%
1996	16%	7%	0%	0%	2%	2%	3%	0%
1997	25%	11%	2%	3%	2%	2%	7%	0%
1998	23%	11%	0%	2%	1%	1%	8%	0%
1999	19%	6%	1%	2%	7%	2%	0%	0%
2000	24%	6%	5%	1%	5%	2%	5%	0%
2001	31%	7%	4%	1%	6%	3%	11%	0%
2002	41%	9%	3%	3%	7%	3%	15%	0%
2003	50%	11%	3%	4%	5%	2%	24%	0%
2004	40%	9%	2%	2%	3%	1%	22%	0%
2005	50%	8%	6%	5%	8%	3%	20%	0%
2006	32%	10%	2%	3%	3%	1%	13%	0%

Table 5.6.1-9 provides estimates of harvest impacts for tule Chinook populations based on an aggregate of coded wire tag indicator stocks. Total exploitation rates were generally higher through 1993 (averaging 69%), lower from 1994 to 1999 (averaging 34%), then increasing since 2000 (averaging 49%) (Table 5.6.1-9). From 2002 to 2006 fisheries were managed subject to a 49% exploitation rate limit. Total exploitation rates have been higher in some years but have averaged 49% from 2002 to 2006 (Table 5.6.1-9). The average exploitation rates for non-Indian fisheries in the Columbia River for these same periods were 16%, 8% and 9% respectively (Table 5.6.1-9).

Table 5.6.1-9. Total adult equivalent exploitation rates for LCR tule populations (Simmons 2008).

Year	Ocean					Columbia River	
	Total Exp. Rate	SEAK Exp. Rate	Canada Exp. Rate	PFMC Exp. Rate	Pgt Snd Exp. Rate	Non-Treaty Exp. Rate	Treaty Exp. Rate
1983	69%	4%	34%	21%	3%	7%	0%
1984	70%	4%	40%	6%	3%	16%	1%
1985	66%	4%	35%	16%	3%	9%	0%
1986	82%	3%	38%	15%	4%	22%	0%
1987	82%	2%	27%	20%	4%	28%	0%
1988	81%	3%	25%	15%	2%	36%	0%
1989	59%	4%	19%	10%	3%	23%	0%
1990	60%	4%	26%	19%	3%	9%	0%
1991	63%	3%	28%	15%	4%	12%	0%
1992	65%	3%	31%	21%	4%	8%	0%
1993	61%	3%	27%	18%	3%	9%	0%
1994	33%	4%	26%	2%	1%	0%	0%
1995	36%	4%	21%	6%	2%	3%	1%
1996	26%	3%	4%	7%	1%	9%	0%
1997	35%	5%	12%	7%	2%	10%	0%
1998	33%	4%	13%	6%	0%	9%	0%
1999	42%	3%	10%	13%	0%	15%	0%
2000	48%	4%	23%	9%	0%	13%	0%
2001	51%	2%	29%	12%	0%	7%	0%
2002	51%	3%	24%	14%	0%	9%	0%
2003	47%	4%	21%	10%	0%	12%	0%
2004	45%	4%	25%	9%	0%	7%	0%
2005	51%	4%	28%	11%	0%	7%	0%
2006	51%	4%	28%	12%	0%	7%	0%

Lower Columbia River Coho

Table 5.6.1-9 includes the available information on exploitation rates of Lower Columbia River coho in ocean and freshwater fisheries. Previously, Oregon Coast Natural coho were used as a surrogate for estimating ocean fisheries impacts to Lower Columbia River coho. In 2006, largely as a consequence of increased attention resulting from its listing, the methods for assessing

harvest in ocean fisheries were changed so that these were more specific to natural-origin Lower Columbia River coho.

Until 1993 the exploitation rates in salmon fisheries on Lower Columbia River coho have been very high, contributing to their decline (Table 5.6.1-10). The combined ocean and in-river exploitation rates for Lower Columbia River coho averaged 91% through 1983, averaged 68% from 1984-1993, and decreased to an average of 17% from 1994-2007.

Table 5.6.1-10. Estimated Ocean (all marine area fisheries) and Inriver Exploitation Rates on Lower Columbia River Natural Coho, 1970-2006.

Year	Ocean Exploitation Rate	Inriver Exploitation Rate	Total Exploitation Rate
1970	65.2%	28.4%	93.6%
1971	82.5%	9.9%	92.4%
1972	84.3%	8.6%	92.9%
1973	81.9%	11.2%	93.1%
1974	83.5%	9.2%	92.7%
1975	81.4%	10.1%	91.5%
1976	89.9%	5.5%	95.4%
1977	88.8%	5.3%	94.1%
1978	82.5%	7.9%	90.4%
1979	79.4%	9.5%	88.9%
1980	73.1%	24.5%	97.6%
1981	81.1%	6.8%	87.9%
1982	61.6%	20.8%	82.4%
1983	78.7%	3.9%	82.6%
1984	31.9%	27.0%	58.9%
1985	43.2%	22.3%	65.5%
1986	33.5%	39.7%	73.2%
1987	59.5%	19.4%	78.9%
1988	56.4%	20.3%	76.7%
1989	55.3%	22.7%	78.0%
1990	68.9%	7.5%	76.4%
1991	45.4%	19.1%	64.5%
1992	50.9%	8.7%	59.6%

Year	Ocean Exploitation Rate	Inriver Exploitation Rate	Total Exploitation Rate
1993	42.3%	10.5%	52.8%
1994	7.0%	3.5%	10.5%
1995	12.0%	0.3%	12.3%
1996	8.0%	4.4%	12.4%
1997	12.0%	1.6%	13.6%
1998	8.0%	0.2%	8.2%
1999	9.0%	18.5%	27.5%
2000	7.0%	17.5%	24.5%
2001	7.0%	6.4%	13.4%
2002	12.0%	2.1%	14.1%
2003	14.0%	8.9%	22.9%
2004	15.0%	9.3%	24.3%
2005	11.0%	6.5%	17.5%
2006	6.8%	6.5%	13.3%
2007	11.9%	6.7%	18.6%

Columbia River Chum

Columbia River (CR) chum salmon are not caught in tribal fisheries above Bonneville Dam. CR chum are caught occasionally in non-Indian fall season fisheries below Bonneville. There are no fisheries in the Columbia River that target hatchery or natural-origin chum. The later fall return timing of chum is such that they are vulnerable to relatively little potential harvest in fisheries that target primarily Chinook and coho. CR chum rarely take the kinds of sport gear that is used to target other species.

Harvest rates are difficult to estimate since NOAA Fisheries does not have good estimates of total run size. However, the incidental catch of chum amounts to a few tens of fish per year. The harvest rate in proposed state fisheries in the lower river is estimated to be 1.6% per year and is almost certainly less than 5%.

5.7 Large-scale Environmental Variation

Salmonid population abundance is substantially affected by inter-annual changes in the freshwater and marine environments, particularly by conditions early in their life histories. Generally, the inland environment (including rivers, tributaries, and the associated uplands) is most favorable to salmon when there is a cold, wet winter, leading to substantial snowpack. This normally results in higher

levels of runoff during spring and early summer, when many of the juvenile salmon are migrating to the ocean. The higher levels of runoff are associated with lower water temperatures, greater turbidity, and higher velocity in the river, all of which are beneficial to juvenile salmon. However, severe flooding may constrain populations. The low return of Lewis River bright fall Chinook salmon in 1999, for example, has been attributed to flood events during 1995 and 1996.

Within the ocean environment, near-shore upwelling, which brings nutrients up from depth into the photic zone, is a key determinant of ocean productivity as it affects the availability of food for juvenile salmon at the critical point when they first enter the ocean. The upwelling results from ocean currents that appear to be driven by spring and early summer winds which, in turn, result from oscillations in the jet stream that follow certain cycles. Within a year, there are cycles of 20-40 days that affect upwelling, and among years there are longer-lasting conditions, such as El Nino/La Nina cycles of 2-3 years and the Pacific Decadal Oscillation (PDO) which may have cycles of 30-40 years or more that influence upwelling.

Scheuerell and Williams (2005) showed that the coastal upwelling index is a strong determinant of year-class strength and subsequent smolt-to-adult return ratios. The Northwest Fisheries Science Center currently monitors a number of ocean conditions and provides a forecast on their website for salmon returns to the Columbia River based on these and other observations.

In some instances, the inland conditions and ocean conditions appear to be correlated; that is, the same weather patterns producing a cold, wet winter with good snowpack and high spring runoff are also likely to bring the later winds that yield good upwelling and favorable feeding conditions in the ocean. However, it is also possible for inland and ocean conditions to diverge, and years have been observed where there have been favorable river conditions but poor ocean conditions, and vice versa.

While strong salmon runs are a product of both good in-river conditions and good ocean conditions, favorable ocean conditions appear to be especially important. For example, 2001 was the second-lowest flow year recorded on the Columbia River, but the near-shore temperatures were generally cool, observed ocean productivity was good, and resulting adult returns from the 2001 juvenile outmigration class were in the average or better range for most of the runs.

This section discusses inter-annual climatic variations (e.g. El Niño and La Niña), longer term cycles in ocean conditions pertinent to salmon survival (e.g. Pacific Decadal Oscillation), and ongoing global climate change and its implications for both oceanic and inland habitats and fish survivals. Because these phenomena have the potential to affect salmonids survival over their entire range and multiple life stages, they are an area of substantial scientific investigation.

5.7.1 The Southern Oscillation Index, El Niño & La Niña

In an effort to predict the likely strength of the annual monsoons over India, which greatly affected human life through floods and famines, in the 1920s Sir Gilbert Walker conducted extensive statistical analyses of long-term weather observations for many locations around the globe. Among his many

findings was that deviations from long-term average seasonal differences in atmospheric pressure between the western Pacific and the eastern Pacific (typically Darwin, Australia to Tahiti), correlated strongly with subsequent climatic conditions in other parts of the globe. Walker termed these deviations, the "Southern Oscillation Index" (SOI). In general, substantial negative SOIs tend to correlate well with above average tropical sea-surface temperatures and positive SOIs tend to correlate with below average sea-surface temperatures, particularly in the eastern Pacific. Both have been found to have "teleconnections" to climatic and oceanic conditions in regions far distant from the south Pacific, including the Pacific Northwest. Although in modern usage a broader array of oceanic and atmospheric characteristics have been found to provide greater predictive power, these teleconnections between conditions in the south Pacific and subsequent climatic conditions elsewhere have come into routine use, including pre-season predictions of runoff in some portions of the Columbia basin.

Atmospheric conditions correlated with unseasonably warm south Pacific sea-surface temperatures are termed El Niños. El Niños typically last 6 to 18 months. Among the consequences are warmer near-surface ocean water temperatures along the U.S. west coast and generally warmer, drier weather in the inland Pacific Northwest, particularly during the winter. When winds do not blow south, the forces that create upwelling off the U.S. coast are reduced, as are nutrient inputs to the euphotic zone (well lit, near surface zone), reducing near-shore ocean productivity. This reduction in ocean productivity has been shown to reduce juvenile salmon growth and survival (Scheurell and Williams 2005). Warmer surface waters can also change the spatial distribution of marine fishes with potential predator-prey effects on salmon.

The warmer, drier weather in the Pacific Northwest often associated with El Niño can also cause or increase the severity of regional droughts. Droughts reduce streamflows through the Columbia and Snake River migratory corridor, increase water temperatures, and reduce the extent of suitable habitat in some drainages. Each of these physical effects has been shown to reduce salmon survival. Thus, El Niño events are associated with poor returns of salmon and steelhead.

Unseasonably cool south Pacific sea surface temperatures, typically associated with a positive SOI, tend to have quite different effects in the north Pacific and the Columbia basin. Termed La Niña, positive SOIs tend to be associated with cooler north Pacific surface water temperatures, and cooler, wetter fall and winter conditions inland. Conditions associated with La Niña tend to increase snowpack and runoff in the Columbia basin, improving outmigration conditions, and ocean conditions tend to be more conducive for coastal upwelling early in the spring, providing better feeding conditions for young salmon.

Currently, NOAA Physical Sciences Division calculates a "Multivariate El Niño Southern Oscillation Index" or MEI, which effectively inverts the SOI relationships: a positive MEI indicates El Niño conditions and a negative MEI a La Niña. Once established, El Niño and La Niña conditions tend to persist for a few months to two years although prevalent El Niño conditions have dominated the Pacific since 1977 and persisted from 1990 through 1995 (Figure 5.7.1-1 below). It is likely that the dominance of El Niño conditions since the late 1970s has contributed to the depressed status of many stocks of anadromous fish in the PNW.

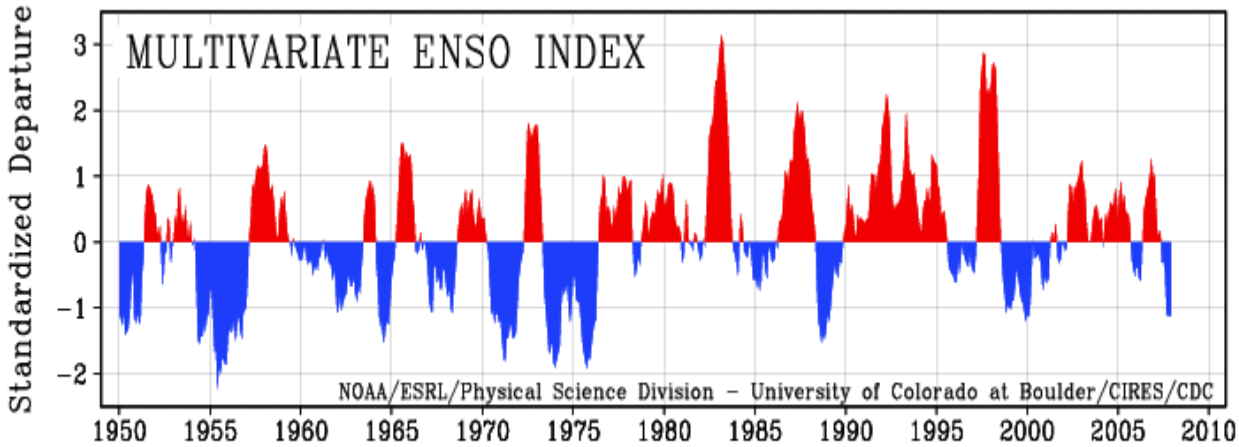


Figure 5.7.1-1. Time-series of MEI conditions from 1950 through November 2007. Source: NOAA 2008

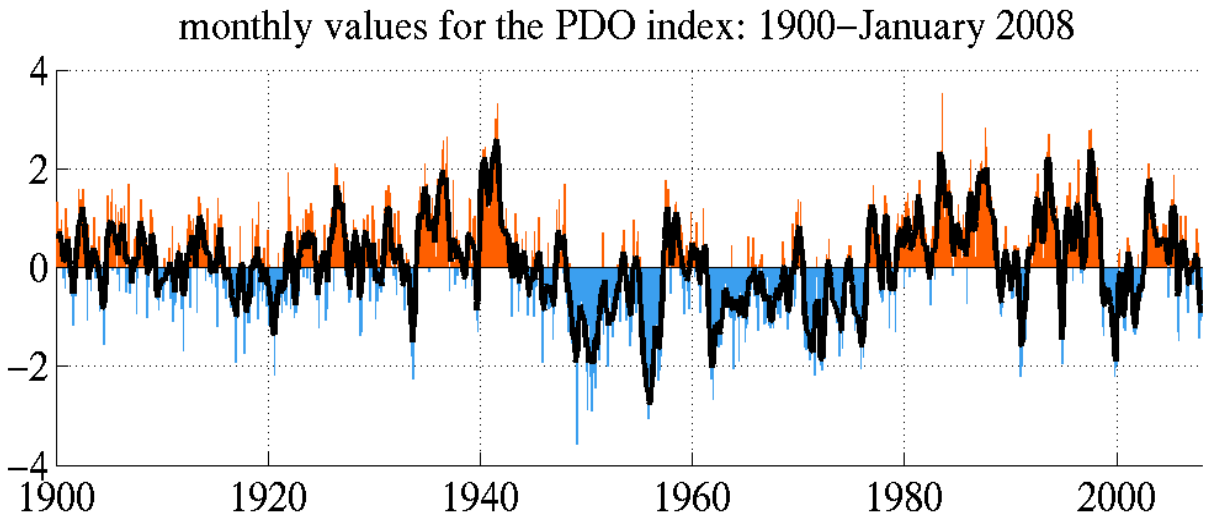
5.7.2 PDO

First defined by Steven Hare in 1996, the Pacific Decadal Oscillation (PDO) index is the leading principal component (a statistical term) of North Pacific sea surface temperature variability (poleward of 20° N to the 1900-1993 period (Mantua et al. 1997).

Major changes in northeast Pacific marine ecosystems have been correlated with phase changes in the PDO; warm eras have seen enhanced coastal ocean biological productivity in Alaska and inhibited productivity off the west coast of the contiguous United States, while cool PDO eras have seen the opposite north-south pattern of marine ecosystem productivity (e.g., Hare et al. 1999). Thus, smolt-to-adult return ratios for Columbia basin salmon tend to be high when the PDO is in a cool phase and low when the PDO is in a warm phase.

Two main characteristics distinguish the PDO from El Niño: first, 20th century PDO "events" persisted for 20-to-30 years, while typical El Niño events persisted for 6 to 18 months; second, the climatic fingerprints of the PDO are most visible in the North Pacific/North American sector, while secondary signatures exist in the tropics – the opposite is true for El Niño. Several independent studies find evidence for just two full PDO cycles in the past century: "cool" PDO regimes prevailed from 1890-1924 and again from 1947-1976, while "warm" PDO regimes dominated from 1925-1946 and from 1977 through (at least) the mid-1990s (Figure 5.7.2-1). Shoshiro Minobe (1997) has shown that 20th century PDO fluctuations were most energetic in two general periods, one from 15 to 25 years, and the other from 50 to 70 years.

Figure 5.7.2-1. Monthly Values for the PDO Index: 1900-January 2008.



Mantua and Hare (2002) state, "The physical mechanisms behind the PDO are not currently known." Likewise, the potential for predicting this climate oscillation is not known. Some climate simulation models produce PDO-like oscillations, although often for different reasons. Discovery of mechanisms giving rise to the PDO will determine whether skillful decades-long PDO climate predictions are possible. For example, if a PDO arises from air-sea interactions that require 10 year ocean adjustment times, then aspects of the phenomenon could, theoretically, be predictable at lead times of up to 10 years. Even in the absence of a theoretical understanding, PDO climate information improves season-to-season and year-to-year climate forecasts for North America because of its strong tendency for multi-season and multi-year persistence. From the perspective of societal impact, recognition of PDO is important because it shows that "normal" climate conditions can vary over time scales (decades) used to describe the length of a human's lifetime.

Recent evidence suggests that marine survival of salmonids fluctuates in response to the PDO's 20 to 30 year cycles of climatic conditions and ocean productivity (Cramer et al. 1999). Ocean conditions that affect the productivity of Northwest salmonid populations appear to have been in a low phase of the cycle for some time and to have been an important contributor to the decline of many stocks. The survival and recovery of these species will depend on their ability to persist through periods of unfavorable hydrologic and oceanographic conditions.

5.7.3 Global Climate Change

Ongoing global climate change has implications for the current and likely future status of anadromous fish in the Pacific Northwest. Recent studies, particularly by the Independent Scientific Advisory Board (ISAB),[10] describe the potential impacts of climate change in the

[10] ISAB (Independent Scientific Advisory Board). 2007c. Climate change impacts on Columbia River basin fish and wildlife. ISAB, Report 2007-2, Portland, Oregon.

Columbia River Basin. These effects, according to the ISAB, may alter precipitation and temperature levels in the basin and, in particular, impact the hydrosystem and habitat life-stages of Columbia Basin salmon and steelhead. In a basin reliant on cooler winter temperatures to store a spring/summer water supply in the snowpack, alterations to the precipitation and temperature levels may have the following physical impacts:

- Warmer air temperatures will result in a shift to more winter/spring rain and runoff, rather than snow that is stored until the spring/summer melt season.

- With a shift to more rain and less snow, the snowpacks will diminish in those areas that typically accumulate and store water until the spring freshet.

- With a smaller snowpack, these watersheds will see their runoff diminished and exhausted earlier in the season, resulting in lower streamflows in the June through September period.

- River flows in general and peak river flows are likely to increase during the winter due to more precipitation falling as rain rather than snow.

- Water temperatures will continue to rise, especially during the summer months when lower streamflow and warmer air temperatures will contribute to the warming regional waters.

Such responses to warming air temperatures and precipitation alterations will not be spatially homogeneous across the entire Columbia River Basin. Following anticipated air temperature increases, the distribution and duration of snowpack in those portions of the basin at elevations high enough to maintain temperatures well below freezing for most of the winter and early spring would be less affected. Low-lying areas that historically have received scant precipitation contribute little to total streamflow. This condition would also be relatively unaffected. The most noticeable changes will occur in the "transient snow" watersheds where the threshold between freezing and non-freezing temperatures is much more sensitive to warming (e.g. the Willamette Basin). Not only would changes in the distribution of precipitation between rain and snow affect the shape of the annual hydrograph and water temperature regimes, but more frequent and more severe rain on snow events could affect flood frequency with implications for scouring out incubating and young-of-the-year-fish (ISAB 2007c).

According to the ISAB report, it is anticipated that large-scale ecological changes will also occur over a 35 year time period. For example, the scale of insect infestations of forested lands and the frequency and intensity of forest fires are likely to become more prevalent during this time period as well. As reported by the ISAB (2007c), "fire frequency and intensity have already increased in the past 50 years, and especially the past 15 years, in the shrub steppe and forested regions of the West. Drought and hot, dry weather already have led to an increase in outbreaks of insects in the Columbia Basin, especially mountain pine beetle, and insect outbreaks are likely to

become more common and widespread."[11] Such landscape changes have implications for salmon habitat and survival.

The ISAB (2007c) identified the following list of likely effects of projected climate changes on Columbia basin salmon:

- Anticipated water temperature increases, and the subsequent depletion of cold water habitat, could reduce the areal extent of suitable inland salmon habitats. O'Neal (2002, as cited in ISAB 2007c) assessed the potential impacts of climate warming on Pacific Northwest salmon habitat. Locations that were likely to experience an average weekly maximum temperature that exceeded the upper thermal tolerance limit for a species were considered to be lost habitat. Projected salmon habitat loss would be most severe in Oregon and Idaho with potential losses exceeding 40% of current by 2090. Loss of salmon habitat in Washington would be a less severe case of about 22% loss by 2090. O'Neal's approach assumed a high rate of greenhouse gas emissions and used a climate model that projected a 5 degree C in global temperatures by 2090, a value that is higher than the scenarios considered most likely (ISAB 2007c). This conservative estimate of potential habitat loss does not consider the associated impact of changing hydrology.

- Variations in intensity of precipitation may alter the seasonal hydrograph. With reduced snowpack and greater rainfall, the timing of stream flow will likely shift, depreciably reducing spring and summer stream flow, and increasing peak river flows (ISAB 2007c). This reduction in stream flow may impact the quality and quantity of tributary rearing habitat, greatly affecting spring and summer salmon and steelhead runs. In addition, the Pacific Northwest's low late-summer and early-fall stream flows are likely to be further reduced. Reduced late-summer and early-fall flows, in conjunction with rising water temperatures, are likely to adversely impact juvenile fall Chinook and chum salmon by depleting essential summer shallow mainstem rearing habitat.

- Considering both the water temperature and hydrologic effects of climate change, Crozier et al. (2008) showed that the abundance of four studied Snake River spring/summer Chinook populations would be substantially decreased (20-50% decline from simulated average abundance based on historical 1915-2002 climate) and extinction risks substantially increased by long-term exposure to climate conditions likely to exist in 2040. Hydrologic and physical changes in the Pacific Northwest environment have implications for the habitat, populations, and spatial distributions of Pacific salmonids (Zabel et al. 2006).

[11] Removal of trees from riparian areas by fire or insects will lead, at least temporarily, to an increase in solar radiation reaching the water and exacerbate the water temperature. The potential for climate-induced fire and insect outbreaks has the potential to disproportionately impact habitats of key importance to native fish and wildlife populations (ISAB 2007c).

- Eggs of fall and winter spawning fish, including Chinook, coho, chum, and sockeye salmon, may suffer higher levels of mortality when exposed to increased flood flows. Higher winter water temperatures also could accelerate embryo development and cause premature emergence of fry.

- Increases in seasonal mainstem Snake and Columbia River water temperature would accelerate the rate of egg development of fall Chinook that spawn in the mainstem of the Snake and Columbia rivers, and lead to earlier emergence at a smaller average size than historically. Also, dam and reservoir passage survival is affected by water temperatures with the lowest rates of survival typically occurring when water temperatures are warmest. Potential impacts of increased water temperatures on adult salmon include delay in dam passage, failure to enter fish ladders, increased fallback, and loss of energy reserves due to increased metabolic demand. Increases in mortality also may be caused by fish pathogens and parasites as these organisms often do not become injurious until their host becomes thermally stressed.

- Earlier snowmelt and earlier, higher spring flows, warmer temperatures, and a greater proportion of precipitation falling as rain rather than snow, may cause spring Chinook and steelhead yearlings to smolt and emigrate to the estuary and ocean earlier in the spring. The early emigration coupled with a projected delay in the onset of coastal upwelling could cause these fish to enter the ocean before foraging conditions are optimal. The first few weeks in the ocean are thought to be critical to the survival of salmon off Oregon and Washington, so a growing mismatch between smolt migrations and coastal upwelling would likely have significant negative impacts on early ocean survival rates.

- Within the Columbia estuary, increased sea levels in conjunction with higher winter river flows could cause the degradation of estuary habitats created by increasing wave damage during storms. Numerous warm-adapted fish species, including several non-indigenous species, normally found in freshwater have been reported from the estuary and might expand their populations with the warmer water and seasonal expansion of freshwater habitats. Climate change also may affect the trophic dynamics of the estuary due to upstream extension of the salt wedge in spring-early summer caused by reduced river flows. The landward head of the salt wedge is characterized by a turbulent region known as the estuary turbidity maximum, an area with high concentrations of fish food organisms such as harpacticoid copepods. Changes in the upstream extension of the salt wedge will influence the location of this zone, but it is difficult to forecast the effect this change will have on juvenile salmon.

- Scientific evidence strongly suggests that global climate change is already altering marine ecosystems from the tropics to polar seas. Physical changes associated with warming include increases in ocean temperature, increased stratification of the water column, and changes in the intensity and timing of coastal upwelling. These changes will alter primary and secondary

productivity, the structure of marine communities, and, in turn, the growth, productivity, survival, and migrations of salmonids.

- Changing ocean temperatures may alter salmon behavior, distribution, and migrations, increasing the distance to migrations from their home streams to ocean feeding areas. Energetic demands are increased at warmer temperatures, requiring increased consumption of prey to maintain a given growth rate. This could lead to intensified competition among species, as well as an increased reduction in growth rates, further exacerbating the prey/predator relationship. In addition, food availability in the ocean may be altered by climate change. Increasing concentrations of CO_2 in the oceans lowers pH, which reduces the availability of carbonate for shell-forming marine animals. Pteropods are expected to be negatively affected, and they can comprise up to 40% or more of the diet of some salmon species although another suitable prey item might replace them in the ecosystem. If salmon migrate farther to the north and/or food is less available, longer times may be required to reach maturity, delaying the usual times of adult migrations into coastal water and rivers.

- Global climate change in the Pacific Northwest may be similar to those experienced during past periods of strong El Niños and warm phases of the PDO.

The effects of climate change are considered both quantitatively and qualitatively in Chapter 7 of this document. In addition, the Biological Opinion explicitly considers actions which are consistent with the ISAB's mitigation recommendations (see ISAB recommendations in Chapter 8.1 for further detail). However, the time frame, and the scope of climate change is not clear. Many climate change predictions describe changes up to 100 years. For the ten year term of this Opinion, NOAA Fisheries employs conservative assumptions and sets the stage for mitigation actions should they become necessary.

This Page Intentionally Left Blank

Chapter 6

Cumulative Effects

This Page Intentionally Left Blank

Chapter 6
Cumulative Effects

As part of the Biological Opinion Collaboration process, the states of Oregon, Washington, and Idaho provided information on various ongoing and future or expected projects that NOAA Fisheries determined are reasonably certain to occur and will affect recovery efforts in the Interior Columbia Basin (see lists of projects in Chapter 17 in Corps et al. 2007a). All of these actions are either completed or ongoing and are thus part of the environmental baseline, or are reasonably certain to occur.[1] Examples of these projects specific to each species are given in the section on Cumulative Effects in each species chapter. They address protection and/or restoration of existing or degraded fish habitat, instream flows, water quality, fish passage and access, and watershed or floodplain conditions that affect stream habitat. Significant actions and programs include growth management programs (planning and regulation), a variety of stream and riparian habitat projects, watershed planning and implementation, acquisition of water rights and sensitive areas, instream flow rules, stormwater and discharge regulation, Total Maximum Daily Load (TMDL) implementation, and hydraulic project permitting. Responsible entities include cities, counties, and various state agencies. Many of these actions will have positive effects on the viability (abundance, productivity, spatial structure, and/or diversity) of listed salmon and steelhead populations and the functioning of PCEs in designated critical habitat. Therefore these activities are likely to have cumulative effects that will significantly improve conditions for the species considered in this consultation. These effects can only be considered qualitatively, however.

Some types of human activities that contribute to cumulative effects are expected to have adverse impacts on populations and PCEs, many of which are activities that have occurred in the recent past and have been an effect of the environmental baseline. These can be considered reasonably certain to occur in the future because they occurred frequently in the recent past, especially if authorizations or permits have not yet expired. Within the freshwater portion of the action area for the Prospective Actions, non-Federal actions are likely to include human population growth, water withdrawals (i.e., those pursuant to senior state water rights) and land use practices. In coastal waters within the action area, state, tribal, and local government actions are likely to be in the form of legislation, administrative rules, or policy initiatives, and fishing permits. Private activities are likely to be continuing commercial and sport fisheries and resource extraction, all of which can contaminate local or larger areas of the coastal ocean with hydrocarbon-based materials. Although these factors are ongoing to some extent and likely to continue in the future, past occurrence is not a guarantee of a continuing level of activity. That will depend on whether there are economic, administrative, and legal impediments (or in the case of contaminants, safeguards). Therefore, although NOAA Fisheries finds it likely that the cumulative effects of

[1] The State of Oregon identified potential constraints (e.g., funding, staffing, landowner cooperation) for many of its projects submitted as reasonably certain to occur.

these activities will have adverse effects commensurate to those of similar past activities, it is not possible to quantify these effects.

Chapter 7

Analytical Methods for Salmonids

7.1 **Life-cycle analyses to evaluate whether populations are likely to have a sufficiently low short-term extinction risk and are likely to trend toward recovery**

7.2 **Life-stage and action-specific analyses to support the life-cycle analysis and to estimate incidental take**

7.3 **Methods for considering population level analysis at ESU/DPS level**

7.4 **Critical habitat analysis methods**

This Page Intentionally Left Blank

Chapter 7
Analytical Methods for Salmonids

These are the methods NOAA Fisheries used to detail how the Prospective Actions identified in Chapter 2 are likely to affect the thirteen listed species of salmon and steelhead of the Columbia River and the critical habitat designated for twelve of those species (please see Chapter 4 for further detail).

Ultimately the purpose of this analysis is to apply the jeopardy and critical habitat degradation standards of ESA § 7(a)(2) as discussed in § 1.7 of the FCRPS Biological Opinion, § 1.5 of the USBR Upper Snake Biological Opinion, and § 1.1 of the 2008-2017 *United States v. Oregon* Management Agreement Biological Opinion. The analysis in this SCA serves the application of those standards in the associated biological opinions. The results of the analysis described in this chapter are presented in Chapter 8 for each listed species of salmon or steelhead.

These species of anadromous fish have similar biological requirements and a hierarchical structure of populations and major population groups (MPGs) that make up the ESA-listed unit (either ESUs or, for steelhead, DPS') as detailed in Chapter 4 (See Figure 4.3-1 for example, and in Chapter 8 for each species). There are also important differences among these listed species that requires that NOAA Fisheries' analytical methods be tailored for the application of the ESA standards. The status of each species varies, the amount of relevant quantitative information available for each varies, and the extent to which the Prospective Actions are likely to affect them also varies. For this reason, NOAA Fisheries divides the thirteen species and their critical habitat into the following groups:

Interior Columbia River species with sufficient data to evaluate relevant quantitative metrics:

- Snake River Spring/Summer Chinook
- Snake River Fall Chinook
- Snake River Steelhead
- Upper Columbia River spring Chinook
- Upper Columbia River steelhead
- Middle Columbia River steelhead

Interior Columbia River species without data sufficient to evaluate relevant quantitative metrics:

- Snake River Sockeye

Lower Columbia River species which are less affected by most Prospective Actions than interior populations:

- Lower Columbia River Chinook

- Lower Columbia River steelhead
- Lower Columbia River Coho
- Lower Columbia River Chum
- Upper Willamette River Chinook
- Upper Willamette River steelhead

NOAA Fisheries performed a quantitative analysis of the status of the six Interior Columbia River ESUs or DPS' for which there is sufficient empirical data available to support such an analysis. Generally, that analysis evaluated the most relevant empirical data which serves as its base or starting point. Since productivity, trend and extinction risk estimates require multiple years of recent observations, portions of these "base period" observations are influenced by management actions that have been superseded by current management actions and therefore are no longer relevant. The next step in the analysis, therefore, was to adjust the base information to account for changes made to activities affecting the listed fish, such as operations at the dams, since the base period empirical data was gathered. In this way, NOAA Fisheries reaches its judgment about the current status of the listed species derived from what it calls the "base-to-current adjustment." The final phase of the analysis was to further adjust the current status to predict the status of the species that is likely to result from the effects of the Prospective Actions, such as further modifications at the dams, on the current status of these species.

In addition to this quantitative analysis for the six Interior Columbia River listed species, NOAA Fisheries conducted a qualitative analysis further evaluating their status and considering information that cannot be numerically measured or quantified. NOAA Fisheries also conducted a qualitative analysis for the remaining seven listed species.

In particular, this chapter describes:

- Methods for evaluating life-cycle effects at the population level that are applicable to the jeopardy standard (Section 7.1);
- Methods to evaluate action-specific and life-stage-specific effects that contribute to the life-cycle jeopardy analysis (Section 7.2);
- The method for evaluating effects at the MPG and species level (Section 7.3);
- Methods for evaluating effects on critical habitat for the adverse modification analysis (Section 7.4).

Methods for evaluating life-cycle effects at the population level (7.1)

Section 7.1.1 describes quantitative methods applicable to populations of six interior species and Section 7.1.2 describes qualitative methods for the same six species, plus the remaining seven species. The purpose of both the quantitative and the qualitative analyses is to evaluate whether:

- Short-term extinction risk is sufficiently low to meet the *survival prong* of the jeopardy standard; and whether
- The populations within a species are expected to be on a trend toward recovery, the *potential for recovery* prong of the jeopardy standard.

Within the Section 7.1.1 quantitative analysis, NOAA Fisheries evaluates certain metrics indicative of the survival prong of the jeopardy standard (24-year extinction risk) and indicative of the recovery potential prong (average returns-per-spawner, median population growth rate, and abundance trend). While each metric primarily informs one of the two prongs of the jeopardy standard, each metric contributes to both prongs. For example, a population with high productivity (e.g., average returns per spawner) is less likely to go extinct than one with low productivity.

As described above, this is a three-step process: For each of these metrics, NOAA Fisheries first determines what the values have been over the last two decades (referred to as "base" metrics). Then, because some management actions have changed over this time period, the metrics are adjusted to reflect "current" management practices. Finally, the metrics are further adjusted to reflect new management actions that are included in the Prospective Actions and to represent a range of expectations regarding future climate and other environmental factors.

It is not possible to evaluate the metrics quantitatively for every population of every species, so Section 7.1.2 includes additional qualitative approaches to determine if populations of a species are on a trend to recovery and if they are likely to have a low risk of extinction in the near term. Some qualitative factors include whether safety-net hatcheries protect important populations, if limiting factors are being addressed and threats reduced through management actions, and consideration of recent abundance levels and changes in abundance over time.

Methods to evaluate action-specific and life-stage-specific effects

Section 7.2 describes detailed action-specific methods that are necessary to support the analysis in Section 7.1. Because the analysis in Section 7.1 requires information about changes from the base-to-current management practices and additional changes associated with Prospective Actions, effects of those changes must be calculated. Section 7.2 describes the methods of evaluating changes in survival associated with hydro actions, tributary and estuary habitat actions, harvest, hatchery actions, RM&E actions, and changes in predation resulting from management actions.

Methods for evaluating effects at the MPG and species level

All of the methods described in Sections 7.1 and 7.2 apply to individual populations of listed salmon and steelhead. Section 7.3 describes methods for evaluating these population-level effects at the MPG and ESU level. The approach is qualitative, based largely on information regarding the importance of particular populations to each MPG and other information pertinent to MPG and ESU evaluations from recovery plans and TRT documents.

Methods for evaluating effects on critical habitat for the adverse modification analysis
Sections 7.1 through 7.3 apply to the jeopardy analysis, but an analysis of the effect of Prospective Actions on critical habitat is also necessary. Section 7.4 describes the qualitative methods that are applied to this evaluation. These methods describe the effects of the Prospective Actions on the functioning of primary constituent elements and the resulting effects on the conservation value of critical habitat.

7.1 Life-cycle analyses to evaluate whether populations are likely to have a sufficiently low short-term extinction risk and are likely to trend toward recovery

This analysis must first determine the short-term extinction risk and the expected trend of populations for each listed species. The following section describes the calculations and metrics used to inform the aggregate analysis for the populations of six interior Columbia species.

7.1.1 Population-level quantitative analytical methods for six interior Columbia Basin species

Data Sets

Information is sufficient to conduct quantitative analyses for populations of six interior Columbia River species. These species include:

- SR spring/summer Chinook,
- SR steelhead,
- SR fall Chinook,
- UCR spring Chinook,
- UCR steelhead, and
- MCR steelhead.

All estimates in the Supplemental Comprehensive Analysis (SCA) are derived from data sets produced by the Interior Columbia River Technical Recovery Team (ICTRT). The data sets have been updated since the 2007 Draft SCA, and match data used by the ICTRT in recent analyses submitted to the ISAB (ICTRT 2007c, ICTRT and Zabel 2007). For further information regarding the specific data sources, please see the tables in Chapter 8 and the Aggregate Analysis Appendix of the SCA.

Survival Gaps

The values of metrics that indicate a trend toward recovery are described in Section 7.1.1.2. The "survival gap," as defined by NOAA Fisheries, refers to the change in density-independent survival[1] that would need to occur in order to change the current value to the desired value of a given metric. Methods for estimating the survival gap differ, depending on whether the metric represents an annual (e.g., median population growth rate, or "lambda") or brood-cycle process (e.g., returns-per-spawner, or R/S). Annual estimates of the survival gap must be raised to the power of the mean generation time. The fundamental principle, common to all metrics, is that the quantitative component of the jeopardy analysis seeks to determine if the survival changes associated with the Prospective Actions, after taking into consideration the environmental baseline and cumulative effects, meet or exceed the remaining survival gap.

It is important to understand that the "survival gap" terminology applies to the needed survival change associated with achieving any goal, based on any survival-based metric. Here, it applies to the goal of being on a trend toward recovery and having a low short-term risk of extinction. The ICTRT (2007c, 2006) also uses the "survival gap" terminology. The ICTRT defines survival gaps associated with the long-term viability of populations. These ICTRT viability survival gaps are based on somewhat different target metrics, and represent the gap between the condition of populations over approximately the last two decades and the condition that the ICTRT considers viable. If a sufficient mixture of populations reaches this level, then the species is considered viable.

In contrast, this analysis is directed at a different question than the ICTRT's analysis of long-term recovery. This analysis focuses on the survival changes needed to ensure that populations support species (ESU or DPS) that are on a "trend toward recovery;" i.e., moving toward recovery even though full recovery of the species may not be achievable during the period of the Prospective Actions. In general, the needed survival changes for full recovery are higher than the needed survival changes associated with the "trend toward recovery."

The ICTRT (2007c) noted that some populations, particularly several of the MCR steelhead populations, currently have relatively high productivity but are below minimum abundance thresholds. For these populations, the ICTRT states that gaps are expressed as proportional increases in productivity, but could also be filled by increasing the "effective capacity" of the population. The effective capacity can be increased either by making new habitat available for spawning and rearing or by increasing the productivity (e.g., smolts per adult) of existing habitat.

NOAA Fisheries has not identified quantitative values of metrics that would indicate a sufficiently low short-term risk of extinction because the estimation of extinction risk is dependent on specific

[1] "Density-independent" refers to a change in survival that is not influenced by the number of fish in the population. Generally speaking, most factors influencing survival after the smolt stage are assumed to be density independent. During the egg-to-smolt stage, the density of adults and juveniles can influence survival as a result of competition for limited habitat or other factors. For evaluation of survival gaps, estimates of survival changes resulting from actions affecting early life stages of salmon and steelhead are made under the assumption of low density.

model functions and assumptions (such as quasi-extinction abundance threshold, QET, and treatment of listed hatchery fish) about which there is considerable uncertainty. The ability of a particular set of actions to achieve a goal of no more than any assumed percentage risk of extinction may vary considerably among models and assumptions. For convenience, the SCA includes estimates of survival gaps necessary to reduce 24-year extinction risk to no more than 5%, given the range of assumptions considered in the analysis. Ultimately, the acceptable level of short-term extinction risk is a qualitative policy determination made by NOAA Fisheries consistent with the ESA and its implementing regulations.

General Approach: Base, Current, and Future (with Prospective Actions) Analyses

Figures 7.1-1 and 7.1-2 demonstrate the approach for evaluating each metric according to the survival and potential for recovery prongs of the jeopardy analysis. Figure 7.1-1 demonstrates the approach for directly assessing the effect of the Prospective Actions on metrics such as average returns-per-spawner (R/S). In doing so, the Marsh Creek population of SR Spring/Summer Chinook is used as an example. Figure 7.1-2 demonstrates an indirect method for assessing the effect of the Prospective Actions on closing the "survival gap" between the base status of a metric, such as extinction risk, and the desired status. Again, the Marsh Creek population of SR Spring/Summer Chinook is used as an example. The sections following Figures 7.1-1 and 7.1-2 describe these general approaches.

Figure 7.1-1. Schematic showing the method of applying survival changes that have occurred during the base period to a "base-to-current" productivity adjustment factor and method of applying expected prospective survival changes to a "current-to-future" productivity adjustment factor. Detailed methodology is described in the accompanying text. This example uses average returns-per spawner (R/S) as the productivity estimate, applied to the Marsh Creek population of SR Spring/ Summer Chinook salmon.

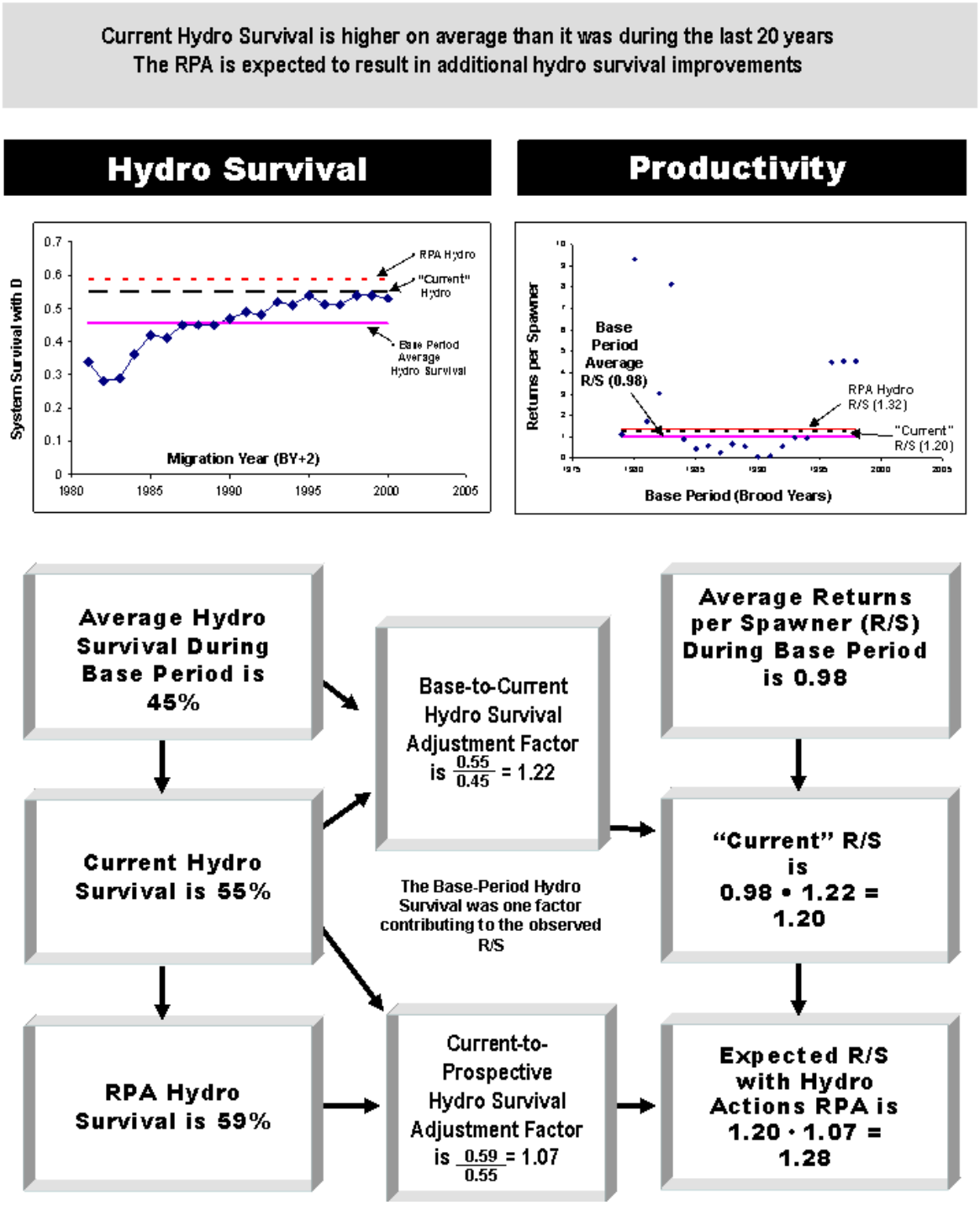
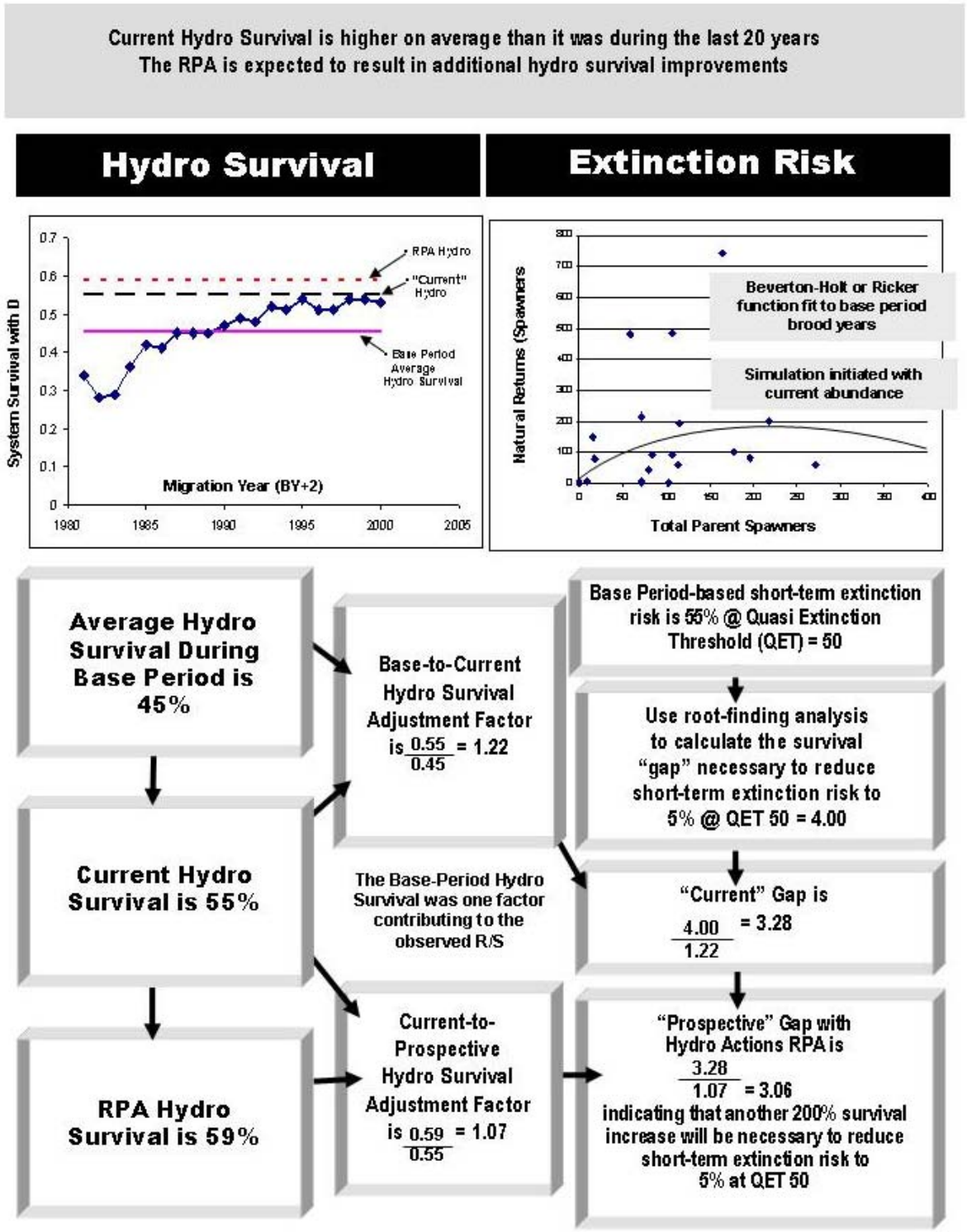


Figure 7.1-2. Schematic showing the method of applying survival changes that have occurred during the base period to a "base-to-current" adjustment factor for an extinction risk survival gap and method of applying expected prospective survival changes to a "current-to-future" adjustment factor. Detailed methodology, including estimation of survival gaps, is described in the accompanying text. This example uses a survival gap based on 24-year extinction risk and QET=50, applied to the Marsh Creek population of SR Spring/Summer Chinook salmon.



Base-to-Current and Current-to-Future Adjustments

Various metrics can inform the analysis of the survival and potential for recovery prongs of the jeopardy analysis. All life-cycle metrics considered here are based on the retrospective performance of populations during a historical time period and an assumption that, unless something affecting the survival or reproduction of the population changes in the future, the future performance can be projected from the pattern of past performance. NOAA Fisheries evaluated alternative historical time periods for these "base" estimates, but focused on the time period used by the ICTRT for recovery planning, which encompasses approximately the 1980 through 1999 brood years (which include spawner returns at age through about 2004 or 2005). Apart from the precedent of the ICTRT's use of this time period, it also corresponds approximately with that considered in the 2000 FCRPS Biological Opinion. NOAA Fisheries considers this time period a reasonable representation of a long enough time period to encompass variability in climate and biological performance. Additionally, the 1980 through 1999 brood years is considered a sufficiently recent time period to include many of the major changes in management actions that have occurred in recent decades.

As indicated by the ICTRT (2007c), some factors such as hydro operations and configuration have continued to change over that time period, and if the current management actions continue into the future, the projected biological performance will be different from that predicted from base period patterns alone. The ICTRT (2007c) includes an analysis that adjusts productivity estimates to reflect current hydro operations and configuration. The ratio between current hydro survival and the average hydro survival during the base period is calculated as an adjustment factor.

For the jeopardy analysis, adjustment factors are calculated for all ongoing and completed management activities that are likely to continue into the future. The product of these life-stage specific adjustment factors represents the "base-to-current survival adjustment factor." A similar process is used to estimate the survival changes likely to occur as a result of the Prospective Actions and cumulative effects, and to calculate the product of the changes as the "current-to-prospective survival adjustment factor."

For some metrics, such as R/S, the prospective R/S can be estimated by multiplying the base period R/S by the survival adjustment factors. To evaluate survival gaps, such as that associated with a particular level of extinction risk, the base survival gap is divided by the survival adjustment factors.

This approach of evaluating proportional changes in mean survival rates is consistent with the methods used during discussions in the *NWF v. NMFS* remand collaboration process resulting from Judge Redden's Order of October 7, 2005. It is also consistent with the approach used to evaluate recovery actions in the Final Recovery Plan for Upper Columbia River Spring Chinook Salmon and Steelhead (NMFS 2007c). Alternative methods of evaluation using more complex models that incorporate density dependence in estimating future trends following survival rate changes exist but, to date, have only been available for a limited number of populations. These more complex models also rely on a broader set of assumptions and parameter estimates that have not been thoroughly evaluated at the time this document was prepared. Therefore, they are not used in this analysis.

It is important to understand that the proportional change approach applied in this analysis (and the others described above) has a single time step. This means that the analysis assumes that all survival changes occur instantaneously and that average life-cycle survival is immediately affected. For the extinction risk analysis, two alternatives for considering implementation of Prospective Actions were considered, as described below in Section 7.1.1.1. However, for productivity estimates, the time period associated with the estimates begins with full implementation of the expected survival changes. The best way to think of the productivity estimates is that they represent the initial productivity following achievement of the expected survival rate changes resulting from the Prospective Actions. As described in Section 7.1.1.2, there is a relationship between abundance and productivity, such that abundance will increase following a change in survival and productivity. However, as abundance increases, density-dependent interactions will also increase, which will reduce average productivity over time. Therefore, the estimates of average prospective productivity calculated in this analysis are not expected to be maintained indefinitely and over time will be reduced to a lower rate.

Weather and Climate Assumptions

Qualitative considerations of weather and climate, as it affects salmon and steelhead survival, are described in Section 5.7 (Environmental Baseline). That section also summarizes recent literature on potential climate change, such as the Independent Scientific Advisory Board's comprehensive review (ISAB 2007c). This section describes how weather and climate information is applied in quantitative analyses to both the ocean and freshwater life-stages of salmon and steelhead. Qualitative analyses are described in Section 7.1.2.

Mechanically, the quantitative analyses, unless otherwise specified, apply the same climate conditions that influenced survival throughout the life cycle during the "base period" to projections regarding the future. That is, the analysis can be thought of as the base period repeating itself, except for the specific survival changes (e.g., resulting from management actions) that are applied. As described above, the "base period" from which productivity and extinction risk are derived is that used by the ICTRT: completed brood returns generally between 1980 and approximately 2001 (influenced by adult returns through approximately 2005). The exact tie period differs by population and by the particular metric being evaluated. Use of the 1980-2001 time period represents a conservative assumption for climate effects on salmon, compared to a longer historical record. As discussed in Section 5.7, only 4 of the 22 years during this time period had negative (favorable) Pacific Decadal Oscillation (PDO) averages and 18 of the 22 years had positive (unfavorable) PDO averages during the months influencing salmon survival. Similarly, from 1980 through 2001 the El Niño index (MEI) has been dominated by positive deviations from the long-term average (see Figure 5.7.1-1 in Chapter 5) – conditions known to reduce salmon survival. The baseline period therefore represents a regime that is less favorable to salmon than would typically have occurred in the past century.

While climate assumptions in this analysis clearly are conservative relative to climate patterns observed during the past century, many comments on the 2007 Draft Biological Opinion questioned whether NOAA Fisheries was sufficiently cautious in the face of continuing global climate change. As discussed in Section 5.7, Pacific Northwest air temperatures have increased by approximately 1

degree C since 1900 and are expected to increase 0.1-0.6 degrees C per decade over the next century. The ISAB (2007c) described various mechanisms by which this increase in temperature could reduce survival of salmon and steelhead in freshwater and marine life stages.

Ocean Climate Assumptions

In response, NOAA Fisheries explicitly modeled a climate scenario that addresses potentially worsening survival of salmon and steelhead in the ocean. The ISAB (2007c) stated that global climate change in the Pacific Northwest is predicted to result in changes in coastal ecosystems and salmon production that "may be similar to or potentially even more severe than those experienced during past periods of strong El Niño events and warm phases of the PDO." The choice of a 1980-2001 base period largely addresses this concern because it is dominated by El Niño and warm PDO events, representing climatic conditions expected to increase in the future. However, because of the uncertainty in future climate effects, a sensitivity analysis of alternative weather and climate scenarios is included in the Aggregate Analysis Appendix of the Supplemental Comprehensive Analysis. This sensitivity analysis includes an alternative weather-related early-ocean survival multiplier from ICTRT (2007 c) and ICTRT and Zabel (2007) that represents a future climate regime associated with poorer survival of salmon than was experienced during the base period (warm PDO climate scenario of ICTRT 2007c). This scenario is based on the survival experienced by the 1975-1997 brood years, all of which were associated with warm phases of the PDO. Survival under the warm PDO climate scenario is 12% lower than the "base" period survival for SR spring summer Chinook, 3% lower for Upper Columbia River spring Chinook, and 2% lower for listed interior Columbia River steelhead species (ICTRT 2007a).

The ISAB (2008) commented that future climate change may result in ocean conditions even worse than those captured in the warm PDO ocean climate scenario. While that may be true over a longer time period, it is unlikely to apply to the period of the Prospective Actions and the metrics considered in this opinion. The ISAB (2008) also commented that "there has been quite a bit of modeling of what to expect, and there are a range of scenarios available to the NOAA team." NOAA Fisheries requested clarification of which models the ISAB was referring to and if they were specific to ocean conditions. Huntly and Pearcy (2008) replied that "We are referring to general circulation models (GCMs) as provided in the IPCC-2007 report and others, which clearly predict increased global warming in the future. Others predict increased ocean stratification. 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 will affect the ocean survival of Columbia River salmonids. We are not aware of any such models."

A second, more optimistic, alternative climate scenario affecting early ocean survival is also included as a sensitivity analysis. This scenario is included because the ICTRT (2007c) stated that, while at this time it is not technically possible to identify likely specific future conditions, the alternative future scenarios discussed in this section "bound a likely plausible range of future scenarios." It also responds to a comment on the 2007 Draft Biological Opinion that the 1980-present base period is biased toward poor ocean conditions because it is too short to include periods of more favorable climate. The second alternative climate scenario represents a longer historical period of 50 or more

years that encompasses both good and bad ocean conditions ("Historical Climate Scenario" of ICTRT 2007c). Survival under the historical climate scenario is 37% higher than the "base" period survival for SR spring summer Chinook, 44% higher for Upper Columbia spring Chinook, and 11-19% higher for listed interior Columbia steelhead species (ICTRT 2007c).

Freshwater Climate Assumptions

Expected changes in climate can also affect survival during freshwater life stages, as described in Section 5.7 and ISAB (2007c). NOAA Fisheries did not attempt to explicitly model quantitative effects of climate change on survival during freshwater life stages; rather, Section 7.1.2 describes use of a qualitative approach. The primary reason for not attempting quantitative modeling is lack of available information regarding effects of climate change on survival of anadromous salmonids of the Columbia basin. The sole quantitative approach that we are aware of is that of Crozier et al. (2008), which is based on instantaneous attainment of expected 2040 climate conditions and its affect on life-stage survival, abundance, and population growth rate (lambda). Crozier et al.'s (2008) estimated reduction in life-stage survival, compared to survival estimated under current climate conditions, is significant (18-34% decline in parr-smolt survival with combination of 10 climate prediction models) but the applicability of this estimate to the base period survival estimates used in the SCA analysis is unclear (i.e., it is not clear whether the 18-34% decline is relative to the SCA base period survival or relative to another survival rate). Additionally, the instantaneous implementation of 2040 climate is of questionable relevance to the time period under consideration in the SCA, especially without a modeled ramp-up to the 2040 condition. Finally, Crozier et al. (2008) note that density-dependent processes compensated for declines in parr-smolt survival to some extent. This is an important study and analytical approach to evaluating effects of climate change on anadromous salmonids of the Columbia basin, but at this point additional information is needed before attempting to quantify effects of climate change on freshwater survival over the course of the SCA actions. The method of qualitative evaluation, based on ISAB recommendations for pro-active actions, is described in Section 7.1.2.1.

7.1.1.1 Quantitative Methods Applied to Interior Columbia Species for Assessing the Survival Prong of the Jeopardy Analysis

Extinction Risk Methods

As described in Hinrichsen (2008), which is Attachment I to the "Aggregate Analysis Appendix," quantitative assessment of short-term (24-year) extinction risk is calculated in a manner that is similar to that used by the ICTRT for calculating long-term (100-year) extinction risk. This analysis encompasses the entire lifecycle and, therefore, applies to the entire action area of all associated biological opinions. Briefly, observed abundance and productivity estimates during the base period are used to define a stock-recruitment function that predicts the number of progeny that will return to spawn from a given number of parental spawners. The production functions are the Beverton-Holt (for spring Chinook ESUs) and Ricker (for steelhead DPSs and SR fall Chinook), which are standard in fisheries literature. The Ricker function is used for steelhead because valid parameter estimates could not be found with the Beverton-Holt function for about half the steelhead populations. The hockey stick, which is used by the ICTRT, Beverton-Holt, and Ricker functions all predict high

numbers of recruits per parental spawner at low spawner densities and lower recruitment at higher densities, up to a capacity limit. There is uncertainty in the estimates caused by random error and by the tendency of a series of high-or low-survival years to follow each other (autocorrelation).

Estimates of extinction probability are based on simulations. These start with current abundance and then project a 24-year time series of future spawners. Each projection will have a different outcome due to random error and autocorrelation terms, so the projections are repeated thousands of times to generate a range of outcomes. The proportion of simulation runs that fall below the quasi-extinction threshold within the 24-year time period represents the probability of short-term extinction. That is, of 1000 simulations, if 300 predict salmon abundance that is below QET at the end of the 24-years there is a 30% risk of extinction.

Survival "gaps," as defined in Section 7.1.1, were calculated for Chinook populations with sufficient data by determining the change in the slope at the origin of the Beverton-Holt production function that corresponded to short-term extinction risk of 5% or less (see Hinrichsen 2008, included as Attachment 1 to the Aggregate Analysis Appendix). The change in survival was estimated strictly from changes in this slope parameter, with no changes in the Beverton-Holt capacity parameter. This conservative approach estimates a larger survival gap for a given data set than will an approach that assumes density-independent survival improvements that would also affect the capacity parameter, such as the approach the ICTRT used to estimate long-term extinction risk gaps (ICTRT 2007a, 2007c). Similar estimates were not possible for steelhead because of mathematical constraints of using this procedure with the Ricker production function.

Determining the Quasi-Extinction Threshold (QET)

Extinction, for the purpose of this analysis, was defined as falling below a quasi-extinction threshold (QET) four years in a row (representing a full brood cycle of mature male and female spawners) per the ICTRT (2007a). Choice of QET level can significantly influence extinction risk estimates. In the 2000 FCRPS Biological Opinion, the QET was set to the absolute extinction level of one fish:

> Absolute extinction is used instead of a quasi-extinction level because of the unambiguous interpretation of this criterion, whereas quasi-extinction levels such as 20, 50, or 100 fish have different meanings for populations of different sizes and capacities in different river systems. (NMFS 2000b)

The problem with the use of absolute extinction as a criterion is that it is very difficult to predict the dynamics of populations at extremely low abundance. Various reviews since the 2000 FCRPS Biological Opinion have suggested that it would be more appropriate to evaluate extinction risk relative to a higher quasi-extinction threshold. Such a threshold does not necessarily represent true biological extinction, but it represents an abundance below which there is great concern from a management perspective and high analytical uncertainty regarding persistence. As the Independent Scientific Advisory Board pointed out in their review of the ICTRT's draft viability criteria (ISAB 2007d):

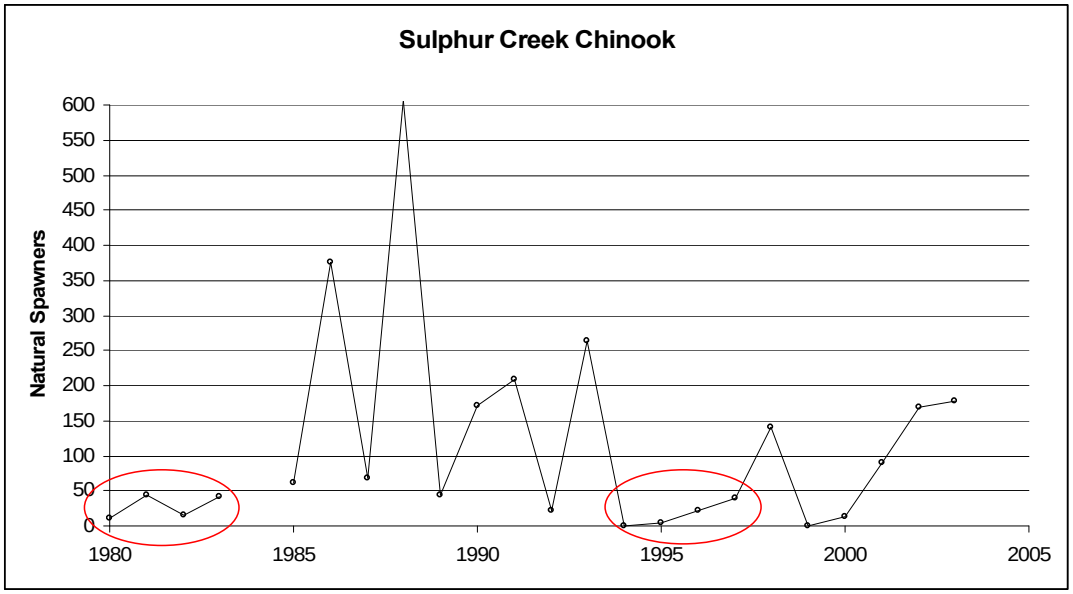
> The probabilities of quasi-extinction should not be considered equivalent to the probability of biological extinction. Rather, the former should be interpreted as the probability of entering a state where the risk of extinction cannot be modeled but is considered to be unacceptably high. The true probability of extinction could be bounded by probabilities derived using quasi-extinction thresholds of 1 and 100.

For their 100-year extinction risk analysis, the ICTRT selected a QET of 50 fish. The ICTRT (2007a) selected 50 fish based on four considerations; [1] consistency with theoretical analyses of increasing demographic risks at low abundance; [2] uncertainty regarding low abundance productivity of Interior Columbia ESU populations due to paucity of escapements of less than 50 spawners in the historical record; [3] sensitivity analyses indicating that the probability of multiple very low escapements increases substantially as the QET approaches one spawner per year; and [4] consistency with the Puget Sound and Lower Columbia/Willamette TRTs.

The ICTRT further elaborated on the first point by stating that three factors contributing to highly elevated extinction risk at low density (presumably 50 fish) are demographic stochasticity (the impact of random events and processes that could drive a small population to zero), Allee effects (such as inability to find mates at low densities), and loss of genetic variability. The first two of these factors likely affect short-term as well as long-term risk of extinction. However, the loss of genetic variability may be expressed over a longer time period and may be less likely to influence short-term extinction risk.

While the ICTRT's observation of a paucity of observations of less than 50 spawners is true across a broad range of populations in the Columbia basin, there are certain populations that have dropped below 50 fish over four years (in some cases more than once) and that have not gone extinct. An example is displayed in Figure 7.1-3.

Figure 7.1-3. Adult spawners in the Sulphur Creek population of SR spring/summer Chinook salmon. Circles indicate four consecutive return years that are below 50 spawners. ICTRT abundance estimates are from Cooney (2007).



The ICTRT does not address nor recommend a reasonable QET for shorter-term extinction risk. The analysis in this SCA includes the 50-fish QET recommended for evaluating 100-year extinction risk by the ICTRT, but it includes also a sensitivity analyses to alternative choices of QET. These may also be appropriate for assessment of short-term extinction risk since many populations in the Columbia Basin have dropped below 50 fish and returned to higher abundance levels during the past 20 years.

The ICTRT determined that for single years in which spawner numbers are as low as 10 fish, successful reproduction is highly uncertain (referred to as the "reproductive failure threshold," RFT). The analysis in this SCA also is based on RFT = 10 and assumes, as did the ICTRT, that successful reproduction occurs when abundance is greater than 10 fish. A sensitivity analysis of QET=1 assumed a RFT of two spawners, as described in the Aggregate Analysis Appendix. This assumption was also applied by the ICTRT for a sensitivity analysis to QET=1 (ICTRT 2007a).

Assessing Short-Term Extinction Risk

Short-term extinction risk with the Prospective Actions in place is estimated with a range of adjustment factors. While many of these actions will occur in the near future and have near-term biological effects, others will take longer to implement and have a biological impact. Because the analysis is based on a single time step and because the exact timing of Prospective Actions and attainment of biological effects is unknown, two adjustment factors are considered: A conservative approach assumes that extinction risk will not be influenced by any improvements associated with Prospective Actions. Only actions that are implemented already and that are captured in the base-to-current adjustment factor, as described in Section 7.1.1, are included in this calculation. A more

optimistic assumption is that all Prospective Actions and all effects of those actions expected to occur within the next 10 years will affect the short-term risk of extinction. This approach includes Prospective Actions that will be implemented quickly, but is also optimistic because it includes actions that may not result in biological improvements for up to 10 years. The true extinction risk associated with the Prospective Actions is expected to be somewhere between these two extremes.

Uncertainty about the extinction risk estimates in the form of 95% confidence intervals is calculated using statistical bootstrapping methods, as described in the Aggregate Analysis Appendix. The confidence intervals are one method of indicating the statistical uncertainty of the quantitative extinction risk estimates and the degree to which they should be relied upon for decisions.

NOAA Fisheries received several comments on the 2007 Draft Biological Opinion regarding this approach to analyzing the survival prong of the jeopardy standard.

Some suggested that NOAA Fisheries evaluate a 100-year extinction risk time horizon, rather than a 24-year period, or else set standards for both periods. The rationale was that the 24-year extinction risk is lower than the 100-year extinction risk (i.e., it "inflates" survival probability compared to the 100-year time horizon). It has been well-documented that extinction risk increases with longer time horizons, with the probability of extinction "approaching 100% for all species if the period is long enough" (NRC 1995). For example, Oregon's comments (page 5) include a Figure 2 that shows a low likelihood of extinction over 24 and 48 years and a high likelihood of extinction over 100 years for Upper John Day spring Chinook. This population is not listed under ESA, and is considered by the state of Oregon to be healthy (ODFW 2006a). While NOAA Fisheries is not familiar with the data or assessment methodology used in Oregon's 100-year extinction risk estimates for this population, their result suggests that even healthy salmon stocks may appear to have a high likelihood of extinction under this assumption. It has been equally well-documented that the precision of the risk estimate decreases with longer time horizons. For example, Fieberg and Ellner (2000) estimated that reliable estimates of extinction risk may only be possible when the number of base period observations is 5-10 times greater than the number of years in the time horizon.

NOAA Fisheries continues to rely primarily on the 24-year time horizon for this analysis because the main purpose of the metric is to inform our judgment regarding the ability of the species to survive while actions to promote recovery are implemented under the Prospective Actions and through other processes. The 24-year period is more than twice that of most of the Prospective Actions and is identical to the short-term period considered in the 2000 FCRPS Biological Opinion (NMFS 2000b). However, NOAA Fisheries did calculate extinction risk over the 100-year time horizon to allow comparison of the 24-year extinction risk results with the 100-year extinction risk results of interest to some parties in the region. The 100-year extinction risk estimates and associated confidence intervals are reported in the Aggregate Analysis Appendix.

Some comments on the 2007 Draft Biological Opinion (NMFS 2007d) recommended that NOAA Fisheries use only a QET of 50 or higher (up to 100) in assessing extinction risk and disregard the sensitivity analysis of QET=30, 10, and 1. These comments said that NOAA Fisheries did not

provide adequate explanation for considering results less than QET=50 in reaching conclusions. On the other hand, one comment stated that QET=50 is conservative and recommended displaying and discussing QET=10 more prominently. The same commenter opined that the real ESA standard is absolute extinction (QET=1), not "entering a state where the risk of extinction can't be modeled" (ISAB 2007c) definition of quasi-extinction threshold).

NOAA Fisheries primarily considered QET=50 in evaluating extinction risk because this is the threshold used by the ICTRT for long-term extinction risk. For the reasons discussed above, this threshold may be overly conservative for smaller populations, particularly those that have demonstrated the ability to return to higher levels after dropping below 50 spawners (e.g., Figure 7.1-3), and it may also be conservative for short-term extinction risk since at least one of the ICTRT's reasons for QET=50 is related to long-term genetic considerations. Regarding suggestions for higher QET levels, a population of at least 50 spawners clearly has not gone extinct and no evidence was presented in comments to suggest that a population below some higher level (e.g., 100) is more helpful in determining real extinction risk. Regarding emphasizing lower QET levels, NOAA Fisheries agrees that "true extinction" is defined as dropping to 0 or 1 spawner four years in a row. However, the ability of available data and models to accurately predict population behavior at this low level is extremely limited and the risk tolerance in such an analysis would have to be extremely low. It is reasonable to evaluate "quasi-extinction" thresholds above 1 fish, although there is little information favoring use of any particular level.

Two comments on the 2007 Draft Biological Opinion questioned details of the analytical approach used to calculate extinction risk. The first questioned whether variability and autocorrelation were adequately considered in the extinction risk analysis. NOAA Fisheries agrees that variance and autocorrelation are important parameters in any extinction risk analysis, and therefore both were estimated and used in developing the extinction risk estimates. The nonlinear regression method for estimating these parameters was carefully developed and details of methodology are included in the Aggregate Analysis Appendix. That appendix also outlines how these estimates were used in developing estimates of extinction probability. In short, as variance increases and autocorrelation increase, extinction probability estimates increase. Extinction probability curves were not used, although their use was assumed in the comment. Instead NOAA Fisheries used the best estimates of productivity, density dependence, current abundance, variance, and autocorrelation and estimated the resulting extinction probability. The exercise of developing hypothetical extinction probability curves was not needed.

A second technical comment opined that use of the Beverton-Holt function "alpha" parameter (i.e., the slope at the origin) to estimate the extinction risk survival gap under estimates this gap, compared to the methods used by the ICTRT. In fact, this approach generally results in very similar or larger survival gaps than the ICTRT method, as can be seen by comparing the SR spring/summer Chinook base 100-year extinction risk gap at QET=50 in the Aggregate Analysis Appendix with the ICTRT (2007c) 5% risk "observed" survival gap. Most of the estimates differ only slightly between the two approaches, with approximately equal numbers being higher in one or the other model. However, there are five populations with very different survival gap estimates, all of which are much larger (i.e.,

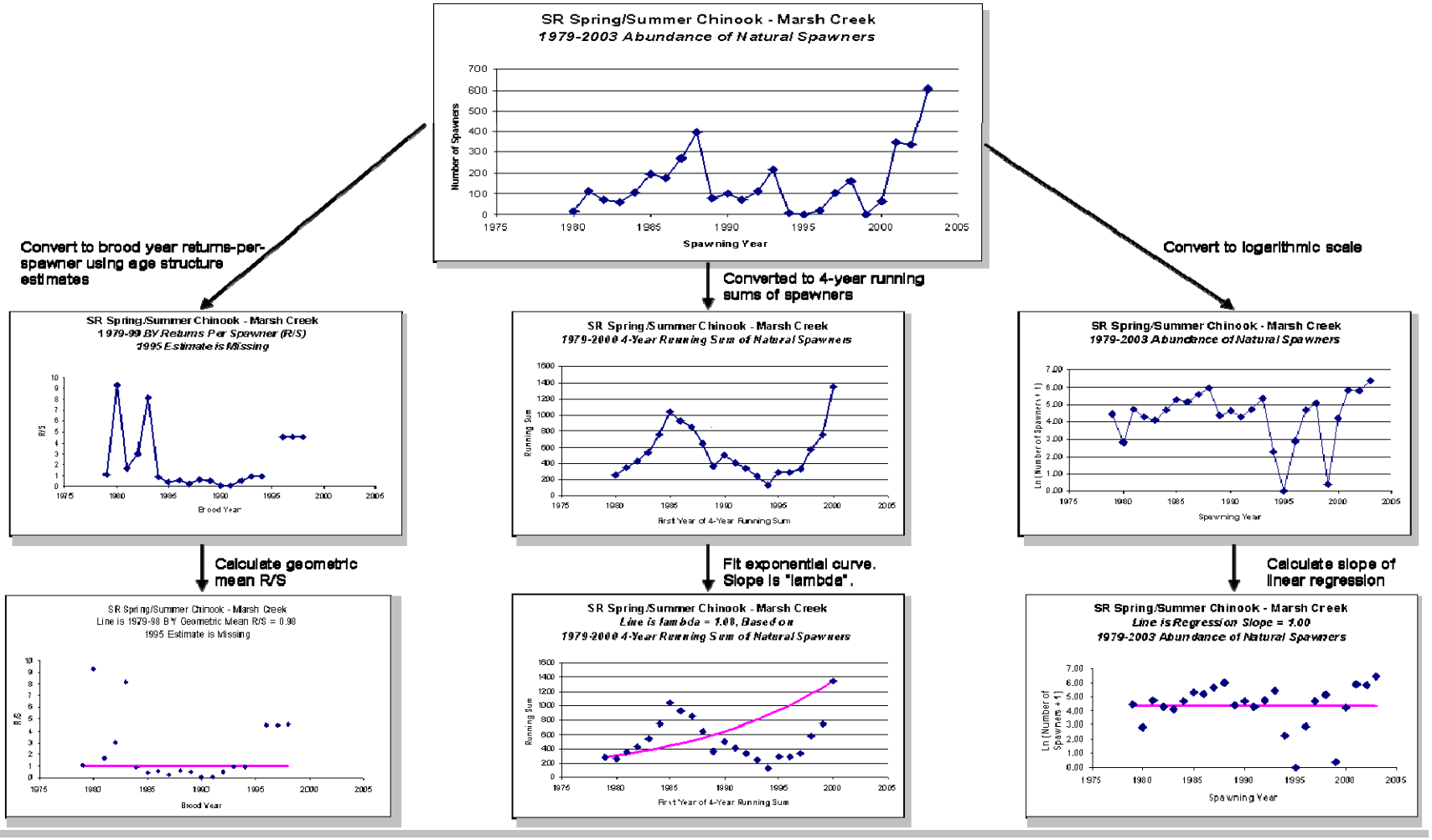
a much greater improvement is needed) using the Beverton-Holt approach. For steelhead, SCA gaps using the Ricker function are nearly always higher than gaps using the ICTRT hockey-stick function.

It is clear from many of the comments and from the results of the analyses that quantitative estimates of extinction risk are subject to considerable uncertainty. In light of this, NOAA Fisheries also considered a variety of qualitative factors, which are described in Section 7.1.2. Included among these factors are important considerations that are not captured in quantitative assessments, such as the relevance of safety-net hatchery programs for reducing or eliminating short-term extinction risk for some populations.

7.1.1.2 Quantitative Methods Applied to Interior Columbia Species for Assessing the Potential for the Recovery Prong of the Jeopardy Standard

Figure 7.1-4 compares the three quantitative metrics indicative of the potential for recovery prong of the jeopardy analysis. All three metrics encompass the entire lifecycle and, therefore, applies to the entire action area of all associated biological opinions. There is great uncertainty in the calculations that characterize the current status of most populations, as well as in estimates of projected performance. The three metrics considered to evaluate the potential for recovery for the jeopardy analysis have different 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 looks at all available tools because the Independent Scientific Advisory Board recommended that policy-makers draw on all available analytical tools (ISAB 2001a).

Figure 7.1-4. Graphic comparison of methods used to calculate average returns-per-spawner (R/S), mean population growth rate (lambda), and the BRT abundance trend (regression of log-transformed abundance). All calculations are based on 1979- 2003 spawner abundance estimates for the Marsh Creek SR spring/summer Chinook population. The estimates in this figure match those in Table 8.2.2-1 for the "base case" Marsh Creek population. The Marsh Creek population has no hatchery-origin spawners; this simplifies the methods compared to populations with both hatchery-origin and natural-origin spawners.



Viable Salmonid Population (VSP) Characteristics

McElhany et al. (2000) define characteristics of viable salmonid populations that are likely to result in persistence for at least 100 years. The VSP characteristics are adequate abundance, productivity (or population growth rate), population spatial structure, and biological diversity. The ICTRT (2007a) apply these general characteristics to interior Columbia River populations in the form of long-term viability criteria. In the context of the SCA, all four VSP characteristics relate to the recovery prong of the jeopardy analysis. This section presents methods for quantitative estimation of abundance and productivity metrics relevant to the jeopardy analysis at the population level. Section 7.1.2 discusses qualitative methods relevant to spatial structure and diversity, as well as qualitative factors relevant to abundance and productivity for those populations with insufficient data for quantitative estimates. Section 7.3 discusses the consideration of these population-level criteria at the MPG and species level.

Average Returns-Per-Spawner (R/S)

Returns-per-spawner (also referred to as recruits-per-spawner) is a measure that determines whether a population is maintaining itself, declining, or growing. If 100 parental spawners produce 100 progeny that survive to maturity and successfully spawn, then R/S=1.0 and the population abundance has been maintained over that brood cycle. If, however, only 80 progeny survive to spawn, then R/S=0.8 and the population is declining. Since each female produces thousands of eggs, there is also the potential for much higher return rates. So, for example, 200 progeny might survive to spawn, which would result in R/S=2.0. In this case, the population abundance has doubled in one generation.

This analysis considers average R/S, with the average calculated as the geometric mean of brood year R/S estimates over the base period. The geometric mean is consistent with the general patterns in variability of annual return rates of anadromous salmon. Use of this metric reduces the influence of the relatively infrequent, extreme high-survival years during the period of interest. The sources of the average R/S estimates used are the ICTRT's Current Status Summaries and a summary of the average R/S metrics generated using the ICTRT data base (Cooney and Matheson 2006), updated to incorporate more recent data from the ICTRT (ICTRT 2007d; Cooney 2007, 2008a)

The estimates of average R/S in Hinrichsen (2008; included as Attachment 1 to the SCA Aggregate Analysis Appendix) applied a slightly different time period and different data sets for some populations. To avoid confusion, only the (ICTRT) estimates of average R/S were used in the SCA calculations for the jeopardy analysis.

It is important to distinguish the average R/S productivity estimates generated from the ICTRT data base from *intrinsic* productivity, which is a critical productivity metric in the ICTRT's long-term risk calculations. Intrinsic productivity, as applied by the ICTRT, is the R/S productivity calculated from the base period years with low spawner abundance (ICTRT 2007a). In other words, average productivity is based on R/S for all brood cycles during the time period of interest. Intrinsic productivity, however, considers a subset of those brood cycles with the lowest parental spawner abundance. The reason the ICTRT places importance on intrinsic productivity is because it represents one method of displaying the resilience of populations to declines in abundance. High intrinsic productivity indicates that populations can increase their abundance after periods of low abundance.

The reason the SCA uses average productivity, rather than intrinsic productivity, as an indicator of a trend toward recovery is because it is a metric that can be calculated and updated over any time period and therefore it is more suitable for a 10-year biological opinion. The relevant brood years in the ICTRT base period for intrinsic productivity are primarily the low abundance years in the late 1980s through mid-1990s for many populations. Intrinsic productivity cannot be recalculated directly until the populations again drop to low levels, and the productivity of the new low-abundance brood years cannot be calculated until their progeny return to spawn in another 4-6 years. Alternative methods of estimating intrinsic productivity based on fitting a stock-recruit function would also be dependent on progeny return data from the same time frame. It may take a decade to update intrinsic productivity estimates, whereas average productivity can be updated and monitored continuously. Average productivity may not be the best indicator of the resiliency of a population, but it is a clear indicator of the current status. When average R/S is greater than 1.0, the population is surviving at a rate that leads to increasing abundance.

R/S, as calculated by the ICTRT (2007a), considers all fish that spawn naturally in the parental generation (i.e., as the S in the R/S calculation). That is, the parents include natural-origin natural spawners and hatchery-origin natural spawners. The returning spawners in the next generation, however, are only the fish produced by those parents (i.e., the recruits are all natural-origin spawners). Therefore, hatchery-origin spawners cannot count in the R part of the R/S calculation. With this approach, one need not attempt to distinguish the productivity of natural-origin natural spawners from that of hatchery-origin natural spawners, at least not for the base period calculations.[2] However, if changes in either the proportion of hatchery-origin fish or the survival of hatchery-origin fish are relevant to base-to-current or current-to-future adjustments, a more complex approach is required (Section 7.2.4 and Quantitative Hatchery Appendix).

Of the three metrics relevant to the recovery prong of the jeopardy standard, average R/S provides the most realistic assessment of the likelihood that a population will trend toward recovery in the absence of continued hatchery programs. This is because the metric considers only the survival of natural-origin fish. This metric also requires the most data for each population, since brood-year specific estimates of hatchery fraction and age structure are necessary. For a number of populations, this requires assumptions and extrapolations from other populations or time periods. Because R/S evaluates brood cycles, it is only as current as the last completed brood cycle. As discussed previously, the last complete brood year is generally 1999, which makes this metric the least up-to-date of the productivity estimates.

Uncertainty associated with average R/S is calculated using the method of the ICTRT, which assumes a geometric distribution of R/S and calculates standard error and the t-statistic based on this distribution (Cooney and Matheson 2006). Cooney and Matheson (2006) also provide a formula for estimating 95% confidence intervals about the geometric mean from those statistics, which is applied

[2] Please note that this approach differs from one of the methods of calculating productivity that is described in the SCA Artificial Propagation for Pacific Salmon Appendix. The description of "productivity" in Section 2.1.2 of that appendix refers to the productivity of natural-origin spawners only.

in the SCA. A second method included in the Aggregate Analysis Appendix is bootstrap estimation techniques to calculate 95% confidence intervals (Hinrichsen 2008). This method generally results in wider confidence intervals than the ICTRT method, in part because it incorporates serial correlation in the estimates. However, to avoid confusion, only the ICTRT approach is applied in the SCA calculations for the jeopardy analysis.

NOAA Fisheries received a comment on the 2007 Draft Biological Opinion that the R/S level associated with the recovery prong of the jeopardy standard should be 1.42, rather than 1.0. This productivity rate would result in doubling population size within two generations, or approximately 10 years. NOAA Fisheries defined the goal for this metric as simply being greater than 1.0 because it is not possible to define a specific level greater than 1.0 that would be relevant to all populations, since they are all of different sizes, with different carrying capacities, and at different levels of current abundance versus carrying capacity. Proponents did not describe why they believed that R/S=1.42 was necessary to avoid jeopardy for every population. However, conclusions in the 2007 Draft Biological Opinion relied in part on estimates of R/S and other productivity measures being higher than 1.0 for many populations, and in some cases the estimates were substantially higher than 1.42. NOAA Fisheries continues to conclude that a goal of R/S greater than 1.0 is reasonable, with consideration of the mix of populations at higher levels an important qualitative consideration for reaching species-level conclusions. NOAA Fisheries does note that results are presented in the Aggregate Analysis Appendix in a manner that allows comparison to 1.42 or any other particular average R/S level of importance to parties in the region.

Median Population Growth Rate (Lambda, λ)

The median population growth rate is the metric primarily relied on in the 2000 FCRPS Biological Opinion. This metric indicates the change in 4-year running sums of population abundance over time. The ICTRT includes lambda estimates in its Current Status Summaries and ICTRT staff provided an updated summary of their average lambda estimates (Cooney 2008b, c). The lambda estimates are calculated using NOAA Fisheries' Salmon Population AnalyZer (SPAZ) model (McElhany and Payne 2006).

The SPAZ model has several options for calculating lambda. The lambda estimates included in the 2007 Draft Biological Opinion did not distinguish between hatchery-origin and natural-origin spawners; however, the ICTRT has changed its approach and now bounds the range of lambda estimates by either assuming that hatchery-origin spawners have success equal to that of natural-origin spawners (HF=1) or that they are entirely unsuccessful (HF=0). Lambda estimates based on HF=1 are similar to R/S estimates, while those based on HF=0 are similar to BRT trend estimates for populations with a significant hatchery influence.

Like R/S, a mean population growth rate of 1.0 indicates a stable population, lambda > 1.0 indicates that the population is growing, and lambda < 1.0 indicates that the abundance is decreasing.

This metric requires less information than R/S, since an average age structure is assumed by the 4-year running sums. But unlike the lambda estimates included in the 2007 Draft Biological Opinion,

estimates of the fraction of hatchery-origin natural spawners are now required. New lambda estimates are based on the estimates of hatchery fraction that are used to calculate R/S productivity. Lambda can be generated from any index of abundance, such as redd counts, without being converted into numbers of spawners. Lambda, like R/S, involves a time lag such that the most recent 4-year running sum is approximately the 2001-2004 spawning years.

Uncertainty is also calculated by the SPAZ model using standard statistical methods, and results include estimates of the 95% confidence limits and the probability that the estimate is greater than 1.0. The 95% confidence limits are estimated for both the base and the prospective lambda estimates. Based on comments on the 2007 Draft Biological Opinion recommending that NOAA Fisheries display the probability that the productivity is greater than 1.0, this metric is included in the Aggregate Analysis Appendix. It was calculated, using the methods in (McElhany and Payne 2006). Although one commenter recommended that the "potential for recovery" prong of the jeopardy standard required demonstrating with 95% confidence that the estimated productivity is greater than 1.0, NOAA Fisheries did not adopt a particular statistical standard and displays this metric only for comparison with alternative goals recommended by others. This metric was calculated only for lambda estimates, but because of the wide range of hatchery assumptions, the results are similar to those expected from both the R/S and BRT trend estimates.

NOAA Fisheries received a comment on the 2007 Draft Biological Opinion that the population growth rate associated with the recovery prong of the jeopardy standard should be 1.08, rather than 1.0. This productivity rate would result in doubling population size within two generations, or approximately 10 years. NOAA Fisheries defined the goal for this metric as simply being greater than 1.0 because it is not possible to define a specific level greater than 1.0 that would apply to all populations, for reasons described above. However, conclusions in the 2007 Draft Biological Opinion relied in part on estimates of lambda and other productivity measures being higher than 1.0 for many populations, and in some cases the estimates were substantially higher than 1.08. NOAA Fisheries continues to conclude that a goal of lambda greater than 1.0 is reasonable, with consideration of the mix of populations at higher levels an important qualitative consideration for reaching species-level conclusions. However, results are presented in a manner that allows comparison to 1.08 or any other particular lambda value of importance to parties in the region

Biological Review Team (BRT) Trend

NOAA Fisheries' West Coast BRT completed a status review of all listed Pacific Coast salmon and steelhead in 2005 (Good et al. 2005). In addition to estimating lambda and R/S for selected populations, the BRT calculated simple trends in abundance for all available populations. Trend is calculated as the slope of the regression of the number of natural-origin spawners (log-transformed) over the time series (Good et al. 2005). To mediate for zero values, 1 was added to the natural spawners before transforming the data. The BRT calculated the trend for 1990 to the most recently available year and for the longest time period available. The most recent year available was generally 2001 for interior Columbia River populations.

For this SCA, NOAA Fisheries updated the BRT to include returns through the most recent year available, which was generally 2004 or 2005, using the SPAZ model (Cooney 2008b, c; McElhany and Payne 2006). The methods NOAA Fisheries used are identical to the BRT's methods and the data used is the detailed population data set provided by the ICTRT (Cooney 2007, 2008a). Only the abundance of natural-origin natural spawners was considered in the analysis. To be consistent with the other two productivity metrics and to attempt to be as consistent as possible with recent management actions, the BRT's longer time period was set to 1980 as the earliest year.

Based on the log-transformed data, a slope of 1.0 indicates a stable population (if the data were back-transformed to the original units, this slope would be zero). If the log-transformed slope is greater than 1.0, the population abundance is increasing; if it is less than 1.0, the abundance is decreasing.

The BRT trend does not track the ability of the population to sustain itself and grow in the absence of hatchery production like the R/S estimates. However, it does depict the trend in abundance of natural-origin natural spawners (including F2 progeny of hatchery-origin natural spawners) under current management, which can also be a useful characterization of status. This metric requires less information than R/S, since age structure is not required. Like the estimation of lambda described above, it is necessary to have an estimate of hatchery fraction each year. Also, like lambda, the BRT trend can be generated from any representative index of abundance consistent across a time series, such as redd counts, without being converted into numbers of spawners. The BRT trend reflects the most recent data more strongly than the other indices, since the most recent year's spawner abundance is weighted equally to all other years (i.e., not just a fraction of the last 5-year running sum or the last brood year returns).

In addition to the method of estimating uncertainty using the BRT approach as applied in the SPAZ model, a second method is also applied in the Aggregate Analysis Appendix. The second method uses a statistical bootstrap technique to generate 95% confidence intervals for the slope. This method does not match the BRT method of estimating uncertainty, which assumes that the observations are normally distributed and independent.

Alternative Productivity Metrics & Goals

NOAA Fisheries received comments on the 2007 Draft Biological Opinion suggesting the adoption of alternative productivity metrics and goals indicative of the "potential for recovery" prong of the jeopardy standard. Two have been described in previous sections: a goal of achieving R/S = 1.42 and a goal of achieving lambda = 1.08. As described above, NOAA Fisheries does not agree that it is possible to define a specific level greater than 1.0 that would be relevant to all populations, since they are all of different sizes, with different carrying capacities, and at different levels of current abundance relative to carrying capacity. However, the Aggregate Analysis Appendix does provide results that can be directly compared with these alternative goals.

One commenter also suggested an alternative goal of achieving the ICTRT's 5% abundance/productivity goal, which represents a combination of reaching the ICTRT viability abundance threshold and of reducing extinction risk to 5% or less. This goal is associated with

recovery and delisting in the Final Recovery Plan for Upper Columbia River Spring Chinook Salmon and Steelhead (NMFS 2007c) and in drafts of other Interior recovery plans. It therefore goes beyond the "potential for recovery" prong of the jeopardy standard and would require attainment of abundance and productivity associated with long-term recovery. While NOAA Fisheries does not agree that a jeopardy determination depends on achieving this goal. Nonetheless, NOAA Fisheries finds that it is relevant to compare the survival changes expected from the Prospective Actions with the survival changes needed to attain this recovery goal. NOAA Fisheries provides this information in figures in the Aggregate Analysis Appendix.

Some comments on the 2007 Draft Biological Opinion recommended that NOAA Fisheries pay closer attention to certain steps within the *NWF v. NMFS* remand collaboration process and set goals based on work products of the remand collaboration process. In particular, a collaboration workgroup prepared a report to support "Step 4" of the collaboration's analytical framework and attempted to apportion the ICTRT's survival gap among different sources of human-caused mortality, including the existence and operation of the FCRPS, based on the estimated magnitude of each source of mortality (Framework Work Group 2006). NOAA Fisheries does not consider the apportionment of survival gap responsibility of Step 4 of the Collaboration Framework to be relevant to a jeopardy analysis. Nonetheless, NOAA Fisheries presents results of a Step 4 analysis in the Aggregate Analysis Appendix so that they can be compared with this alternative goal. The specific estimates of needed survival change are derived from the relative proportional impacts in Framework Work Group (2006) applied to the ICTRT's 5% viability gaps in an analysis presented in various chapters of the CA. The CA results are displayed in the Aggregate Analysis Appendix.

Abundance versus Productivity

NOAA Fisheries received comments on the 2007 Draft Biological Opinion suggesting adoption of an explicit abundance metric and abundance "performance standards." Discussions with some of the commenters clarified that they are primarily interested in tracking abundance during implementation of the Prospective Actions and comparing it to benchmarks such as the ICTRT's abundance viability thresholds, rather than recommending a prospective analysis of the probability of reaching a particular abundance level under the Prospective Actions. Reporting requirements during implementation of the Prospective Actions are described in Section 2 (Proposed Action) and/or Section 4 (RPA) of the biological opinions associated with each of the Prospective Actions, and it is anticipated that population status, including abundance, will be reported.

These comments do point to a larger issue regarding the relationship between the productivity metrics included in this analysis and population abundance. As described in Section 7.1.1, the estimates in this 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. The ICTRT and Zabel (2007) used a matrix simulation model to analyze the expected changes in productivity and abundance over time for a few

populations with sufficient data, following incremental changes in FCRPS hydro survival. Three examples for populations of SR spring/summer Chinook salmon are displayed in Figures 7.1-5 through 7.1-7. These examples compare the initial productivity (R/S) calculated by the proportional change method with average R/S and spawner abundance over time, projected by the simulation model.

Figure 7.1-5. Abundance and productivity (R/S) of the Catherine Creek population of SR spring/summer Chinook salmon predicted in ICTRT and Zabel (2007, their Table 7) using a matrix simulation model. A 6.5% survival improvement is applied to the model at simulation year 1. The matrix model estimates represent means of 100,000 model runs. Matrix model results are compared to an estimate of the initial R/S productivity following instantaneous achievement of a 6.5% survival improvement using the proportional increase method in the SCA.

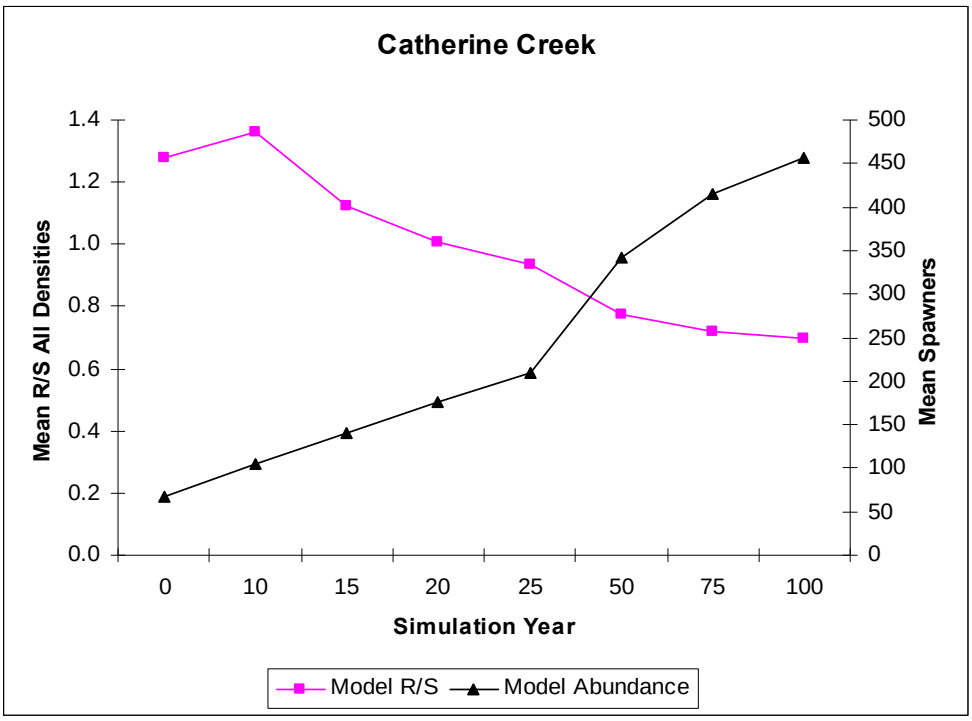


Figure 7.1-6. Same as Figure 7.1-5 for the South Fork Salmon River population of SR spring/summer Chinook salmon

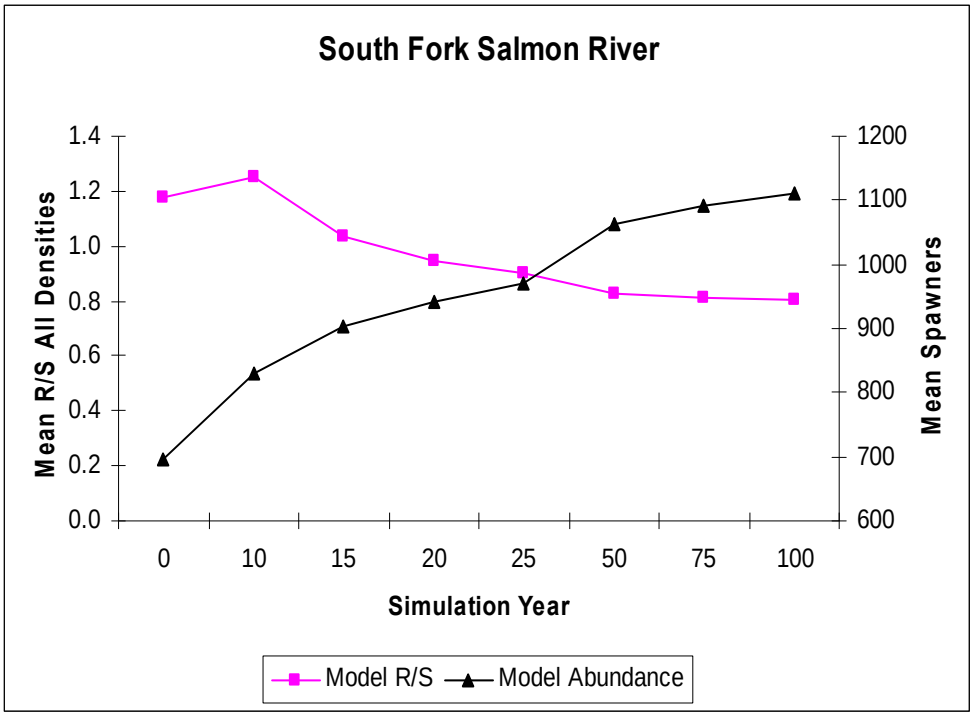
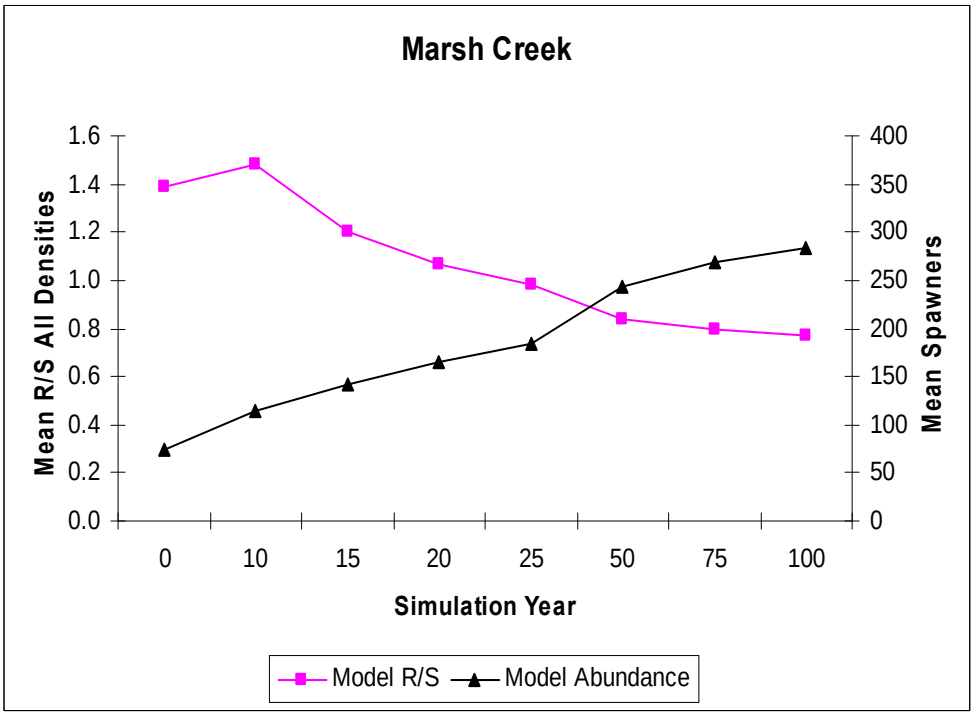


Figure 7.1-7. Same as Figure 7.1-5 for the Marsh Creek population of SR spring/summer Chinook salmon.



7.1.1.3 Summary of Key Assumptions in Analyses

Table 7.4-1 displays key assumptions in the analysis. They are characterized by whether they are somewhat optimistic, pessimistic, or neutral.

Table 7.4-1 Key analytical assumptions for the life-cycle analysis, characterized by their effect on conclusions.

Optimistic Assumptions	*The response to survival changes in terms of a change in productivity is not affected by density*. Moreover, the change in productivity represents the initial change that would occur before abundance increases. It is considered optimistic because, as abundance increases in response to the higher survival rate, productivity will decline over time due to density-dependent effects such as competition for resources. This approach is considered a reasonable way of characterizing the potential for recovery and expected progress toward recovery with the simple productivity ratio method described in this analysis and used in the *NWF v. NMFS* remand collaboration process. However, more complex modeling approaches incorporating density dependence are currently available only for a limited number of populations. *All actions are implemented and biological responses occur in a single time step.* This assumption will underestimate short-term extinction risk; therefore, risk is bounded by the assumption that no Prospective Actions will help to reduce risk (only continuation of current actions), as well as the more optimistic assumption that all Prospective Actions will be implemented within a time period that will influence the risk of short-term extinction. *Climate effects are explicitly analyzed only for early ocean survival*. Climate change will also affect survival in freshwater life stages but it was not possible to quantify this effect. Therefore, it is treated qualitatively by considering factors described in Section 7.1.21, such as consistency of Prospective Actions with ISAB recommendations for proactive actions in response to climate change.
Neutral Assumptions	*The base range of uncertainty also applies to current and prospective estimates.* This is identical to the ICTRT assumption that the base variance applies to alternative scenarios. In the absence of data suggesting that variability will change, this is the most supportable assumption. *Processes affecting population dynamics during the base period will continue into the future (i.e., they are stationary) unless modified in the analysis by explicit changes in survival expected from management actions or alternative climate conditions.* This assumption is supported primarily by choice of a 1980-present

	time period that is long enough to capture variability in biological processes but short enough to be influenced primarily by the significant management changes that have occurred in recent years. *The quasi-extinction threshold (QET) is no higher than 50 spawners (ICTRT QET for long-term recovery level), and may be lower for short-term risk,* especially for historically small populations that have not gone extinct after dropping below 50 spawners for four years in a row. This analysis also considers results of sensitivity analyses for QET less than 50 spawners. *Reproductive failure in a given year occurs at or below 10 fish,* per the analysis in ICTRT (2007a). Productivity at different spawner abundance levels can be described by Beverton-Holt and Ricker functions for short-term extinction risk analyses.
Pessimistic Assumptions	*The climate scenario given the greatest weight is that base period climate will continue.* This "Current" ICTRT climate scenario is dominated by poor ocean conditions and does not include a full cycle of favorable ocean conditions. This assumption is much more pessimistic than the historical climate record and is only marginally more optimistic than the worst of the recent years. For further discussion, please see Section 7.1. *Quantitative survival changes expected to result from habitat actions only are those anticipated to accrue within 10 years.* It is likely that many habitat actions will result in additional survival improvements after 2018; however, it was not possible to estimate their effects quantitatively. *Expected survival changes as a result of new actions are not affected by density.* Only density-independent survival changes are considered. For example, quantitative survival changes related to increasing habitat capacity only represent the effects of increased capacity at low density. The benefit of opening up new habitat would likely be greater at higher densities. *Short-term extinction risk estimates are based on the assumption that supplementation ceases immediately.* Sensitivity analyses to demonstrate effects of continuing supplementation on short-term extinction risk are included for selected populations. *Hatchery operations in the basin will continue unchanged, except where specified changes are occurring or will soon occur (e.g., 8.6.5.4).* Current hatchery practices

	have varying effects ranging from positive to adverse. Due to the instances where there are adverse hatchery effects, NOAA Fisheries considers the continuation of current hatchery practices a pessimistic assumption. As described in RPA 39, hatchery reform is a component of the proposed action but will be evaluated in future site-specific consultations.

7.1.2 Population-Level Qualitative Analytical Methods for all Thirteen Columbia Basin Species

In addition to the quantitative methods described above for six interior Columbia species, the jeopardy analysis considers qualitative factors for all species.

7.1.2.1 Climate Change Considerations for Both the Survival & Recovery Prongs of the Jeopardy Analysis

Qualitative considerations of weather and climate, as it affects salmon and steelhead survival, are described in Section 5.7 (Environmental Baseline). That section also summarizes recent literature on potential climate change, such as the Independent Scientific Advisory Board's comprehensive review (ISAB 2007c). Section 7.1.1 describes how weather and climate information is applied in quantitative analyses. This section describes how climate change was considered qualitatively in evaluating the effects of the Prospective Actions on listed species.

The primary qualitative method NOAA Fisheries uses to evaluate the Prospective Actions is to determine the degree to which the Prospective Actions implement recommendations by the ISAB (2007c) to reduce impacts of climate change on anadromous salmonids. The specific recommendations against which the Prospective Actions are evaluated are described in Table 7.1.2.1-1.

NOAA Fisheries also evaluates the Prospective Actions on the basis of the extent to which the Prospective Actions include:

- monitoring climate change effects on listed salmon and steelhead;
- a mechanism for continually updating and synthesizing new information regarding the effects of climate change on listed salmon and steelhead; and
- mechanisms for modifying implementation plans as necessary to respond to new information about climate change.

Table 7.1.2.1-1. Measures recommended by ISAB (2007c) to mitigate the anticipated adverse effects of climate change on Columbia basin salmon and steelhead.

Tributary Habitat
1. Minimize temperature increases in tributaries by implementing measures to retain shade along stream channels and augment summer flow. a. Protect or restore riparian buffers, particularly in headwater tributaries that function as thermal refugia. b. 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. a. Buy or lease water rights b. 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. a. Identify cool-water refugia (watersheds with extensive groundwater reservoirs) b. Protect these groundwater systems and restore them where possible c. May include tributaries functioning as cool-water refugia along the mainstem Columbia where migrating adults congregate

Mainstem & Estuary Habitat (Non-Hydro)
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.
2. Use removable spillway weirs (RSW) to move fish quickly through warm forebays and past predators in the forebays. - Target to juvenile fall Chinook salmon
3. Reduce water temperatures in adult fish ladders

Mainstem Hydropower
a. Use water drawn from lower cool strata of forebay b. Cover ladders to provide shade
4. Transportation a. Develop temperature criteria for initiating full transportation of juvenile fall Chinook salmon b. Explore the possibility of transporting adults through the lower Snake River when temperatures reach near-lethal limits in late summer c. 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 catfish) 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 a. 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 b. Use stock identification to target hatchery stocks or robust wild stocks, especially when ocean conditions are not favorable

7.1.2.2 Qualitative Factors Affecting the Survival Prong of the Jeopardy Analysis

As defined by the ESA regulations, §402.02, "'recovery' means improvement in the status of the listed species to the point at which listing is no longer appropriate under the criteria set out in section 4(a)(1) of the Act." This is consistent with ESA §4(c)(2) where a determination to remove a species from the list "shall be made in accordance with the" listing criteria. NOAA has stated that recovery depends on two types of criteria. "[E]valuating a species for potential de-listing requires both an explicit analysis of population or demographic parameters (biological recovery criteria) and also of the physical or biological conditions that affect the species' continued existence, categorized under the five ESA listing factors (listing factor criteria). Together these make up the "objective, measurable criteria" required under section 4(f)(1)(B)." See "Adaptive Management for ESA-Listed Salmon and Steelhead Recovery: Decision Framework and Monitoring Guidance," May 1, 2007, found at: http://www.nwr.noaa.gov/ Salmon-Recovery-Planning/ESA-Recovery-Plans/upload/ Adaptive_ Mngmnt.pdf. The qualitative factors relevant to evaluation of the potential for recovery prong of the jeopardy standard therefore are biological factors and listing factors, also referred to as "threats." The

VSP factors (abundance, productivity, spatial structure, and diversity; see Section 7.1.1.2) inform the biological factors evaluation.

Recent abundance

Particularly low abundance levels (especially levels currently below the QET) would indicate relatively high short-term extinction risk due to factors such as demographic stochasticity (tendency for populations at low abundance to bounce around, possibly going to zero) and Allee effects (difficulty finding mates at low abundance). Conversely, relatively high abundance, especially if coupled with an indicator of sufficient productivity, would indicate a reduced likelihood of short-term extinction.

Recent productivity

In some cases productivity can be estimated but extinction risk cannot. In these cases, recent productivity, especially if coupled with information regarding abundance, can be informative. If productivity is low (e.g., the population is not replacing itself each generation or the trend in abundance has been declining), the risk of short-term extinction may be high. Conversely, a growing population can indicate a lower risk of short-term extinction.

The Degree to which Safety-Net and/or Supplementation Programs Meet Program Objectives

Some hatchery programs provide a short-term cushion to prevent extinction while longer-term recovery measures are being implemented. The hatchery programs that would serve this function are described in the individual species sections of this document, Sections 8.2 through 8.14.

The Degree to which Limiting Factors are Addressed

For some populations it is either not possible to quantify the survival changes associated with current actions and the Prospective Action or there is great uncertainty in the estimates. In this situation a qualitative description of the degree to which current and Prospective Actions reduce limiting factors is relevant to the assessment of extinction risk. Previously implemented actions and Prospective Actions with expected near-term biological benefits would likely reduce extinction risk if they substantially reduce limiting factors and threats.

Monitoring and Adaptive Management

Because there is uncertainty associated with quantitative estimates of risk and expected biological effects of current and prospective actions, it is important to have an effective monitoring program and adaptive management contingencies. It is possible to accept higher uncertainty in the ability of the Prospective Actions to avoid short-term extinction risk if a monitoring program will ensure that unexpected reductions in species status are detected in a timely manner so that contingent adaptive management actions can be implemented in response.

7.1.2.3 Qualitative Factors Affecting the Recovery Potential Prong of the Jeopardy Analysis

The qualitative factors relevant to evaluation of the potential for recovery prong of the jeopardy standard are the VSP factors: abundance, productivity, spatial structure, and distribution.

Abundance and Productivity

It is not possible to quantify abundance and/or productivity for many populations. In these cases, qualitative considerations include the similarity of populations without adequate data to populations with adequate data. In some cases, data is available for one time period but not another, so again, a qualitative consideration can substitute for quantitative analysis in those particular time periods.

Snake River steelhead is an example of a species with limited quantitative information. Data supporting abundance and productivity estimates are available for only three of the 24 extant populations. The ICTRT also estimates average abundance of A-run and B-run populations based on dam counts and assumptions about the distribution of steelhead among populations (ICTRT 2007a, c). Here, the average A-run and B-run base period estimates are applied to individual A-run and B-run populations, respectively. Then population-specific survival changes (e.g., resulting from prospective tributary habitat actions) are applied to the individual populations. This approach is taken because of a desire to match population specific actions with individual populations and the need to consider effects at the MPG level as an intermediate step to making species conclusions.

Snake River sockeye salmon are at very low abundance levels with current returns originating from a captive rearing program. As a result of the virtual absence of naturally produced returns in recent years, specific quantitative estimates of trend and productivity of that component of the ESU are not currently feasible. Qualitative characterizations of abundance and productivity are apparent just from inspection of available information.

The analysis of lower Columbia River species relies more on qualitative analysis than that for interior Columbia River species. The BRT (Good et al 2005) and the Willamette/Lower Columbia TRT (WLCTRT 2004, and McElhany et al. 2007) estimated abundance and trends for available populations in the Willamette and lower Columbia Rivers, but little or no information was available for many populations. The available data sets for Washington populations generally ended in 2001 and those for Oregon populations ended in 2005. No attempt was made to quantify changes from base period productivity to current productivity or to productivity resulting from the Prospective Action. Instead, changes were expressed mainly in terms of direction (improvement/reduction) with qualitative descriptions of magnitude.

Action-specific and life stage-specific survival trends are considered quantitatively in analyses if appropriate (e.g., hydro adjustment factors for interior Columbia River species' productivity estimates), but are also considered qualitatively for all species. An important consideration is whether improving trends in abundance and productivity are solely a result of fortuitous climate conditions or if they are also a result of beneficial human activities. Correspondence of changes in human activities, trends in life-stage survival influenced by those management activities, and trends in population abundance and productivity support the qualitative conclusion that changes in management actions are contributing to improved population status.

The qualitative factors described under Section 7.1.2.1 also apply to the recovery potential prong of the jeopardy standard, with the exception of safety-net hatcheries.

Spatial Structure

The ICTRT (2007a) and WLCTRT (2003) describe viability criteria for spatial structure. These include consideration of the number and spatial arrangement of major spawning areas (MaSA) and minor spawning areas (MiSA), the proportion of the historical range that is occupied, and increases or decreases in gaps between occupied MaSAs. The ICTRT Current Population Status Summaries (Cooney 2007) characterize the current status of spatial structure as "very low" through "high" risk for each population. The WLCTRT (2004) viability assessment provides a formalized expert opinion-based characterization and numerical rating of the spatial structure of each Willamette and lower Columbia River population. Although the ratings are presented as numbers, they actually represent qualitative categories scored through a structured expert opinion process.

In this analysis, Prospective Actions are evaluated in the context of whether they are contributing toward improving spatial structure for affected populations.

Diversity

The ICTRT (2007a) and WLCTRT (2003) described viability criteria for diversity. These include retention of major life history expressions (e.g., summer vs. spring runs), maintenance of phenotypic and genetic variability, maintenance of natural patterns of gene flow (including various criteria for assessing impacts of hatchery programs), and reduction of selective changes resulting from human activities (e.g., large fish selection in fisheries). The ICTRT Current Population Status Summaries (2007d) characterize the current status of diversity as "very low" through "high" risk for each population. The WLCTRT (2004) viability assessment provides a formalized expert-opinion-based characterization and numerical rating of the diversity of each Willamette and lower Columbia River population. Although the ratings are presented as numbers, they actually represent qualitative categories scored through a structured expert opinion process.

In the SCA, Prospective Actions are evaluated in the context of whether they are contributing toward improving diversity for affected populations.

7.2 Life-Stage-Specific & Action-Specific Analyses to Support the Life-Cycle Analysis and to Estimate Incidental Take

Section 7.1 describes methods to estimate productivity and extinction risk that incorporate population survival throughout the life cycle. In conducting the analyses described in Section 7.1, information regarding the effects of specific actions that affect survival at different life stages is needed. Section 7.2 describes methods of estimating effects of actions relevant to particular life stages. These methods also apply to the estimation of incidental take associated with Prospective Actions.

7.2.1 Hydro Methods

This section describes NOAA Fisheries' analytical approaches to estimating how proposed changes in FCRPS system and individual project operations and changes in individual project configurations (e.g. new RSWs, etc.), collectively termed Hydro Actions, will affect fish survival This involves a

quantitative analysis of the hydrologic effects of the Prospective Actions, detailing how proposed operations affect flows through the system and the distribution of flows through various systems at each project (i.e. spillway, versus turbine flow). These operational effects are then combined with proposed changes in system configuration and known and estimated performance characteristics of those systems to estimate the fish survival effects of the Hydro Actions through quantitative biological modeling (when possible) or through qualitative evaluations. Section 3.2.1 and Appendix B-1 of the CA provide more detailed descriptions of these analytical methods.

Sufficient information is available to quantitatively assess the effects of the hydro actions on SR spring/summer Chinook and steelhead, UCR spring Chinook and steelhead, and MCR steelhead (Section 7.2.1.1). This assessment also provides surrogate information that is pertinent to populations of lower river ESUs that migrate to and from tributaries entering the Columbia River between Bonneville and The Dalles dams. For the remaining ESUs, a more qualitative assessment was required for assessing hydro effects. This approach is described in 7.2.1.2.

7.2.1.1 Quantitative Juvenile Analysis of Hydro Actions on Five Interior ESUs

General Approach

In developing the overall analysis of the effects of the Proposed Hydro Action on listed anadromous fish, this SCA relies on hydrologic, operations, and biological model outputs and previous analyses for assessing the effects of the hydropower system on ESA-listed salmon and steelhead. In general, the analysis consists of an ESU-by-ESU analysis for three primary time periods of hydropower system existence, the Base (corresponding to the general conditions that were experienced by juveniles during the 1980-2001 outmigrations), Current (2004 FCRPS Biological Opinion operations and actions implemented through 2006), and Prospective conditions with results reported as the average across all years (the 70 year water record included the 1929 to 1998 water years).

The SCA's quantitative analysis begins with baseline survival estimates primarily provided by the TRT or other relevant sources, with consideration of estimates for key parameters (i.e., direct in-river survival, percent transported). Next, the effects of operation and configuration changes that have already occurred (Current) were estimated and compared to the Base condition (Base to Current adjustment).[3] And finally, the effects of future changes in hydrosystem operations and configurations (Prospective) were estimated and compared to the Current condition (Current to Prospective adjustment). The resultant Hydro adjustments were incorporated into the life-cycle analysis (Section 7.1).

Because juvenile migrant survival is affected by flows and project operations (e.g., spill rates) and because river flows vary due to both natural climate variation and project operations, a series of

[3] Note: The Base-to-Current adjustment assumes no changes have occurred in post-Bonneville survival relationships between the Base and Current periods. This is likely a conservative assumption because many actions that were implemented in the latter part of the Base period through the Current condition (increased spill, improved juvenile bypass systems, RSWs, etc.) should have generally improved the fitness (quality) of fish arriving at the Bonneville tailrace compared to the average fitness of fish observed during the entire Base period.

models were employed to estimate the survival effects of alternative operating strategies. These models were:

- A hydrologic model
- An operations model (HYDSIM)
- A survival model (COMPASS)

Hydrologic Modeling

Historical streamflows, to the extent measured data are available, are inadequate for system regulation studies because through time, differing levels of storage and irrigation development have affected streamflows and reservoir operations. Thus, even if precipitation conditions were similar during a recent year to that experienced decades earlier, total streamflow and the streamflow pattern at a given point could be quite different due to changes in water development. For this reason, the FCRPS Action Agencies have simulated the flow conditions that would have existed throughout a 70-year hydrologic record had the current (circa 2000) level of water development been in existence during the entire period. Termed "Modified Streamflow," the 70-year time-series used for the hydro system effects analyses conducted for this consultation approximates the expected flow conditions that would occur today over the range of hydrologic conditions experienced over the period (October 1928 through September 1998). BPA 2004 provides details on how this hydrologic simulation was accomplished.

Operations Modeling

Operations modeling refines the output of the hydrologic models, storing and releasing water from reservoirs according to operations defined by the Prospective Actions. Two system operations models were used to route the modified flows described above through the hydro system. Reclamation's MODSIM model (updated Upper Snake MODSIM - May and June 2007 runs) was used for the upper Snake River above Brownlee Reservoir, and BPA's HYDSIM model was used for the remainder of the Snake and Columbia River basins.

MODSIM was used to estimate inflows to Brownlee Reservoir resulting from the existence and operation of Reclamation's upper Snake River projects and all private diversions and depletions. Input hydrology into the model includes 1928 through 2000 historical water supply period of record. The model is then configured to represent the current level of basin development, including diversions and groundwater pumping, as well as Reclamation's operations. Thus, the model takes into account Reclamation operations (water storage, flood control releases, irrigation deliveries, delivery for flow augmentation), current level of ground water pumping, irrigation return flows, and current private activities (private water surface diversions and subsequent return flows).

The Brownlee Reservoir inflows developed by MODSIM and modified streamflows for the remainder of the Columbia basin were then incorporated into BPA's HYDSIM model. Hydro Simulator Program (HYDROSIM, also known as HYDSIM) (BPA 1997) simulates operation of all Columbia basin projects, excluding those on the Snake River upstream from Brownlee Reservoir. For this

analysis we assumed that Idaho Power Company's Brownlee Reservoir would be operated in a manner designed to protect downstream anadromous fish including: refilling by July 1 each year, drafting 237 thousand acre-feet (kaf) during July each year, and operating through the fall and winter to maintain spawning and incubation flows for SR fall Chinook salmon.[4]

The model produces an array of outputs including reservoir elevation, generation, and spill. User supplied constraints allow simulation of a wide array of operations. Such constraints include specified spill schedules for fish protection, reservoir drafting and refill operations for flood control, electrical power demands, reservoir drafts for flow augmentation, and irrigation withdrawals.

System operations are simulated for 14 periods per year, one for each month with April and August each divided into two periods. Based on inflows and user supplied constraints, the model routes inflows through the system creating a set of operational outputs (e.g. generation, total outflow, spill flow, reservoir storage) for each project. HYDSIM's project-specific time-series of total flow and spill flow are principal inputs to the fish survival modeling process.

Using historical flow data for each water year in the 70-year record, MODSIM and HYDROSIM can be used to project how water would pass through the upper Snake, lower Snake, and Columbia River systems, respectively. For example, the models can be used to project how flows would be distributed through any one of the periods (14 for HYDSIM and 12 for MODSIM) for multiple locations in the system for a selected high-, medium-, or low-flow year and the models can estimate the water distribution effects of alternative project operations.

The output of HYDSIM is then modulated into estimated daily flows (NMFS 2008g) for use in the biological modeling – which incorporates flow as a predictive variable for estimating fish survival through the FCRPS. The overall results of the hydroregulation modeling are presented in CA Appendix B.

Biological Modeling

In collaboration with regional parties, NOAA's Northwest Fisheries Science Center developed a Comprehensive Fish Passage (COMPASS) model (see Corps et al. 2007a Appendix B.3) to assess the likely effects of alternative hydrosystem operations on juvenile survival and post-Bonneville dam survival for five interior basin ESUs: SR spring/summer Chinook salmon, SR steelhead, UCR spring Chinook salmon, UCR steelhead, and MCR steelhead. The model was populated with the best empirically derived estimates of route-specific passage and survival rates available for juvenile Chinook or steelhead to reflect the current configuration of the hydrosystem. The FCRPS Action

[4] In order to provide an analysis of the aggregate effects of both the Upper Snake Reclamation projects and the FCRPS projects on flows in the lower Snake and Columbia Rivers, some assumption of the operation of Idaho Power Company's Hells Complex (which includes Brownlee Reservoir) was required, because of its physical location between these two systems. NOAA Fisheries chose to assume an operation that is generally reflective of recent operations of this project. However, because the relicensing of the Hells Canyon Complex is a future Federal action that has not yet undergone consultation, NOAA Fisheries does not otherwise consider the effects of this project in this Supplemental Comprehensive Analysis.

Agencies assessed the likely benefits of prospective action configuration actions to assess their overall effect on survival in the prospective analysis. The operations modeling results were modulated into appropriate formats for input into COMPASS (daily flows and spill rates) (NMFS 2008g), and then the model was run to estimate the effects (across the 70 year water record) of Current and Prospective operations of the mainstem Snake and Columbia River dams and reservoirs on fish survival.

A paper describing the COMPASS model has been provisionally accepted for publication in Hydrobiologia (Zabel et al. 2007). The COMPASS model is composed of five modules: 1) reservoir survival, 2) dam passage and survival, 3) fish travel time, 4) hydrology, and 5) post-Bonneville survival. The COMPASS model was generally reviewed by the Independent Scientific Advisory Board (ISAB) during its development (ISAB 2006a, b). The ISAB also reviewed post-Bonneville survival hypotheses, including the Scheuerell – Zabel hypothesis used in the COMPASS model for the analysis in this SCA (ISAB 2007b). NOAA Fisheries considers the COMPASS model to represent the best scientific information available for the purposes of assessing the biological effects of alternative hydrosystem operations. A detailed description of the COMPASS model can be found in the COMPASS model documentation (NMFS 2008g).

Key parameters estimated by the COMPASS model provided for both the Current and Prospective operations include:

- direct system survival (combined survival of both in-river and transported fish starting at Lower Granite Dam for Snake River ESUs and McNary Dam for Upper Columbia River ESUs) to the Bonneville Dam tailrace;
- smolt to adult returns (SARs) of both transported and in-river migrating juveniles from the Bonneville dam tailrace, to the ocean, and back to the Lower Granite Dam for Snake River fish, or to Rock Island dam for Upper Columbia River fish (Scheuerell and Zabel 2007**);**
- total SARs for Snake River (system survival estimates) *x* (post-Bonneville smolt to adult returns).

For the Snake and Upper Columbia River ESUs, total SARs were used to inform the hydro adjustment (current-to-base). For upper Columbia River ESUs, the biological effects were aggregated with the observed (base-to-current) or expected (current-to-prospective) survival improvements resulting from actions taken to improve juvenile survival through the mid-Columbia PUD dams. This was a result of settlement agreements and Biological Opinions (NMFS 2006e hydro module for recovery planning) (effects that are in the environmental baseline considered in this SCA). For Mid Columbia River steelhead, which includes populations that migrate through one to four lower Columbia River dams, there was insufficient information to assess a post-Bonneville survival relationship. For this ESU, the CA only utilizes changes in estimates of system survival in the Base, Current, and Prospective adjustments and does not include an assumption that post-Bonneville survival might be affected through the implementation of the Prospective Actions. The Current and Prospective condition estimates are provided in Chapters 5, 7, 8, 9 and 10 of the CA and in Appendices B.3 and B.4. The COMPASS modeling results for the Prospective Actions considered in this SCA are located in the SCA Hydro Modeling Appendix.

It should be specifically noted that the in-river survival estimates reported for the Base, Current, and Prospective analysis, aggregate the three primary sources of mortality (existence, operational, and natural) between Lower Granite dam on the Snake, Rock Island Dam on the middle Columbia, and Bonneville dam tailrace. Natural mortality certainly existed prior to the existence and operation of the FCRPS. However, no attempt is made to distinguish current natural mortality from other sources within the hydro analysis for this document.

7.2.1.2 Analysis for Juvenile Migrants of Other ESUs

For the Lower Columbia and Willamette ESUs and for Snake River Sockeye, for which existing information is not sufficient for quantitative analysis of hydropower system effects, NOAA Fisheries must rely on a more qualitative approach.

The first approach uses information obtained through the quantitative assessment described in 7.2.1.1 for the more data rich ESUs. They provide a surrogate analysis for the effect of the FCRPS hydro actions on ESUs having one or more populations that commonly migrate through Bonneville reservoir and dam (LCR Chinook salmon, Coho salmon, and steelhead). Specifically, the in-river Bonneville reservoir and dam survival estimates (for the most closely related species) produced by COMPASS for the Current and Prospective periods are used as the estimated hydro survival adjustment for those populations spawning upstream of Bonneville Dam. For LCR coho salmon, the expected benefit for spring Chinook salmon would be used. NOAA Fisheries also considers qualitatively, information provided by the FCRPS Action Agencies in the CA's species specific analysis (CA Chapters 12, 13, and 14) in considering the overall effects of the FCRPS and the hydro actions required by the RPA on these ESUs.

The second approach relies on providing professional judgment to qualitatively assess the likely effect of the FCRPS hydro actions on the ESUs for which empirical information is insufficient to provide useful quantitative assessments (SR fall Chinook salmon, SR sockeye, and CR chum). In this case, NOAA Fisheries considers the qualitative assessment made by the FCRPS Action Agencies in the CA and also any other information that would aid in the assessment of how these species are currently affected by the FCRPS and their likely response to the hydro actions required by the FCRPS RPA.

Lastly, no portion of the UWR Chinook salmon and steelhead ESUs migrate upstream of Bonneville Dam, other than as infrequent strays. For this ESU, NOAA Fisheries assumes that the FCRPS effects on the quantity and timing of flows (as described in the Environmental Baseline) will continue to affect these ESUs, but hydro actions required by the Prospective Actions will not benefit these ESUs in any substantial way.

7.2.1.3 Methods for Adult Migrants of All ESUs

Recent survival of adult salmon and steelhead migrating through the FCRPS was assessed to identify ESU specific adult performance standards (and to estimate incidental take). NOAA Fisheries and the FCRPS Action Agencies, in collaboration with the Policy Work Group, adopted a methodology that

removes the influence of several confounding variables (harvest and "natural" or transportation related stray rates)[5] that obscure the true effect of the mainstem FCRPS dams on the survival of migrating adults. The assessment is based on returning adults[6] detected at Bonneville Dam and redetected upstream at McNary dam or Lower Granite Dam (depending upon the ESU in question). Only returning adults of known origin, PIT-tagged as juveniles that migrated in-river to below Bonneville were included in the analysis to correct for the confounding variables identified above. See BA Section 2.1.2.2, Appendix B.2.6-2, and SCA Adult Survival Estimate Appendix for a more detailed description of this methodology.

This methodology is also used to develop standards for adult steelhead, recognizing the limitations/uncertainties of the harvest rate information available at this time. Similarly, this methodology is applied to the available information for Lake Wenatchee and Okanogan River sockeye salmon as a surrogate for adult Snake River sockeye survival. In this analysis, NOAA Fisheries qualitatively assesses the likely survival and effects of the Prospective Actions on migrating adults from these ESUs.

7.2.2 Tributary Habitat Analysis Methods

The approach the Action Agencies used to estimate habitat improvement and survival benefits, which NOAA Fisheries adopts for its analysis, is briefly described here and more fully described in Appendix C of the CA. For the reasons that follow, NOAA Fisheries finds that this approach utilizes the best science available for the task of assessing the effects of actions occurring across the basin, affecting a variety of listed salmonid ESUs/DPSs.

The method to identify the status and potential to improve survival and recovery of listed salmon and steelhead through improvement of tributary habitat conditions is based on an approach developed by the Remand Collaboration Habitat Workgroup (CHW). The CHW convened at the request of the Policy Work Group (PWG), formed as part of the court-ordered remand of NOAA Fisheries' 2004 FCRPS Biological Opinion. The CHW reviewed and updated the method described in Appendix E of the 2004 FCRPS Biological Opinion (NMFS 2004a). The Appendix E method was employed by NOAA Fisheries in 2004 to estimate the potential improvement from habitat mitigation actions. The approach in Appendix E used the best available information at the time to estimate effects of the tributary habitat proposed action for the 2004 FCRPS Biological Opinion. However, additional information has become available from recovery planning and other efforts that have occurred since the 2004 FCRPS Biological Opinion was issued.

The CHW met regularly during the spring and summer of 2006 (See § 2.2.1, Appendix C, Attachment C-1, of Corps et al. 2007a). CHW members included representatives from the sovereign States and

[5] As will be demonstrated in Chapter 8, for some species, transportation of fish as juveniles results in elevated straying rates of returning adults.
[6] Chinook salmon jacks (small, male fish returning to freshwater to spawn after spending only one year in the ocean) were excluded because these smaller fish are not as vulnerable to the fisheries upstream of Bonneville Dam as are the larger 2+ ocean "adult" fish.

Tribes and Federal Agencies involved in the Collaboration process. The CHW consideration of a number of approaches, such as best professional judgment and EDT. Ultimately the CHW developed a process and provided information that could be used to update the Appendix E method from the 2004 FCRPS Biological Opinion. Appendix C of the Action Agencies' CA contains a full description of their approach.

The CHW's approach to estimating habitat benefits relies on the following sequence of steps:

1. Identify the primary factors limiting the recovery of salmon and steelhead populations,
2. Identify the tributary habitat actions (or types of actions) that could be implemented to address those limiting factors,
3. Estimate the current habitat function,
4. Estimate the habitat function that could be obtained by 2018 (within 10 years) by implementing all tributary habitat restoration actions that were identified for implementation by 2018,
5. Estimate the habitat function that could be obtained after 2018 (within 25 years) by implementing all tributary habitat restoration actions that were identified as planned by 2018, and
6. Convert estimated overall habitat functions to survival estimates.

This sequence of steps can produce estimates of the habitat condition and of the potential for salmon survival improvement from habitat actions. Briefly, the logic path began with the identification of individual populations and the population-specific limiting factors. If limiting factors could be further differentiated by subpopulation, the proportional subpopulation area was identified. Then, the degree that actions implemented to address those limiting factors in those areas would improve habitat quality in that subarea was estimated. This logic path provided the basis for estimating changes in habitat function for salmon and steelhead populations as a result of implementing habitat actions. Local biologists provided information for steps 1-5, the products of which the Action Agencies use to complete step 6 based on general habitat/survival relationships developed within the CHW.

This approach is thus based on best available information from local field biologists and recovery planners and general empirical relationships between habitat quality and salmonid survival. Local biologists considered the primary limiting factors identified in recovery planning as well as the tributary habitat actions needed to address those limiting factors. These biologists then estimated the change in habitat function that would accrue if habitat actions were completed as intended. Professional judgment by expert scientists provided a large part of the determination of habitat function in all locations given the limited extent of readily-available empirical data and information. Although NOAA Fisheries recognizes that empirical data and information provides the best insight for determining habitat functioning and salmonid survival, the extent of readily-available empirical data was not adequate to make a precise determination of habitat function and salmonid response uniformly throughout the

Columbia River Basin. NOAA Fisheries finds that the approach developed, and information gathered, through the CHW and subsequently applied here represents the best available information that consistently can be applied over the larger Columbia Basin to estimate the survival response of salmonids to habitat mitigation actions.

The Action Agencies used this method to estimate survival improvement from specific actions completed from 2000 to 2006 and those to be implemented from 2007 to 2009 (see Table 1-6 in Attachment B.2.2-2 to Appendix B of the FCRPS BA [Corps et al. 2007b]). The FCRPS Action Agencies also identified further survival commitments for specific populations which will guide their development of projects to be implemented from 2010-2018. These population-specific survival commitments are identified in CA Appendix C-1, Tables 1-5 (Corps et al. 2007a). Although these future projects have not yet been identified, the resulting estimated survival will be determined during the project selection process using the same approach as described in Appendix C of the CA. The performance of this habitat mitigation program will be measured against these survival commitments.

NOAA Fisheries finds, from available scientific literature on the subject of salmon habitat restoration, that many habitat restoration projects can improve salmon survival over relatively short periods of time. Examples include increases in instream flow, access improvements to blocked habitat and reducing mortality resulting from entrainment at water diversion screens. However, other habitat improvements, such as sediment reduction in spawning gravels and the restoration of riparian vegetation and stream structure, may take decades to realize their full benefit (Beechie et al. 2003). NOAA Fisheries was able to quantitatively or qualitatively consider the post-2018 effect of identified actions proposed for implementation between 2007 and 2009 (Corps et al. 2007a, Appendix C Attachment C-1). In contrast, because the specific habitat projects that will be funded between 2010 and 2018 have not been identified, the type and magnitude of the long-term benefits emerging beyond 2018 cannot be described. NOAA Fisheries recognizes that there will be qualitative improvements that accrue for some populations beyond 2018 even thought the actual benefit cannot be quantified at this time. Nevertheless, NOAA Fisheries expects that future projects will be selected in a similar method as those identified for 2007 through 2009, as the Action Agencies have committed to implement habitat projects that address population-specific limiting factors to achieve identified population survival commitments. The Action Agencies will implement a habitat restoration strategy which will result in both short and longer-term accrual of survival benefits to focus populations. In NOAA Fisheries' analysis it is assumed that for the duration of the Biological Opinion the Action Agencies will continue to implement a mixture of actions which will result in short and long-term accrual of survival benefits to those populations.

NOAA Fisheries' analysis of the effect of the habitat Proposed Actions is based on the assumption that all estimated life-stage and population-specific survival benefits (or ESU/DPS for the estuary) estimated by the Remand Collaboration Habitat Workgroup process will be realized as a result of implementing actions to improve overall habitat quality. NOAA Fisheries' confidence in this assumption is supported by the following observations. First, the application of the general empirically-based relationships between habitat quality and salmonid survival that the CHW method uses to convert improvement in habitat quality into salmonid survival response is a reasonable

approach given the qualitative nature of the information available. Second, the survival improvements estimated to accrue as a result of the Proposed Actions are within the range of potential survival benefits identified in completed or developing recovery plans. NOAA Fisheries' analysis and conclusions are based on those biological survival commitments by the Action Agencies which NOAA Fisheries finds can be achieved through project implementation through 2018.

7.2.3 Estuary Habitat Analysis Methods

Habitat projects in the Columbia River estuary were evaluated for their potential to improve the survival of salmon and steelhead in the estuary, which extends from Bonneville Dam at River Mile 146 to the mouth of the Columbia, including the river's plume. The approach used builds on information in the *Guidance from the Habitat Technical Subgroup of the FCRPS Hydropower BiOp Remand Collaboration for Providing Columbia River Basin Estuary Habitat Action Information*, provided to the Policy Work Group on August 18, 2006 (Habitat Technical Subgroup 2006a).To estimate project-specific survival benefits, each project was linked to a recommended recovery action which addressed significant limiting factors in NOAA Fisheries' draft *Columbia River Estuary Recovery Plan Module* (NMFS 2006b), and then evaluated in terms of the project's relative contribution to complete implementation of the recommended recovery action. The evaluation included baseline projects (those completed between 2000 and 2006), current projects in various stages of development (2007 through 2009), and future anticipated projects not yet identified (years 2010 through 1017). The approach used to estimate habitat improvement and survival benefits is fully described in Appendix D, Attachment D-1 of the CA. The projects are described in the CA, Appendix D, Attachment D pages D-1-7-10.

7.2.4 Hatchery Methods

Qualitative and quantitative assessments for analyzing hatchery effects are used in this Supplemental Comprehensive Analysis.

7.2.4.1 Qualitative Assessments of Hatchery Effects

Available information, including NOAA Fisheries' Salmonid Hatchery Inventory and Effects Evaluation Report (SHIEER [NMFS 2004b]), the Hatchery Effects Appendix, and NOAA Fisheries' Artificial Propagation for Pacific Salmon Appendix were used to provide qualitative assessments of every hatchery program located in the Columbia Basin, including programs in the lower Columbia and Willamette Rivers.

7.2.4.2 Quantitative Assessment of Hatchery Effects

The hatchery benefits estimation methodology is described in Stier and Hinrichsen (2008), which is included as Attachment 1 of Quantitative Analysis of the Hatchery Actions Appendix. This methodology was quantitatively applied to assess hatchery effects on the UCR steelhead DPS and on SR spring/summer Chinook in the Grande Ronde MPG. The following considerations are important for using the Stier and Hinrichsen (2008) methodology and are used by NOAA Fisheries to estimate

changes in natural productivity from hatchery reform actions for Upper Columbia River steelhead, Upper Columbia River spring Chinook and Snake River spring/summer Chinook salmon.

The Stier and Hinrichsen (2008) methodology:

- is most useful when direct measures of natural productivity are not available,
- estimates changes in productivity for natural-spawning hatchery fish, and not naturally-spawning, natural-origin fish,
- is particularly sensitive to the quality and quantity of spawner composition data (i.e., the number and proportion of natural spawners comprised of hatchery-origin and natural-origin fish) and to natural-origin and hatchery-origin natural spawner spatial and temporal distribution data,
- assumes density-independent population dynamics,
- should not be used to estimate prospective changes in natural productivity when hatchery reforms are not reasonably certain to occur. Reforms included in NOAA Fisheries' approved Tribal Resource Management Plans, Hatchery and Genetic Management Plans, and Endangered Species Act Section 10 permits or Section 7 consultations are considered reasonably certain to occur,
- does not account for genetic and ecological effects on natural productivity from naturally spawning hatchery-origin fish quantitatively, so NOAA Fisheries will describe these factors qualitatively in the effects analysis (Chapter 8) for each species, and
- recognizes and accounts for limiting factors that reduce or preclude the potential for hatchery reform to increase natural productivity (see Artificial Propagation for Pacific Salmon Appendix). For example, hatchery supplementation may offer little potential to increase the number of recruits and establish a trend toward recovery if the quality and or quantity of spawning habitat is limiting natural productivity.

Where natural-origin fish (NOF) and hatchery-origin fish (HOF) spawn naturally, estimating the natural productivity of a population requires estimates of the proportion of natural spawners comprised of HOF, and the relative effectiveness of HOF. Information on historical natural spawner composition is provided by the ICTRT and is used in the Quantitative Analysis of Hatchery Effects Appendix estimates. Berejikian and Ford (2004) provide the basis for hatchery effectiveness estimates and the Quantitative Analysis of Hatchery Effects Appendix also uses results from Araki et al. (2007a).

Four categories, based on broodstock management scenarios, are used for determining HOF effectiveness relative to NOF:

Category 1 includes non-local domesticated broodstock, HOF<30% as effective as NOF,

Category 2 hatchery broodstock is comprised almost exclusively of local-origin NOF broodstock, HOF 90-100% as effective as NOF,

Category 3 includes local-origin NOF and HOF broodstock, <30% (6-45% based on Araki et al. 2007a) as effective as NOF,

Category 4 includes captive and farmed broodstocks.

7.2.5 Predation Methods

7.2.5.1 Tern Predation Analysis Methods

The estimated benefit of reducing predation on juvenile salmon and steelhead by Caspian terns on East Sand Island was calculated by modeling a reduced prospective tern population level. This prospective population was based on the 'Future 2' population objective, or 3,125 breeding pairs established in the 2005 *Caspian Tern Management to Reduce Predation of Juvenile Salmonids in the Columbia River Estuary FEIS* (USFWS 2005) The effect of reducing tern predation was estimated at the ESU level since insufficient information was available at the level of the individual population. A more detailed treatment of the method used to estimate the benefit of reducing Sand Island tern predation is presented in Chapter 3 and Appendix F, Attachment F-2 of the CA.

Any estimate benefit of reduced tern predation is sensitive to assumptions about the additive or compensatory nature of mortality from tern predation. The projected benefits identified in the CA (Appendix F) assume complete additivity (no compensatory mortality), i.e., every salmonid not consumed by terns survives all other sources of mortality. However, if some portion of the tern's predation consists of salmonids predestined to die as a result of illness, poor condition or other predators, the survival improvements modeled above would need to be reduced accordingly to estimate the actual survival improvements from tern relocation. Since current literature and empirical data do not identify more specific estimates or ranges, NOAA Fisheries assumes that tern predation likely falls between being completely additive or completely compensatory (Roby et al. 2003). Consequently, in estimating the effect of reducing tern predation NOAA Fisheries assumed a hypothetical compensatory mortality of 50% (Roby et al. 2003).

7.2.5.2 Pikeminnow Predation Analysis Methods

To assess the likely effect (current-to-prospective survival adjustments for juvenile salmon and steelhead) of continuing the expanded Northern Pikeminnow Management Program (NPMP) on salmon and steelhead populations, NOAA Fisheries uses the methodology described in CA Appendix F-1.1. This methodology relies on the Oregon Department of Fish and Wildlife's evaluations of the effectiveness of the NPMP to date and on modeling (consistent with the general assumptions and model parameters used in evaluating the cumulative benefits of the NPMP) the juvenile salmon survival benefits associated with implementing an increased incentive program (Prospective Predation Management Action 1 – BA Section 2.6.1). The general approach employed by NPMP analysts involves applying an appropriate northern pikeminnow consumption rate on juvenile salmonids (temporally and spatially) to the number of additional northern pikeminnow removed (temporally and

spatially) to determine "number of smolts" not eaten. This provides an indication of potential incremental benefit of increased removals, assuming no significant inter-or intra-specific compensation.

7.2.5.3 Marine Mammals Predation Analysis Methods

The method NOAA Fisheries uses to assess the likely effect (base-to-current survival adjustment) of marine mammal predation on adult salmon and steelhead in the Bonneville Dam tailrace is described in NMFS 2007e. The analysis generally relies on estimates of annual consumption made by Robert Stansell (Corps) reported in WDFW et al. (2006) updated with 2007 estimates and fishway counts of Chinook salmon and steelhead at Bonneville Dam through May 31. Based on the effectiveness of management actions taken to date, NOAA Fisheries assumes Predation Management Action 7 (Corps et al. 2007 Section 2.6.3) to limit or reduce the potential for sea lion predation in the future will prevent increases above current levels in the future (i.e., the current-to-prospective adjustment is zero).

7.2.6 Methods for Evaluating the Effect of RM&E Actions

The research and monitoring Prospective Actions which will be implemented to ensure hatchery-and habitat-based RM&E actions are comparable (and often identical) to those analyzed in several recently completed scientific research and enhancement biological opinions (NMFS 2004a; NMFS 2005f, 2005g, 2005h, 2005i, 2005j, 2005k, 2005l, 2005m; NMFS 2006f and 2006g). NOAA Fisheries used these analyses within these Biological Opinions as a basis for evaluating the effects of the research and monitoring actions covered in the habitat and hatchery Prospective Actions. Similarly, hydro-related RM&E Prospective Actions are likely to be qualitatively and quantitatively similar to hydro RM&E activities that occurred in 2007 and their effects are likely to be nearly identical to the level of injury and mortality authorized in 2007.

7.3 Methods for Considering Population Level Analysis at ESU/DPS level

The Jeopardy and Metrics memos outline NOAA Fisheries' expected technical considerations in making its jeopardy determination in biological opinions that reference this Supplemental Comprehensive Analysis and state in part:

> In the end, NOAA Fisheries will exercise its best scientific and professional judgment as to whether the mitigation measures are sufficient to reasonably expect that: (1) the ESUs currently on a trend toward recovery will maintain that trend, and (2) ESUs not currently on such a trend will be started on such a trend. [NMFS 2006h]

Additionally, NOAA Fisheries considers that:

> [t]he ESA requires the jeopardy determination to be made at the ESU level. NOAA Fisheries will consider metrics and other information relevant to the population and major population group (MPG) in making a jeopardy determination for an ESU. [NMFS 2006h]

Consistent with this, NOAA Fisheries evaluated all information at the population and MPG level in its ESU level determination, including the TRT products and other relevant scientific information (NMFS 2006h). Both the Willamette/Lower Columbia and Interior Columbia TRTs, when considering long term recovery goals, recommended that for an ESU/DPS to be considered at low risk of extinction (and therefore viable), all MPGs in that ESU/DPS should be at low risk.

Based on these TRT recommendations, other information and the two guidance memos cited above, NOAA Fisheries considered the population level analyses described earlier in this chapter in assessing the trend of each MPG. For this jeopardy analysis, NOAA Fisheries considered an MPG to have a trend toward recovery if a sufficient number of populations within the MPG have a trend toward recovery.

NOAA Fisheries has determined that it may not be necessary for all of the populations to have a trend toward recovery in order for an MPG to have a trend toward recovery, and likewise, it may not be necessary for all of the MPGs to have a trend toward recovery in order for the ESU/DPS as a whole to be on such a trend. In other words, there is more than one combination of populations and MPGs at various risk levels and trends that constitutes an ESU/DPS on a trend toward recovery. In making this determination, NOAA Fisheries considered all factors, including the importance of each population in the ESU/DPS, the strength of each population, and the presence of safety net programs.

In its assessments, NOAA Fisheries considered the aggregated effects of the environmental baseline, cumulative effects and the Prospective Actions, using quantitative analyses at the population level as well as qualitative considerations. NOAA Fisheries also identified any limiting factors (i.e., threats) at the population level likely to be affected by the Prospective Action.

For species with sufficient data, NOAA Fisheries first describes the performance of each population within an MPG with respect to quantitative and qualitative indicators of short-term extinction risk and a trend toward recovery under the Prospective Actions. If there are differences in performance by population, we review the relative importance of each population to the MPG and ESU, based primarily on information from TRTs and recovery planning documents. For example, some populations may be particularly important because of unique life history characteristics, while others may be important because they are relatively large populations that represent the main repositories of fish in a given area.

The degree to which each population and MPG is individually analyzed varies with the species, due to varying amounts of relevant information as described in previous sections. In general, this process has resulted in more detail for most interior Columbia populations than for lower Columbia populations and Snake River sockeye salmon due to available information and degree of the impact of the FCRPS on the populations.

NOAA Fisheries considers additional factors in evaluating whether the Prospective Actions avoid jeopardy for each species:

- If a particular VSP factor is not expected to be sufficiently addressed by the Prospective Actions, is this because it is affected by a long-term listing factor or threat that will require many years to correct? Correcting some problems may in fact take many generations. In this case, NOAA Fisheries considers whether the Prospective Actions are addressing this factor, and if the level of effort is reasonable in the context of what is feasible to accomplish during the next 10 years.
- If it is unlikely that all important populations in an MPG will have low short-term extinction risk and be on a trend toward recovery under the Prospective Action, is the Prospective Action providing higher benefits for other populations in the MPG to help offset the poorer-performing populations?

In evaluating the likelihood that an ESU will survive and trend toward recovery, NOAA Fisheries has been informed by the descriptions and priorities of the TRTs and other sources. Ultimately, NOAA Fisheries relies on its own judgment to determine if the aggregated effects of the Prospective Actions, environmental baseline, and cumulative effects result in the ESU as a whole, meeting those standards.

One comment on the 2007 Draft Biological Opinion recommended that the jeopardy determination be dependent on achieving MPG viability scenarios recommended by the ICTRT. While NOAA Fisheries considered these scenarios, they were presented by the ICTRT as one possible way of achieving long-term recovery goals and not as the sole method of doing so. They also represent long-term viability scenarios, rather than a product intended to be used in reaching jeopardy determinations.

7.4 Critical habitat analysis methods

The ESA requires, in part, that the Prospective Actions are not likely to result in the destruction or adverse modification of designated critical habitat. ESA § 7(b)(3)(A), see Section1.7 above.

This section describes how NOAA Fisheries determines that the Prospective Action meets this requirement. The value of the species' habitat for their conservation, resulting in their recovery and delisting, is a guiding factor in the designation of critical habitat and therefore also in assessing any destruction or adverse modification. 16 U.S.C.A § 1532(5)(A).

The factors that directly influence the conservation value of critical habitat, and thus are relevant to NOAA Fisheries' assessment of the status of critical habitat within the action area, are the essential physical and biological features of that habitat. These include substrate, water quality, water quantity, water temperature, food, riparian vegetation, access, water, velocity, space, and safe passage.

The specific habitat requirements for each species differ by life history type and life stage. These are described in more detail for each species in Sections 8.2 through 8.14. NOAA Fisheries uses the following framework for analyzing the effects of a Prospective Action on designated critical habitat for each species (NMFS 2005n).

Status of Designated Critical Habitat—Rangewide and Under the Environmental Baseline [7]

- Identify and describe the primary constituent elements of designated critical habitat for each species.
- Describe the conservation role that the designated critical habitat provides in terms of its primary constituent elements (PCEs) referring to available recovery plans and recovery planning materials.
- Describe the current pre-Prospective Action condition of designated critical habitat relative to the functionality of its PCEs as needed to support the species' near term survival and long term trend toward recovery.

Cumulative Effects

- Describe beneficial and adverse effects of non-Federal actions that are reasonably certain to occur relative to the functionality of PCEs needed to support the species' near term survival and long term trend toward recovery.

Effects of the Proposed Action

- Describe both the beneficial and adverse effects of the Prospective Action, including its mitigation measures, on PCEs and how they will influence PCE function and the conservation role of the various critical habitat areas affected.
- Describe the nature, distribution, magnitude, duration, timing, intensity, frequency, and proximity of the effects and relate these to the species' life history characteristics and requirements.
- Describe the resulting trend of PCEs, including short-term degradations that are eventually offset by mitigation actions.
- Evaluate the certainty of any Prospective Actions intended to improve PCE function and the consequence for the species of any delay expected in their implementation.
- Consider the effects of the action on the success of future recovery planning, i.e., determine whether the Prospective Action limits options available for future recovery planning.

Synthesis and Conclusion

- Describe the aggregate effects of the environmental baseline, cumulative effects and the Prospective Action on PCE function and the conservation value of critical habitat.
- After implementation of the action, would critical habitat remain functional (or retain the current ability for the PCEs to become functionally established) to serve the intended conservation role for the species in the near and long terms?

[7] For the interior species, the action area encompasses almost all designated critical habitat of the species. Therefore, the description of the status of critical habitat in the action area is the same as that for all designated critical habitat.