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UNITED STATES DISTRICT COURT
DISTRICT OF OREGON
PORTLAND DIVISION

NATIONAL WILDLIFE FEDERATION, et al.,

Plaintiffs,

v.

NATIONAL MARINE FISHERIES SERVICE, et al.,

Defendants.

Case No.: 3:01-CV-00640-SI

2015 DECLARATION OF CHRISTOPHER TOOLE, Ph.D. NATIONAL MARINE FISHERIES SERVICE, WEST COAST REGION
In support of Federal Defendant's' Cross-Motion for Summary Judgment

I, Christopher Toole, declare and state as follows:

1. I am a fisheries biologist with the National Marine Fisheries Service (NMFS), in the West Coast Region (WCR), which includes the states of Oregon, Washington, Idaho and Montana, in addition to California. I have worked for NMFS on the impacts of hydropower operations and other human activities on salmon and steelhead since 1991. My previous assignments have included serving as a Team Leader and as Acting Assistant Regional Administrator in the former Northwest Region's Hydro Division and serving as the Northwest Region's Endangered Species Act (ESA) Section 7 Coordinator. I currently work for the WCR Deputy Regional Administrator on special assignments, including serving on the WCR Section 7 Team, leading the WCR Climate Team, and, from 2012-2014, assisting with development of the Federal Columbia River Power System (FCRPS) Supplemental Biological Opinion ("2014 Supplement").

2. I have a Ph.D. in fisheries science from Oregon State University, awarded in 1994. I obtained a B.A. in biology from the University of California, Santa Barbara, in 1973, a B.S. in fisheries biology from Humboldt State University in 1975, and a masters degree in biology from Humboldt State University in 1978. My masters and doctoral research and peer-reviewed publications concern marine fisheries.

3. For NMFS, I have participated in each ESA consultation concerning the FCRPS since Snake River sockeye salmon were listed in 1991. During the most recent consultation, my principal assignment was to collect information, obtain analysis and scientific opinion from all relevant sources, and provide contributions for the drafting of the final 2014 Supplement.

4. I previously provided declarations in support of the 2008 FCRPS Biological Opinion ("2008 Biop") on October 24, 2008 ("Toole 2008 Declaration"), and on December 12, 2008 ("Toole 2008 Reply Declaration").

5. In preparation for this declaration, I have reviewed NMFS' Supplemental Comprehensive Analysis (SCA), the 2008 Biop, the FCRPS 2010 Supplemental Biological Opinion ("2010 Supplement"), the 2014 Supplement, and supporting materials for these documents. Additionally, I reviewed the declarations filed on behalf of the plaintiffs' motions for summary judgment by Mr. Anthony Nigro, Dr. Brendan Connors, and Mr. Frederick Olney.

6. This declaration is also based on information provided and analyses prepared by NMFS biologists in the Northwest Fisheries Science Center and the WCR Interior Columbia Basin Area Office. The purpose of this declaration is to address technical issues raised by the above declarants concerning the 2014 Supplement's description of rangewide status of interior Columbia Basin salmon and steelhead and the efficacy of the 2014 Supplement's RPA actions.

7. In this declaration I address the following topics:

1) NMFS Appropriately Calculated and Applied Information Regarding Density Dependence In Reaching a Conclusion That the Status of Interior Columbia River Species Has Not Changed, Compared To the Status Description in the 2008 Biop.

2) The Majority of Survival Improvements That NMFS Relied Upon in the 2008 Biop Analysis Are Expected to Occur in Life Stages Encompassed by the Smolt-to-Adult Return (SAR) Metric, Not In Life Stages Residing in Tributary Habitat.

3) The Relative Mortality Caused By the FCRPS, Compared To Other Sources of Human-Caused Mortality, Is Highly Uncertain

4) NMFS Continues To Rely On ICTRT Recovery Abundance Thresholds As the Best Available Information Regarding Population Abundance Required for Delisting

5) The 2014 Supplement Correctly Describes the Current Risk Faced By Interior Columbia Salmon and Steelhead Species

6) New Information Regarding Snake River Steelhead Does Not Affect Estimates of Habitat Quality Improvements. The Impact of This New Information On Snake River Steelhead

Productivity Is Uncertain, Possibly Resulting In Some Populations Having Higher Productivity and Some Lower Productivity Than Estimated in the 2008 Biop.

I. NMFS APPROPRIATELY CALCULATED AND APPLIED INFORMATION REGARDING DENSITY DEPENDENCE IN REACHING A CONCLUSION THAT THE STATUS OF INTERIOR COLUMBIA RIVER SPECIES HAS NOT CHANGED, COMPARED TO THE STATUS DESCRIPTION IN THE 2008 BIOP.

8. Dr. Connors states that he was "asked to review Appendix C" of the 2014 Supplement[1] "and the discussion in that Opinion related to Appendix C" (Connors ¶ 3). In this section of my declaration I will describe the purpose and results of the Appendix C (Exhibit 1; 2014 Corps AR4) density-dependence analysis and the discussion in the 2014 Supplement related to the Appendix C analysis. I then review Dr. Connors' declaration and point out that he does not dispute the methods or conclusions of the Appendix C density dependence analysis, and he does not discuss or dispute the discussion in the 2014 Supplement related to Appendix C. Instead, he raises a different issue regarding the efficacy of tributary habitat improvements called for in the 2014 Supplement's reasonable and prudent alternative (RPA) based on the hypothesis described in his declaration, ¶¶ 10-18, which is reviewed in Dr. Zabel's declaration.

A. PURPOSE AND RESULTS OF THE 2014 SUPPLEMENT'S APPENDIX C DENSITY-DEPENDENCE ANALYSIS

9. Appendix C supports a review in the 2014 Supplement of new information "to determine if the updated status of interior Columbia basin salmonids differs from our understanding in the 2008 BiOp. If there is change in the species status, a second step would be to determine if that change reveals effects of the action that may affect the listed species in manner or to an extent not previously considered" (2014 Biop:45). Methods of conducting this review are described in Section 2.1.1.1 (2014 Biop:45-69).

[1] Please note that this Appendix C to the 2014 Supplement is different than the Comprehensive Analysis Appendix C, 2014 NOAA B422:45179-45222, which addresses tributary habitat improvements and is cited extensively in the 2014 Supplement.

10. One of the methods applied new estimates of adults returning to spawning grounds to update the 2008 Biop's "Base Period"[2] calculations of population-level jeopardy indicator metrics[3] (2014 Biop:46). The 2014 Supplement described the indicator metrics (24-year extinction risk and three measures of productivity), the method of calculating each metric, treatment of uncertainty in the calculations, the method of updating the 2008 Biop's estimates, and the method of determining if the updated estimates represent a change from the 2008 Biop's estimates (2014 Biop:47-69). An important point regarding the definition and calculation of indicator metrics is that these Base Period estimates are reliant on observed, empirical data – not on estimates of future population performance that are expected to occur as a result of recent changes in management actions or implementation of the 2008 Biop's RPA. In particular, they do not include projections of the effects of tributary habitat improvements, which Dr. Connors refers to in his ¶ 17.

11. Section 2.1.1.5 of the 2014 Supplement presents the comparison of Base Period and Extended Base Period indicator metrics (2014 Biop:73-108). In general, extinction risk declined

[2] The "Base Period" years of empirical observations described in the 2008 Biop included parental spawning years ("brood years") through the most recent available year of 1998, 1999, or 2000, depending upon population, and returns of progeny as adults through 2003, 2004, 2005 or 2006, depending upon population (Table 2.1-3, 2014 Biop:77-78). New empirical information available for the 2014 Supplement allowed calculation of updated indicator metrics over an "Extended Base Period" that included 5 to 8 additional years (2014 Biop:77-78) for the original populations considered in the 2008 Biop.

[3] "Population-level jeopardy indicator metrics are quantitative metrics (calculated numbers) indicative of the 2008 BiOp's application of the jeopardy standard, as described in Section 1 of this Supplemental Opinion and Section 7.1 of the 2008 BiOp, and in the following subsections. The 2008 BiOp considered the quantitative metrics and other relevant data in making a qualitative judgment on whether the RPA is likely to jeopardize six interior Columbia species or adversely modify critical habitat. Each metric and consideration—like average abundance—shows something relevant to the inquiry. All factors, including abundance data, inform a qualitative assessment of the survival and recovery prongs of the jeopardy standard." 2014 Biop:47.

(2014 Biop:84-88); average abundance[4] increased (2014 Biop:79-83); productivity measured by the BRT abundance trend generally increased (2014 Biop:104-108); productivity measured by the median population growth rate (lambda) generally decreased for Chinook and either generally increased or was mixed for steelhead, depending upon hatchery-related assumptions (2014 Biop:94-103); and productivity measured by average returns-per-spawner[5] (R/S, also referred to as recruits-per spawner) generally declined (2014 Biop:89-93). To summarize, "abundance and extinction risk both show that most populations are improving, while average productivity indicates a decline" (2014 Biop:109).

12. If all metrics had increased or decreased together the interpretation would be obvious, but because some improved while others declined, NMFS examined the issue more closely to determine why the trends were mixed. (2014 Biop:67). NMFS expected annual variation in

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[4] Although not an indicator metric, abundance is the starting point for all other calculations and 10-year geometric mean abundance is a recovery metric reported in NMFS Status Reviews and previously presented in the 2008 Biop, and 2010 Supplement. (2014 Biop:54-55; 2014 NOAA C034293:288224-288225). NMFS considered abundance in all five steps of the jeopardy analysis (Toole 2008 Declaration ¶¶ 8-16; Toole 2008 Reply Declaration ¶ 21).

[5] Returns (or recruits) per spawner, R/S, is a per-generation productivity metric that determines whether a population is maintaining itself, declining, or growing (2008 BiOp at 7-22 to 7-24; 2014 Biop:61-64). Self-maintenance is a key part of the definition and it is the reason this indicator metric was given special consideration in the 2008 Biop (p. 7-23): "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" (emphasis added). A population can grow even if R/S is less than 1.0 if "there is an additional source of spawners; e.g., from straying or hatchery programs" (2014 Biop:61), but such a population would not be considered "self-sustaining." All sources of mortality prior to adults reaching spawning tributaries are included in the R/S calculation applied in the 2008 Biop and in the updated status sections of the 2010/2014 Supplements. (2008 Biop at 7-20, "All three [recovery prong] metrics encompass the entire life cycle..."). However, in Appendix C, R/S was calculated both in the usual manner and with the number of "recruits" adjusted to "represent the number of naturally-produced fish that would have appeared on the spawning grounds had there not been a harvest" (Exhibit 1, p. 8). The purpose of this harvest adjustment was to better examine the underlying productivity function, in the absence of differential harvest rates across time periods. As discussed in Appendix C (Exhibit 1, p. 36), the density dependence parameter (Ricker "*b*" term) was nearly identical using each approach, so this difference in methods did not affect the results or conclusion of the analysis.

abundance and productivity based on the historical record (2010 Biop, Section 4, p. 8), and the 2014 Supplement demonstrates annual variation in abundance (Figure 2.1-23; 2014 Biop:111) and productivity (Figure 2.1-24; 2014 Biop:112) for multiple populations over the last 30 years. Some of that variation is a response to natural variability in the freshwater and marine environment and measurement error (2014 Biop:66), but there is also a distinct pattern in that variability. When the abundance of spawners is high (e.g., 2001-2004 spawner abundance in Fig. 2.1-23), productivity is generally low (e.g., R/S for brood years 2001-2004 in Fig. 2.1-24). When both abundance and productivity are combined for a given population, a pattern known as a "stock-recruit function" (Exhibit 1, p. 4) shows that R/S is high when abundance is low and R/S is low when abundance is high (e.g., Figure 2.1-25; NMFS000114). As stated in Appendix C, (Exhibit 1, p.4), "stock-recruit functions predict interference or competition for resources at high abundance, which reduces the number of recruits produced per spawner, compared to the productivity at low abundance and density." The 2014 Biop at 67 points out that "Such density-dependent mortality in Pacific salmonids is a well-established principle in fishery population dynamics (e.g., Ricker 1975; Hilborn and Walters 1992; Zabel et al. 2006)." This pattern was previously described in the 2008 Biop and the 2010 Supplement: "Variations in annual abundance and productivity were anticipated in the 2008 BiOp – in particular, Chapter 7.1 described the expectation that productivity would decline as abundance increased based, in part, on density dependence. These variations are expected to continue in the future and to fluctuate both positively and negatively." (2010 Biop, Section 4, p. 3).

13. The purpose of Appendix C was to provide a formal analysis of the effects of spawner density on productivity, as measured by the R/S metric. (2014 Biop:68). Specifically, the

purpose was to statistically test “whether the pattern of ln(R/S)[6] versus spawner abundance during the Base Period was consistent with a density-dependent model commonly used in fisheries management (Ricker 1954), and whether the new estimates contributing to the Extended Base Period were within the prediction limits generated from the model using the Base Period data. If so, the new R/S estimates can be considered consistent with the Base Period R/S estimates for a given abundance of spawners.” In other words, this analysis could test whether average R/S productivity declined because there were fewer returning adults-per-spawner at all spawner abundance levels (including at the lower spawner abundance levels for which productivity had previously been estimated), or because of the occurrence of a few unusually high abundance years (compared to the Base Period observations and, for several populations, compared to ICTRT abundance thresholds), which had lower productivity as expected, reducing the average productivity for the longer time period.

14. NMFS determined that density dependence effects could be demonstrated statistically for most populations and that addition of Extended Base Period data did not result in a decline in productivity for a given number of spawners, compared to the Base Period. Appendix C included detailed analytical methods and results showing that 20 of 26 Chinook populations and 18 of 18 steelhead populations demonstrated statistically significant density-dependent relationships (Exhibit 1, p. 9; 2014 Biop:115). When the more recent data points were plotted against the 95% prediction intervals for populations with significant Base Period relationships, only one Chinook

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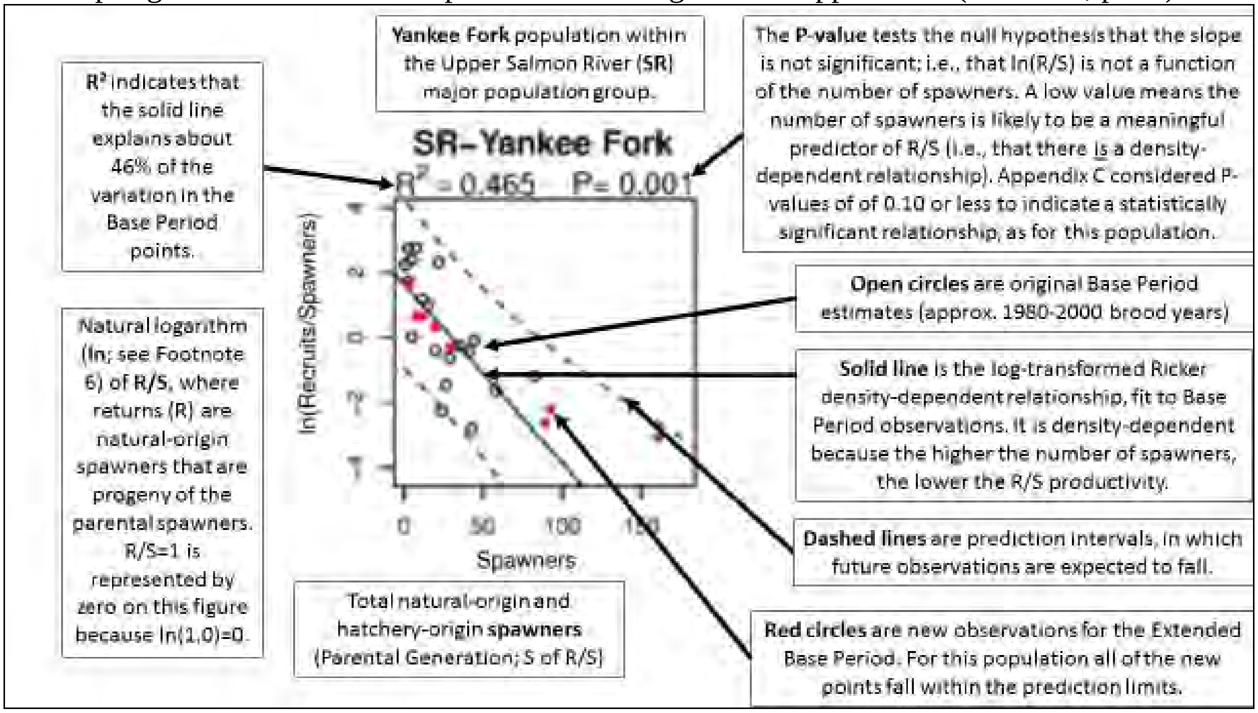
[6] “ln” refers to the natural logarithm of R/S. This logarithmic transformation is used in Appendix C because it converts the curvilinear Ricker density-dependence relationship (e.g., Ricker 1975, NOAA 2014 B350:36792) to a linear form, which makes it easy to fit to data using standard linear regression techniques (Exhibit 1, p. 8-9). Technically, the natural logarithm of any number (x) is the power to which the constant e (approximately 2.718) would have to be raised to equal x. For example, when R/S = 1.0, ln(R/S) = 0; when R/S is less than 1.0, ln(R/S) is a negative number (e.g., R/S = 0.9, ln(R/S) = -0.105); and when R/S is greater than 1.0, ln(R/S) is a positive number (e.g., R/S = 1.2, ln(R/S) = +0.18).

point fell below the interval and four points fell above, "providing no support for the hypothesis that recent conditions are less productive than those experienced during the Base Period" for Chinook populations (Exhibit 1, p. 9; 2014 Biop:115). Only three steelhead points fell below the prediction intervals and 14 points fell above, providing "little support for the hypothesis that recent conditions are less productive than those experienced during the Base Period" for steelhead populations (Exhibit 1, p. 9, 10; 2014 Biop:115). When all results were considered in the Appendix C "Discussion" section, the authors concluded that they provided "strong support for the hypothesis that productivity has not decreased for these populations when comparing base to recent time periods but that the decreased R/S resulted from density-dependent processes as a result of the increased abundance observed recently (Tables 1-2, Figures 5-8)" (Exhibit 1, p. 10).

15. Figure 1 shows a plot of results from the Appendix C analysis for one population (the Yankee Fork population of Snake River spring/summer Chinook), with annotations to better explain the figure and the terminology. This plot was included along with others as Figure 2 of Appendix C (Exhibit 1, p. 16) and was reproduced as Figure 2.1-27 in the 2014 Supplement (2014 Biop:117). For this population, the density-dependent relationship (i.e., the solid line showing decreasing R/S productivity with increasing spawner abundance) fit to Base Period observations was statistically significant (i.e., the P-value was less than 0.10; see Exhibit 1, p. 9). When the new observations from recent years were added, all fell within the statistical prediction intervals for the Base Period density-dependent relationship. Because the points fell within the prediction intervals, the Yankee Fork is an example of a population that illustrates the Appendix C conclusion that recent conditions are not less productive than during the Base Period.

Figure 1. Annotated result of Appendix C analysis for the Yankee Fork population of Snake River spring/summer Chinook. Reproduced from Figure 2 of Appendix C (Exhibit 1, p. 16).



B. DISCUSSION OF THE APPENDIX C DENSITY-DEPENDENCE ANALYSIS IN THE 2014 SUPPLEMENT

16. The discussion of Appendix C in the 2014 Supplement, is found in Section 2.1.1.8 (2014 Biop:129-134); see also (2014 Biop:115-19). There, the results are listed as one of several factors supporting the conclusion that, “Additional years of data and new analyses provide support for NOAA Fisheries’ continued reliance on the 2008 BiOp’s description of the rangewide status of these species and the Base Period metrics applied in the 2008 BiOp’s quantitative aggregate analysis.” (2014 Biop:129). The only other mention of the 2014 Supplement’s Appendix C is a short summary in the Conclusions section:

> The pattern of lower R/S productivity in some high abundance years was consistent with expectations of density dependence described in the 2008 BiOp and in the 2010 Supplemental BiOp. The NWFSC statistically tested this interpretation and concluded that there is strong support for the hypothesis that productivity has not decreased for these populations when comparing base to recent time periods; rather, the decreased R/S resulted from density-dependent processes as a result of the increased abundance

observed recently (see Section 2.1.1.4.4 and Appendix C in this document). (2014 Biop:464).

C. DR. CONNORS' REVIEW OF APPENDIX C AND THE 2014 SUPPLEMENT'S DISCUSSION OF THE ANALYSIS

17. Dr. Connors includes only a limited discussion of Appendix C, which does not dispute the methods or results of that analysis. Dr. Connors' review of Appendix C consists of one sentence describing the analysis ("...a formal analysis of density dependence using currently available information on spawner abundance and corresponding recruits per spawner;" Connors ¶ 9); two sentences directly citing the Appendix C conclusions (Connors ¶ 9); and one phrase that acknowledges "the density dependence that NOAA identifies in Appendix C" (Connors ¶ 15). There is no other mention of Appendix C in the declaration. Notably, Dr. Connors' declaration does not discuss or dispute the methods applied in the Appendix C analysis, the results of the analysis, or the conclusions of the analysis. Specifically Dr. Connors does not dispute or comment at all on the Appendix C conclusion that there is strong support for the hypothesis that productivity has not decreased for Chinook populations between the Base and more recent time periods and the conclusion that there is no support for the hypothesis that recent conditions are less productive for steelhead than those experienced during the Base Period.

18. Dr. Connors' declaration does not appear to actually review the 2014 Supplement's "discussion of Appendix C." Although he cites and confusingly paraphrases ("In other words...") some language in the 2014 Supplement in his "Background" ¶ 9, his "Discussion" section never discusses or analyzes the manner in which NMFS describes or applies the results of the Appendix C density dependence analysis in the 2014 Supplement. Specifically, there is no mention and no critique in Connors' ¶¶ 10-15 of NMFS' comparison of productivity during two time periods (Base Period and Extended Base Period), its conclusion that productivity did not

change between those periods, and its reliance on the Appendix C density dependence analysis as support for this conclusion. He introduces a tangential hypothesis regarding the efficacy of tributary habitat improvements (see declarations of Dr. Zabel and Mr. Tehan), but never explains how this hypothesis might influence the 2014 Supplement's discussion of Appendix C or relate to the 2014 Supplement's conclusion of no change in productivity between the two time periods, which relied in part upon the analysis in Appendix C.

19. In short, Dr. Connors does not meaningfully dispute NMFS' conclusions and merely introduces a new hypothesis that, as Dr. Zabel explains, is not supported by empirical observations. NMFS' conclusion that increasing abundance in some of the recent years decreased the average R/S productivity metric as a result of density dependence is consistent with previous demonstrated relationships and is supported by the data and Appendix C's statistical analysis. Nothing in Dr. Connor's declaration provides a meaningful basis to question the conclusions in Appendix C or the treatment of the Appendix C results in the 2014 Supplement.

II. THE MAJORITY OF SURVIVAL IMPROVEMENTS THAT NMFS RELIED UPON IN THE 2008 BIOP ANALYSIS ARE EXPECTED TO OCCUR IN LIFE STAGES ENCOMPASSED BY THE SMOLT-TO-ADULT RETURN (SAR) METRIC, NOT IN LIFE STAGES RESIDING IN TRIBUTARY HABITAT

20. In this section of my declaration I describe statements of Mr. Nigro and Dr. Connors, which imply that the 2008 Biop's tributary habitat improvement actions are inadequate, based on results of Mr. Nigro's introduced SAR analyses and Dr. Connors' hypothesis regarding causes of density dependence. Putting aside technical issues questioning the validity of Mr. Nigro's analysis and Dr. Connors' hypothesis, as described in Dr. Zabel's declaration, I point out that the supposed problem they describe is not relevant for two reasons. First, the goals they claim that the 2008 Biop's tributary habitat actions fail to meet are in all but one case related to achieving

full recovery and delisting, not to avoiding jeopardy for the action under consultation. The single case in which one of Mr. Nigro's goals corresponds to a 2008 Biop jeopardy metric does not contradict results in the 2014 Supplement, although it does potentially leave a false impression through omission. Second, the management action they describe (sole reliance, or a "focus," on tributary habitat actions) that purportedly fails to achieve the described management goals, does not represent the RPA or other management actions relied upon in the 2008 Biop. For all but one population, the survival improvements relied upon in the 2008 Biop analysis are greater for life stages that occur outside of tributary habitat (i.e., life stages encompassed by the SAR metric) than for life stages expected to occur within tributary habitat. The analysis of the one population, for which the 2008 Biop anticipates the greatest survival improvements from tributary habitat actions, relies upon survival improvements that are distributed approximately equally between life stages occurring within and outside of tributary habitat.

A. MR. NIGRO'S SAR ANALYSES COMPARE PERFORMANCE TO RECOVERY GOALS, RATHER THAN GOALS RELEVANT TO THE JEOPARDY ANALYSIS; OR, THEY SIMPLY RE-CAST INFORMATION ALREADY PRESENTED IN THE 2014 SUPPLEMENT

21. Mr. Nigro describes in ¶¶ 23-44 and his Appendix A, a method of calculating the smolt-to-adult return (SAR) survival rates that would be needed to achieve a specified abundance target. He presents the results of three analyses applying that methodology to 10 Snake River spring/summer Chinook populations and to the unlisted Warm Springs population of Middle Columbia Spring-Run Chinook salmon. The three analyses are:

(1) a comparison of combinations of estimated average smolts-per-adult and average SARs for recent brood years[7] and for a 1962-1982 aggregate run, in comparison with a curve

[7] The time period appears to vary by population, given different numbers of points in the Appendix A figures, but is likely to be approximately the 1997-2007 brood years, based on one of the main data sources cited (Copeland et al. 2014). As noted in the declaration of Dr. Zabel, Mr. Nigro appeared to use information from a number of sources that in some cases were based

representing the combinations of smolts-per-adult and SARs that would equate to average productivity of R/S = 1.0 (Nigro Figure 8);

(2) a comparison of estimated recent annual SARs with a curve showing the SARs that would be needed to achieve the ICTRT (2007; 2014 NOAA B177) recovery abundance thresholds, given a smolts-per-spawner productivity curve derived from estimated recent smolt and spawner estimates (Nigro Figures 9-11 and Appendix A); and

(3) the same comparison as in (2), after adjusting the Marsh Creek and Pahsimeroi smolt production curves upwards to represent potential habitat improvements (Nigro Figures 12-13).

22. The results of Mr. Nigro's first application of the SAR analysis (Nigro Figure 8) are the only ones that compare population performance to a goal that appears to be equivalent to one of the 2008 Biop's indicator metrics, average R/S productivity, and those results do not contradict or add additional insights to the Extended Base Period average R/S productivity estimates in the 2014 Supplement.

23. In interpreting these results, it is important to keep in mind that Mr. Nigro's analysis simply splits the estimation of R/S productivity over the full life cycle into two sub-components (Figure 2), a spawner-to-smolt stage and a smolt-to-spawner (SAR) stage, although the precise location of the split and whether all sources of life-cycle mortality have been included is not clear from Mr. Nigro's declaration (see declaration of Dr. Zabel). R/S productivity, as applied in the 2008 Biop's jeopardy analysis (2008 Biop p. 7-22 through 7-24; 2014 Biop:61-64), is an adult-to-adult metric generated from counts of adults on the spawning ground and the number of their progeny that return to the same spawning ground as adults. It encompasses the entire life cycle (2008 Biop p. 7-20; Figure 2 [below]), and all sources of mortality. Mr. Nigro proposes that by multiplying his smolts-per-spawner estimates times his SAR survival rates, the result

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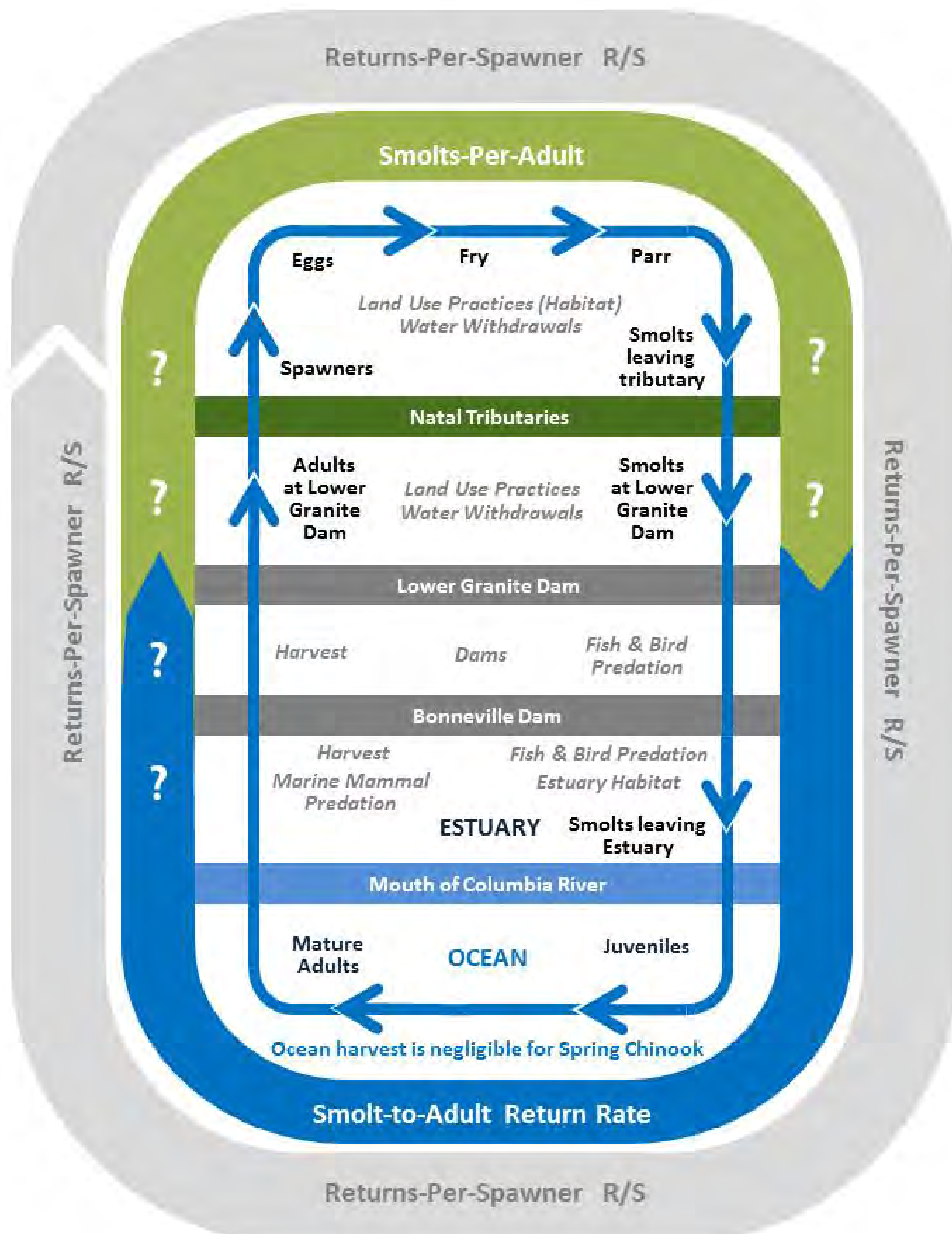
on different methods and included different time periods, and Dr. Zabel was unable to reproduce Mr. Nigro's results based on the information provided.

should be equal to the adult-to-adult R/S estimates. (See Nigro paragraph 23, describing the "simple algebra" of this approach).

Figure 2. Diagram of life cycle of Snake River spring/summer Chinook salmon, showing life stages encompassed by the return-per-spawner (R/S) productivity metric and possible depictions of the life stages encompassed by the smolts-per-spawner and smolt-to-adult return (SAR) metrics included in Mr. Nigro's analysis. Life stages are identified by bold black text; some of the sources of mortality affecting each life stage are indicated by light italic text. Question marks (?) represent possible starting and ending points for Mr. Nigro's metrics. As the declaration of Dr. Zabel points out, it is not possible to determine the exact locations and life stages associated with these metrics from the information in Mr. Nigro's declaration.



24. Mr. Nigro's Figure 8 results show that, on average, recent (1997-2007?) combinations of smolts-per-spawner and SAR survival, when multiplied together, fail to reach the population replacement line equivalent to R/S = 1.0 for 9 of the 10 populations that he displays. This figure does not provide information that informs whether smolts-per-spawner, SARs, or both were too low for the 9 populations to have replaced themselves, on average, over the approximately 11 brood years that preceded the 2008 Biop. It simply shows that, during this time period, 9 of the displayed populations had average R/S less than 1.0 and one of the displayed populations had R/S greater than 1.0.

25. This result neither contradicts nor further informs the analysis already included in the 2008 Biop and 2010/2014 Supplements. While Mr. Nigro's choice of brood years appears to represent only a subset of those years included in the Extended Base Period, the 2014 Supplement's Table 2.1-9 (2014 Biop:90) also shows that R/S productivity for the same 9 populations averaged less than 1.0 and the 10th population (Secesh) averaged higher than 1.0. What Mr. Nigro does not display are results for the Big Creek, Bear Valley, Sulphur Creek, Chamberlain Creek, Valley Creek, Upper Salmon, Lower Salmon, and East Fork Salmon populations of Snake River spring/summer Chinook, all of which have average R/S productivity greater than 1.0 for the Extended Base Period (2008 Biop Table 2.1-9 2014 Biop:90). If these other populations were included, their points would show up above the replacement curve in Mr. Nigro's Figure 8. Additionally, the "Historic Snake River Spring Chinook Lower Granite Aggregate (1962-1982)" data point in Mr. Nigro's Figure 8 is not directly comparable to the 10 individual populations displayed because it represents nearly all 28 extant populations of this species.[8]

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[8] The Tucannon population is located downstream from Lower Granite Dam so presumably is not included. However, because Lower Granite Dam was not actually built until 1975, the Tucannon data probably were included

26. It is possible that Mr. Nigro did not display these populations because smolts-per-spawner data may not be available for them. The lack of a sufficient time series of smolt production data for most populations is an additional constraint of using Mr. Nigro's SAR approach as a performance standard and NMFS cited this in the 2014 Supplement as one reason for analyzing only aggregate SARs at Lower Granite Dam (2014 Biop:124-125).

27. In short, Mr. Nigro's Figure 8, through omission, presents an incomplete and potentially misleading picture of the average R/S productivity of Snake River spring/summer Chinook populations during the Extended Base Period. The 2014 Supplement's Table 2.1-9 and Figure 2.1-14 (2014 Biop:90-91) present a more complete picture of average R/S in relation to the goal of R/S greater than 1.0 for these populations. Additionally, Mr. Nigro's presentation in Figure 8 of average R/S as a function of SAR and smolts-per-adult does not add additional information to the 2014 Supplement's R/S productivity description because it does not provide information that informs whether smolts-per-spawner, SARs, or both are limiting R/S productivity.

28. <u>The results of Mr. Nigro's second application of the SAR analysis</u> (Figures 9-13 and Appendix A) indicate that, "given the current freshwater production capabilities of the populations, the observed SARs (the squares) are less than what is needed for the populations to reach the abundance targets... (Nigro ¶ 29)."

29. The abundance targets to which Mr. Nigro compares current productivity are the Interior Columbia Technical Recovery Team (ICTRT) (2007; 2014 NOAA B177) recovery abundance thresholds. These are recovery (delisting) goals and exceed what the 2008 Biop describes as necessary to avoid jeopardy:

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for 1962-1974 . Again, as pointed out in Dr. Zabel's declaration, the exact methods used by Mr. Nigro are not described.

> BRT and ICTRT products were developed as primary sources of information for the development of delisting or long-term recovery goals. They were not intended as the basis for setting goals for "no jeopardy" determinations. Although NOAA Fisheries considers the information in the BRT and ICTRT documents in this consultation, its jeopardy determinations are made in a manner consistent with the Lohn memos dated July 12, and September 6, 2006 (NMFS 2006h, i). [2008 Biop p. 8.3-5]

30. The ICTRT abundance thresholds are recognized as recovery goals. "The biological viability criteria described in this report were explicitly developed to inform long term regional recovery planning efforts and delisting criteria." (ICTRT 2007; 2014 NOAA B177:14227). The ICTRT abundance thresholds have been incorporated as delisting criteria in completed recovery plans (e.g., Upper Columbia Recovery Plan [2014 NOAA B413] and Mid-Columbia Recovery Plan [2014 NOAA B284]) and draft plans (e.g., Idaho spring/summer Chinook and steelhead [2014 NOAA B295] and Snake River [2014 NOAA B308]). Mr. Nigro does not explain how achieving recovery abundance thresholds relates to avoiding jeopardy in this consultation. He also does not explain how his Appendix A analyses, which show that recent combinations of smolt production and SAR do not currently meet recovery abundance goals, differs from the 2014 Supplement's more straight-forward tables and figures that compare recent average abundance with ICTRT abundance thresholds (2014 Biop:79-83) for every population with sufficient data, rather than just the 10 depicted by Mr. Nigro, or its description of that same information in the most recent status review (2014 Biop:70-71).

31. This issue also was raised in previous declarations and here I quote my previous explanation in ¶ 31 of the 2008 Toole Reply Declaration:

> "Mr. Bowles' Paragraphs 34-37 go to great lengths to demonstrate that a greater change in survival is necessary for most populations to achieve recovery, as defined by the ICTRT, than is necessary for populations to be on a trend towards recovery, as defined for the recovery prong of the BiOp jeopardy analysis. This observation is undisputed but irrelevant:
>
> > 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 [jeopardy] 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." (2008 Biop page 7-7).

In short, Mr. Bowles' point is irrelevant because the survival gap that he seeks to close is that to a recovered population, which is not the same as the survival gap for a trend to recovery, which is relevant to this Section 7(a)(2) consultation."

32. Mr. Nigro's analysis similarly evaluates the goal of attaining recovery and, while the ICTRT products inform our jeopardy analysis, as the 2008 Biop points out, section 7 does not require NMFS to find that the RPA will achieve full recovery. The survival gaps that Mr. Nigro describes do not accurately depict the relevant question in this section 7 consultation.

33. <u>The results of Mr. Nigro's third application of the SAR analysis</u> (Figures 12-13) are identical to those of the second analysis, except that in this case the predicted smolts-per-spawner productivity has been increased incrementally for two populations. In other words, this analysis continues to compare 1997-2007 SARs to a curve showing the SARs that would be needed to achieve the ICTRT recovery abundance thresholds, given an adjusted smolts-per-spawner productivity curve. As described above for Mr. Nigro's second application of the SAR analysis, achieving the ICTRT abundance thresholds associated with delisting is not relevant to the 2008 Biop's jeopardy analysis.

B. DR. CONNORS SIMILARLY COMPARES PERFORMANCE TO A GOAL OF ACHIEVING RECOVERY, RATHER THAN TO GOALS RELEVANT TO A JEOPARDY ANALYSIS

34. Dr. Connors' description of the implications of his density-dependence hypothesis relative to the performance of certain management actions is also stated in terms of a recovery goal, rather than as a jeopardy analysis. Dr. Connors describes a goal of allowing a "metapopulation" to grow to "the point where population viability and conservation status is improved" (¶ 17). The exact meaning of this goal is not clear, since the 2008 Biop, as supplemented, is expected to result in such improvements to the conservation status of the species. However, because Dr. Connors' declaration is not being offered in support of NMFS' jeopardy analysis, the most likely interpretation is that he is referring to a goal of full recovery. As such, the same considerations as described in my ¶¶ 28-32 apply. This goal, like Mr. Nigro's, exceeds the requirements in the 2008 Biop for avoiding jeopardy, and its intended relevance to the 2008 Biop's jeopardy analysis is not explained.

C. MR. NIGRO INTRODUCES AN ALTERNATIVE INTERPRETATION OF THE RESULTS OF HIS SAR ANALYSIS, RELATIVE TO A GOAL OF ADEQUATE COMPENSATION FOR FCRPS IMPACTS

35. Although Mr. Nigro's third application of the SAR analysis (his Figures 12 and 13) addresses only the variables of spawners, smolts-per-spawner, ICTRT abundance thresholds, and SARs, Mr. Nigro in ¶ 44 describes the results of this analysis in relation to a new variable: adequate compensation for FCRPS impacts. ("Without concurrent improvements in SARs, the benefits of improved tributary habitats cannot adequately compensate for FCRPS impacts." "Improvements in freshwater production of smolts alone will not allow populations to overcome FCRPS-related mortality.")

36. Mr. Nigro does not define or quantify adequate compensation for FCRPS impacts or even "FCRPS mortality," and I can find no representation of the specific effects of the FCRPS in his SAR analysis (Figures 8-13 and Appendix A). Instead, this appears to be Mr. Nigro's personal opinion, based on some other source of information. If Mr. Nigro's understanding of "FCRPS impacts" is reflected in the description in ¶¶ 6-11 of his declaration, it includes the impacts of hydro development outside of the United States and aspects of the FCRPS that are not associated with the proposed action of operating the FCRPS (see declaration of Mr. Graves). Additionally, it is not clear if adequate compensation refers to what Mr. Nigro believes is necessary to avoid jeopardy in this consultation, whether it refers to Mr. Nigro's preferred allocation of the recovery burden to the FCRPS action agencies (which is not included in final or draft interior Columbia River recovery plans), or both. In short, Mr. Nigro offers no definition of adequate compensation for the FCRPS, no analysis to evaluate adequate compensation for the FCRPS, and no explanation of its relevance to the 2008 BiOp's RPA or other actions relied upon in that biological opinion or its supplements.

D. MR. NIGRO AND DR. CONNORS DESCRIBE PURPORTED SHORTCOMINGS OF A HYPOTHETICAL MANAGEMENT STRATEGY, WHICH DOES NOT CORRESPOND TO THE ACTIONS CONSIDERED IN THE 2008 BIOP AND 2010/2014 SUPPLEMENTS

37. Mr. Nigro's ¶ 44 concludes that "improvements in freshwater production of smolts alone will not allow populations to overcome FCRPS-related mortality" and that "without concurrent improvements in SARs, the benefits of improved tributary habitats cannot adequately compensate for FCRPS impacts." (Emphasis added). Dr Connors' ¶ 17 states that "...a focus on restoration of additional tributary habitat is unlikely to be sufficient to allow the overall metapopulation to increase its productivity, expand the number of habitat patches occupied and

ultimately grow to the point where population viability and conservation status is improved." (Emphasis added).

38. Each of these conclusions describes a hypothetical management action that either solely or primarily relies on tributary habitat improvements that result in increased survival in the spawner-to-smolt life stage. These hypothetical management actions include either no survival improvements (Mr. Nigro) or possibly a small survival improvement (Dr. Connors) in smolt-to-adult (SAR) life stages (Figure 2, above). Neither Mr Nigro's or Dr. Connors' declaration describes how this hypothetical management action relates to the actions considered in the 2008 Biop and 2010/2014 Supplements, but without further explanation, they leave the impression that this is in fact the action that NMFS analyzed in these biological opinions. This is not the case.

39. First, the RPA consists of actions to improve survival in multiple life stages. The 2008 Biop's RPA (2008 Biop Appendix 1, as amended by the 2010 Supplement and the 2014 Supplement) includes: 4 adaptive management actions (1, 1A, and 2-3); 30 FCRPS hydropower actions (4-33); 2 tributary habitat actions (34-35); 2 estuary habitat actions (36-37; 38 has been deleted); 4 hatchery actions targeted to all interior Columbia River species and Columbia River chum salmon (39-42); 7 predator reduction activities throughout the Columbia Basin and estuary (43-49); and 24 research, monitoring, and evaluation studies (50-73).

40. Second, the RPA was not the only source of survival improvements relied upon in the 2008 Biop for determining that the RPA would not jeopardize listed species. As described in the 2008 Biop ("General Approach: Base, Current, and Future (with Prospective Actions) Analyses", p. 7-8 to 7-12) and the 2014 Supplement ("How Are Base Period Indicator Metrics Adjusted to Reflect Expected Survival Changes?" 2014 Biop:51-54), the analysis in the 2008 Biop evaluated two general sources of expected survival changes from the average Base Period productivity that

was observed from approximately the 1980-2000 brood years. Because some management activities changed from the early years of the Base Period to 2008, survival changes (either positive or negative) reflective of continuing "current" (as of 2008) management were included in the analysis. These included changes between approximately 1980 and 2008 in harvest rates and changes in FCRPS juvenile survival, which the ICTRT had also included in its recovery survival gap analysis (2014 Biop:51). The 2008 Biop referred to these changes as "Base-to-Current" survival adjustments. The 2014 Supplement reviewed the continuing validity of the Base-to-Current estimates in the Environmental Baseline section and, for two effects (cormorant predation and hatchery actions for some populations), described an adjustment to the 2008 Biop estimates (2014 Biop:202-203).

41. The additional survival improvements expected from the RPA were included as "Prospective" survival estimates. These also were reviewed in the 2014 Supplement (2014 Biop:225-455). The combination of these two types of survival changes represents the survival changes that NMFS relied upon for its indicator metric analysis for six interior Columbia River species.

42. The survival changes for Snake River spring/summer Chinook salmon, the species which Mr. Nigro and Mr. Connors addressed, are displayed in 2008 Biop Tables 8.3.3-1 and 8.3.5-1, pages 8.3-52 to 8.3-55. The first thing to note is that the expected survival changes resulting from "current" (as of 2008) management and RPA actions affect multiple parts of the species' life cycle. Most of these survival improvements occur in life stages encompassed by the smolt-to-adult (SAR) metric (Figure 2, above). In fact, for eight[9] of the nine Middle Fork Salmon populations referenced by Mr. Nigro (including Marsh Creek, depicted in his Figures 8, 9, 10,

[9] Tributary habitat actions that would result in a 1% improvement were included for Big Creek. Table 8.3.5-1 (2008 Biop p. 8.3-54).

12, and Appendix A), no tributary habitat actions contribute to the survival improvements that NMFS relies on in the 2008 Biop.

43. The survival changes that NMFS expects to occur in SAR life stages (primarily FCRPS hydro improvements) exceed the survival changes expected from tributary habitat improvements for nearly all populations (Table 1). NMFS clearly did not rely exclusively, or even primarily, on tributary habitat survival improvements in the 2008 Biop. The purported shortcomings of the hypothetical tributary-focused management strategy described by Mr. Nigro and Dr. Connors are not relevant to the management actions that NMFS actually relied upon in the 2008 Biop.

Table 1. Survival multipliers for estimated survival changes from Base Period productivity in the 2008 Biop. A multiplier of 1.0 represents no change, 1.50 represents a 50% survival increase, and 2.00 represents a 100% survival increase. Estimated survival changes due to tributary habitat actions (Tributary) are compared to survival changes expected from all other actions (Non-Tributary), which affect life stages encompassed by the SAR metric (Figure 2). These comparisons are shown for survival changes based on "current" management actions as of 2008 (Base-to-Current Survival Multiplier), for 2008 Biop RPA actions (RPA Survival Multiplier), and for the combination of both (Total Survival Multipliers). The few comparisons in which survival changes expected from tributary habitat improvements are greater than survival changes expected from other actions are highlighted. Average expected survival changes for all 28 populations are also displayed.

MPG	Population	Base-to-Current Survival Multiplier		RPA Survival Multiplier		Total Survival Multiplier in 2008 Biop	
		Non-Tributary[1]	Tributary[2]	Non-Tributary[3]	Tributary[4]	Non-Tributary[5]	Tributary[6]
Lower Snake	Tucannon	1.21	1.04	1.15	1.17	1.39	1.21
Grande Ronde / Imnaha	Catherine Creek	1.45	1.04	1.15	1.23	1.67	1.28
	Lostine/Wallowa Rivers	1.24	1.01	1.15	1.02	1.43	1.03
	Minam River	1.47	1.00	1.15	1.00	1.70	1.00
	Imnaha River	1.21	1.01	1.15	1.01	1.39	1.02
	Wenaha River	1.68	1.00	1.15	1.00	1.93	1.00
	Upper Grande Ronde	1.46	1.04	1.15	1.23	1.68	1.28
South Fork	S. Fk. Salmon Mainstem	1.21	1.00	1.15	1.01	1.39	1.01

MPG	Population	Base-to-Current Survival Multiplier		RPA Survival Multiplier		Total Survival Multiplier in 2008 Biop	
		Non-Tributary[1]	Tributary[2]	Non-Tributary[3]	Tributary[4]	Non-Tributary[5]	Tributary[6]
Salmon	Secesh River	1.21	1.00	1.15	1.01	1.39	1.01
	E. Fk. S. Fk. Salmon	1.21	1.00	1.15	1.00	1.39	1.00
	Little Salmon River	1.21	1.01	1.15	1.00	1.39	1.01
Middle Fork Salmon	Big Creek	1.21	1.00	1.15	1.01	1.39	1.01
	Bear Valley/Elk Creek	1.21	1.00	1.15	1.00	1.39	1.00
	Marsh Creek	1.21	1.00	1.15	1.00	1.39	1.00
	Sulphur Creek	1.21	1.00	1.15	1.00	1.39	1.00
	Camas Creek	1.21	1.00	1.15	1.00	1.39	1.00
	Loon Creek	1.21	1.00	1.15	1.00	1.39	1.00
	Chamberlain Creek	1.21	1.00	1.15	1.00	1.39	1.00
	Lower Middle Fk Salmon	1.21	1.00	1.15	1.00	1.39	1.00
	Upper Middle Fk Salmon	1.21	1.00	1.15	1.00	1.39	1.00
Upper Salmon	Lemhi River	1.21	1.01	1.15	1.07	1.39	1.08
	Valley Creek	1.21	1.01	1.15	1.01	1.39	1.02
	Yankee Fork	1.21	1.00	1.15	1.30	1.39	1.30
	Upper Salmon River	1.21	1.01	1.15	1.14	1.39	1.15
	North Fork Salmon River	1.21	1.00	1.15	1.00	1.39	1.00
	Lower Salmon River	1.21	1.01	1.15	1.01	1.39	1.02
	East Fork Salmon River	1.21	1.01	1.15	1.01	1.39	1.02
	Pahsimeroi River	1.21	1.01	1.15	1.41	1.39	1.42
	Average	1.25	1.01	1.15	1.06	1.44	1.07

[1] Estimated by dividing the "Total Base-to-Current Survival Multiplier" in 2008 Biop Table 8.3.3-1 by the "Tributary Habitat" survival multiplier in that table.
[2] The "Tributary Habitat" survival multiplier in 2008 Biop Table 8.3.3-1.
[3] Estimated by dividing the "Total Current-to-Future Survival Multiplier" in 2008 Biop Table 8.3.5-1 by the "Tributary Habitat (2007-2017)" survival multiplier in that table.
[4] The "Tributary Habitat (2007-2017)" survival multiplier in 2008 Biop Table 8.3.5-1.
[5] Product of the "Non-Tributary" Base-to-Current Survival Multiplier and the "Non-Tributary" RPA Survival Multiplier in this table.
[6] Product of the "Tributary" Base-to-Current Survival Multiplier and the "Tributary" RPA Survival Multiplier in this table.

III. THE RELATIVE MORTALITY CAUSED BY THE FCRPS, COMPARED TO OTHER SOURCES OF HUMAN-CAUSED MORTALITY, IS HIGHLY UNCERTAIN

44. Mr. Nigro in ¶ 7 states that "there is general agreement in the scientific community" that FCRPS impacts "exceed the impacts due to other sources of human-caused mortalities." He cites three documents supporting this statement. One of the studies that Mr. Nigro cites is the National Research Council's review of salmon and society in the Pacific Northwest (Committee on the Protection and Management of Northwest Anadromous Salmonids 1996; excerpts in 2014 NOAA B322:34432-34478). I can find nowhere in the report a statement concluding that the FCRPS-caused mortality exceeds that of other sources of human-caused mortality, as Mr. Nigro claims. Additionally, the discussion of dam impacts in Chapter 9 of that reference ("Dams and the Mitigation of Their Effects") does not distinguish the impacts of FCRPS dams and operations from the impacts of other dams in the basin. The description of dam impacts explicitly includes effects of other Columbia River dams (e.g., FERC projects and irrigation dams) and Canadian storage dams in addition to effects of FCRPS dams, and I see no attempt to summarize those effects separately or to compare them with other sources of human-caused mortality.

45. Mr. Nigro also cites a 1997 Pacific Marine Fisheries Commission "fact sheet" titled "When Salmon Are Dammed" (Exhibit 2). I see a single sentence with no citations that says "Scientists estimate that about 70%-95% of the human-induced kills of salmon in the Columbia Basin are dam related." I cannot determine the source of this statement or which dams are included in this estimate. However, if the next sentence, which is attributed to the U.S. Fish and Wildlife Service (no citation), is intended to explain the statement, it appears to include dozens of dams throughout the Columbia Basin that are not part of the FCRPS: "the major decline of the runs coincides with the construction and operation of dams for electrical power, irrigation, and

flood control. Between 1930 and the late 1970's about 200 dams, including 19 major hydro-electric dams, were constructed in the Columbia Basin to provide water for irrigation, flood control, barging, and cheap electricity for the aluminum smelters and cities of the region. Hardly any major stream was left untouched."

46. The third report that Mr. Nigro refers to is a 1976 review by George Collins of NMFS, "Effects of Dams on Pacific Salmon and Steelhead Trout" (Exhibit 3). In reviewing this paper, I found one introductory sentence claiming that the impacts of "dams" exceeded impacts of other sources of mortality, but there is no documentation in support of this statement and no further discussion of the relation of dam mortality to other sources of human mortality. It also is not clear if the dams he is referring to are only those comprising the FCRPS or if they include additional non-FCRPS dams. He refers in the same introduction to non-FCRPS dams in the Willamette River and to the Brownlee FERC-licensed dam. His Figure 2, also referenced in the introduction ("Because there were many dams (Fig. 2)..."), includes eight FERC-licensed dams as "major dams on the Columbia and Snake Rivers" and suggests that he was also considering these non-FCRPS dams in his comparison with other sources of mortality.

47. In summary, at least one of the three references Mr. Nigro cites does not appear to actually say that FCRPS impacts are greater than for other sources of human mortality, two make a statement that "dams" cause the highest mortality but do not explain or provide support for the statements, and all three appear to consider significant non-FCRPS dams in describing "dam" impacts. In short, the relevance of these citations to the FCRPS operations that are the subject of this consultation is questionable.

48. Mr. Nigro also states that a report prepared by the Framework Work Group of the *NWF v NMFS* Collaboration Process ("FWG Interim Report;" 2014 NOAA B143) estimated that the

relative impact of the FCRPS ranged from 35% to 74% of the total human mortality affecting Snake River salmon and steelhead. I was the co-chair of the Framework Work group and am familiar with this report. Mr. Nigro's presentation of these precise estimates, without additional information, implies a level of certainty that is not warranted. There are a number of points regarding the FWG Interim Report, which are important to understand in order to interpret the numbers presented by Mr. Nigro.

49. First, this was an "interim report, summarizing work to date" that "may be updated later in the remand collaboration process as new information becomes available" (2008 NOAA B143, page 1). It is described as a "Discussion Draft" on all pages. This report was never finalized or adopted by the Policy Work Group (PWG) of the *NWF v NMFS* Collaboration Process.

50. The report represented a review of existing information "within a short time period (approximately two months)" and "the PWG acknowledged that precision of the analysis would be limited by the short time period and direction to use existing sources of information" (2008 NOAA B143, p. 2). A section of the report titled "Caveats Regarding Methods" stated:

> As described in Section 2.1, this report is intended as general, coarse scale, guidance regarding the relative impacts of various sources of mortality. The estimation methods described in Section 2.3.2 attest to the wide range of uncertainty or data limitations that characterize the information and judgment considered in this report. The ranges for different factors used this report generally represent different opinions regarding interpretation of data or hypotheses with little or no direct measurements. The estimates of $S_{With(i)}$ and $S_{Without(i)}$, based on this mixture of information and judgment, and the subsequent calculations, can be presented to any number of decimal places, giving the illusion of great precision and certainty. Readers are cautioned to interpret the results presented in this report as very general characterizations of relative impacts that should be interpreted broadly at a coarse scale. (2008 NOAA B143, p. 18).

51. In addition, the workgroup members disagreed on the characterization of some areas of uncertainty. In February 2006, the Framework Work Group notified the PWG of significant disagreements among members pertaining to FCRPS latent mortality assumptions, as well as

assumptions regarding delayed mortality associated with other sources of mortality" (2008 NOAA B143, p. 2). These disagreements were not resolved and the wide range of estimates reflects uncertainty in these and other assumptions.

IV. NMFS CONTINUES TO RELY ON ICTRT RECOVERY ABUNDANCE THRESHOLDS AS THE BEST AVAILABLE INFORMATION REGARDING ABUNDANCE REQUIRED FOR DELISTING

52. Mr. Nigro describes the status of listed salmon and steelhead in his ¶¶12-22. Most of the information he includes is already presented in the 2008 Biop and 2010/2014 Supplements, but some of the information he presents is incomplete or incorrect.

53. In ¶ 15 and ¶ 16 Mr. Nigro discusses five scientific papers and one news article (Culotta 1995; Exhibit 4) and implies that NMFS did not previously consider this information when developing recovery abundance levels. Additionally, in ¶ 16, Mr. Nigro expresses his opinion that the ICTRT's recovery abundance thresholds "do not represent recovery since healthy populations should approach 10,000 organisms." NMFS does not agree, and continues to rely for recovery and delisting goals on the ICTRT (2007; 2014 NOAA B177) abundance thresholds, which range from 500 spawners-per-year to 3,000 spawners-per-year, depending upon population and species. The ICTRT abundance thresholds "were based on the demographic and genetic rationale provided by McElhany et al. (2000) and reflect estimates of the relative amount of historical spawning and rearing habitat associated with each population" (2014 NOAA B177:14253).

54. The discussion of population size in the McElhany et al. (2000) Viable Salmonid Populations (VSP) report (2014 NOAA B250), which the ICTRT relies upon, is extensive, citing many scientific papers (including two of the papers cited by Mr. Nigro), and covering the demographic and genetic issues raised by Mr. Nigro in great detail (2014 NOAA B250:20553-

20566). This report also considers the two scientific papers[10] that are described in the Culotta (1995) news article. In discussing various recommendations for minimum abundance in the scientific literature, McElhaney et al. (2000) point out that many are derived from studies of other organisms and that factors important to salmon viability (e.g., overlapping generations, degree of environmental variability, gene flow, and partial tetraploidy[11]; 2014 NOAA B250:20557-561) need to be considered when determining appropriate abundance levels. These factors can lead to alternative recommendations for salmon species.[12]

55. The only reference that Mr. Nigro cites that might represent new information not previously considered in setting the ICTRT abundance thresholds is a 2007 paper by Traill et al. (Exhibit 5), which was produced after the McElhany et al. (2000) VSP report, and was contemporaneous with ICTRT (2007). Traill et al. (1997) is a meta-study of scientific literature that estimates minimum viable population size for over 200 species of vertebrate animals. Table 2 of this paper shows that, for the category "Fish," the average minimum viable population (MVP) is estimated to be <u>1.24 million adults</u>. This number was apparently averaged with estimates for other vertebrate groups to reach the overall vertebrate species MVP

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[10] For example, McElhaney et al. (2000) explains why results of one of the papers, Lande (1995), should be interpreted cautiously: "Second, the genetic parameters that form the basis for the Franklin (1980) and Lande (1995) recommendations were estimated from data obtained from only one species (*Drosophila melanogaster* [fruit fly]), and must therefore be regarded as preliminary." (2014 NOAA B250:20561)

[11] Most species whose cells have nuclei have two sets of chromosomes, one from each parent, and are considered "diploid." Tetraploidy means that the cells have four sets of chromosomes. "Partial tetraploidy may reduce the severity of inbreeding depression in comparison to the amount seen in diploid organisms because, all else being equal, tetraploids are less homozygous than diploids." (2014 NOAA B250:20558)

[12] For example, most recommendations in the literature pertain to minimum abundance per generation. McElhany et al. (2000) demonstrate that minimum abundance recommendations from a variety of sources in the literature, which range from 1,670 to 16,700 per generation, translate to approximately 417-4170 annual spawners for Pacific salmon. (2014 NOAA B250:20561).

recommendation cited by Mr. Nigro. According to the paper's supplementary materials, the Traill et al. (2007) "Fish" estimate is based on MVP estimates for 8 fish species, including herring, anchovies, sole, whiting, and two trout species. Two salmon MVP studies are included, one addressing listed Sacramento winter-run Chinook (Botsford and Brittnacher 1998) and one that addresses unlisted South Umpqua River spring Chinook (Ratner et al. 1997). Both of these papers were cited and considered in the McElhaney et al. (2000) VSP paper (e.g., 2014 NOAA B250:20580-020583).

56. In summary, NMFS considered the issues that Mr. Nigro raises when determining characteristics of viable salmonid populations in McElhaney et al (2000) and when applying those characteristics to develop the ICTRT's recovery abundance thresholds. NMFS continues to regard the ICTRT abundance thresholds as the best available information regarding population abundance necessary for recovery and delisting.

V. THE 2014 SUPPLEMENT CORRECTLY DESCRIBES THE CURRENT RISK FACED BY INTERIOR COLUMBIA SALMON AND STEELHEAD SPECIES.

57. In ¶ 22, Mr. Nigro states that "the combination of low abundance persistently below viability thresholds, and low productivity precluding population growth, places the populations at <u>very high risk of extinction</u>" (emphasis added). Mr. Nigro cites NMFS' 2011 5-year status review summaries for each interior Columbia River species (e.g., 2014 NOAA B290 for Snake River species) as the source of this information, but those summaries do not discuss the level of risk to each population, as is presented in Ford (2011; 2014 NOAA B128). Neither Ford (2011) nor the three 5-year status review summaries place any populations in a category of "very high risk" and 44% of populations are not included in a category of "high risk." Table 2.1-1 of the 2014 Supplement (2014 Biop:71) accurately describes the overall risk ratings from the Ford (2011) review, which are also discussed qualitatively in the three 5-year status review

summaries. This table shows that 2 populations are considered "highly viable," 2 are considered "viable," 1 is considered "viable (maintained)," 14 are considered "maintained," 7 are considered "maintained?"[13], 39 are considered "high risk," and 12 are considered "high risk?". In short, Mr. Nigro significantly overstates the risk to these Interior Columbia populations.

58. The 5-year status review summaries that Mr. Nigro cites also include risk ratings for the entire Evolutionary Significant Unit (ESU) (a "species" under the ESA), which consider additional factors such as total abundance of all populations, the number of populations, and their distribution. In some cases, these ESU risk ratings differ from those that would be expected based solely on the individual population risk ratings. For example, although all individual populations in the Snake River spring/summer Chinook ESU are considered to be at "high risk," the overall risk for the ESU is considered "moderate" (2014 NOAA B290:30647):

> ...the SR spring/summer Chinook salmon MPGs do not meet the ICTRT viability criteria for the ESU (i.e., all five MPGs should be viable for the ESU to be viable). Therefore, the ESU is not currently considered to be viable. Overall, there is no new information to indicate an improvement in the biological risk category since the time of the last status review. There is also no new information to indicate that this ESU's extinction risk has increased considerably in the past five years. This ESU remains well distributed over 28 extant populations in three states. Total ESU abundance is depressed but not at critically low levels. Some populations have experienced increased abundance in the last five years. New information considered during this review confirms that this DPS remains at moderate risk of extinction.

59. Risk ratings for the entire listed species were also considered "moderate" for Snake River fall Chinook (2014 NOAA B290:30648), Snake River steelhead (2014 NOAA B290:30652), and Mid-Columbia steelhead (p.15 of NMFS 2011a; Exhibit 6). Upper Columbia River spring Chinook and steelhead at the species level were considered "moderate-to-high" risk and "not viable," respectively (p. 17 and 18 of NMFS 2011b; Exhibit 7). In summary, aside from overstating the risk for Interior Columbia populations, as described above, Mr. Nigro overlooks

[13] The report included question marks along with risk ratings for some populations because of uncertainty or lack of sufficient data.

the more optimistic characterization of risk to entire listed species described in the NMFS Status Review Summaries that he cites.

VI. NEW INFORMATION REGARDING SNAKE RIVER STEELHEAD DOES NOT AFFECT ESTIMATES OF HABITAT QUALITY IMPROVEMENTS. THE IMPACT OF THIS NEW INFORMATION ON SNAKE RIVER STEELHEAD PRODUCTIVITY IS UNCERTAIN, POSSIBLY RESULTING IN SOME POPULATIONS HAVING HIGHER PRODUCTIVITY AND SOME LOWER PRODUCTIVITY THAN ESTIMATED IN THE 2008 BIOP.

60. Mr. Olney, in ¶¶ 62-65, states that NMFS did not address implications of its inability to update Snake River steelhead productivity estimates for all but the three populations, for which direct estimates of productivity are available. In the 2008 Biop and currently, population-specific empirical productivity estimates are available for only three SR steelhead populations. To supplement the information from these populations, the ICTRT (2007) developed "Average A-Run" and "Average B-Run" productivity estimates that were derived by apportioning the aggregate returns to Lower Granite Dam into A-run and B-run categories, based on an understanding of which populations could be classified into each category and by allocating the Lower Granite Dam returns proportionately among populations (ICTRT 2007 2014 NOAA B176:14192; 2008 Biop p. 8.5-5).

61. The 2008 Biop applied the ICTRT average A- and B-run productivities to individual SR steelhead populations that lacked empirical productivity estimates, based on the individual populations' categorization as A-run or B-run in the ICTRT analysis. This was done in order to evaluate population-specific survival changes that could be assigned to individual populations, such as tributary habitat or hatchery actions (2008 Biop p. 8.5-5 and elsewhere; Toole 2008 Declaration ¶¶ 61-62). The 2008 Biop clearly described the assumptions and uncertainty of this approach when reporting SR steelhead results in the 2008 Biop (Toole 2008 Declaration ¶ 62).

62. Because our understanding has changed, such that populations can no longer reliably be classified as A-run or B-run, NMFS did not update the 2008 Biop base period or prospective estimates for these populations (2014 Biop:74-75). Mr. Olney does not dispute this approach or suggest any alternative methods that NMFS should have applied at this time. Mr. Olney does suggest that NMFS should have more clearly described the impact of this new information on the uncertainty associated with the 2008 Biop estimates.

63. He mentions two sources of uncertainty that he believes NMFS should have described in more detail. The first, in his ¶ 64, is the estimation of the effectiveness of tributary habitat actions for Snake River steelhead (i.e., prospective estimates of habitat quality improvements that are described in the 2008 Biop and estimates of the degree to which individual populations have met these projected improvements in the 2014 Supplement). The short answer to this concern is that I see no way in which the classification of a population as A-run, B-run, or some new as-yet unnamed category would have any effect on the estimation of habitat quality improvements for any Snake River steelhead population. Those estimates are made by expert panels familiar with the individual populations and the habitat conditions and limiting factors affecting the populations (see Methods for Estimating Habitat Benefits 2014 Biop:245-264). The habitat quality improvements are dependent upon the expert panels' ability to identify and weight habitat function and determine how a given tributary habitat action will change that function, neither of which is dependent upon the A- or B-run classification of the population or the estimate of that population's productivity.

64. Mr. Olney goes on in ¶ 65 to state that NMFS also should describe additional uncertainty associated with continuing to rely on the 2008 Biop's productivity estimates, which are based on average A-run and average B-run productivity. I don't believe that this uncertainty can

accurately be evaluated with information available at this time. However, I will discuss two approaches using currently available information that can provide a range of perspectives. Both approaches have shortcomings that make them inappropriate for anything other than illustrative purposes.

65. The first approach would rely entirely on the Base Period productivity estimates for the three populations that do have empirical information sufficient to calculate their abundance and productivity. With this approach, the productivity estimates for these three populations implicitly would be assumed to represent the remainder of the populations. This assumption would indicate that productivity may be considerably higher than that estimated in the 2008 Biop for most Snake River steelhead, with very little likelihood that it would be lower. This approach does not appear reasonable, however, based on the Ford (2011) qualitative determination that two out of three of these populations have lower combined abundance and productivity risk than other populations (2014 NOAA B128:9982-9983).

66. An alternative approach would rely on currently-available aggregate returns to Lower Granite Dam, not separated by A-run, B-run, or any other classification, to represent all populations except the three with empirical data. This aggregate productivity would be higher than that estimated in the 2008 Biop for populations identified as B-run and average productivity would be lower for those populations previously identified as A-run because B-run productivity estimates in the 2008 Biop were lower than the A-run productivities (2008 Biop Table 8.5.2-1, page 8.5-50). Therefore, poorer-performing populations could be doing better than the description in the 2008 Biop, while better-performing populations could have lower productivity. That is, it is possible that some populations identified as B-run in the 2008 Biop, which did not achieve prospective goals in that analysis, could have met the goals under this assumption. On

the other hand, it is possible that some populations identified as A-run in the 2008 Biop, which did achieve prospective goals in the analysis, could have missed the goals under this assumption.

67. This second approach also does not seem reasonable, based on what we know at this time of the emerging studies of Snake River steelhead genetics. "Initial results indicate that some populations assumed to be either A-run or B-run may support mixtures of the two run types. Results from this ongoing effort and the companion study based on adult PIT tag detections should allow for improved population specific assessments in the next 5-year status review" (2014 Biop:75). In other words, the real situation is likely to be more complex than that represented by a single aggregate productivity estimate for most populations.

68. In summary, Mr. Olney's concerns about the new steelhead information affecting tributary habitat quality index estimates are unfounded because those estimates do not rely on the information that has changed. Regarding the 2008 Biop's estimates of productivity for those Snake River steelhead populations lacking population-specific data, it is not possible to determine the additional uncertainty, but it is possible that some populations may have higher productivity and some lower productivity than that estimated in the 2008 Biop.

I declare under penalty of perjury that the foregoing is true and correct. Executed on March 4, 2015 in Portland, Oregon

Christopher Toole, Ph.D.

Appendix C
Recruits-per-Spawner in base versus current time periods—do they differ?

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Recruits-per-Spawner in base versus current time periods—do they differ?

August 29, 2013

Rich Zabel and Tom Cooney

NOAA Fisheries

Northwest Fisheries Science Center

Background

The 2008 Supplemental Comprehensive Analysis[1] (SCA) included a quantitative evaluation of the effects of 2008-2018 harvest and hydropower activities[2] on populations of six species of interior Columbia River salmon and steelhead (Appendix Table 1) listed under the Endangered Species Act. The SCA estimated the following measures of population performance during a "Base Period" for which empirical data were available (approximately 1980-2004, corresponding to the ~1980-2000 completed brood cycles [BY]):

24-year extinction risk

Geometric mean of recruits-per-spawner (R/S)

Median population growth rate (lambda) under two assumptions regarding effectiveness of hatchery-origin spawners

Trend of ln(abundance+1), referred to as "BRT Trend"

The ~1980-2000 BY Base Period metrics were the starting point for all subsequent calculations and projections in the SCA for the six interior Columbia basin species. There are now 5-7 new years of population data and NOAA Fisheries' Northwest Regional Office has requested assistance in determining whether the new observations represent a change in the original Base Period estimates or if they are within the expected range of variability.

In general, incorporating the new observations into "extended Base Period" (~1980 to most recent year) estimates[3] indicates:

either unchanged or reduced extinction risk for most populations;

[1] Supplemental Comprehensive Analysis of the Federal Columbia River Power System and Mainstem Effects of the Upper Snake and Other Tributary Actions. May 5, 2008. NOAA Fisheries, Northwest Regional Office, Portland, Oregon. Available at: http://www.nwr.noaa.gov/publications/hydropower/fcrps/final-sca.pdf
[2] Activities were: Columbia River harvest under *US v Oregon*, operation of the Federal Columbia River Power System (FCRPS), and operation of Bureau of Reclamation water storage projects in the Upper Snake River.
[3] Personal communication, C. Toole, NOAA Fisheries Northwest Regional Office, March 22, 2013.

higher abundance trends for nearly all populations;

variable lambda estimates, depending in part on hatchery assumptions, but including reductions for a number of populations; and

reduced mean R/S estimates for most populations.

Looking at the new observations independently, rather than combined with the original Base Period estimates, the contrast between improved abundance and reduced mean R/S productivity is even more apparent. Twenty-six out of 26 populations of spring and summer Chinook increased in abundance, measured as geometric mean abundance during the previous 10 years, when comparing the recent period to the Base Period, and 14 out 18 steelhead populations increased in abundance over the same period (Tables 1 and 2). However, mean R/S decreased in 22 out of 26 spring and summer Chinook populations and 14 out of 18 steelhead populations (Tables 1 and 2).

Although the decrease in productivity might suggest that overall population performance has declined, it is also consistent with expectations that recruits-per-spawner will decline as abundance increases due to density-dependent processes (Ricker 1954, Zabel et al. 2006). This is commonly observed in fish populations, and in fact forms the basis of most fisheries management models (e.g., Hilborn and Walters 1992). Here we test the density-dependent hypothesis by first testing whether the spawner and recruit data during the Base Period are consistent with a density-dependent model. Then we examine whether the current data fall within 95% prediction intervals for new observations.

Table 1. Geometric mean abundance and recruits-per-spawner during base (brood years from approximately 1980-2000) and recent (approximately 2001 and later) time periods for interior Columbia basin spring and summer Chinook populations. To calculate the geometric means, we first added 1 to all spawner counts (because some counts were 0), and then subtracted 1 from the calculated mean.

Population	Mean Abundance		Mean Recruits–Per-Spawner	
	Base	Recent	Base	Recent
LS-Tucannon	246	534	0.74	0.60
GR-Wenaha	249	561	0.71	0.72
GR-Lostine	213	661	0.81	0.47
GR-Minam	290	487	0.87	1.03
GR-Upper Mainstem	86	146	0.46	0.30
GR-Catherine Cr	159	276	0.42	0.30
GR-Imnaha	526	1592	0.82	0.17
SF-Mainstem	592	1208	0.89	0.51
SF-Secesh	292	868	1.22	0.46
SF-East Fork	190	325	1.06	0.53
MF-Big Creek	80	182	1.42	0.99
MF-Camas Cr	32	89	0.94	0.54
MF-Loon	39	146	1.32	0.52
MF-Sulfur Cr	38	50	1.1	1.18
MF-Bear Valley/Elk	163	429	1.46	0.72
MF-Marsh Cr	127	203	1.08	1.18
SR-Lemhi	95	116	1.2	0.61
SR-Pahsimeroi	58	376	1.29	0.64
SR-Lower Mainstem	79	177	1.31	0.64
SR-East Fork	106	306	1.32	1.08
SR-Yankee Fork	16	24	1.17	0.54

SR-Valley Cr	42	74	1.36	1.23
SR-Upper Mainstem	164	647	1.71	0.56
UC-Wenatchee	844	915	0.75	0.40
UC-Methow	541	1277	0.92	0.26
UC-Entiat	152	206	0.79	0.51

Table 2. Geometric mean abundance and recruits-per-spawner during base and recent time periods for interior Columbia basin steelhead populations. To calculate the geometric means, we first added 1 to all spawner counts (because some counts were 0), and then subtracted 1 from the calculated mean.

Population	Mean Abundance		Mean Recruits–Per-Spawner	
	Base	Recent	Base	Recent
UC-Wenatchee	1645	2965	0.29	0.33
UC-Entiat	166	656	0.37	0.20
UC-Methow	1297	4942	0.15	0.11
UC-Okanogan	988	2504	0.07	0.06
MC-Fifteenmile Cr	455	828	1.32	0.59
Deschutes-W	483	951	1.03	0.58
JD-Lower Mainstem	1626	2886	1.64	0.40
JD-North Fork	1412	2273	1.37	0.70
JD-Upper Mainstem	939	662	1.24	0.69
JD-Middle Fork	1063	1032	1.37	0.49
JD-South Fork	459	385	1.15	1.06
MC-Umatilla	1632	3211	1.07	0.70
YR-Satus	451	673	1.01	1.73
YR-Toppenish	154	562	1.57	1.06
YR-Naches	392	806	1.14	1.47
YR-Upper Yakma	72	143	1.14	1.57
GR-Upper Mainstem	1538	1333	0.93	1.08
GR-Joseph Cr	1959	2484	1.26	0.80

Data

The spawning time series data for interior Columbia basin Chinook salmon and steelhead populations include estimates for the most recent annual returns obtained from state, tribal and Federal managers. The data series are generated using protocols agreed upon through the Interior Columbia Technical Recovery Team and are updated versions of the data series available through the Salmonid Population Summary (SPS) data base maintained by the NWFSC (https://www.webapps.nwfsc.noaa.gov/apex/f?p=261:home:0#). The SPS includes documentation and is designed to accommodate annual updates. The additional years included in the analysis described below will be available in the SPS later this year.

Spawning abundance, hatchery/wild proportions and age composition follow the follow the protocols used in previous Biological Review Team and Technical Recovery Team reports (e.g., Good et al. 2005). Annual spawning abundance represents the estimated number of hatchery and wild origin fish contributing to spawning in natural production reaches for each population. Spawning abundance does not include 3-year olds (jacks). Brood year recruits are calculated assigning natural origin returns to age at return and then using this information to assign adult recruits to brood year. Because these recruits were estimated after any harvest occurred, we adjusted recruits to account for harvest:

$$R_t = \frac{A_t}{1 - h_t}$$

where R_t are estimated recruits from brood year t, A_t are post-harvest returning adults, and h_t is the harvest rate for adults from brood year t. R_t represent the number of naturally produced fish that would have appeared on the spawning grounds had there not been a harvest. We adjusted recruits to account for harvest because our goal here is to examine whether the inherent productivity of populations, measured as recruits-per-spawner, has changed between the baseline and recent time periods. Harvest removes recruits, and if harvest occurred differentially across time, it could alter the underlying relationships. In Appendix 2, we examined the impacts on results of adjusting for harvest versus not.

Annual estimates of mainstem harvest rates were obtained from the most recent U.S. v Oregon Technical Advisory Team report. Tributary harvest-rate estimates were provided by regional state and tribal fisheries managers.

Analysis

The first step in the analysis was to test whether the spawner and recruit data, by population, are consistent with a density-dependent recruitment model. We used a Ricker model because it is a simple linear model and therefore does not have the potential model-fitting issues that exist with nonlinear models, such as the Beverton-Holt model, when sample sizes are small.

The Ricker model relates recruits (R_t), referenced to brood year t, to spawners (S_t) as

$$R_t = S_t \cdot \exp(a - b \cdot S_t) \quad (1)$$

where a and b are density-independent and density-dependent model parameters, respectively. After rearranging terms and taking the natural log of both sides, the Ricker model can be expressed as

$$\ln(R_t / S_t) = a - b \cdot S_t \quad (2)$$

which is a linear model and easily fit to data using standard linear regression. We can express this in linear regression form as

$$\ln(R_t / S_t) = a + b \cdot S_t + \varepsilon_t \tag{3}$$

where ε_t is the error term which is distributed normally with mean 0 and variance σ^2. The data support the hypothesis of density-dependence if the b parameter is significantly different from 0 and negative. When this occurs, recruits-per-spawner decreases as spawners increase.

We note that in several populations, there were years where the estimate of spawners was 0. Because this would produce undefined terms in equation 3, we added 1 to every spawner and recruit estimate. This is a standard approach, but we acknowledge that other approaches, such as removing years in which spawner estimates were 0, are also justifiable. In Appendix 3, we assessed the implications of the various approaches.

We fit equation (3) to 44 populations of interior Columbia basin spring and summer Chinook and steelhead populations. To perform these fits, we only used data from the Base Period. For each population, we estimated model parameters, and we also calculated an R^2 and *P*-value. If the model was deemed significant ($P < 0.1$), we plotted the predicted relationship along with the data points. In addition, we also estimated 95% prediction intervals (Zar 2009) about the predicted relationships. This interval covers the envelope in which 95% of new data points would fall if they follow the modeled relationship and variability. If the model was not deemed significant ($P > 0.1$), we only plotted the data points. We chose this significance level because of the relatively low sample sizes in some of the populations.

For the populations that demonstrated significant relationships, we plotted the current data points and determined whether they fell within the 95% prediction interval, below the interval (indicating the R/S was lower than expected), or above the interval (indicating the R/S was greater than expected). Note that we expect 5% of the points to fall outside the interval by chance alone.

Results

For spring and summer Chinook populations, 20 out of 26 demonstrated significant relationships (Table 3). In all cases where the model was significant, the *b* (slope) parameter was negative, providing evidence for density dependence. When we plotted the “recent” data points onto the plots with the 95% prediction intervals, the vast majority of points fell within the 95% prediction intervals. In addition, only 1 point fell below the interval and 4 points fell above, providing no support for the hypothesis that recent conditions are less productive than those experienced during the Base Period (Figures 1-2).

For steelhead populations, 18 out of 18 demonstrated significant relationships (Table 4). In all cases, the *b* parameter was negative, providing strong evidence for density dependence. When we plotted the “recent” data points onto the plots with the 95% prediction intervals, the vast majority of points fell within the 95% prediction interval. In addition, 3 points fell below the interval and 14 points fell above, providing little support for the hypothesis that recent conditions are less productive than those experienced during the Base Period (Figures 3-4).

Discussion

These analyses provide strong support for the hypothesis that density-dependent recruitment is occurring in these populations. Further, when we plotted “recent” data points onto relationships derived from the “base” period data, the vast majority of these points fell with the 95% prediction intervals, providing strong support for the hypothesis that productivity has not decreased for these populations when comparing base to recent time periods but that the decreased R/S resulted from density-dependent processes as a result of the increased abundance observed recently (Tables 1 and 2, Figures 5-8).

One issue with this analysis was that the basic density-dependence model did not significantly fit the data for some of the populations. This was particularly the case for spring and summer Chinook populations, where 6 out 26 populations did not exhibit a significant density-dependent relationship. We believe that this was partially due to the fact the base time period encompassed a period where population abundance was generally low and thus did not cover a broad range of abundance levels. In contrast, abundance levels during the recent time period were generally higher. We thus combined the base and recent time periods together and re-fit Ricker model to the combined datasets. When we did this, 24 out of 26 spring and summer Chinook populations had significant fits (Figures 9-12).

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Table 3. Results from the regression analysis for interior Columbia basin spring and summer Chinook populations. a and b are model parameters. "above" refers to the number of recent points that fell above the 95% prediction interval, and "below" refers to the number of points that fell below the 95% prediction interval.

Population	a	b	R^2	P	above	below
LS-Tucannon	0.68	-0.0028	0.257	0.023	0	0
GR-Wenaha	0.365	-0.0023	0.124	0.128	NA	NA
GR-Lostine	0.893	-0.0036	0.433	0.002	0	0
GR-Minam	1.03	-0.003	0.420	0.002	0	0
GR-Upper Mainstem	0.0697	-0.0045	0.351	0.006	0	0
GR-Catherine Cr	0.109	-0.0036	0.294	0.014	0	0
GR-Imnaha	0.69	-0.0015	0.215	0.040	0	0
SF-Mainstem	0.726	-0.0011	0.395	0.003	0	0
SF-Secesh	0.566	-0.0011	0.033	0.441	NA	NA
SF-East Fork	0.335	-0.0012	0.031	0.459	NA	NA
MF-Big Creek	1.11	-0.0054	0.211	0.042	0	0
MF-Camas Cr	0.892	-0.016	0.237	0.035	0	0
MF-Loon	0.0679	0.0016	0.001	0.893	NA	NA
MF-Sulfur Cr	1.06	-0.0098	0.204	0.045	0	0
MF-Bear Valley/Elk	0.787	-0.0016	0.110	0.152	NA	NA
MF-Marsh Cr	1.03	-0.0045	0.147	0.095	0	0
SR-Lemhi	1.39	-0.0085	0.489	0.001	0	0
SR-Pahsimeroi	2.12	-0.021	0.451	0.006	4	0
SR-Lower Mainstem	1.28	-0.0095	0.412	0.002	0	0
SR-East Fork	1.52	-0.0077	0.331	0.008	0	0
SR-Yankee Fork	1.65	-0.055	0.465	0.001	0	0
SR-Valley Cr	1.49	-0.017	0.438	0.001	0	0
SR-Upper Mainstem	1.51	-0.0039	0.277	0.017	0	0

UC-Wenatchee	0.162	-0.00037	0.060	0.298	NA	NA
UC-Methow	1.13	-0.0014	0.234	0.031	0	1
UC-Entiat	0.658	-0.0045	0.254	0.024	0	0

Table 4. Results from the regression analysis for interior Columbia basin steelhead populations. a and b are model parameters. "above" refers to the number of recent points that fell above the 95% prediction interval, and "below" refers to the number of recent points that fell below the 95% prediction interval.

Population	a	b	R^2	P	above	below
UC-Wenatchee	-0.799	-0.00019	0.445	0.001	1	0
UC-Entiat	-0.447	-0.0027	0.270	0.019	0	0
UC-Methow	-0.868	-0.00066	0.537	0.000	4	0
UC-Okanogan	-2.18	-0.00037	0.385	0.004	0	0
MC-Fifteenmile Cr	1.11	-0.0016	0.449	0.006	0	0
Deschutes-W	0.977	-0.0017	0.372	0.004	0	0
JD-Lower Mainstem	1.43	-0.00038	0.514	0.000	0	0
JD-North Fork	1.45	-0.0006	0.785	0.000	0	0
JD-Upper Mainstem	1.01	-0.0006	0.434	0.002	0	1
JD-Middle Fork	1.24	-0.00068	0.547	0.000	0	2
JD-South Fork	0.98	-0.0013	0.404	0.003	0	0
MC-Umatilla	1.19	-0.00064	0.369	0.005	0	0
YR-Satus	1	-0.0018	0.627	0.000	3	0
YR-Toppenish	1.45	-0.0057	0.223	0.076	0	0
YR-Naches	1.28	-0.0026	0.505	0.003	3	0
YR-Upper Yakma	1.16	-0.012	0.536	0.002	3	0
GR-Upper Mainstem	0.968	-0.00056	0.640	0.000	0	0
GR-Joseph Cr	1.33	-0.00042	0.619	0.000	0	0

Appendix C I R/S Base vs. Current

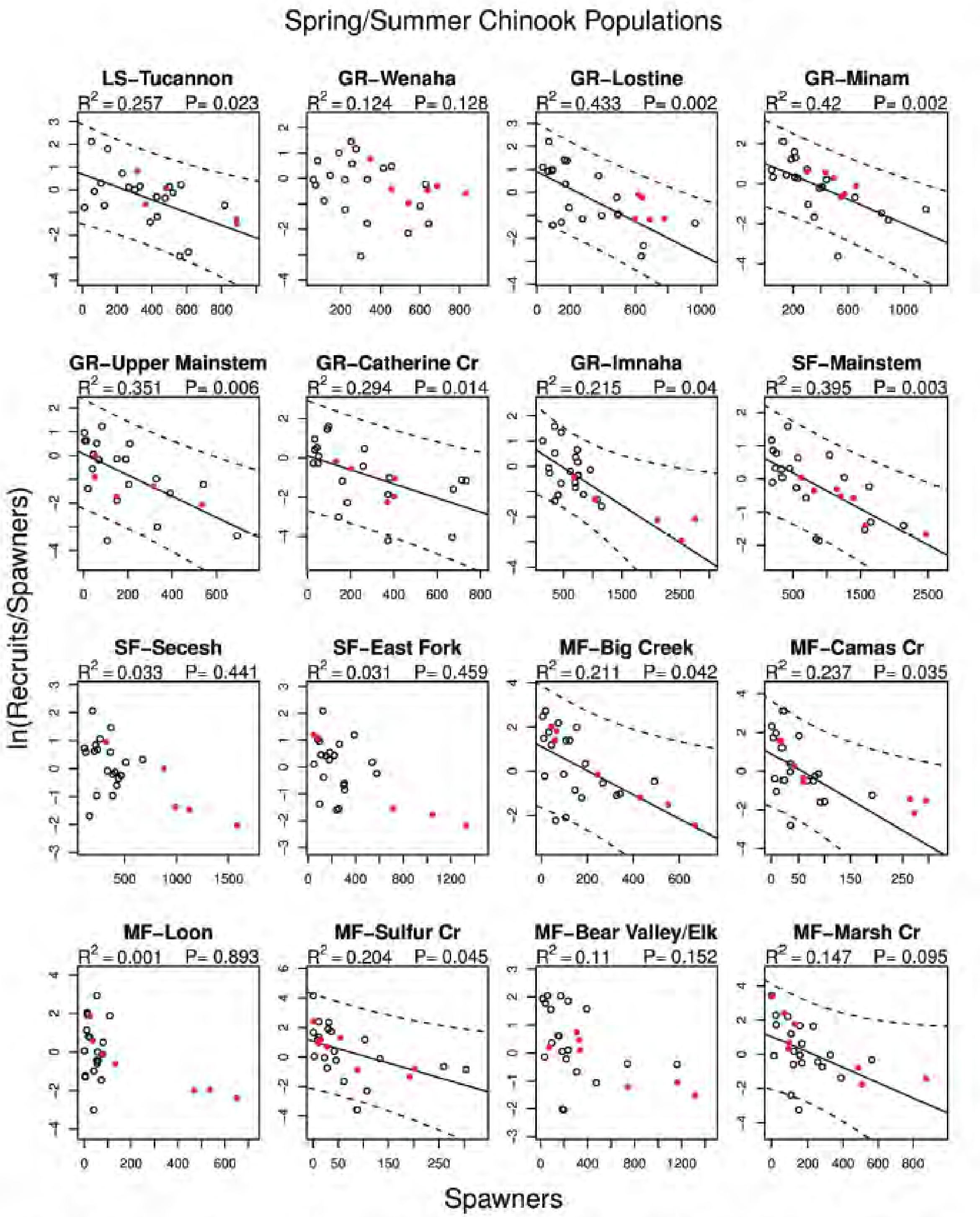

Figure 1. Ln(recruits/spawner) versus spawners for Interior Columbia River spring and summer Chinook populations. Open black points represent base period (1980-2000), and red points represent recent period. Based on linear regression, if P < 0.1, the dark line is the best fit, and the dashed lines are the 95% prediction interval for the data.

Appendix C I R/S Base vs. Current

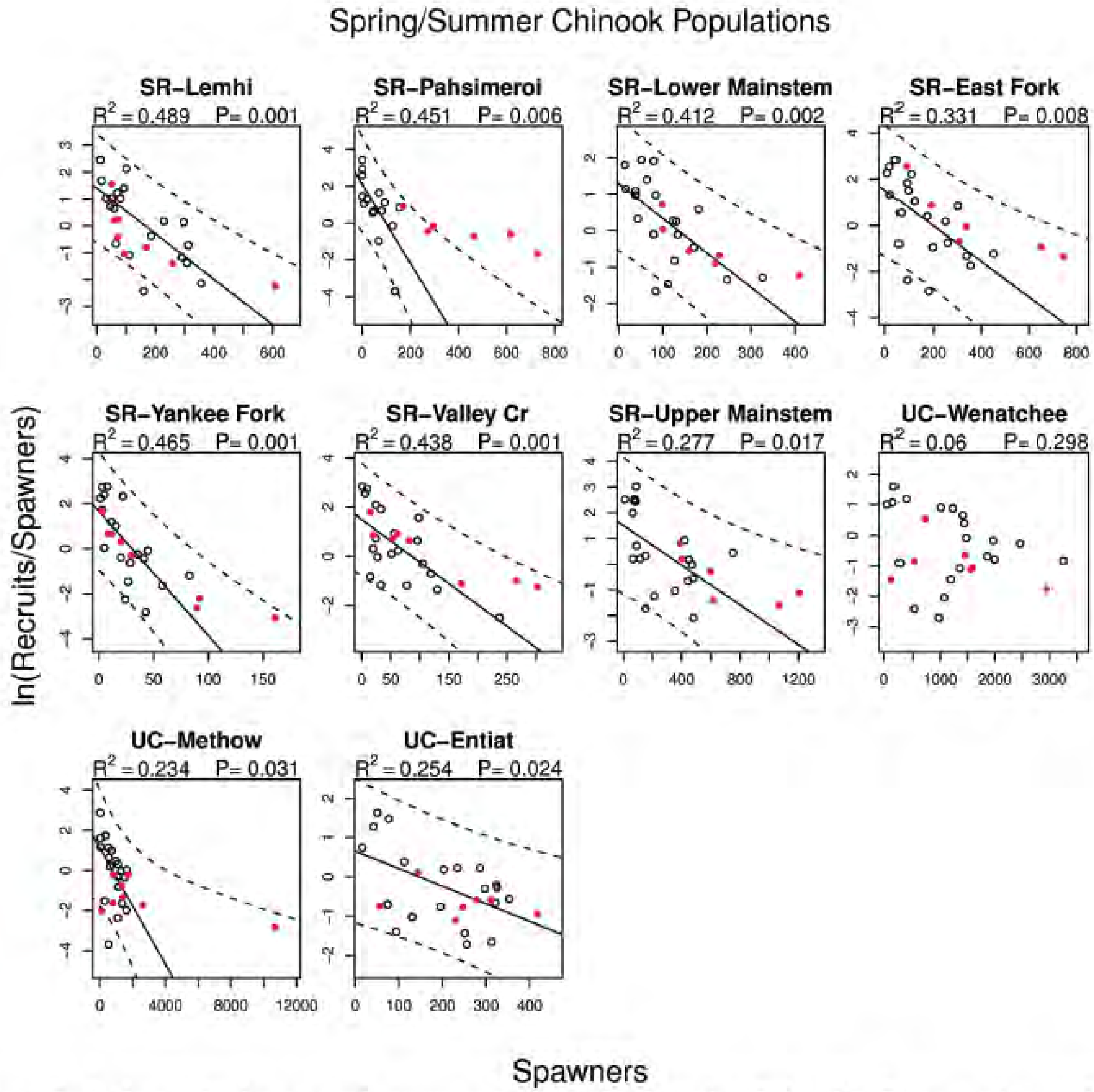

Figure 2. Ln(recruits/spawner) versus spawners for Interior Columbia River spring and summer Chinook populations. Open black points represent base period (1980-2000), and red points represent recent period. Based on linear regression, if P < 0.1, the dark line is the best fit, and the dashed lines are the 95% prediction interval for the data.

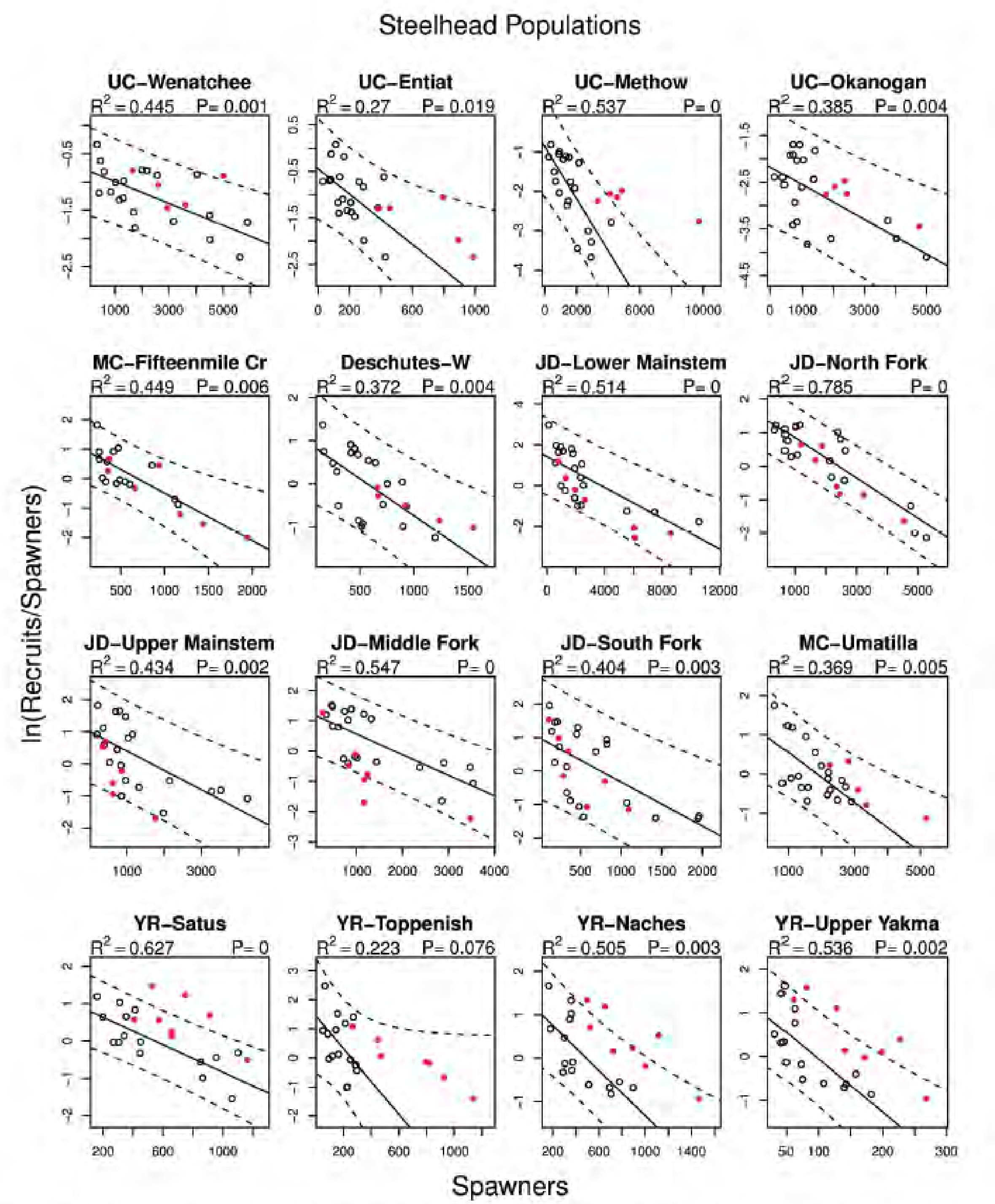

Figure 3. Ln(recruits/spawner) versus spawners for Interior Columbia River steelhead populations. Open black points represent base period (1980-2000), and red points represent recent period. Based on linear regression, if P < 0.1, the dark line is the best fit, and the dashed lines are the 95% prediction interval for the data.

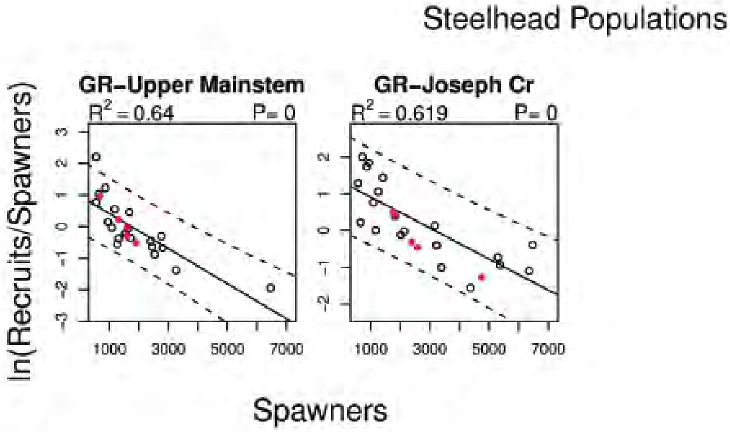

Figure 4. Ln(recruits/spawner) versus spawners for Interior Columbia River steelhead populations. Open black points represent base period (1980-2000), and red points represent recent period. Based on linear regression, if $P < 0.1$, the dark line is the best fit, and the dashed lines are the 95% prediction interval for the data. Note that these 2 populations did not have any harvest data.

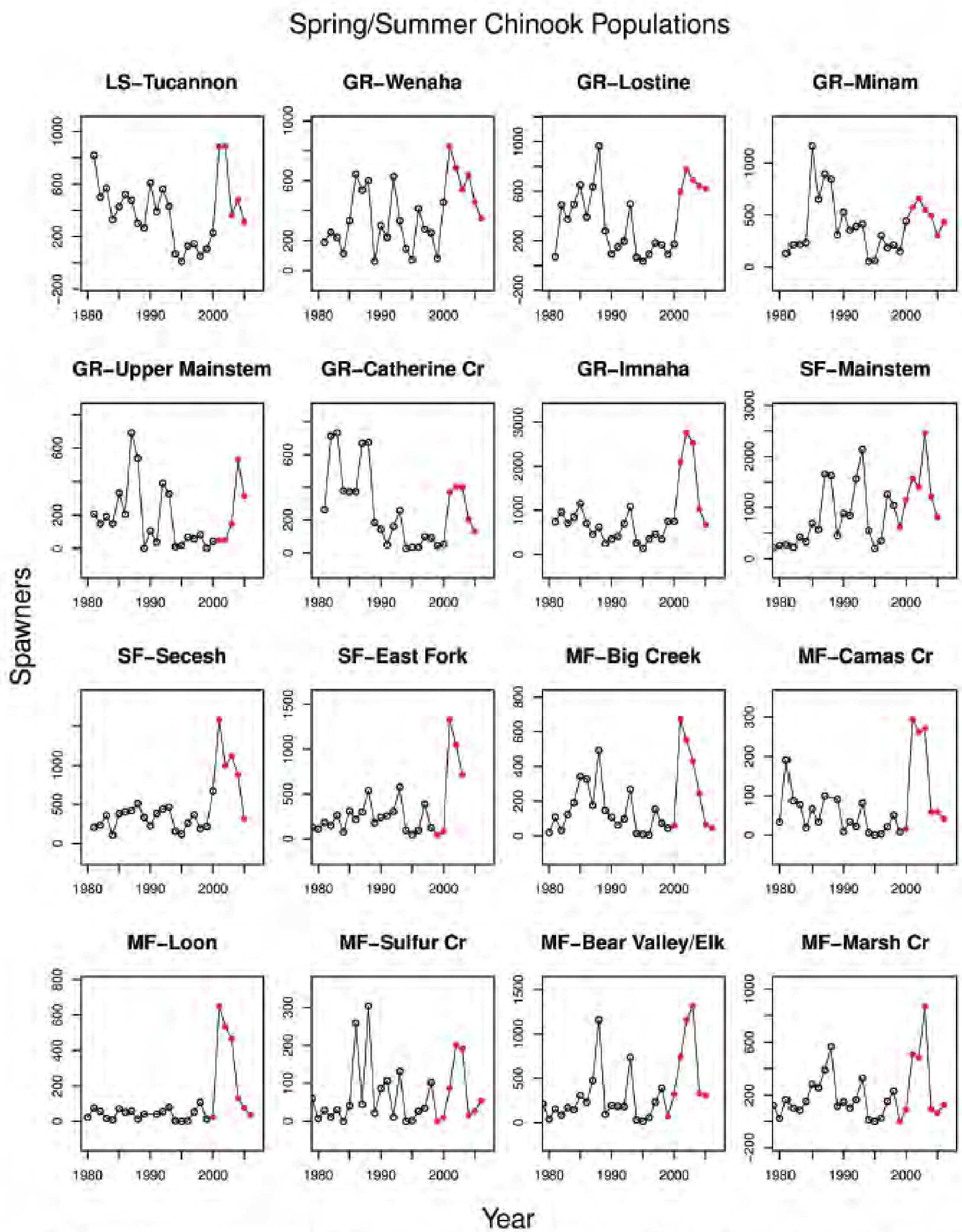

Figure 5. Spawners versus year for Interior Columbia River spring and summer Chinook populations. Open black points represent base period (1980-2000), and red points represent recent period.

Appendix C I R/S Base vs. Current

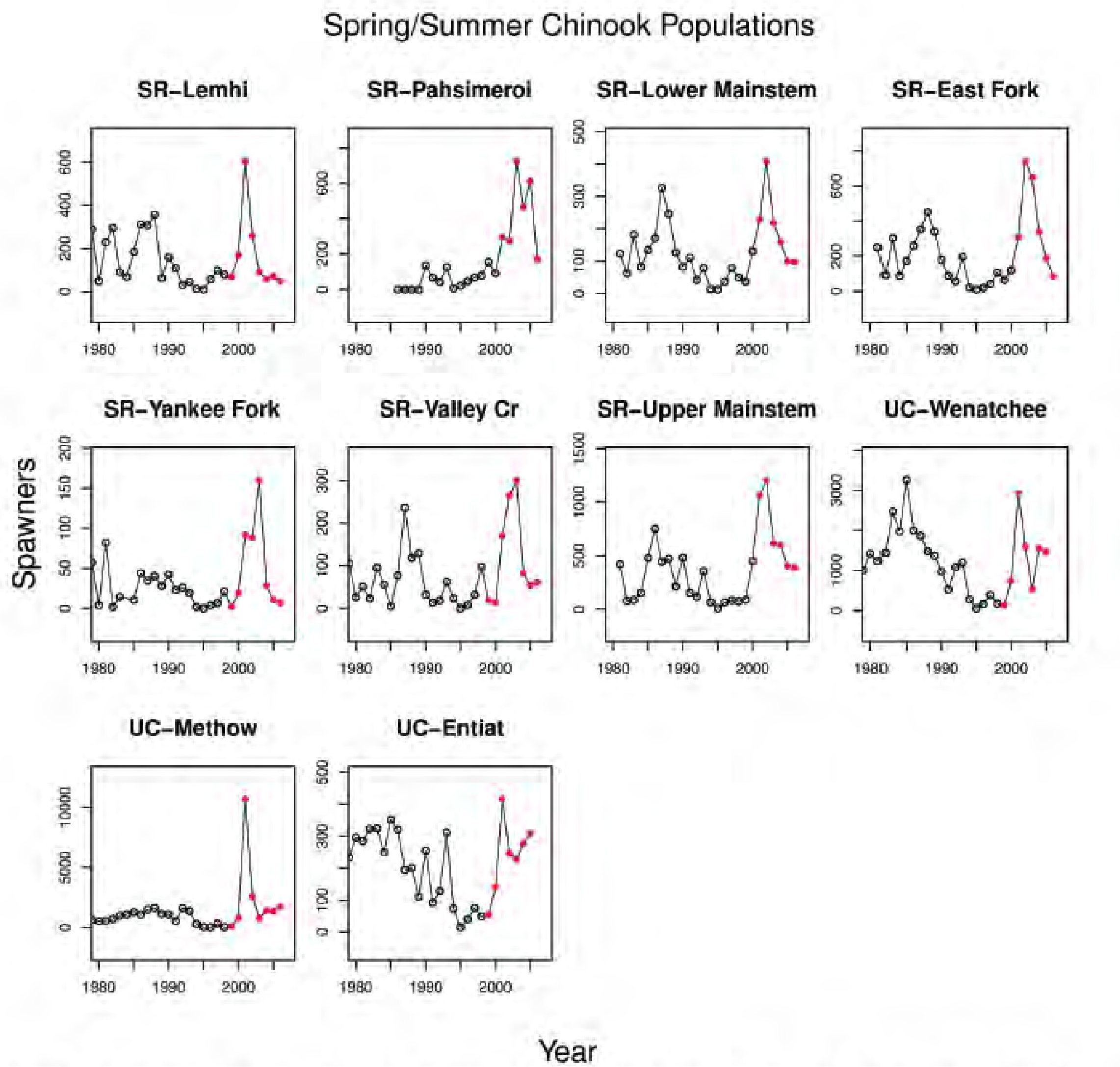

Figure 6. Spawners versus year for Interior Columbia River spring and summer Chinook populations. Open black points represent base period (1980-2000), and red points represent recent period.

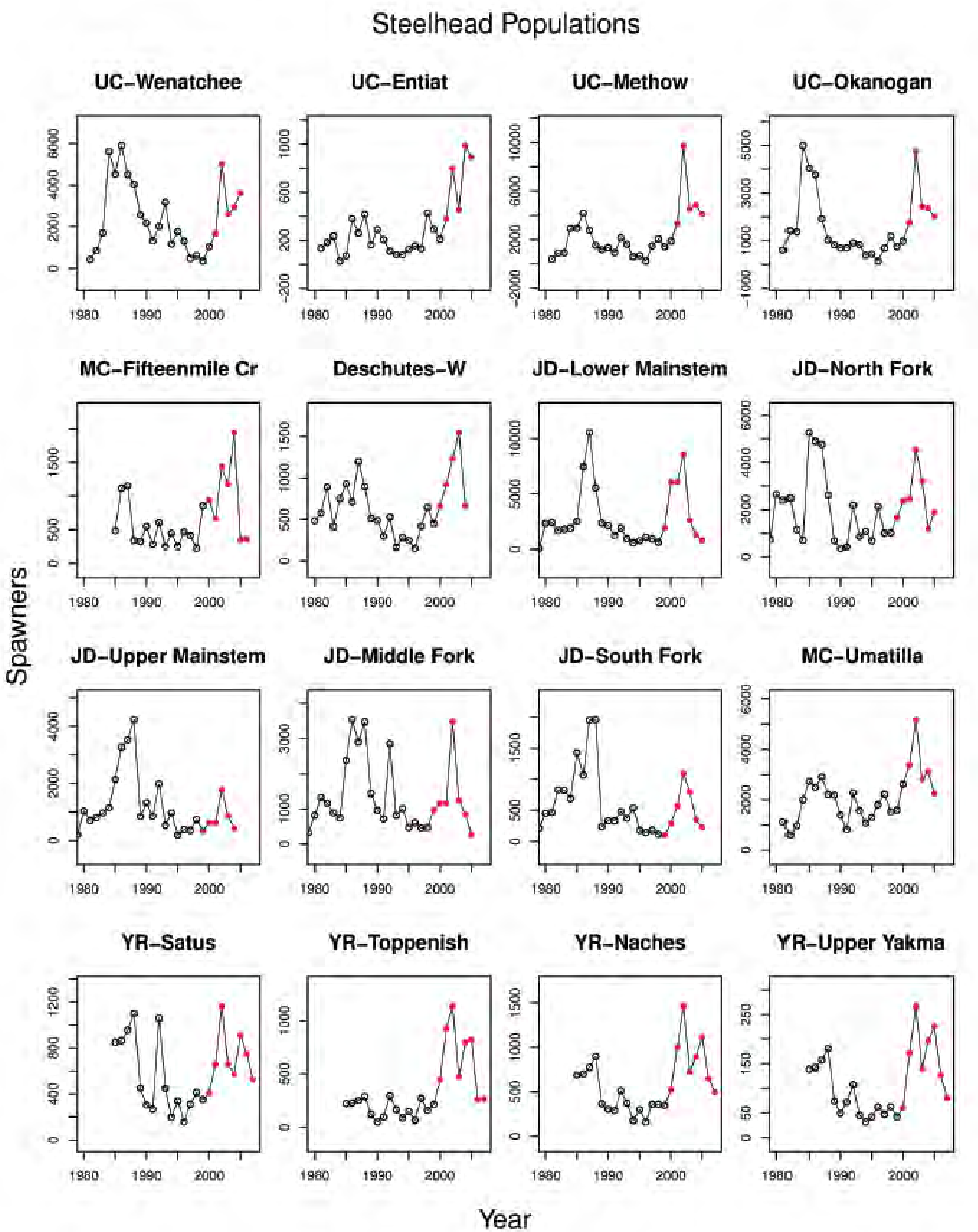

Figure 7. Spawners versus year for Interior Columbia River steelhead populations. Open black points represent base period (1980-2000), and red points represent recent period.

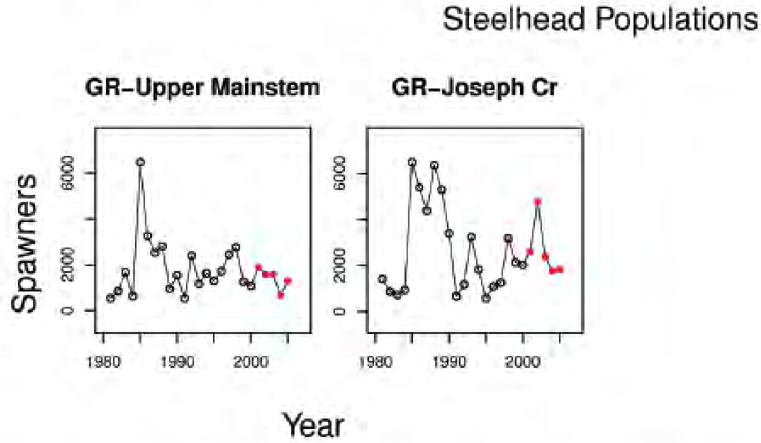

Figure 8. Spawners versus year for Interior Columbia River steelhead populations. Open black points represent base period (1980-2000), and red points represent recent period. Note that these 2 populations did not have any harvest data.

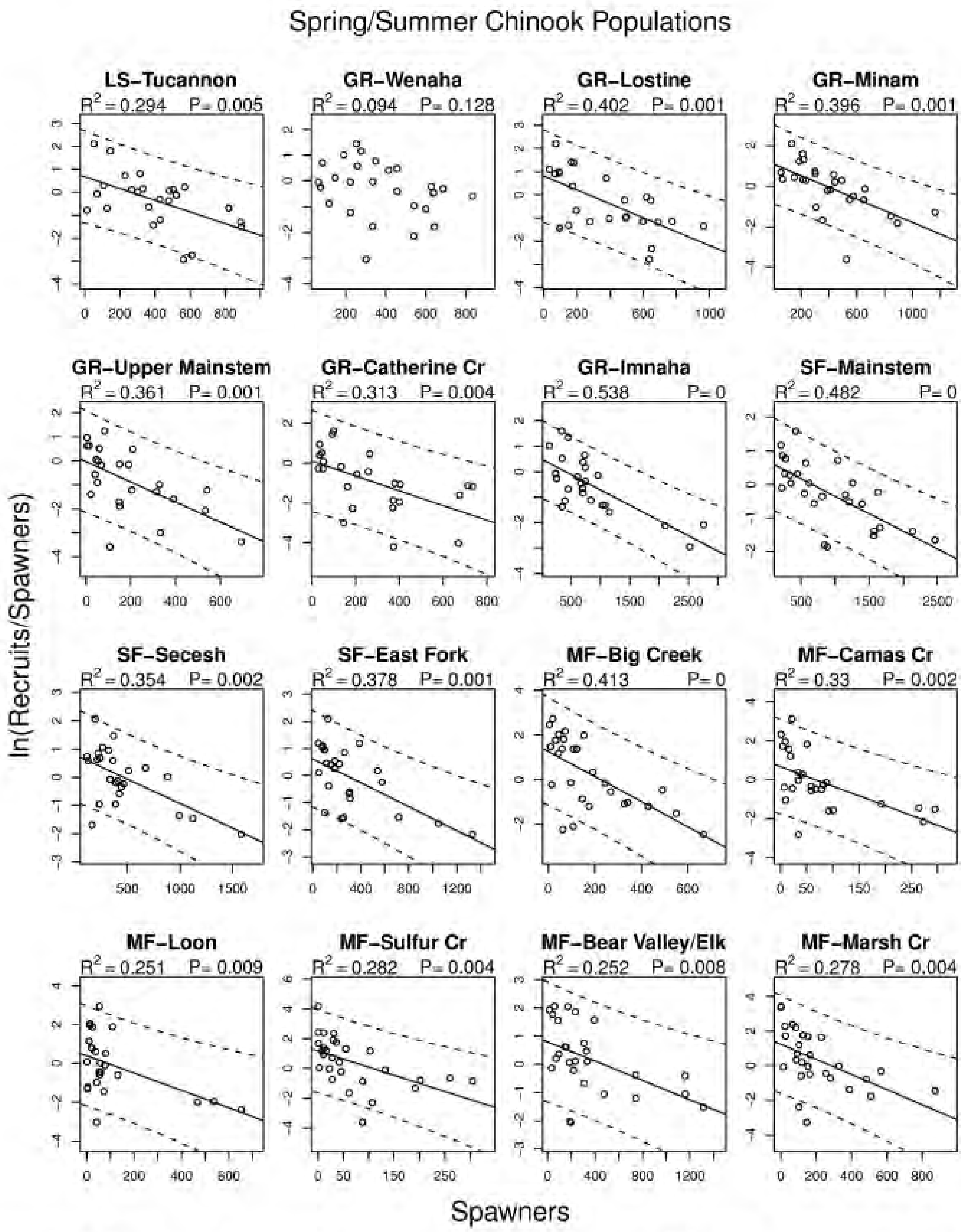

Figure 9. Ln(recruits/spawner) versus spawners for Interior Columbia River spring and summer Chinook populations. Open black points represent base period (1980-2000), and red points represent recent period. **The regression model was fit to all data (base and recent)**. Based on linear regression, if P < 0.1, the dark line is the best fit, and the dashed lines are the 95% prediction interval for the data.

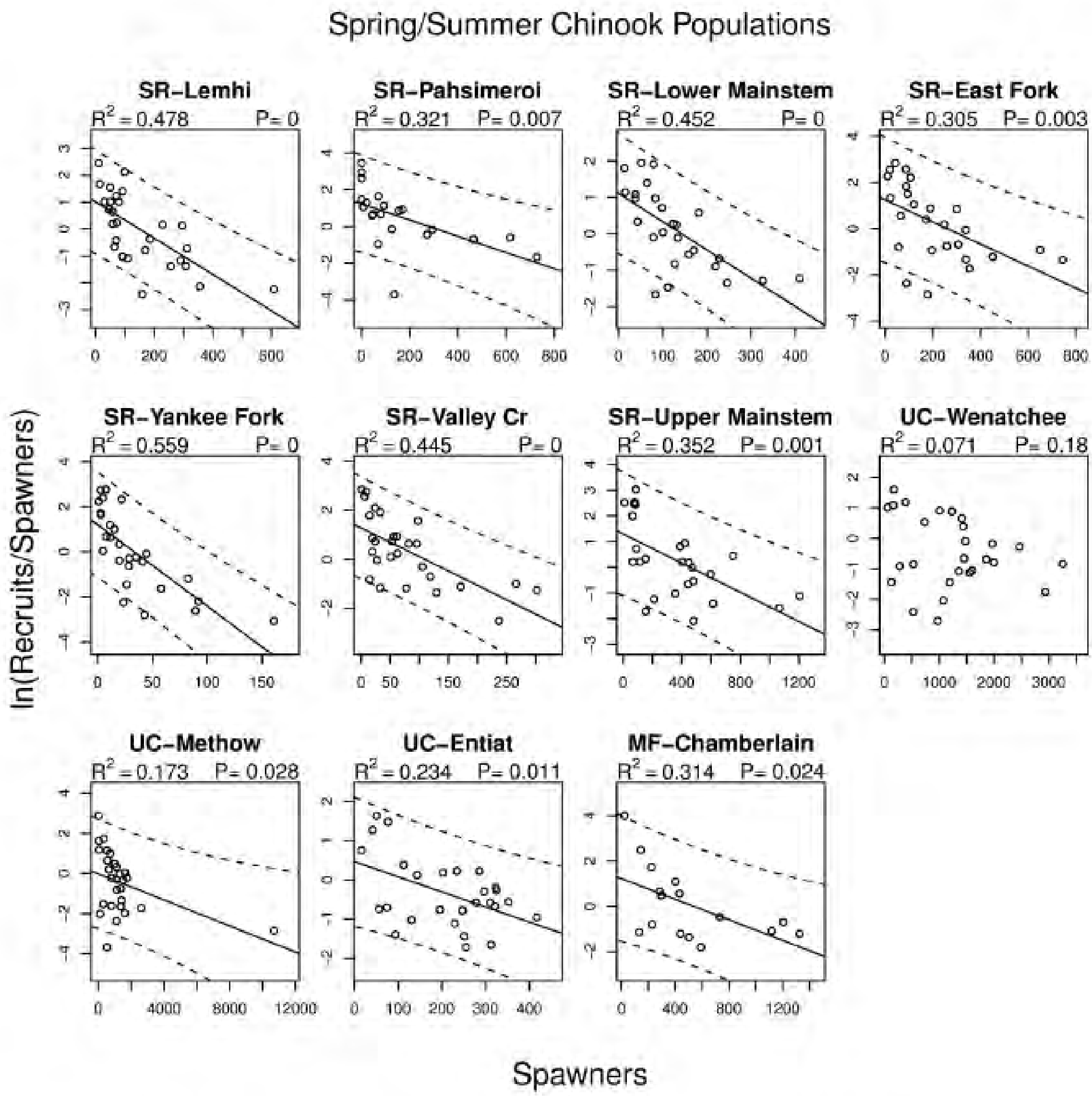

Figure 10. Ln(recruits/spawner) versus spawners for Interior Columbia River spring and summer Chinook populations. Open black points represent base period (1980-2000), and red points represent recent period. **The regression model was fit to all data (base and recent).** Based on linear regression, if $P < 0.1$, the dark line is the best fit, and the dashed lines are the 95% prediction interval for the data. The MF-Chamberlain population did not have any "base period" data, and was not included in the previous analyses.

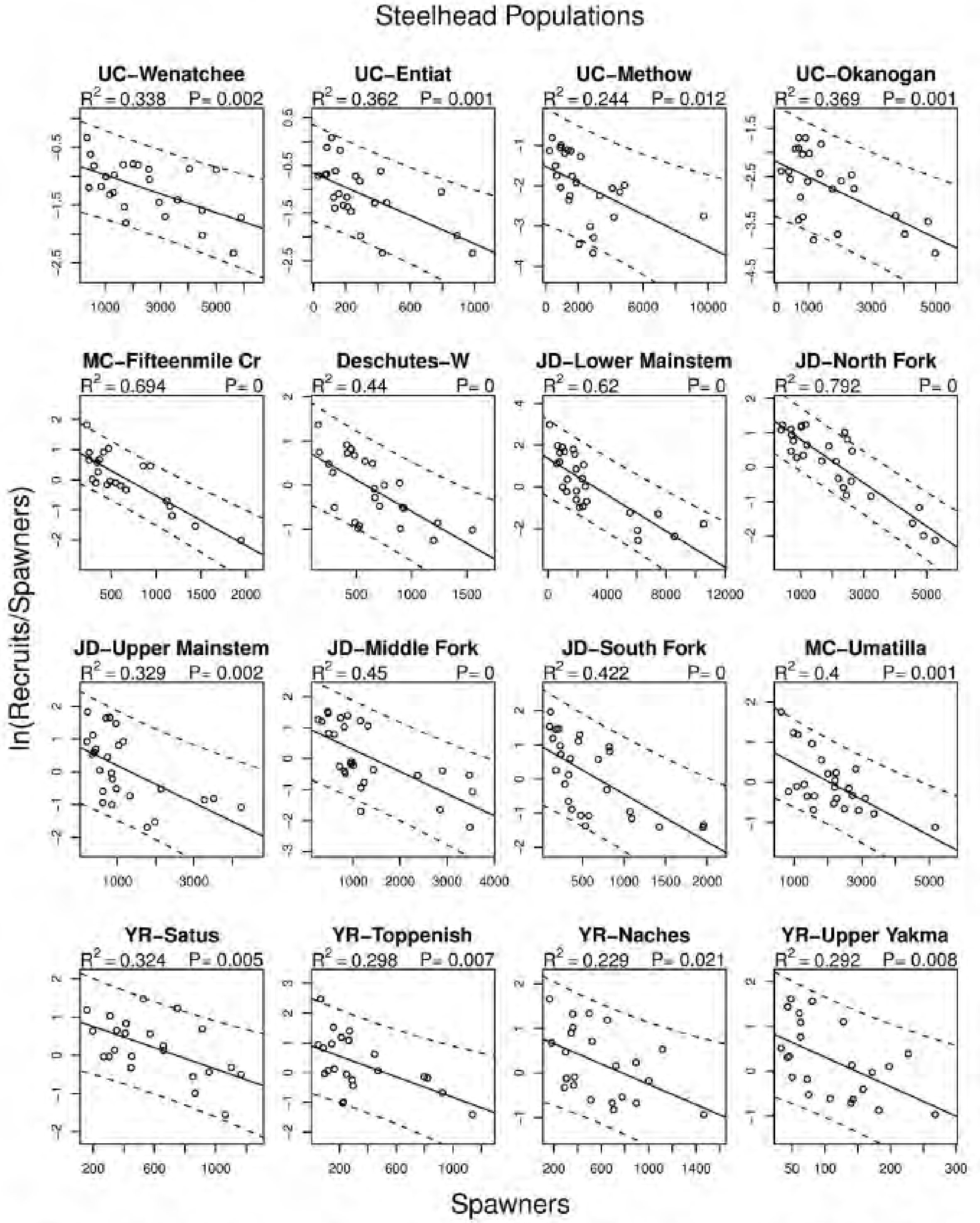

Figure 11. Ln(recruits/spawner) versus spawners for Interior Columbia River steelhead populations. Open black points represent base period (1980-2000), and red points represent recent period. **The regression model was fit to all data (base and recent).** Based on linear regression, if $P < 0.1$, the dark line is the best fit, and the dashed lines are the 95% prediction interval for the data.

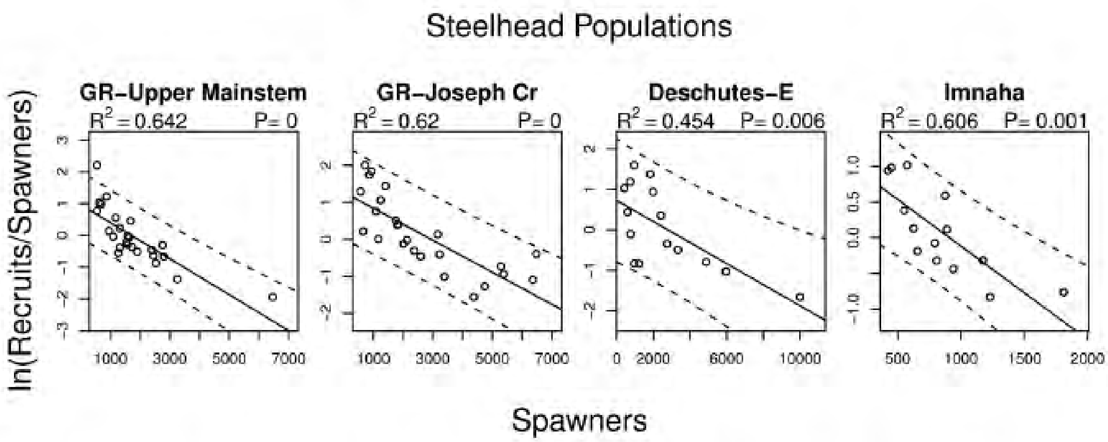

Figure 12. Ln(recruits/spawner) versus spawners for Interior Columbia River steelhead populations. Open black points represent base period (1980-2000), and red points represent recent period. **The regression model was fit to all data (base and recent).** Based on linear regression, if $P < 0.1$, the dark line is the best fit, and the dashed lines are the 95% prediction interval for the data. Note that the GR-Upper Mainstem and GR-Joseph Cr populations did not have harvest data. Also, the Deschutes-E and Imnaha populations did not have any "base period" data, and were not included in the previous analyses.

Appendix Table 1. Populations, major population groups (MPG), evolutionarily significant units (ESU), and distinct population segments (DPS) of salmon and steelhead addressed in this report. Shading indicates populations for which data were lacking or insufficient for the analysis and populations that are functionally extirpated.

ESU	MPG	Population	Codes for Populations Addressed in This Report
Snake River Spring/ Summer Chinook Salmon	Lower Snake	Tucannon River	LS-Tucannon
		Asotin Cr Functionally Extirpated	
	Grande Ronde Imnaha	Catherine Creek	GR-Catherine Cr
		Upper Grande Ronde	GR-Upper Mainstem
		Minam River	GR-Minam
		Wenaha River	GR-Wenaha
		Lostine/Wallowa Rivers	GR-Lostine
		Imnaha Mainstem	GR-Imnaha
		Big Sheep Creek Functionally Extirpated	
		Lookingglass- Functionally Extirpated	
	South Fork Salmon	South Fork Salmon Mainstem	SF-Mainstem
		Secesh River	SF-Secesh
		East Fork S. Fork Salmon (including Johnson Cr)	SF-East Fork
		Little Salmon River (including Rapid R.)	
	Middle Fork Salmon	Big Creek	MF-Big Creek
		Bear Valley/Elk Creek	MF-Bear Valley/Elk
		Marsh Creek	MF-Marsh Cr
		Sulphur Creek	MF-Sulphur Cr
		Camas Creek	MF-Camas Cr
		Loon Creek	MF-Loon
		Chamberlain Creek	MF-Chamberlain
		Lower Middle Fork Salmon (below Ind. Cr.)	
		Upper Middle Fork Salmon (above Ind. Cr.)	
	Upper Salmon	Lemhi River	SR-Lemhi
		Valley Creek	SR-Valley Cr
		Yankee Fork	SR-Yankee Fork
		Upper Salmon River (above Redfish L.)	SR-Upper Mainstem
		North Fork Salmon River	
		Lower Salmon River (below Redfish L.)	SR-Lower Mainstem

Appendix C I R/S Base vs. Current

		East Fork Salmon River	SR-East Fork
		Pahsimeroi River	SR-Pahsimeroi
		Panther Extirpated	

Upper Columbia Spring Chinook Salmon	**Eastern Cascades**	Wenatchee R.	UC-Wenatchee
		Methow R.	UC-Methow
		Entiat R.	UC-Entiat
		Okanogan R. (extirpated)	
Snake River Fall Chinook Salmon	**Main Stem and Lower Tributaries**	Lower Mainstem Fall Chinook	

DPS	MPG	Population	Codes for Populations Addressed in This Report
Upper Columbia River Steelhead	**Eastern Cascades**	Wenatchee River	UC-Wenatchee
		Methow River	UC-Methow
		Entiat River	UC-Entiat
		Okanogan River	UC-Okanogan
Snake River Steelhead	**Lower Snake**	Tucannon River	
		Asotin Creek	
	Imnaha River	Imnaha River	Imnaha
	Grande Ronde	Upper Mainstem	GR-Upper Mainstem
		Lower Mainstem	
		Joseph Cr.	GR-Joseph Cr
		Wallowa R.	
	Clearwater River	Lower Mainstem	
		Lolo Creek	
		Lochsa River	
		Selway River	
		South Fork	

Appendix C I R/S Base vs. Current

		North Fork (Extirpated)	
	Salmon River	Upper Middle Fork Tribs	
		Chamberlain Cr.	
		South Fork Salmon	
		Panther Creek	
		Secesh River	
		North Fork	
		Lower Middle Fork Tribs	
		Little Salmon/Rapid	
		Lemhi River	
		Pahsimeroi River	
		East Fork Salmon	
		Upper Mainstem	
Mid Columbia Steelhead	Yakima	Upper Yakima R.	YR-Upper Yakima
		Naches R.	YR-Naches
		Toppenish Cr	YR-Toppenish
		Satus Cr	YR-Satus
	Eastern Cascades	Deschutes West	Deschutes-W
		Deschutes East	Deschutes-E
		Klickitat R.	
		Fifteenmile Cr.	
		Rock Cr.	
		White Salmon Extirpated	
	Umatilla/ Walla Walla	Umatilla R.	MC-Umatilla
		Walla-Walla R.	
		Touchet R.	
	John Day	Lower Mainstem	JD-Lower Mainstem
		North Fork	JD-North Fork
		Upper Mainstem	JD-Upper Mainstem
		Middle Fork	JD-Middle Fork
		South Fork	JD-South Fork

Appendix 2: Comparisons of alternative approaches

When we compiled the spawner and recruit data for interior Columbia River salmonid populations, we needed to make the following choices: 1) how to treat harvested fish in the estimation of recruits, and 2) how to treat years when few or no spawners returned. In this appendix, we made comparisons of alternative approaches to determine how influential these approaches were to final results.

When we calculated brood year recruits, R_t, we had to choose how to treat fish that were harvested during upstream migration. Harvest removes potential recruits, and if harvest occurred differentially across time, it could alter the underlying relationships that characterize population dynamics. Therefore we chose to add harvested fish to fish that returned to spawning sites in the following manner:

$$R_t = \frac{A_t}{1 - h_t}$$

where R_t are estimated recruits from brood year t, A_t are post-harvest returning adults, and h_t is the harvest rate for adults from brood year t. R_t represent the number of naturally produced fish that would have appeared on the spawning grounds had there not been a harvest. For comparison purposes, we performed an analysis where we did not add harvested to fish to estimate recruits. In this case, we just set $R_t = A_t$.

In some populations for a few years, few or no adults returned to the spawning area. Because the analysis required dividing recruits by spawners, dividing by zero spawners would result in an undefined term. Further, dividing by 5 or fewer spawners could produce biased results (ICTRT analysis). Accordingly, we examined the following three approaches: 1) deleting all years in a population where zero spawners returned; 2) deleting all years in a population where 5 or fewer spawners returned; 3) adding 1 to spawners and recruits for all years.

In this appendix, we made the following 3 comparisons:

1) Calculating recruits by adjusting for harvest rate *versus* calculating recruits without adjusting for harvest rate.

2) Deleting years with 0 spawners *versus* deleting years with 5 or fewer spawners.

3) Deleting years with 0 spawners *versus* adding 1 to spawners and recruits and using all data.

For all comparisons, we made pairwise comparisons by population of the following 4 outputs: 1) *a* parameter in Ricker model; 2) *b* parameter in Ricker model; 3) P-values from Ricker model fit; 4) Variance of residuals from Ricker model fit.

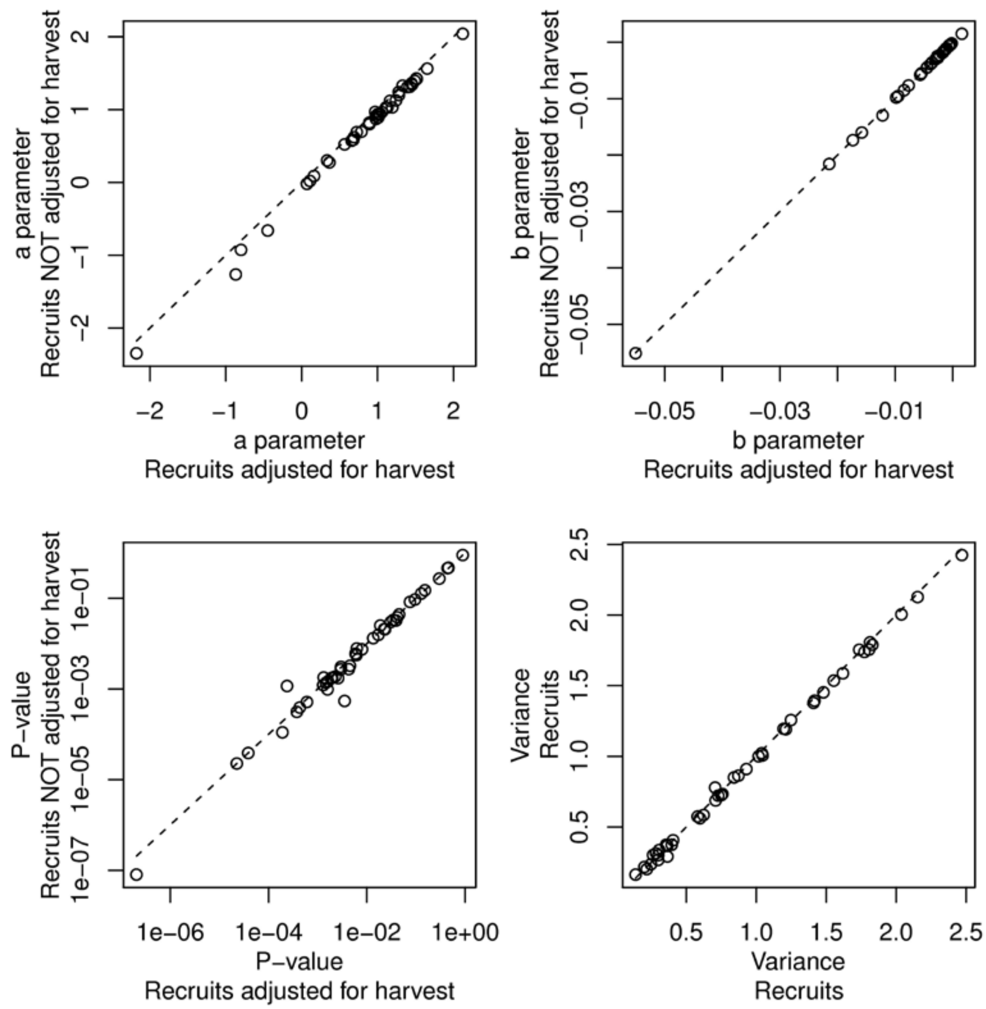

Figure 1. Comparison of calculating recruits by adjusting for harvest rate *versus* calculating recruits without adjusting for harvest rate. In each comparison, each point represents a population. Note that the axes for the comparison of P-values are on a log scale to spread out the points. The dashed line is the one-to-one line.

Appendix C I R/S Base vs. Current

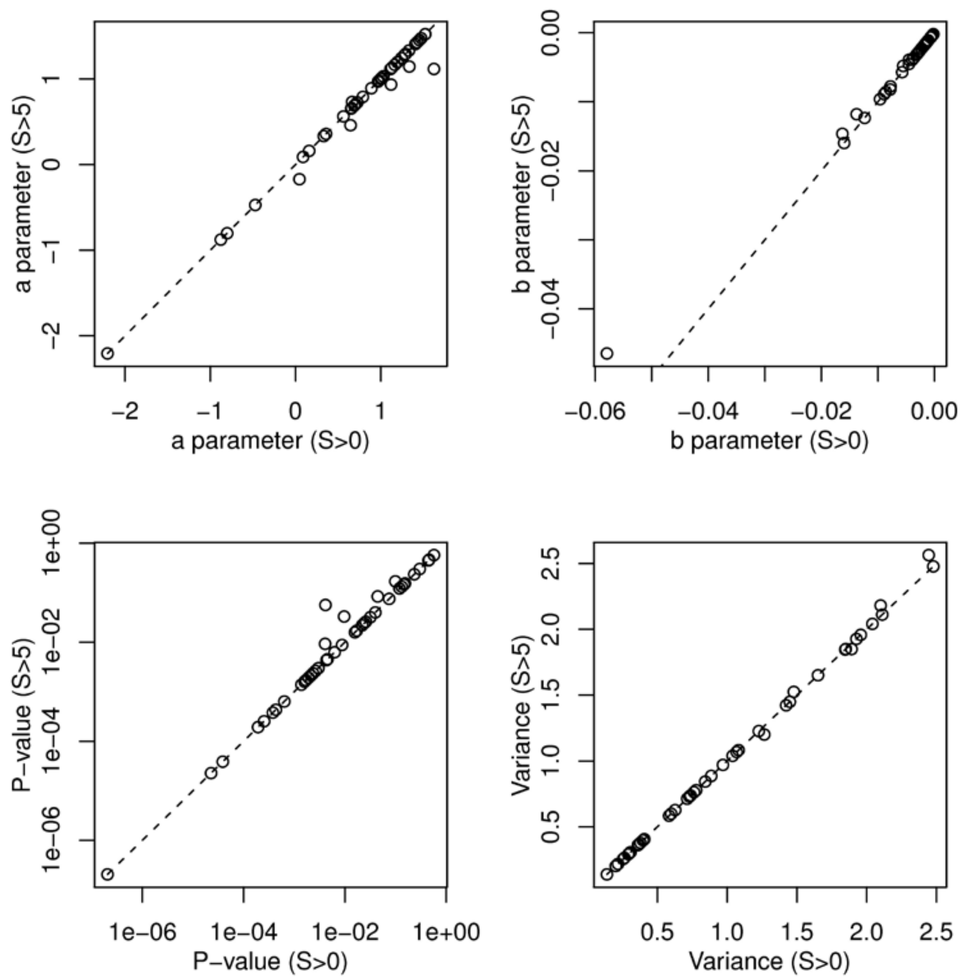

Figure 2. Comparison of deleting years with 0 spawners *versus* deleting years with 5 or fewer spawners. In each comparison, each point represents a population. Note that the axes for the comparison of P-values are on a log scale to spread out the points. The dashed line is the one-to-one line.

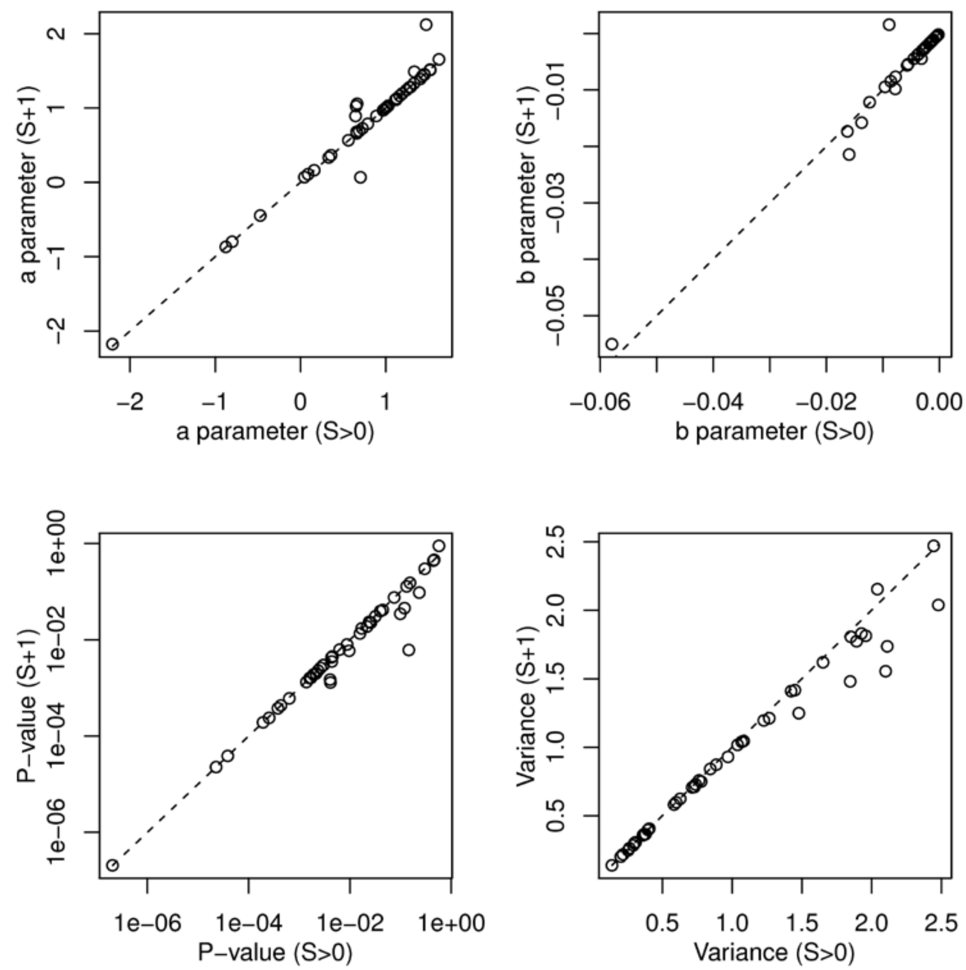

Figure 3. Comparison of deleting years with 0 spawners versus adding 1 to spawners and recruits and using all data. In each comparison, each point represents a population. Note that the axes for the comparison of P-values are on a log scale to spread out the points. The dashed line is the one-to-one line.

Results and Discussion

The comparison between adding harvested fish to recruits versus not adding harvested fish demonstrated little difference in the approaches (Figure 1). The Ricker *a* parameter (productivity) was slightly greater when harvested fish were added to recruits, but this is expected. Importantly, the Ricker *b* parameter (density dependence) was nearly identical between the two approaches. Because our analysis in the main document is focused on whether population dynamics have changed across time periods, we chose to add harvested fish to estimate recruits. However, we note that analyses with other goals might choose to ignore harvested fish when estimating recruits.

The comparison between deleting years with 0 spawners versus deleting years with 5 or fewer spawners demonstrated that these two approaches produced very similar results (Figure 2). For one population (Yankee Fork Chinook), deleting years with 0 spawners resulted in a greater *b* parameter than did the approach of deleting years with 5 or fewer spawners. This was not concerning because this population had the strongest density dependence regardless of approach.

The comparison between deleting years with 0 spawners and adding 1 to spawners and recruits in all years produced slightly more scatter in the Ricker *a* and *b* parameters (Figure 3). But there were no apparent biases between approaches because the points fell above and below the 1-to-1 line. However, the variance and P-values were smaller when we added 1 to spawners and recruits. This is expected because removing years from the dataset results in smaller sample sizes. Because of this reduced variance, we adopted the approach of adding 1 to spawners and recruits for all years.

WHEN SALMON ARE DAMMED

Problems for the Columbia Basin's Salmon

RIVERS OF NO RETURN

Before the coming of settlers to the Northwest, ten to sixteen million salmon and steelhead returned each year to the streams and rivers of the Columbia Basin. The chinook salmon run was once the greatest in the world. Today, runs have declined by 90% to less than 1.5 million fish and about 75% of these fish are hatchery raised.

Some 37 genetically distinct salmon runs have been lost forever. Extinct salmon include the coho of the Snake, Grande Ronde, Yakima, Walla Walla and Bull Run rivers, the sockeye of the Metolius and Wallowa rivers, the fall chinook of the Willamette and Umatilla rivers, and the spring chinook of the Lewis, White Salmon, and Klickitat rivers.

The American Fisheries Society fears that about 36 runs of salmon and steelhead in the Columbia Basin are now at high risk for extinction. The Snake River sockeye, spring/summer chinook and fall chinook salmon have already been listed under the Endangered Species Act.

WHAT'S HAPPENED TO THE SALMON?

Scientists estimate that about 70%-95% of the human-induced kills of salmon in the Columbia Basin are dam related. According to the U.S. Fish and Wildlife Service "the major decline of the runs coincides with the construction and operation of dams for electrical power, irrigation, and flood control. Between 1930 and the late 1970's about 200 dams, including 19 major hydro-electric dams, were constructed in the Columbia Basin to provide water for irrigation, flood control, barging, and cheap electricity for the aluminum smelters and cities of the region. Hardly any major stream was left untouched. For example, the 1214 mile Columbia River was turned into a series of back to back dams and reservoirs. Less than 200 miles of the Columbia River in the United States remain free-flowing today.

Dams have decimated salmon in many ways including:

- Blocking and flooding salmon habitat.
- Killing or stunning fish as they pass through dam turbines.
- Increasing migration times, predation, and stress.

If salmon are to survive, dams must be modified to increase water flow and provide safer passage. The "other solutions" that have been tried for decades have not worked:

- Hatcheries are not able to compensate for dam impacts.
- Barging salmon around the dams has not restored the runs.
- Severe reductions in commercial and sport fishing have not stopped the decline (e.g. Idaho has not had a general salmon fishing season since 1978; Columbia River commercial fishing for summer chinook was closed in 1965).

WHAT NEEDS TO BE DONE TO HELP SALMON SURVIVAL?

Some scientists feel that the quickest and simplest way to rebuild Columbia Basin salmon populations is to remodel the dams. The dams must be fixed to allow safer, quicker passage for young migrating salmon. This means:

- Screening the dams so young fish are kept away from the turbines.
- Spilling more water and more salmon over the dams during migration times, rather than collecting them for barging.
- Increasing water velocity during salmon migration. This is most effectively done by temporarily drawing down the water levels in the reservoirs behind the four lower Snake River dams by 30 to 40 feet and by reducing the water level of the John Day reservoir by 5 to 7 feet.

Toole Declaration, Exhibit 2, page 1

It means modifying the dams to allow for these drawdowns.

Other measures such as water conservation, screening of pumps and diversions, and restoring stream-side habitat are also necessary for salmon survival, but will be insufficient unless the dams are fixed.

WHAT WILL CHANGES COST?

It will cost money to fix the dams and to mitigate for the impacts on other users of the river, but it is affordable for the region's rate payers. The required changes will also have little or no net impact on prices or jobs, according to university agricultural economists.

Dam draw-downs will mean spending money to fix the dams to allow for the reservoir reductions, adjusting the fish passage facilities for adult and juvenile fish, and armoring the reservoir embankments. It will also mean paying to relocate irrigation pump intakes and marina docks to deeper water so they can be used during the drawdowns, and compensating barge transporters and some port operators for temporary interruption of their work.

It is estimated that the full costs for facility modifications and river user compensation will raise the average residential electrical bill from $9-$18 per year ($0.75-1.50/month). This increase to household bills could be eased if there was a reduction in some of the energy subsidies to the aluminum industries, which use a fifth of all the power generated in the Northwest. According to a 1994 story in *Willamette Week*, the average household pays $45 a year to subsidize this industry's electrical rates.

The Northwest Power Planning Council estimates that the loss of firm power due to a 2-month reservoir draw-down will be 25 average megawatts—a minor amount in the total power grid of 16,000 average megawatts. Effects of this loss of power and the associated revenue can be minimized by making power exchange agreements with Southern California and increasing existing programs in energy efficiency.

WHY DAMS KILL SALMON

Dams kill salmon because salmon must migrate up and down the river to survive. Salmon are born in the gravel at the bottom of fresh water streams. They grow to a few inches in the streams, then must migrate downstream to the estuaries and out to the sea. They live in the ocean for three to five years, before returning to their home stream to spawn.

Some dams were built with no way for salmon to get either down or upstream. The Grand Coulee Dam blocked 1100 miles of Columbia River habitat. The Hells Canyon Dam blocked another 2,000 miles in the Snake River Basin. Additional spawning habitat was lost when rivers and streams were made into lakes. In total over 30% of the habitat originally available to salmon has been lost.

Scientists generally agree that in the Upper Columbia River Basin dams are responsible for the death of 70-96% of the downstream migrating young fish and about 40% of the upstream migrating adults. Many salmon pass at least 8 major dams on their journey to and from the ocean.

Adult salmon mortality may be due in part to trouble finding and negotiating the fish ladders.

The high death toll for young salmon is caused, in part, by passage through the dam's turbines. Some are killed directly by the turbines; others are stunned and become easy prey.

Young salmon also die because of the dam-caused changes in migration times. Salmon are genetically programmed for a one to two week swim to the sea, swept and shielded by the cold, cloudy, fast-flowing water associated with spring snow melt. Now young salmon may take one to two months trying to find their way downstream in such still water as the 76 mile reservoir behind the John Day dam. The longer the migration in the clearer, warmer water, the higher the loss of salmon to predators such as squawfish. In addition, the salmon may lose the urge to migrate.

The water stored behind the dams turned the arid Columbia Basin into fertile lands through irrigation. That water also allowed cities to grow and prosper. But now, often, too little water is left in the streams of the Columbia Basin for salmon survival. In the John Day River, for example, some areas simply dry up in the summer, killing any fish or salmon eggs present. In other areas, the water gets much hotter than the 68 degrees salmon can tolerate.

Withdrawing water for irrigation and municipal uses can also kill salmon if pumps and canals are not adequately screened to keep fish out. A 1994 study of 53 water pumping sites on Oregon's side of the Columbia River found 80% were not adequately protecting salmon. In one 1992 incident, 44,000 young fall chinook were killed when they were sucked through a pump on the lower Umatilla River and out onto a field; in a similar 1994 incident another unscreened pump killed 45,000 salmon.

WHAT CAN I DO TO HELP SAVE COLUMBIA BASIN SALMON?

Residents of the Pacific Northwest can help speed the necessary changes in dam structure and operation.

Tell your elected officials that recovering healthy salmon runs in the Columbia Basin is important to you. Tell them you support financial expenditures for dam modification for draw-down and screening and that you are willing to pay more for your electricity. Tell them that the aluminum industry should pay more too.

Toole Declaration, Exhibit 2, page 2

Conserve electricity. This will reduce the demand for electricity and more water can be released through the dams for salmon. Northwest residents pay the cheapest electrical rates in the country; they pay 1/4 of what people pay in the Northeast. Cheap energy has led to a lot of waste. Despite Oregon's mild climate, households in Oregon use twice as much energy as the national average. Weatherize your home, lower the thermostat, and be conscientious about turning off lights and other items when not in use.

Recycle aluminum to reduce the energy demanded for making new material. About 20 aluminum cans can be produced out of recycled aluminum for the energy it takes to make an aluminum can from raw materials.

Conserve water to help assure enough is left in the rivers for the salmon. Much municipal and irrigation water is wasted through inefficient systems. Some municipal systems lose up to 20% of their water to leakage. In some areas water use isn't even metered so there is no cost incentive to save. Irrigators can save water too. Farmers in Hermiston were able to reduce their water use by 35% by improving watering techniques and think they can save more by drip irrigation; other may be able to do the same.

Support water price increases to encourage more conservation.

Support enforcement of water laws. Some people withdraw water from the rivers illegally, leaving less for those with water rights and less for the salmon.

Sources: Oregon Department of Fish and Wildlife, Northwest Power Planning Council, State of Idaho Governor's Office, Bonneville Power Administration, American Rivers, Sierra Club.

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Latest update April 4th, 1997

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MFR PAPER 1222

Effects of Dams on Pacific Salmon and Steelhead Trout

Collins

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INTRODUCTION

The need for salmon, sea-run trout, and other anadromous fish to spawn in fresh water has made them particularly vulnerable to many of the activities of man. Forestry, farming, road building, growth of cities, industry, and pollution have all taken their toll. However, none of these developments has had more impact on the survival of salmon than the construction of dams. The watershed of the Columbia River presents a critical illustration of the effects of dams on salmon, reflecting events in progress in the entire Pacific Northwest.

The earliest dams in the Columbia River Basin were relatively small. They appeared on tributary streams in the 1840's, constructed to divert water for irrigation, for logging, and for the operation of sawmills. Their numbers were few and their total effect was relatively minor. In the 1880's dams for hydroelectric power were constructed on larger streams, such as the Spokane and Willamette Rivers, seriously affecting the Pacific salmon, *Oncorhynchus* spp., and steelhead trout, *Salmo gairdneri*, populations in those streams. In the 1930's major hydroelectric dams were built on the mainstem Columbia River (Fig. 1), initiating the large-scale development of the water resources of the Columbia River Basin for electrical power, irrigation, navigation, and flood control. For the next four decades construction of many large dams proceeded on the Columbia River and its major tributaries producing sudden, enormous changes in the environment of anadromous fish. Great dams barred passage to the sea; huge lakes replaced swift-flowing rivers; spawning grounds were inundated; water temperatures were modified; predator, competitor, and disease relations were upset; food supplies were affected.

The necessity for providing safe passage over the physical obstructions of dams was an obvious reality. Of equal importance was the need to protect the fish when the changes made by dams in the basic environment were too severe. Because there were many dams (Fig. 2) the cumulative effect of small losses, injuries, or delays at each dam became serious. Failure to solve fish passage problems at high dams with large impoundments (i.e., Grand Coulee and Brownlee Dams) resulted in a complete barrier to migrating fish in the upper reaches of the Columbia and Snake Rivers (Fig. 3). This barrier denied, to anadromous fish, access to a substantial portion of the entire Columbia River watershed.

PASSAGE OF FISH

Adult Fish Passage at Dams

As dams were constructed on the Columbia River, fishways were provided to permit adult fish to swim over the dams to continue their upstream migration toward their spawning grounds. These fish "ladders" consisted of a long series of pools (Fig. 4), starting from the water level below the dam (tailrace) and ascending approximately 1 foot in elevation at each succeeding pool until reaching the water level behind the dam (forebay). Water flowed from pool to pool and fish could ascend by swimming over the weirs that separated each pool or through holes in the weirs provided for that purpose.

Although fishways of this general design had been in use for many years, the large scale of fishway construction necessary on the Columbia River and the variety of new situations that had to be faced required more information on fish behavior and abilities than was available.

Some of the questions that needed to be answered were surprisingly simple, such as: At what rate do fish ascend fishways? What is the maximum water velocity through which fish can swim? How does light affect the rate of ascent

Figure 1.—Bonneville Dam, the lowermost dam on the Columbia River, was constructed in 1938. A second powerhouse will be constructed on the north shore (left side), reducing the need to spill large amounts of water.

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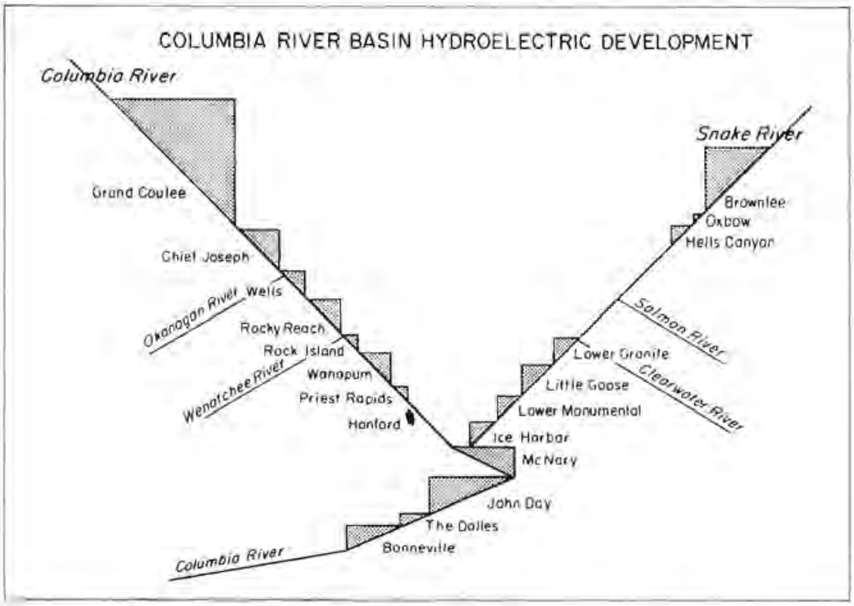

Figure 2.—Diagram showing the sequence of major dams on the Columbia and Snake rivers.

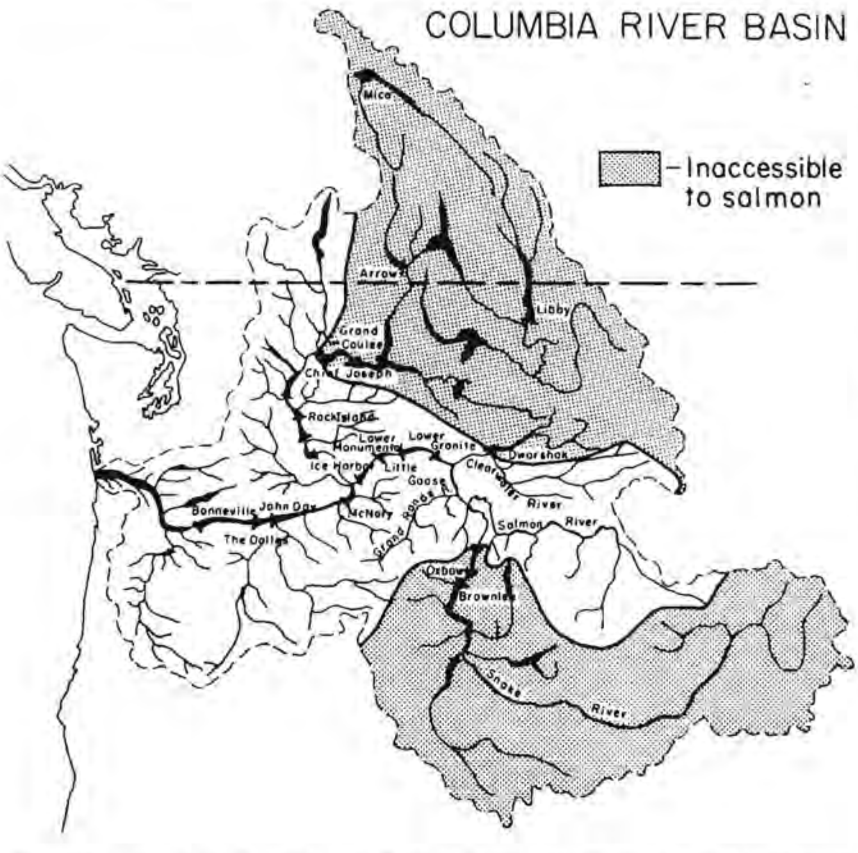

Figure 3.—Areas in the Columbia River Basin no longer accessible to migrating anadromous fish because of dams.

in fishways? Other questions had a direct bearing on the cost of fishways, such as: How large a fishway is needed for a given number of fish? How steep can a fishway be without causing fish to tire or fail to ascend? How long can a fishway be without fatiguing fish? To gain answers to these and similar questions, an intensive research effort was undertaken in which State and Federal fishery agencies, universities, and a major dam constructing agency, the U.S. Army Corps of Engineers, participated.

A special laboratory for fishery-engineering research was constructed at Bonneville Dam in which it was possible to measure the reactions of anadromous fish under controlled experimental conditions while the fish were actually migrating. Fish were diverted from one of the major fishways into the laboratory (Figs. 5 and 6), where their responses to full-scale fishway situations were observed and recorded. Fish then swam out of the laboratory to continue their migration upstream.

Experiments conducted at the laboratory provided data on the spatial requirements of salmon in fishways, on rates of movement of fish ascending fishways, and on the effect of fishway slope and fishway length on fish performance. Scientists measuring both performance and physiological indices such as blood lactate and inorganic phosphate could find no evidence of fatigue from ascending fishways when proper hydraulic conditions were obtained. It was concluded that the ascent of a properly designed fishway was only a moderate exercise for fish, possibly similar to swimming at a "cruising" speed that can be maintained over long periods of time.

Tests to measure swimming abilities (Fig. 7) indicated that the critical velocity of water was between 8 and 13 feet per second (fps). Velocities above this range proved to be an obstacle to a significant number of fish, although some individual fish had a much greater ability. The maximum observed swimming speed was 26.7 fps by a steelhead.

Examination of fish preferences for light conditions revealed marked differences in species. Steelhead, given a choice of light and dark channels, selected a dark channel. Chinook salmon, *O. tshawytscha*, appeared indifferent under the same conditions and moved randomly into both light and dark channels. Steelhead moved more quickly through fishways that were darkened (Fig. 8), yet—in passing through pipes and open channels—showed an increase in speed when light was added. Presented with a choice of

Figure 4.—Pool type fishway (foreground) at Bonneville Dam. The long, windowless building on the opposite shore is the Fisheries-Engineering Research Laboratory.

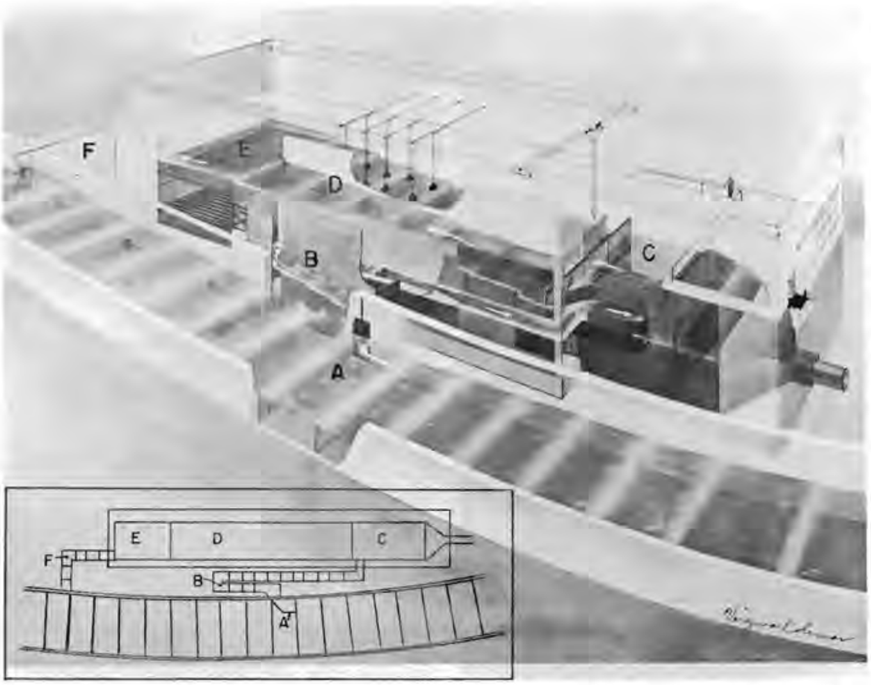

Figure 5.—Sketch of Fisheries-Engineering Research Laboratory at Bonneville Dam showing its relationship to fishway. Fish are diverted from the main fishway by a picketed lead (A) and ascend the entrance fishway (B) to a collection pool (C) in the laboratory. After release they pass through an experimental area (D) to the flow introduction pool (E) and then out the exit fishway (F) where they return to the main fishway. (Insert shows plan view of laboratory.)

channels with a high velocity (13 fps) and a low velocity (3 fps), both salmon and steelhead showed a strong preference for the high velocity.

These are but examples of the types of information gathered at this unique laboratory for use in designing fishways that would be effective and efficient. Full-scale models of complete fishway designs (Fig. 9) were then tested in the laboratory before being put into use at a dam. Even after being constructed at a dam, new fishway designs were carefully evaluated in actual operation (Fig. 10).

The search for information on the behavior of adult fish was also extended into river situations. Individual fish were tracked by means of sonic and radio tags (Figs. 11 and 12) to determine their patterns of movement approaching dams under a variety of flow conditions for improving the design and placement of fishway entrances. Tracking studies of fish movements after leaving fishway exits showed the importance of the proper location of fishway exits because of the possibility of the fish being swept back downstream over the spillway of a dam.

Adult passage at dams is measured at counting stations in each fishway. Trained observers enumerate individual species of anadromous fish as they migrate through the fishway. At some dams migrating fish are directed by picketed leads over a white counting board (Fig. 13) where they can be easily seen and tallied by an observer. At more recently constructed dams, fish counts are made through large viewing windows (Fig. 14) set in the side of a fishway. The data are used in estimating total populations, assessing spawning escapements, and determining effects of changing ecological conditions at dams. Counting is now being done at 12 major dams on the Columbia and Snake Rivers with counting stations in operation from early spring to late fall. When the dam construction phase in the Columbia River Basin has been completed and river flow patterns have been stabilized, however, migrating fish will probably be counted only at a few index dams.

In addition to counting stations in each fishway, most dams have special viewing facilities for the public. The surge of hundreds of thousands of salmon, steelhead, and American shad, *Alosa sapidissima*, passing through the fishways of the Columbia River dams has become a national pride as well as the visible index of the health of a fishing industry and a recreational resource. More visitors come annually to watch salmon and steelhead at the dams on the Columbia River than visit Yellowstone Park or the Grand Canyon (Fig. 15).

Juvenile Fish Passage at Dams

Young salmon migrating to the sea in the Columbia River may have to pass over as many as nine major dams on

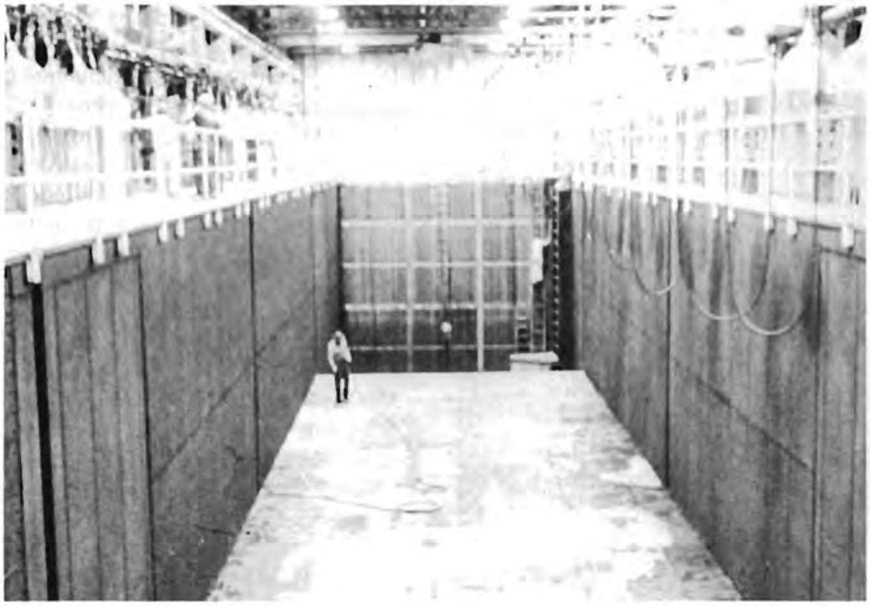

Figure 6.—Interior of Fisheries-Engineering Research Laboratory when empty and unwatered. Experimental area (center) is 104 feet long, 24 feet wide, and 17 feet deep. Fish collection pool at far end is 50 feet long and 24 feet deep.

Figure 8.—Covered fishway used in darkened passage experiments. All laboratory lights were turned off during dark tests.

Figure 7.—Experimental channel with a water velocity of 16 feet per second appears on right. Entrance to channel on left is screened to prevent access during swimming ability tests.

Figure 9.—Test of a full-scale model of a new fishway design in the laboratory.

Figure 10.—New fishway design being evaluated at Ice Harbor Dam. Note four observer stations for measuring rates of fish movement.

Figure 11.—Radio fish tag being inserted into the stomach of an adult chinook salmon.

Figure 12.—A fish tracking team member taking a bearing on a radio-tagged salmon below Lower Monumental Dam. Simultaneous bearings taken by two or more team members will be used to establish the location of the fish by triangulation.

Figure 13.—Adult salmon passing over a white counting board which aids observer in identifying species.

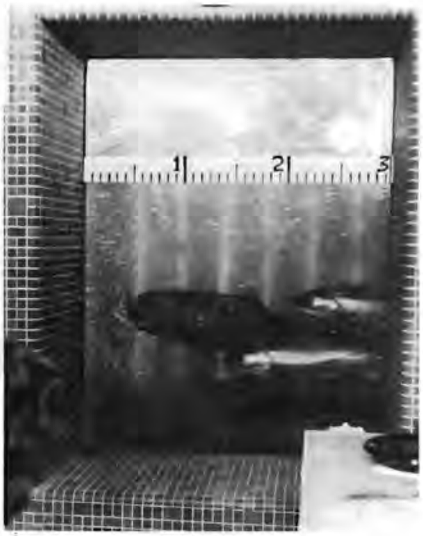

Figure 14.—Adult fish are counted as they pass a viewing window set in the side of a fishway.

their journey downstream. Those that are carried over spillways at each dam pass without injury; those that move with flows through turbines are less fortunate, however. Some are killed outright by turbine blades, high turbulence, shearing flows of high velocity, and sudden pressure changes. Others are injured or temporarily stunned and are easy prey for predators such as sea gulls or northern squawfish, *Ptychocheilus oregonensis*, feeding in the eddies of the tailrace below the dam.

Mortality rates at each dam differ with the relative amounts of water passing through powerhouse and spillway; with the size, species, and condition of the fish; with the type of turbine; with the operating load; etc., but an estimate of 15 percent loss per dam is generally considered to be conservative. With the development of upriver storage reservoirs and increasing water control, a greater percentage of the water (and a higher percentage of the fish) will be passing through turbines so that mortalities might even be expected to increase in the future. These losses are compounded, of course, by the number of dams through which the young fish have to pass.

In response to these critical circumstances, studies were undertaken to develop practical methods of protecting the young migrants at dams.

An investigation of the distribution of young fish in turbine intakes showed that 70 to 80 percent of the migrants were concentrated in the upper 15 feet of water (Fig. 16). The investigation also showed that many of the young migrants entered the gatewell (where the gates that can close off the intake for unwatering the turbine are stored) through a gate slot in the ceiling of the turbine intake. These fish had to leave by the same route or remain trapped in the gatewell. Efforts were focused on a system that enabled the juvenile migrants to bypass the turbines by being diverted through the gatewell and into a passageway leading to the tailrace.

An inclined traveling screen (Fig. 17) was installed that diverted most of the migrants into the gatewell, and holes (labeled "orifice" in Fig. 16) were cut in the gatewell wall, enabling the fish in the gatewell to pass into a channel that connects with the tailrace. This system does not protect all of the migrants entering turbine intakes and it would be expensive to install and maintain in

Figure 15.—"Salmon Watching" at Bonneville Dam.

all of the dams of the Columbia River. It does, however, provide an alternative to excessive mortalities in turbines.

CHANGING ENVIRONMENT OF FISH AND COUNTERACTIVE MEASURES

Dams Bring Change

Vast changes in the environment of salmon have been brought about by the construction of many dams in the Columbia River Basin. Long Chains of lakes now exist where once were rushing rivers, complete with rapids and gravel bars ideally suited for the incubation of salmon eggs. Hundreds of miles of spawning areas were flooded with nearly disastrous effects on fish populations. To replace the loss of so much area critical to salmon reproduction, large scale programs of artificial reproduction were begun by State and Federal fishery agencies. A major share of this effort was begun in 1949 when Congress appropriated funds for the Columbia River Fishery Development Program. This program finances the operation and maintenance of 21 fish hatcheries that produce over 86 million juvenile salmon and steelhead annually in compensation for those that were produced in the wild before dams were constructed.

To fish that had been adapted for thousands of years to existing seasonal patterns of water flow and temperature, the construction of many dams created other environmental stresses. Freshets and floods that had carried young fish swiftly down to the sea were now controlled. In the impoundments behind the dams the water (and the fish) moved more slowly. Research shows that the average impoundment on the Columbia River delayed young migrants about 3 days. Fish from the upper river have been reaching the estuary almost a month later than before the dams were built. This delay in migration through the river extended the exposure of the young fish to hazards such as disease and predation. Temperatures in the river, because of the greater surface area of the impounded waters, increased during the summer at a time when high water temperatures can become critical to salmonids. The habitat of many of the salmon's competitors and predators was increased and improved.

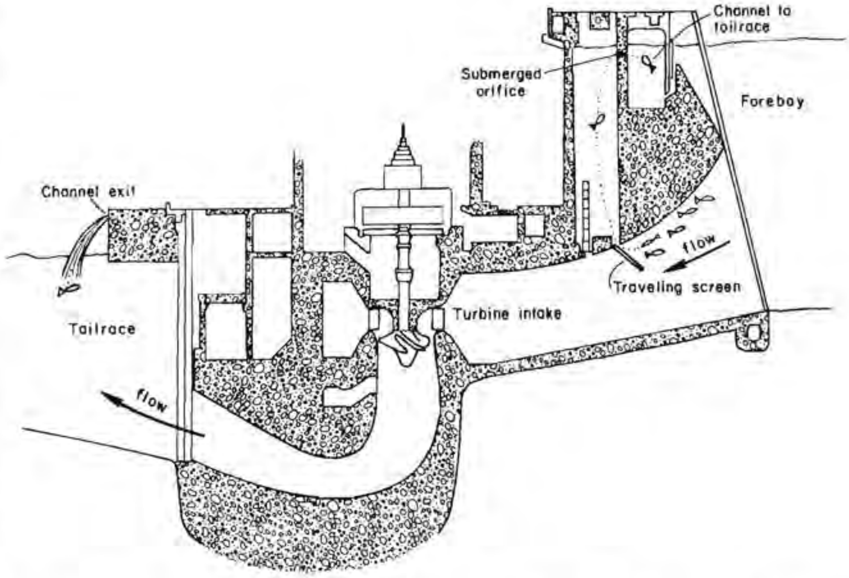

Figure 16.—System to bypass juvenile migrants around turbines. Young fish entering a turbine intake concentrate near the ceiling. Approximately 75 percent of the fish are diverted by traveling screens into the gatewell, then the fish pass through submerged orifices into a channel connected to the tailrace. With this system fish may be bypassed around the turbines of a single dam or the fish may be collected and transported around many dams.

Research on the effects of impoundments on salmon migration showed that the degree of passage success related to the length and volume of the impoundment, to the relative volume of flow through the impoundment at the time of migration, and to both the physical and biological environment in the impoundment. Migration through the impoundments created by the "river run" dams—all about 100 feet high, on the Columbia and Snake Rivers—appears to be generally successful for both adults and juveniles. However, the large impoundments created by dams (i.e., Grand Coulee, 343 feet; Brownlee Dam, 277 feet) proved to be more serious obstacles. Studies made in the Brownlee impoundment showed that while adult fish were able to migrate through the 57-mile long reservoir successfully, the young fish found conditions too severe. A high degree of thermal stratification develops in the reservoir with surface temperatures reaching levels lethal to young salmon while the cooler subsurface water becomes deficient in oxygen. The impoundment, for all practical purposes, is an impassable barrier for juvenile salmon and steelhead.

Figure 17.—Traveling screen shown in operating position on the deck of Little Goose Dam. Hydraulically operated arm is withdrawn to permit lowering of screen through gatewell slot.

Dams are also responsible for creating a condition under which the water becomes supersaturated with gases. Frequently referred to as "nitrogen supersaturation" because air is nearly four-fifths nitrogen, the condition is lethal to fish at high levels of gas pressure. Large volumes of water discharging over a spillway plunge into a deep pool below the dam forcing entrapped air into solution with the water. Under the hydrostatic pressures prevailing at depths of 40 feet or more in the spillway basin, the gases are continually dissolved and added to the water as long as spilling continues. In free-flowing rivers, where riffles and cascades provide for a quick release of dissolved gases, supersaturation rarely becomes a problem because gas pressures in water rapidly return to atmospheric level. In a series of impoundments such as now exist on the Columbia and lower Snake Rivers, there is not sufficient circulation to provide for a rapid release of gases. As a result, gas pressures remain above atmospheric levels.

Fish trapped in supersaturated water suffer from so-called "gas bubble disease." This relates to the physical damage caused by creation of gas bubbles in the tissues and blood vessels (Fig. 18). Dissolved gases are absorbed in the bloodstream and embolisms are formed when the gases leave solution. The symptoms are analogous to the "bends" in human divers when they move too quickly from a high-pressure to a low-pressure environment.

Mortalities created by supersaturation have been high for adult and juvenile fish in high-flow years, in which large volumes of water were surplus to power generation use and were passed over spillways. The most critical circumstances occurred when new dams were completed and a high flow occurred before the turbines could be put into operation. At such times, the entire river flow plunged over the spillway. Saturation levels have reached a deadly 145 percent (100 percent is normal; over 110 percent begins to be lethal to fish).

In an effort to reduce supersaturation, the U.S. Army Corps of Engineers, after an intensive search of alternatives, developed a spillway flow deflector (Fig. 19) that creates a surface flow below the spillway instead of permitting the deep plunging action that is responsible for most of the supersaturation. With the installation of the deflectors at all of the dams on the river, it is hoped that major problems with supersaturation will be solved.

Figure 18.—Gas bubbles beneath the skin on the head of a young chinook salmon. When bubbles burst, infections may set in and kill the fish. Dissolved gases absorbed into the bloodstream form bubbles when the gases leave solution. These embolisms may block the circulatory system and cause death.

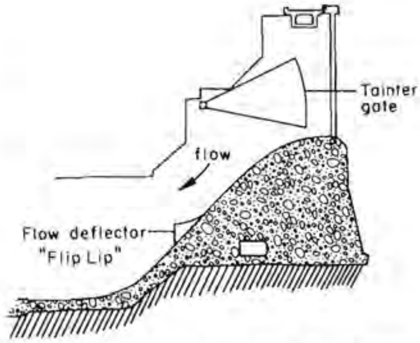

Figure 19.—Cross section of a spillway showing flow deflector (Flip Lip) installed to reduce supersaturation. Deflector creates a surface flow instead of permitting the plunging action responsible for supersaturation.

Collection and Transportation

To avoid the cumulative hazards of a long series of dams and impoundments to upriver stocks of fish, a system is being evaluated that would collect young migrants at the uppermost dam and transport them to the estuary. Under this procedure, losses—from turbines, from predation, from supersaturation, and from other adverse environmental effects in many miles of impoundments—would be eliminated. Collection would be by the use of turbine intake traveling screens and gatewells. Instead of the bypassed fish being released to the tailrace, they would be diverted temporarily into holding ponds, then trucked and released at appropriate locations in the estuary (Fig. 20).

Research is now in progress with fish marked as juveniles by the insertion of a tiny piece of magnetic wire in the snout. Initially some of these fish (test fish) were transported around the dams (Fig. 21); some (control fish) were released to find their way down the long series of dams and impoundments. When these fish return from the sea as adults and ascend the fishway at Little Goose Dam, a detector will recognize the magnetic tag and automatically shunt the fish into a holding tank where they can be examined to determine which treatment they received. When the data are analyzed scientists hope to have the answers to many questions. For example, will the homing of the fish to its native stream be affected by its capture and "rerouting"? What will be the losses associated with collecting, holding, trucking, and releasing fish in

Figure 20.—Tank trucks transport fish from collection and marking area around the hazards of seven dams and six impoundments for release below Bonneville Dam, about 350 miles downstream from Little Goose Dam. Studies are also being carried out at Lower Granite Dam in which eight dams and seven impoundments are being bypassed.

comparison with allowing them to proceed downstream on their own volition? Will the system be economically feasible?

It will be several years before a final judgment can be made, but sufficient information is already available for optimism. Theoretically, by reducing losses of young fish, the system has the potential for increasing the number of adult salmon and steelhead to the Columbia River Basin by 60 percent. The degree to which reality can match this potential remains to be seen.

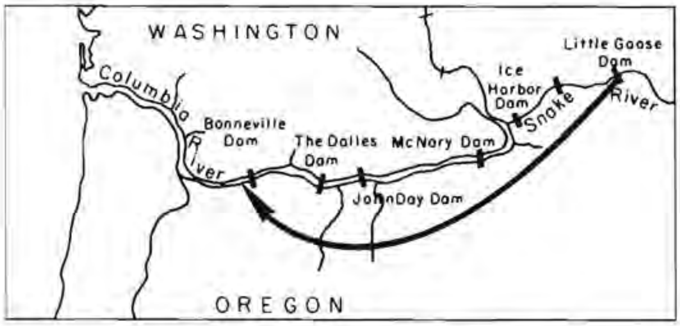

Figure 21.—Transportation route from Little Goose Dam to below Bonneville Dam.

CONCLUSION

Despite the many problems that complicate the maintenance of salmon runs when rivers are interrupted by dams, our runs of salmon can be maintained. Problems of reproduction, passage, temperature, delay, and supersaturation all can be solved if enough effort is made. Even the "impassable" large impoundments can be bypassed. With sufficient determination, there will always be salmon in the "Salmon" River—and all of the other salmon streams of the Northwest.

MFR Paper 1222. From Marine Fisheries Review, Vol. 38, No. 11, November 1976. Copies of this paper, in limited numbers, are available from D825, Technical Information Division, Environmental Science Information Center, NOAA, Washington, DC 20235. Copies of Marine Fisheries Review are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402 for $1.10 each.

MFR PAPER 1223

Effects of Water Diversions on Fishery Resources of the West Coast, Particularly the Pacific Northwest

Blahm

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INTRODUCTION

Man has found it necessary to divert water from its natural courses to enhance his existence and insure his survival. In the United States, for example, the Rio Grande River no longer flows into the sea, and all water of the Colorado River is being used—except for 1.5 million acre-feet, which is allocated to Mexico. The Missouri and Mississippi rivers have been affected by man's water diversion practices. Another example, which has altered the environment of Delaware Bay, is the diversion of Delaware River water to New York City. In 1922 the total water storage capacity in the United States was 33 million acre-feet; in 1962, it was about 300 million acre-feet; and by the year 2,000, an estimated 600 million acre-feet will be stored. By 1980 approximately 50 percent of our stream and river flow will be diverted. By the year 2000, this will increase to more than 80 percent. As we carry out vast programs of water storage and use, we will greatly curtail river flow into the sea (Stilwell, 1962). Even though less than 1 percent of the world's water supply is now diverted or stored (Armstrong, 1972), the manipulation of this seemingly insignificant portion can have a profound effect on the survival of fish species.

In the United States today, the primary water uses are: 1) electrical power production, 2) irrigation, 3) flood control, 4) navigation, 5) industrial, 6) mining, 7) domestic, and 8) recreation. These uses are not listed in order of importance because any one use on any body of water may take precedence over all others; each plays a part in contributing to water diversion problems.

Toole Declaration, Exhibit 3, page 8

Minimum Population Grows Larger

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Yichen Lu at the Virus Research Institute in Cambridge, Massachusetts, who has constructed different SIV-HIV hybrid viruses, called SHIVs, that differ in their ability to infect Langerhans' cells in test-tube studies. In Lu's experiments, monkeys given an intravaginal dose of the SHIV that favors Langerhans' cells were easily infected, while the ones given the SHIV that was nontropic for Langerhans' completely resisted infection.

Essex used this data as a springboard to hypothesize that there are two distinct HIV-1 epidemics. In developed countries, he argued, subtype B predominates and is spread primarily through blood and homosexual sex. In contrast, developing countries are experiencing "epidemic 2," which is driven by the other subtypes being spread primarily through vaginal sex (see table). "If other HIV-1 subtypes take hold in Western Europe or the U.S., we must predict a more significant heterosexual epidemic than we now see in the West," said Essex.

By and large, the response to Essex's presentation was enthusiastic. "I think he's on to something," said epidemiologist Sten Vermund of the University of Alabama, Birmingham. "I think it's highly plausible that E clade HIV could differ in its infectivity." John Mascola of the Walter Reed Army Institute of Research (WRAIR)—which first isolated subtype E—also found the talk provocative. "It's potentially extremely important," said Mascola. "Any single piece [of Essex's argument] is not compelling, but when he puts it together it makes a reasonably compelling case."

Still, some researchers had serious reservations about Essex's conclusions. Ann Duerr of the U.S. Centers for Disease Control and Prevention (CDC), in collaboration with Vinai Suriyanon and colleagues at Chiang Mai University, have been studying transmission rates between "discordant" couples—where only one is initially HIV-infected—in Chiang Mai. Although nearly 90% of these infections are subtype E, their work has shown that the rate of transmission is nearly identical to the rate found in a U.S. study that looked at discordant couples infected with subtype B. "The data I have on hand don't support [Essex's] conclusion," said Duerr, who cautions that they have not done a direct comparison of transmission rates of the two subtypes in their cohort.

Another wrinkle to Essex's theory, as William Heyward of the World Health Organization pointed out, is that subtype B is predominant in the Caribbean, Central America, and Brazil, and these regions all have primarily heterosexual epidemics. Essex countered that this discrepancy may be because anal intercourse is more common in these countries, although he offered no data to support that contention.

WRAIR's Donald Burke, who heads the U.S. military's AIDS program, said his group is now gearing up to do assays of different subtypes' ability to infect different cell types. Until the hypothesis gains more support, says CDC epidemiologist Timothy Mastro, who is based in Bangkok and heads the HIV/AIDS Collaboration, "the data are too thin to say it's true." But he notes: "The fact that there is this remarkable separation [of subtypes] is hard to explain."

–Jon Cohen

TWO HIV-1 EPIDEMICS

Category	Epidemic 1	Epidemic 2
Location	West (U.S., Europe)	South (Africa, S.E. Asia)
Cause	HIV-1B	HIV-1C, -E, -D, -A
Number infected	~1.5 million	15–20 million
Epidemic status	Plateau or decreasing	Increasing
Exposure route	Blood, rectal bleeding	Vaginal intercourse
Exposure cell	Monocyte, lymphocyte	Langerhans' cell

SOURCE: MAX ESSEX

ENDANGERED SPECIES

Minimum Population Grows Larger

When it comes to saving endangered species, Noah's ark offers little practical guidance. As population geneticists have long known, a single breeding pair can't provide enough genetic variability to allow a small population of their progeny to survive an array of environmental onslaughts or an accumulation of deleterious traits. But just how large a population must be to ensure long-term survival has been a matter of some debate. Back in the early 1980s, researchers estimated that at least 500 randomly mating individuals would be required. New studies of the genetics of small populations offer a much more sobering estimate: They suggest that a species must number 10,000 or more to maintain its evolutionary viability.

That's grim news for modern-day Noahs. Recovery goals for many endangered species are in the hundreds, so the new figures imply that current efforts—even if successful for years or decades—won't prevent extinctions hundreds of generations from now. "The implications are that in the very long run, our recovery plans may allow genetic damage to accumulate. Well down the road, we could lose what we've been trying to save," says Robert Lacy, conservation geneticist at the Chicago Zoological Society.

When researchers originally estimated the population size needed for long-term survival, they focused primarily on variation in quantitative, polygenic traits, which are determined by the effects of many different genes; height in humans is a common example. Such genetic variation, which arises by mutation, is important because it is the raw material of evolution. Over many generations, natural selection will favor the few beneficial mutations that allow species to adapt to changes in climate, pests, food, or other environmental factors. In the 1980s, researchers concluded that 500 randomly mating individuals (comprising what geneticists call an effective population) could supply enough variability.

"Well down the road, we could lose what we've been trying to save."

—Robert Lacy

Now population geneticist Russell Lande of the University of Oregon, Eugene, argues that these calculations underestimated the critical population size because they failed to consider the effect that these mutations have on the fitness of organisms. Lande's analysis, published in the August issue of *Conservation Biology*, is based on recent work in which other researchers, particularly geneticists Maria López and Carlos López-Fanjul of Complutense University in Madrid, studied mutations in quantitative traits such as the number of bristles on the abdomen of the fruit fly *Drosophila melanogaster*. The Madrid workers found that the most extreme mutations—those causing dramatic changes in bristle numbers—often had lethal side effects and so had no chance of spreading in the population.

Only mutations with little effect on fly survival and reproduction, the so-called quasi-neutral mutations, could be maintained in the population. But these mutations typically had much smaller effects on the trait, causing only about 10% of the total genetic variation in bristle number. To produce the same amount of variation from quasi-neutral mutations—rather than from all mutations as done in the original calculation—requires 10 times as many individuals, says Lande. This implies that the effective population size needed to preserve a species' evolutionary potential is 5000, not 500. Because the vagaries of mating make a population's effective size much smaller than

Toole Declaration, Exhibit 4, page 2

its actual size, real-world numbers would be even higher—at least 10,000 and often even more, says Lande.

"What Lande has done is partition out the quasi-neutral mutations—the only ones potentially useful for evolution—from all new mutations. The resulting mutational input is lower than expected, so you need a much bigger population," explains geneticist Philip Hedrick of Arizona State University in Tempe.

That conclusion is further buttressed by studies in which Lande and his Oregon colleague Michael Lynch, who was working independently on similar questions, explored another genetic danger faced by small populations: an extinction spiral Lynch has christened "mutational meltdown." In this process, mildly deleterious mutations—whose effects are too small for them to be purged by natural selection—accumulate and become fixed in small populations. Their cumulative impact eventually leads to extinction.

In papers in this month's issue of *American Naturalist* and in press at *Evolution*, Lynch and colleagues John Conery, also at Oregon, and Reinhard Bürger of the University of Vienna use genetic models, computer simulations, and empirical data on mutation frequency to calculate that on time scales of 100 generations, effective populations smaller than 100 individuals are at risk. Lande, using a different genetic model, gets even higher numbers, estimating that an effective population of 1000 is needed to avoid mutational meltdown.

Although their estimates aren't identical, Lynch and Lande agree that when the effects of both genetic perils are considered, the old numbers need to be revised upward, to effective populations on the order of thousands rather than hundreds. Actual populations would be even higher. "The main point is that 500 is too low," says Lynch, who says that a "genetically safe" real-world population would be about 10,000.

All these new estimates are much larger than the populations of most endangered species. On average, only about 1000 individuals remain when an animal species makes the endangered list—and only about 120 individuals of plants—according to a 1993 study by the Environmental Defense Fund. The somber implication for those trying to save endangered species: They're going to need a much bigger ark.

–Elizabeth Culotta

PHYSICS

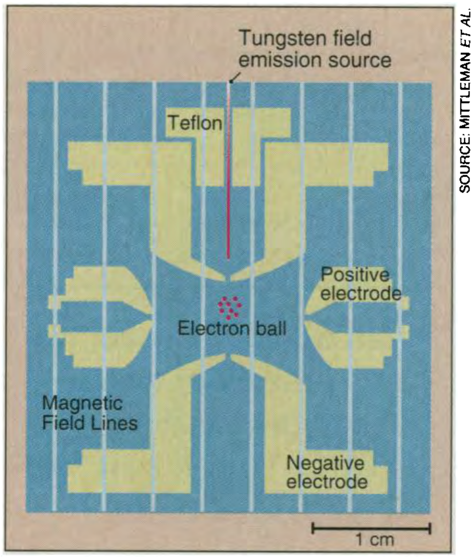
Electron Ball Probes 'House of Mirrors'

All theories strive for accuracy, but none succeeds more spectacularly than quantum electrodynamics. QED's predictions of how particles behave in electric and magnetic fields have held up to within a few parts per billion in some of its most demanding tests, which scrutinize the behavior of a single electron in an electromagnetic trap. Success has made experimentalists greedy for still more accuracy, however. They want to see whether tiny discrepancies between QED's predictions and their measurements result from flaws in the theory or in the experiments—and that means accounting for tiny perturbations introduced by the traps themselves. In an upcoming issue of *Physical Review Letters*, a group at the University of Washington reports a way to do just that, by first creating a superelectron that magnifies those perturbations, then scaling the perturbations down to a single electron.

The group's recipe for a superelectron is simple: Just confine a thousand electrons in the region of the trap ordinarily occupied by one. As a result, all of the electron's properties are multiplied, including one that has been the bane of experimenters: the tendency of the negatively charged electron to induce "image charges" in nearby conductors, which in turn subtly influence the electron's behavior. These image charges, says Richard Mittleman, one of the experimenters, cause a trap to behave like a "house of mirrors." They confuse the search for the slight deviations from QED that might point to a better theory, or perhaps suggest that the electron is not an indivisible particle.

But Mittleman and Washington colleagues Hans Dehmelt and Sander Kim found that an electron ball can amplify the house-of-mirrors effect. As a result, says Dan Dubin of the University of California, San Diego (UCSD), "you see the effect directly instead of having to evaluate it [theoretically]." And that should open the door to more accurate tests of QED with single electrons.

To create the electron ball, the team fired a beam of electrons into a standard electromagnetic trap, a device that can confine electrons along magnetic field lines capped with negatively charged end plates. The energetic beam knocked clouds of slower electrons from residual gas atoms in the trap.



Electrons by the kilo. A ball of 1000 electrons probes the effects of "image charges" on measurements in an optical trap.

These electrons eventually condensed into a ball less than 200 microns across.

Electrons caught in such a trap orbit the magnetic field lines at a rate known as the cyclotron frequency. For a single trapped electron, the ratio of this cyclotron frequency to the rate at which each electron's direction of "spin" precesses, or wobbles, gives a measure of the electron's intrinsic charge and magnetism and how it interacts with the fleeting "virtual" particles that populate free space, according to QED. That's where the house-of-mirrors effect comes in. For the comparison with theory, "you want to measure the properties of an isolated electron in empty space," says Dehmelt, but the image charges cause an unpredictable slowing or speeding up of the cyclotron motion.

Because a 1000-electron ball has the same charge-to-mass ratio as a single electron, its cyclotron frequency—in this case, 164 billion hertz—should also be the same, except for a stronger contribution from image charges. To tease out those effects, the team went on to trap smaller balls, containing hundreds fewer electrons. They saw the frequency increase by about 5 hertz for each electron removed. The increase implies that the image effect, at the same magnetic field strength, should slow a single electron by 5 hertz.

"It's a very nice experiment," says UCSD's Dubin, and it should help remove the largest remaining uncertainty in the single-electron tests. Others, such as Gerald Gabrielse of Harvard University, who has performed related measurements, want to see more data before they're convinced. "It would be nice to show that the [shift] is different at different magnetic field strengths," as theory predicts, he says.

The Washington team plans to go even further than Gabrielse suggests. Taking their cue from another theoretical prediction, they hope to find the precise field strengths at which "the whole frequency shift disappears," says Dehmelt. Then, by running single-electron tests of QED at those field strengths, Dehmelt hopes to feed yet another order of magnitude to the most ravenous obsession with accuracy in physics.

–James Glanz

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Minimum viable population size: A meta-analysis of 30 years of published estimates

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ABSTRACT

We present the first meta-analysis of a key measure in conservation biology: minimum viable population (MVP) size. Our analysis is based on studies published since the early 1970s, and covers 141 sources and 212 species (after filtering 529 sources and 2202 species). By implementing a unique standardization procedure to make reported MVPs comparable, we were able to derive a cross-species frequency distribution of MVP with a median of 4169 individuals (95% CI = 3577–5129). This standardized database provides a reference set of MVPs from which conservation practitioners can generalize the range expected for particular species (or surrogate taxa) of concern when demographic information is lacking. We provide a synthesis of MVP-related research over the past 30 years, and test for 'rules of thumb' relating MVP to extinction vulnerability using well-known threat correlates such as body mass and range decline. We find little support for any plausible ecological and life history predictors of MVP, even though correlates explain >50% of the variation in IUCN threat status. We conclude that a species' or population's MVP is context-specific, and there are no simple short-cuts to its derivation. However, our findings are consistent with biological theory and MVPs derived from abundance time series in that the MVP for most species will exceed a few thousand individuals.

1. Introduction

Conservation practitioners are challenged to make informed choices about the allocation of finite resources to mitigate the current extinction crisis (Ceballos and Ehrlich, 2002; Thomas et al., 2004), while being cognizant of the complex ecological (Shaffer, 1985) and socio-political (Woodroffe et al., 2005) systems in which such decisions are embedded. Accelerating habitat and species losses have mandated consideration of this problem in terms of the number of individuals required for persistence within a specified timeframe (Shaffer, 1981; Shaffer, 1987) because small and range-restricted populations are highly vulnerable to extinction (Terborgh and Winter, 1980; Gilpin and Soulé, 1986; Schoener and Spiller, 1987). The concept of a 'minimum viable population' (MVP; Shaffer, 1981; Lacava and Hughes, 1984) has been used extensively in species recovery and conservation management programs (Clark et al., 2002), and is relevant to the IUCN's Red List (www.iucnredlist.org) criteria concerning small and range-restricted populations. However, the biological and utilitarian value of MVP to species conservation has remained controversial (Shaffer, 1987; Caughley, 1994; Reed et al., 1998).

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Past reviews of the concept (Samson, 1983; Gilpin and Soulé, 1986; Ewens, 1990) and its application (Sjogren-Gulve and Ebenhard, 2000; Bulte, 2001; Stinchcombe et al., 2002) have been theoretical, qualitative or cursory, with the primary literature tending to focus on inherent problems of estimation (Reed et al., 1998; Brook et al., 2000) rather than utility *per se*. Despite both debate on the real-world applicability of the concept (Caughley, 1994; Reed et al., 1998) and its sustained popularity (Bulte, 2001; Reed et al., 2003; Tear et al., 2005; Brook et al., 2006), there has been no broad-scale quantitative assessment of the MVP literature. This is perhaps due in part to the difficulty of standardization (e.g., definition of risk and timeframe, alternative model structures) across studies.

Individual case studies of MVP for any given species cannot reveal: (a) the form and variance of the cross-species distribution of MVP, and whether these agree with theoretical predictions, or match with genetic, demographic or environmental rules of thumb for MVP; (b) the existence (or absence) of taxonomic or life history patterns in MVP; and (c) generalizations useful for conservation management. Here we provide the first quantitative meta-analysis of published MVP estimates, to determine the ensemble properties of MVP and whether useful generalizations emerge.

2. Methods

2.1. Dataset

We conducted an exhaustive meta-analysis of the MVP-relevant literature. All MVP data were obtained from published articles, book chapters and scientific reports. Primary literature was identified through ISI's Web of Science (www.isinet.com) and Elsevier's Science Direct (www.sciencedirect.com) databases. The online search engines Google (www.scholar.google.com) and Yahoo (www.yahoo.com) were used to identify, and where possible source, scientific reports and other grey literature. Search terms such as "minimum & viable" and "extinction" were used, among others. Monographs and book chapters were sourced through university library databases. A cross-check of the reference list of each article permitted further collation, especially for sources published prior to 1992. Each article was reviewed for MVP estimates, and where population viability analysis (PVA) methods were used, populations were considered 'viable' only where $\geqslant$80% of the initial population survived for $\geqslant$20 years (Shaffer, 1981). If the initial population was considered unviable but a target MVP estimate provided, the latter was used. Where MVP was not specified explicitly, we required at least the risk of extinction for a defined timeframe and initial population size to be reported. Data from baseline PVA models were selected and hypothetical scenarios ignored. MVP estimates derived through genetic analyses or population censuses were also included. A database was collated and structured according to taxonomic group. Attributes such as species IUCN Red listing (IUCN, 2006) were later assigned, and the completed database is available online as Supplementary Material (Table S1).

2.2. Controlling for differences in the modelling technique used to derive MVP

Data were collated for 287 MVP estimates, initially by collecting all parameters that some or all of the models used to derive MVP. These were (1) probability of persistence, (2) duration of persistence in years, (3) duration of persistence in generations, (4) model type or method used to derive MVP estimate, (5) sex ratio at birth, (6) adult sex ratio, (7) form of density dependence, (8) carrying capacity, (9) Allee effect (present/absent), (10) inbreeding depression considered, (11) probability of catastrophe, (12) birth to adult survival, (13) adult survival, (14) per cent of female population breeding, (15) fecundity, (16) age at parturition, (17) longevity, (18) density and (19) dispersal ability. In many cases, data for the above parameters were omitted or not given by the authors.

Using logic and previous hypotheses based on extinction theory (Akcakaya, 1998; Brook et al., 2006), we reduced the initial 19 model attributes to six predictors which we hypothesized would be relatively independent and explain much of the methodological variation in MVP among studies: (1) Model used [MOD]: a categorical index of method or model used to derive MVP. This was restricted to: (a) individual-based simulation, (b) matrix/cohort-based simulation (including time series methods), (c) empirical census or (d) genetic analysis; (2) Persistence probability [PER]: a continuous variable of the probability of population persistence over a given time period. If not used, and where the population was stated as viable, the probability was assumed to be 100%; (3) Duration [DUR]: a continuous variable being the period of time over which a population was deemed viable, expressed as a continuous variable in generations (3–1200). When generation length of the species was not provided, we assumed it to be equal to the age at primiparity. Where a MVP was estimated from a census or genetic analysis, or where the time frame of viability was not stated explicitly ($n = 13$), viability was assumed to be 100 years and the number of generations estimated on this basis; (4) Density dependence [DEN]: a categorical factor classified as: (a) density-independent, (b) ceiling-type density dependence or (c) functional-type density dependence. The differentiation between categories (b) and (c) was necessary to account for their opposite effect on MVP – ceiling density dependence increases extinction risk, whereas non-Allee functional density dependence (negative feedback) decreases extinction risk, relative to density-independent models (Ginzburg et al., 1990); (5) Inbreeding depression [INB]: a categorical factor indicating whether the loss of genetic variation in the population was modelled or not. This was most commonly, although not universally, applied as 3.14 diploid lethal equivalents on juvenile survival; and (6) Catastrophes [CAT]: a categorical factor indicating whether random catastrophe outside the normal distribution of environmental stochasticity was included or not.

2.3. Ecological extinction predictors

Following previous work (Brook et al., 2006), we reduced a set of postulated ecological, life history and anthropological extinction correlates to a set of eight composite predictors. Where these correlates were not given in the sourced litera-

Table 1 – Summary of generalized linear and generalized linear mixed-effect model (GLM and GLMM, respectively) comparisons using Akaike's Information Criterion corrected for small sample sizes (AIC_c) and Bayesian Information Criterion (BIC): (a) GLMMs of the MVP-generating model correlates used for standardization (PER = persistence probability, MOD = model type, DUR = duration in generations, DEN = form of density dependence, INB = inbreeding included, CAT = catastrophes included) against the original MVP estimates; (b) GLMMs of the standardized MVP (MVP_{st}) against ecological and life history correlates (BWT = body weight, GNL = generation length, FEC = fecundity SOC = social grouping, HMP = human impact, DSP = dispersal, RAN = range, TRE = population trend); (c) GLM of the ecological and life history correlates against MVP_{st}; and (d) binomial GLMM relating species IUCN Red-Listing (listed or not listed) to ecological and life history correlates

Candidate models	LL	k	ΔAIC_c	$wAIC_c$	ΔBIC	$wBIC$	%DE
(a) *MVP-generating model correlates*							
MVP ~ PER + DUR + INB + CAT	−425.935	7	0.056	0.439	0.000	0.800	6.3
MVP ~ DEN + PER + DUR	−427.324	7	2.834	0.109	2.778	0.199	6.0
MVP ~ PER + DUR	−438.280	5	20.489	<0.001	13.978	<0.001	3.6
MVP ~ MOD + PER + DUR + DEN + INB + CAT	−420.397	12	0.000	0.451	15.708	<0.001	7.5
MVP ~ MOD + PER + DUR	−435.307	8	20.961	<0.001	24.102	<0.001	4.2
MVP ~ null	−454.568	3	48.889	<0.001	35.841	<0.001	0.0
(b) *GLMM of ecological and life history correlates*							
MVP_{st} ~ null	−1.151	3	0.000	0.364	0.000	0.757	0.0
MVP_{st} ~ BWT	−1.116	4	2.025	0.132	5.096	0.059	3.0
MVP_{st} ~ TRE	−1.127	4	2.046	0.131	5.114	0.059	2.1
MVP_{st} ~ HMP	−1.146	4	2.084	0.128	5.151	0.058	0.5
MVP_{st} ~ GNL	−1.147	4	2.087	0.128	5.155	0.058	0.4
MVP_{st} ~ BWT + GNL	−1.112	5	4.136	0.046	10.247	0.005	3.4
MVP_{st} ~ HMP + TRE	−1.127	5	4.167	0.045	10.272	0.004	2.1
MVP_{st} ~ BWT + GNL + FEC	−0.973	6	6.003	0.018	15.142	0.000	15.5
MVP_{st} ~ BWT + GNL + DSP + RAN	−1.052	7	8.333	0.006	20.451	0.000	8.6
MVP_{st} ~ BWT + GNL + SOC	−1.016	8	10.456	0.002	25.555	0.000	11.8
MVP_{st} ~ BWT + GNL + FEC + SOC + DSP + RAN + HMP + TRE	−0.914	13	21.646	0.000	51.184	0.000	20.6
(c) *GLM of ecological and life history correlates*							
MVP_{st} ~ BWT + GNL + FEC	196.466	5	0.000	0.746	0.000	1.000	15.5
MVP_{st} ~ BWT	181.859	3	25.039	0.000	18.502	0.000	3.0
MVP_{st} ~ null	178.585	2	29.528	0.000	19.692	0.000	0.0
MVP_{st} ~ BWT + GNL + SOC	191.868	7	13.454	0.001	19.909	0.000	11.8
MVP_{st} ~ TRE	180.875	3	27.006	0.000	20.469	0.000	2.1
MVP_{st} ~ BWT + GNL + DSP + RAN	188.197	6	18.658	0.000	21.896	0.000	8.7
MVP_{st} ~ BWT + GNL	182.293	4	26.248	0.000	22.989	0.000	3.4
MVP_{st} ~ HMP	179.103	3	30.551	0.000	24.014	0.000	0.5
MVP_{st} ~ GNL	178.968	3	30.821	0.000	24.283	0.000	0.4
MVP_{st} ~ BWT + GNL + FEC + SOC + DSP + RAN + HMP + TRE	203.025	12	2.159	0.253	24.379	0.000	20.6
MVP_{st} ~ HMP + TRE	180.878	4	29.079	0.000	25.820	0.000	2.1
(d) *GLMM of ecological and life history correlates*							
IUCN ~ BWT + GNL + FEC + SOC + DSP + RAN + HMP + TRE	−60.328	13	74.329	0.000	0.000	0.867	54.0
IUCN ~ HMP + TRE	−74.019	5	0.000	0.556	4.571	0.088	43.6
IUCN ~ HMP	−76.136	4	0.452	0.444	5.912	0.045	42.0
IUCN ~ BWT + GNL + DSP + RAN + TRE	−84.747	8	32.400	0.000	36.731	0.000	35.4
IUCN ~ BWT + GNL + DSP + RAN	−89.857	7	37.429	0.000	44.222	0.000	31.5
IUCN ~ BWT + GNL + FEC + TRE	−100.322	7	56.577	0.000	66.842	0.000	23.6
IUCN ~ GNL + TRE	−107.006	5	63.603	0.000	73.362	0.000	18.5
IUCN ~ BWT + GNL + TRE	−105.896	6	64.494	0.000	74.464	0.000	19.3
IUCN ~ TRE	−112.062	4	70.888	0.000	80.100	0.000	14.6
IUCN ~ BWT + GNL + SOC + TRE	−104.677	9	73.018	0.000	82.254	0.000	20.2
IUCN ~ BWT + TRE	−111.778	5	73.039	0.000	83.116	0.000	14.8
IUCN ~ BWT + GNL + FEC	−116.044	6	84.142	0.000	95.822	0.000	11.6
IUCN ~ BWT + GNL	−119.315	5	87.930	0.000	98.583	0.000	9.1
IUCN ~ GNL	−121.283	4	89.159	0.000	99.019	0.000	7.6
IUCN ~ BWT + GNL + SOC	−115.406	8	89.623	0.000	101.176	0.000	12.1
IUCN ~ null	−131.254	3	106.551	0.000	115.564	0.000	0.0
IUCN ~ BWT	−130.474	4	107.425	0.000	117.768	0.000	0.6

All GLMMs include the taxonomic Class (e.g., Mammalia, Aves, etc.) as a random effect. Shown are model log-likelihood (LL), number of parameters (k) change in AIC_c (ΔAIC_c), AIC_c weight ($wAIC_c$), change in BIC (ΔBIC), BIC weight ($wBIC$) and the per cent deviance explained (%DE). %DE is a measure of the structural goodness-of-fit of the model. Models sequences are ordered by $wBIC$ for all model sets, because we were primarily interested in main rather than tapering effects.

ture, data were derived from online databases or published papers on that species (see Appendix S1, Supplementary Material). Predictors used were: (1) Body weight [BWT]: an allometric scaling covariate (mass in g). Body mass data for the mostly herbaceous plants were estimated using a benchmark wet-weight for a similar-sized species, and forestry timber data used to estimate mass for large Monocotyledons; (2) Generation length [GNL]: taken as age at sexual maturity and estimated in months; (3) Fecundity [FEC]: a continuous variable representing the mean number of young produced per female per year. This included the average number of eggs laid/young born, but did not account for the probability of survival to adulthood (such as in birds and herptiles). Multiple broods within a year were taken into consideration to calculate a total yearly output of offspring; (4) Social grouping [SOC]: a categorical index of mating systems. These were (a) colonial (i.e., large breeding colonies and spawning sites), (b) polygamous or gregarious, (c) monogamous and (d) solitary (i.e., a brief period of copulation only or asexual/hermaphroditic breeding, and plants); (5) Dispersal [DSP]: the migratory or dispersive capability of a species, where dispersal and migration are used interchangeably, and categorized broadly as (a) migratory or (b) constrained. A species was considered constrained if it remained within a 20-km radius of its place of birth/hatching; (6) Range [RAN]: the geographic distribution scored as either (a) geographic range spanning more than one major biome (Smith and Smith, 2003), or (b) the species was primarily restricted to a single biome; (7) Human impact [HMP]: a categorical index of the (a) beneficial or (b) generally adverse influence of people. Species considered to benefit from humans were domesticated animals, harvested crops and commensals, for example; and (8) Population trend [TRE]: a categorical index of (a) stable or increasing population or (b) a population in general decline. TRE was assumed to account for deterministic population decline.

2.4. *Statistical analyses*

For all analyses we reduced the population dataset from 287 populations to 212 unique species to avoid potential problems of pseudo-replication caused by multiple representations (different populations) of the same species. Two a priori model sets (Burnham and Anderson, 2002) were constructed to examine the amount of variation explained in MVP (Table 1): (a) six models encompassing a selection of the model characteristics used to derive MVP, and (b) eleven models encompassing a selection of ecological, life history and anthropogenic threat terms.

To gauge the relative importance of each derived variable for predicted MVP, we fitted a series of generalized linear mixed-effects models (GLMM) to $\log_e$MVP in the R Language (R Development Core Team, 2004), using the `lmer` function (in the `lme4` library). MVP was assumed on a priori grounds to be log-normally distributed (Brook et al., 2006). The random effects error structure of GLMM was used to correct for non-independence of species due to potential shared evolutionary life history traits (Felsenstein, 1985) by decomposing the variance across species by hierarchical Linnaean taxonomy (Class) (following Blackburn and Duncan, 2001). Class was selected as the taxonomic random term in preference to Order because of sample size limitations: many Orders were represented by a single species only. The importance of considering taxonomy in the GLMM was assessed also by repeating the analyses using a series of generalized linear models (GLM) with the same ecological and life history correlates. Asymptotic indices of information loss were used to assign relative strengths of evidence to the different competing models (Burnham and Anderson, 2002), with both Akaike's Information Criterion corrected for small sample sizes (AIC_c) and Bayesian Information Criterion (BIC) weights used as an objective means of model comparison (Burnham and Anderson, 2002). AIC_c identifies tapering effects where n, per term, exceed approximately 20 data, whereas BIC only identifies main effects (Link and Barker, 2006). Full model results are shown in Table 1.

Because MVP estimates taken from the literature vary due to the particular methods employed in each case, it was necessary to standardize estimates (MVP_{st}) to a consistent model structure. To do this we used the best-ranked GLMM based on BIC (Table 1) for the model characteristics set (the model including persistence probability, duration of persistence, inbreeding depression and catastrophes, and a phylogenetic correction), setting persistence probability (PER) to 99%, the number of generations (GNL) over which MVP was estimated to 40, and set the β coefficients for the factors to have inbreeding depression (INB) and catastrophes (CAT) included. The standardizing equation was therefore:

$$\log_e MVP_{st} = \log_e MVP_{orig} + \beta_{PER} \cdot \log_e\left(\frac{0.99}{PER}\right) + \beta_{GNL} \cdot \log_e\left(\frac{40}{GNL}\right) + \beta_{INB} + \beta_{CAT}$$

where $\beta_{PER} = 22.5618$, $\beta_{GNL} = 0.4365$, $\beta_{INB} = 1.2306$, $\beta_{CAT} = 0.4258$. The distributions of the original versus standardized MVP estimates are shown in Fig. 1. For each species, the

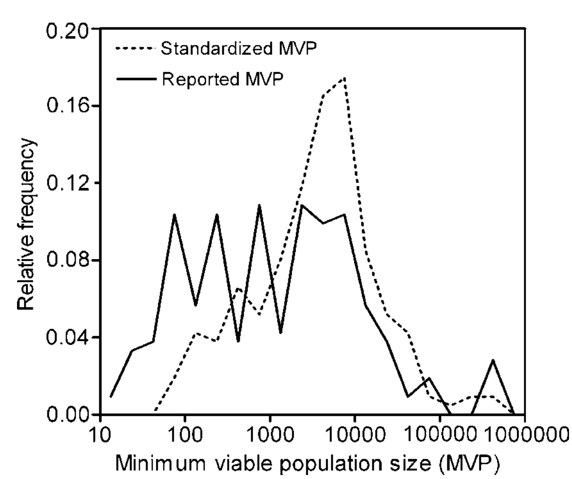

Fig. 1 – Comparison of original versus standardized minimum viable population sizes. Relative frequencies of the 212 MVP species estimates ($\log_{10}$ scale) for the original, uncorrected values, taken directly from the literature (solid line, Supplementary Notes) and the same values after standardization for differing structure of the MVP-generating method/model (dotted line).

respective coefficients were set to zero when its original MVP-generating model matched the defined standardization criterion. Although the per cent deviance explained in MVP by the highest BIC-ranked model was only ~6%, standardization was still required to avoid potentially spurious relationships in the analysis of MVP and ecological correlates.

We tested the ecological predictors by fitting GLMM to $\log_e MVP_{st}$ with Class set as a random effect for phylogenetic control, and then fitted GLM without random effects to examine the importance of including phylogenetic control in the models. To provide an independent check of the biological authenticity of the derived ecological predictors with respect to a measure of extinction proneness, we constructed analogous models using the IUCN Red Listing (IUCN, 2006) of species (17 models). Of the 212 species represented in the meta-analysis, 92 were Red-Listed (anything other than 'Least Concern').

3. Results

We sourced 529 relevant articles published between January 1974 and December 2005, describing up to 2202 species and a minimum of 1444. The exact count of distinct species could not be determined because one large study (Fagan et al., 2001) did not report which species were examined. Excluding a recent study on MVP which fitted a set of simple phenomenological models to 1198 abundance time series (Brook et al., 2006), 141 articles met the selection criteria and listed 287 MVP estimates for 212 species. A gradual increase in MVP-related publications over the past 30 years was matched by a concomitant rise in the number of species studied (Fig. 2). The establishment of public-access online databases (e.g., IUCN Red list and Global Population Dynamics Database [GPDD], www.cpbnts1.bio.ic.ac.uk/gpdd/) and subsequent multi-species analyses (Fagan et al., 2001; Reed et al., 2003; Brook et al., 2006) in recent years were responsible for large increases in the number of species evaluated (Fig. 2).

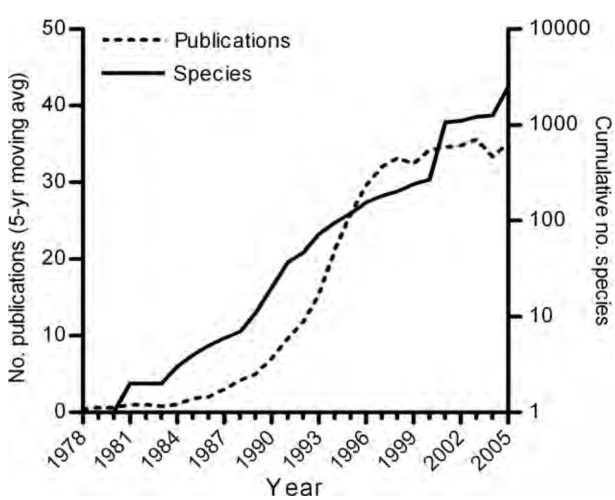

Fig. 2 – Publication trends for minimum viable population size (MVP), 1974–2005. The cumulative number of species in studies related to population viability and extinction ($\log_{10}$ scale, solid line), and a 5-year moving-average of the number MVP-related peer-reviewed and unpublished literature sources (dotted line). A large increase in species studied since 2001 marked the advent of freely-accessible online population databases.

A bias toward large-bodied species in extinction-related research was evident. Ultimately, we found that the frequency distribution of species studied was skewed towards heavier species, with 53.8% of all species and 85.3% of mammals exceeding 1000 g (Fig. 3). By contrast, only 31% of 4049 extant mammals listed in a large database of body masses (Smith et al., 2003) are >1000 g. Moreover, vertebrates accounted for 47% of all species studied, despite this taxon representing only a few percent of named species (IUCN, 2006), and of the 92 species in the meta-analysis that were IUCN Red-Listed, 62.0% were mammals. Surprisingly, the Red Listing of species included in all MVP-related studies showed an over-representation of non-threatened species (Fig. S1, Supplementary Material), likely due to larger studies (Brook et al., 2006) being based on abundance time series collected for purposes not directly related to conservation, such as monitoring and harvesting.

The reported MVP values were not comparable in a quantitative meta-analysis because of differences in the specified risk definitions and structure of the generating models. We therefore collated relevant model type and structure data for each species and fitted a set of GLMM and used AIC_c, and BIC to select the most parsimonious model(s) for standardizing MVP (see Section 2). The most parsimonious model relating MVP to 'generating-model structure' was, according to AIC_c, the one that included all model characteristics; however only 7.5% of the deviance was explained by the saturated model after controlling for phylogeny (Table 1). An analysis on a reduced dataset, using Class/Order as a nested random effect, yielded an equivalent result. It has been shown that with sufficient sample sizes, the Kullback–Leibler prior used to justify AIC_c weighting favours more complex models (Link and

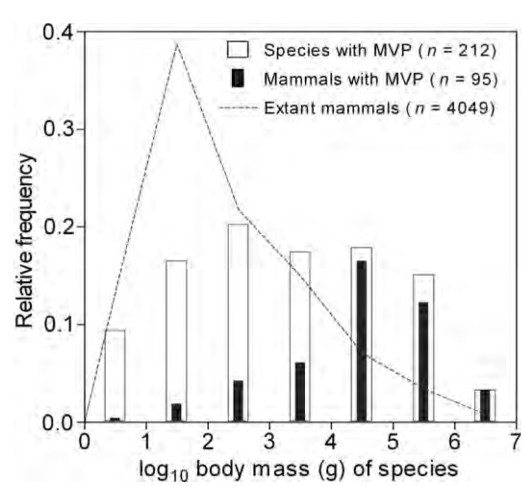

Fig. 3 – Relative frequency distribution of body weight ($\log_{10}$ scale in g). All species (open bars) and mammals (solid bars) with estimates of minimum viable population size are shown, with the relative distribution of body weights for all extant mammals for which data are available (Smith et al., 2003) (dotted line) for comparison.

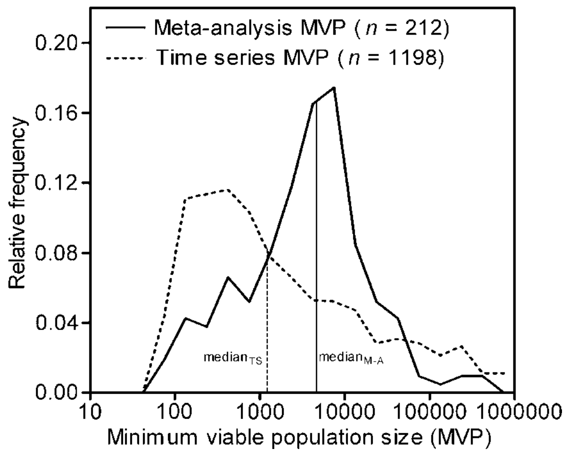

Fig. 4 – Relative frequency distribution of minimum viable population (MVP) estimates (log_{10} scale). Standardized MVPs from the meta-analysis of 212 species examined since 1976 (solid line) are compared to MVP estimates derived independently from models fitted to 1198 species' time series of abundance data (dotted line) (Brook et al., 2006). Median values are represented by vertical lines for each distribution.

Barker, 2006), so we also considered model ranking according to the dimension-consistent BIC weights to identify the main drivers of structural variation in MVP (i.e., ignoring tapering effects). The latter metric signalled that only four of the six correlates considered (probability of persistence, duration, inbreeding and catastrophe – see Section 2) explained an important component (6.3%) of the deviance in MVP (Table 1). Thus, using the best BIC-supported model's coefficients, we standardized MVPs (MVP_{st}) to a 99% persistence probability, and time frame of 40 generations (a previously used time frame – Brook et al., 2006).

Median MVP_{st} was 4169 individuals (3577–5129, 95% CI), compared to the median reported uncorrected MVP of 3299 individuals. This is similar to the recommended effective population size of 4500 individuals based on genetic data (Frankham, 1995), and the median MVP of 5816 reported for vertebrates (Reed et al., 2003). The frequency distribution of the standardized published MVP estimates (Fig. 4) was more symmetrical and peaked at a higher MVP than the model-averaged distribution of MVPs derived from an independent time series analysis (Brook et al., 2006). This result contradicts the view that estimates of population viability derived from scalar models may be overly precautionary (Dunham et al., 2006), probably because Brook et al. (2006) considered functional density dependence, whereas Dunham et al. (2006) only used a population ceiling function.

4. Discussion

Deciding how much habitat is needed to achieve conservation goals requires robust rules of thumb because in many situations there are insufficient data to develop a species-specific population viability analysis (Shaffer et al., 2002). So, can we provide any generalities from this meta-analysis of MVP? Models relating ecological attributes predicted *a priori* to

Table 2 – Summary of median (and bootstrapped 95% confidence bounds) minimum viable population sizes from all available literature (n = number of species; standardized = MVP_{st}; original = MVP_{orig})

	n	MVP_{st}	MVP_{st} 95% CI	MVP_{orig}
Vertebrates				
Birds	48	3742	2544–5244	3310
Fish	8	1,239,727	211,171–2,085,032	500,000
Mammals	95	3876	2261–5095	2901
Herptiles[a]	31	5409	3611–6779	3999
Sum/median	182	4102	3325–5096	3697
Other taxa				
Plants[b]	22	4824	2512–15,992	2097
Insects	5	10,841	1650–103,625	2000
Marine invertebrates[c]	3	3611	1984–1,047,547	2500
Sum/median	30	6111	3165–10,768	2100
Body mass				
<1 kg	98	5137	3577–6947	2509
⩾1 kg	114	3956	2575–4961	3697
IUCN				
Listed	92	3611	2261–5033	2484
Not listed	120	4824	3867–5878	3435
All species	212	4169	3577–5129	3299

a Reptiles and amphibians.
b Mosses, ferns, dicotyledons, monocotyledons and gymnosperms.
c Molluscs and crustaceans.

correlate with extinction risk failed to explain much of the variation in MVP_{st}; the saturated correlates model accounted for 20.6% of the explained deviance after taking phylogeny into account as a random effect (Table 1). The most parsimonious GLMM, according to BIC, failed to find evidence for any main effects. Yet these predictors explained 54% of the deviance in whether or not a species was IUCN Red-Listed. This contrast between the predictability of MVP versus IUCN status has been described in previous work (Brook et al., 2006), using MVP estimated from an independent source (time series data), and effectively highlights two different paradigms (Caughley, 1994). Ecological predictors of threatened status indicate a species' sensitivity to the largely systematic drivers of extinction (Cardillo, 2003), confirmed here by the support for IUCN listing. MVP represents, on the other hand, the small population paradigm (Caughley, 1994); that is, a population already reduced in size and subject to a host of population-specific threats (many stochastic) which cannot be accounted for in broad species comparisons such as ours.

MVP is thus an appropriate measure of the viability of populations that have declined deterministically (or catastrophically) to a small size, but subsequently 'stabilized' (though they continue to fluctuate stochastically). As such, context-specific factors such as variability of the local environment are more relevant for determining MVP than the broad-scale extinction drivers that cause endangerment. MVP size and regional or global extinction risk are thus unrelated (Brook et al., 2006). Note that the majority of vertebrates considered threatened by IUCN are listed under Criterion A, which relates threat to rate and magnitude of population size or range decline (IUCN, 2006). The assessment of vulnerability of IUCN is complementary, but essentially unrelated, to that derived from MVP.

Despite the lack of predictability of MVP based on plausible (and measurable) correlates of extinction risk, we can draw some broad generalizations from the meta-analysis. MVP-related studies have gradually increased over the past three decades, with no apparent decline in the concept's use, and with a trend toward multi-species analyses (Fig. 2). Depending on the strength of density dependence, MVP follows either a weakly right-skewed or symmetrical distribution (Fig. 4), with the highest probability density in the range of a few thousand, rather than hundreds, or tens of thousands of individuals, comparable to the findings of Brook et al. (2006) and Reed et al. (2003). While there was some broad taxonomic variation, the true magnitude of any differences is uncertain because some taxa have been poorly sampled to date (fish and invertebrates – Table 2).

A major product of this collation and standardization of published MVPs, especially when coupled with a previous phenomenological analysis (Brook et al., 2006), is a database of MVPs and species attributes that span a broad range of biomes, body sizes, life histories and threat status. This resource (Table S1, provided as a searchable spreadsheet table in the Supplementary Material) can be used by conservation practitioners as a preliminary guide to the MVP range expected for particular species or surrogate taxa of concern, or indeed to derive a target MVP for data-deficient species (we recommend the upper 95% confidence limit of MVP for the taxon in question, excluding poorly sampled taxa such as insects, fish and marine invertebrates). Moreover, these results provide important baseline data for testing future research hypotheses regarding population size and extinction risk, particularly with the now-evident shift toward the Bayesian paradigm within ecology and the concomitant need for robust informative prior information (Clark and Gelfand, 2006). We also support a disciplinary shift away from charismatic species (as highlighted by the lack of data available for fishes, insects and marine invertebrates) and focus of expertise and resources on IUCN-listed species and hotspots of latent extinction risk (Cardillo et al., 2006).

Acknowledgements

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.biocon.2007.06.011.

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ID	CLA	ORD	Family	Genus	Species
66	Osteichthyes	Clupeiformes	Clupeidae	Clupea	harengus
91	Osteichthyes	Clupeiformes	Engraulidae	Engraulis	mordax
147	Osteichthyes	Lophiiformes	Lophiidae	Lophius	piscatorius
166	Osteichthyes	Gadiformes	Gadidae	Micromesistius	poutassou
181	Osteichthyes	Salmoniformes	Salmonidae	Oncorhynchus	tshawytscha
182	Osteichthyes	Salmoniformes	Salmonidae	Oncorhynchus	tshawytscha
203	Osteichthyes	Pleuronectiformes	Soleidae	Pegusa	lascaris
236	Osteichthyes	Salmoniformes	Salmonidae	Salvelinus	fontinalis
237	Osteichthyes	Salmoniformes	Salmonidae	Salvelinus	leucomaenis

Supplementary Material, Table 1. Summary of the data set for all 287 viable population estimates, listing publications source, sp
in the analysis, probability of survival (assumed at 100 percent if PVA not used), duration in generations (usually 40 generations,
Model correlates: EXT = percentage probability of persistence (1 - extinction risk), DUR = duration of survival expressed in gene
derived and (4) empirically derived, DEN = density dependence, (0) density independent, (1) density dependence through the use
Ecological correlates: BWT = body weight estimated in grams, GEN = generation length in months (taken as age at first parturit
(2) polygamous or gregarious, (3) monogamous and (4) solitary (other than for a brief period of copulation), DSP = dispersal or m
was primarily restricted to one major biome type, HMP = human impact, beneficial or not, TRE = stable/increasing or decreasing

Common name	Estimate	LNStdMVP	EXT	DUR	MOD	DEN	INB	CAT	BWT	GNL	FEC	SOC	DSP	RAN	HMP
Herring	500000	14.606	100	25	2	2	0	0	150	36	150000	1	1	1	2
Anchovy	500000	14.030	100	100	2	2	0	0	50	10	25000	1	1	1	2
Anglerfish	500000	14.030	100	100	2	2	0	0	500	18	500000	4	2	1	2
Blue whiting	500000	14.491	100	33	2	2	0	0	150	36	400000	1	1	1	2
Chinook salmon	20000	12.944	90	16	2	0	0	1	2500	36	3353	1	1	1	2
Chinook salmon	10000	11.212	95	66	2	2	0	0	2500	36	4000	1	1	1	2
Sole	500000	14.767	100	17	2	2	0	0	250	22	200000	1	1	1	2
Brook trout	3869	8.261	99	40	1	1	1	0	1240	24	5000	2	2	1	1
White-spotted charr	250	7.811	95	33	1	2	0	0	3500	36	5000	1	1	1	2

pecies common name, broad taxonomic group, minimum viable population estimate, standardized MVP for the 212 species used
or derived equivalent of 100 years), and the set of model predictors and extinction correlates
erations (assumed at 100 years if not given), MOD = broad method used to derive the estimate, (1) individual-based simulation (2) cohort- or matrix-based simulation
e of ceiling K, (2) functional density dependence, INB = Inbreeding depression, (1) where loss of genetic variation modelled, CAT = probability of random catastrophe
tion, or advent of sexual maturity for non-mammals), FEC = fecundity or number of young/eggs/seed produced per adult female per year, SOC = social gouping of se
igratory ability, where (1) is migratory and (2) constrained, RAN = range or geographic distribution, scored (1) if geographic range occurred outside of one major bior
, IUCN = IUCN Red List categorization.

TRE	IUCN	Author	Year	Journal (abbreviated)
0	LC	Dulvy, Jennings et al	2005	JAPPLEC
0	LC	Dulvy, Jennings et al	2005	JAPPLEC
0	LC	Dulvy, Jennings et al	2005	JAPPLEC
0	LC	Dulvy, Jennings et al	2005	JAPPLEC
0	LC	Botsford & Brittnacher	1998	CONSBI
0	LC	Ratner, Lande et al	1997	CONSBI
0	LC	Dulvy, Jennings et al	2005	JAPPLEC
0	LC	Reed, O'Grady et al	2003	BICONS
0	LC	Morita & Yokota	2002	ECOLMOD

ı or time series model (3) genetically
ɜ, (1) where was used in models
ɜxually active adults, (1) colonial or spawning,
ıme type (SOM - S3) or (2) the species

Notes on data derivation. Ref to Tables/Appendices are those from the literarture - not this article.
Diffusion approximation. Initial N used. Viable for 100 years. See Table 2.
Diffusion approximation. Initial N used. Viable for 100 years. See Table 2.
Diffusion approximation. Initial N used. Viable for 100 years. See Table 2.
Diffusion approximation. Initial N used. Viable for 100 years. See Table 2.
Leslie matrix based model. Spawning abundance of 10 000 females viable.
Estimated current population.
Diffusion approximation. Initial N used. Viable for 100 years. See Table 2.
Corrected MVP (MVP_C) derived from the Appendix.
Viable K used.

Science, Service, Stewardship

5-Year Review:
Summary & Evaluation of
Middle Columbia River Steelhead

National Marine Fisheries Service
Northwest Region
Portland, OR

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5-Year Review: Middle Columbia River Species

Species Reviewed	Distinct Population Segment
Steelhead (*Oncorhynchus mykiss*)	*Middle Columbia River Steelhead*

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1 ▪ General Information

1.1 Introduction

Many West Coast salmon and steelhead (Oncorhynchus spp.) stocks have declined substantially from their historic numbers and now are at a fraction of their historical abundance. There are several factors that contribute to these declines, including: overfishing, loss of freshwater and estuarine habitat, hydropower development, poor ocean conditions, and hatchery practices. These factors collectively led to the National Marine Fisheries Service's (NMFS) listing of 28 salmon and steelhead stocks in California, Idaho, Oregon, and Washington under the Federal Endangered Species Act (ESA).

The ESA, under section 4(c)(2), directs the Secretary of Commerce to review the listing classification of threatened and endangered species at least once every five years. After completing this review, the Secretary must determine if any species should be: (1) removed from the list; (2) have its status changed from threatened to endangered; or (3) have its status changed from endangered to threatened. The most recent listing determinations for most salmon and steelhead occurred in 2005 and 2006. This document describes the results of the review of the ESA-listed Middle Columbia River (MCR) steelhead.

1.1.1 Background on salmonid listing determinations

The ESA defines species to include subspecies and distinct population segments (DPS) of vertebrate species. A species may be listed as threatened or endangered. To identify distinct population segments of salmon species we apply the "Policy on Applying the Definition of Species under the ESA to Pacific Salmon" (56 FR 58612). Under this policy we identify population groups that are "evolutionarily significant units" (ESU) within their species. We consider a group of populations to be an ESU if it is substantially reproductively isolated from other populations, and represents an important component in the evolutionary legacy of the biological species. We consider an ESU as constituting a DPS and therefore a "species" under the ESA.

To identify DPSs of steelhead, we apply the joint U.S. Fish and Wildlife Service-National Marine Fisheries Service DPS policy (61 FR 4722) rather than the ESU policy. Under this policy, a DPS of steelhead must be discrete from other populations, and it must be significant to its taxon.

Artificial propagation programs (hatcheries) are common throughout the range of ESA-listed West Coast salmon and steelhead. Prior to 2005, our policy was to include in the listed ESU or DPS only those hatchery fish deemed "essential for conservation" of a species. We revised that approach in response to a court decision and on June 28, 2005, announced a final policy addressing the role of artificially propagated Pacific salmon and steelhead in listing determinations under the ESA (70 FR 37204) (hatchery listing policy). This policy establishes criteria for including hatchery stocks in ESUs and DPSs. In addition, it (1) provides direction for considering hatchery fish in extinction risk assessments of ESUs and DPSs; (2) requires that hatchery fish determined to be part of an ESU or DPS be included in any listing of the ESU or DPS; (3) affirms our commitment to conserving natural salmon and steelhead populations and the ecosystems upon which they depend; and (4) affirms our commitment to fulfilling trust and treaty obligations with regard to the harvest of some Pacific salmon and steelhead populations, consistent with the conservation and recovery of listed salmon ESUs and steelhead DPSs.

To determine whether a hatchery program is part of an ESU or DPS, and therefore must be included in the listing, we consider the origins of the hatchery stock, where the hatchery fish are released, and the extent to which the hatchery stock has diverged genetically from the donor stock. We include within the ESU or DPS (and therefore within the listing) hatchery fish that are derived from the population in the area where they are released, and that are no more than moderately diverged from the local population.

Because the new hatchery listing policy changed the way we considered hatchery fish in ESA listing determinations, we completed new status reviews and ESA listing determinations for West Coast salmon ESUs and steelhead DPSs. On June 28, 2005, we issued final listing determinations for 16 ESUs of Pacific salmon (70 FR 37160). On January 5, 2006 we issued final listing determinations for 10 DPSs of steelhead (71 FR 834).

1.2 Methodology used to complete the review

On March 18, 2010, we announced the initiation of five year reviews for 16 ESUs of salmon and 10 DPSs of steelhead in Oregon, California, Idaho, and Washington (75 FR 13082). We requested that the public submit new information on these species that has become available since our listing determinations in 2005 and 2006. In response to our request, we received information from Federal and state agencies, Native American Tribes, conservation groups, fishing groups, and individuals. We considered this information, as well as information routinely collected by our agency, to complete these five year reviews.

To complete the reviews, we first asked scientists from our Northwest Fisheries Science Center to collect and analyze new information about ESU and DPS viability. To evaluate viability, our scientists used the Viable Salmonid Population (VSP) concept developed by McElhany et al. (2000). The VSP concept evaluates four criteria – abundance, productivity, spatial structure, and diversity – to assess species viability. Through the application of this concept, the science centers considered new information for a given ESU or DPS relative to the four salmon and steelhead population viability criteria. They also considered new information on ESU and DPS boundaries. At the end of this process, the science teams prepared reports detailing the results of their analyses (Ford et al. 2010).

To further inform the reviews, we also asked salmon management biologists from our Northwest Region familiar with hatchery programs to consider new information available since the previous listing determinations. Among other things, they considered hatchery programs that have ended, new hatchery programs that have started, changes in the operation of existing programs, and scientific data relevant to the degree of divergence of hatchery fish from naturally spawning fish in the same area. They produced a report (Jones et al. 2011) describing their findings. Finally, we consulted biologists and other salmon management specialists from the Northwest Region who are familiar with hatchery programs, habitat conditions, hydropower operations, and harvest management. In a series of structured meetings, by geographic area, these biologists identified relevant information and provided their insights on the degree to which circumstances have changed for each listed entity.

In preparing this report, we considered all relevant information, including: the work of the Northwest Fisheries Science Center (Ford et al. 2010); the report of the regional biologists regarding hatchery programs (Jones et al. 2011); recovery plans for the species in question; technical reports prepared in support of recovery plans for the species in question; the listing record (including designation of critical habitat and adoption of protective regulations); recent biological opinions issued for the MCR steelhead; information submitted by the public and other government agencies; and the information and views provided by the geographically-based management teams. The present report describes the agency's findings based on all of the information considered.

1.3 Background – Summary of Previous Reviews, Statutory and Regulatory Actions, and Recovery Planning

1.3.1 Federal Register Notice announcing initiation of this review

75 FR 13082; March 18, 2010

1.3.2 Listing history

In 1999, NMFS listed MCR steelhead under the ESA and classified it as a threatened species (Table 1).

Table 1. Summary of the listing history under the Endangered Species Act for the MCR Steelhead DPS.

Salmonid Species	ESU/DPS Name	Original Listing	Revised Listing(s)
Steelhead (*O. mykiss*)	Middle Columbia River Steelhead	**FR Notice:** 64 FR 14517 **Date:** 3/25/1999 **Classification:** Threatened	**FR Notice:** 71 FR 834 **Date:** 1/5/2006 **Re-classification:** Threatened

1.3.3 Associated rulemakings

The ESA requires NMFS to designate critical habitat, to the maximum extent prudent and determinable, for species it lists under the ESA. Critical habitat is defined as: (1) specific areas within the geographical area occupied by the species at the time of listing, if they contain physical or biological features essential to conservation, and those features may require special management considerations or protection; and (2) specific areas outside the geographical area occupied by the species at the time of listing if the agency determines that the area itself is essential for conservation. We designated critical habitat for MCR steelhead in 2005.

Section 9 of the ESA prohibits the take of species listed as endangered. The ESA defines take to mean harass, harm, pursue, hunt, shoot, wound, trap, capture, or collect, or attempt to engage in any such conduct. For threatened species, the ESA does not automatically prohibit take, but instead authorizes the agency to adopt regulations it deems necessary and advisable for species conservation including regulations that prohibit take (ESA section 4(d)). For threatened salmonids, NMFS has adopted 4(d) regulations that prohibit take except in specific circumstances. In 2005, we revised 4(d) regulations for MCR steelhead, to take into account our hatchery listing policy.

Table 2. Summary of rulemaking for 4(d) protective regulations and critical habitat for the MCR Steelhead.

Salmonid Species	ESU/DPS Name	4(d) Protective Regulations	Critical Habitat Designations
Steelhead (*O. mykiss*)	Middle Columbia River Steelhead	**FR notice:** 70 FR 37160 **Date:** 6/28/2005	**FR notice:** 70 FR 52630 **Date:** 9/2/2005

1.3.4 Review History

Table 3 lists the numerous scientific assessments of the status of the MCR steelhead DPS. These assessments include status reviews conducted by our Northwest Fisheries Science Center and technical reports prepared in support of recovery planning for this DPS.

Table 3. Summary of previous scientific assessments for the MCR Steelhead.

Salmonid Species	ESU/DPS Name	Document Citation
Steelhead (*O. mykiss*)	Middle Columbia River Steelhead	ICTRT and Zabel 2007 ICTRT 2007a ICTRT 2007b McClure et al. 2005 Good et al. 2005 ICTRT 2003 NMFS 1996 NMFS 1997 NMFS 1999a NMFS 1999b

1.3.5 Species' Recovery Priority Number at Start of 5-year Review Process

On June 15, 1990, NMFS issued guidelines (55 FR 24296) for assigning listing and recovery priorities. We assess three criteria to determine a species' priority for recovery plan development, implementation, and resource allocation: (1) magnitude of threat; (2) recovery potential; and (3) existing conflict with activities such as construction and development. Table 4 lists the recovery priority numbers for the subject species, as reported in the 2006-2008 Biennial Report to Congress on the Recovery Program for Threatened and Endangered Species (available at: http://www.nmfs.noaa.gov/pr/pdfs/laws/esabiennial2008.pdf).

1.3.6 Recovery Plan or Outline

Table 4. Recovery Priority Number and Endangered Species Act Recovery Plans for the MCR Steelhead.

Salmonid Species	ESU/DPS Name	Recovery Priority Number	Recovery Plans/Outline
Steelhead (*O. mykiss*)	Middle Columbia River Steelhead	**1**	**Title:** Middle Columbia River Steelhead Distinct Population Segment ESA Recovery Plan Available at: http://www.nwr.noaa.gov/Salmon-Recovery-Planning/Recovery-Domains/Interior-Columbia/Mid-Columbia/Mid-Col-Plan.cfm **Date:** 9/30/2009 **Type:** Final **FR Notice:** 74 FR 50165

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2 · Review Analysis

In this section we review new information to determine whether the MCR steelhead DPS delineation remains appropriate.

2.1 Delineation of species under the Endangered Species Act

Is the species under review a vertebrate?

DPS Name	YES	NO
Middle Columbia River Steelhead	X	

Is the species under review listed as a DPS?

DPS Name	YES	NO
Middle Columbia River Steelhead	X	

Was the DPS listed prior to 1996?

DPS Name	YES	NO	Date Listed if Prior to 1996
Middle Columbia River Steelhead		X	n/a

Prior to this 5-year review, was the DPS classification reviewed to ensure it meets the 1996 DPS policy standards?

Not Applicable

2.1.1 Summary of relevant new information regarding delineation of the MCR steelhead DPS

ESU/DPS Boundaries

This section provides a summary of information presented in Ford et al. (2010): Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Northwest.

The boundary between coastal and interior populations of Chinook salmon, coho salmon and steelhead coincides with a major biogeographic barrier that lies along the Cascade Crest, and for aquatic species, may have been delineated by Celilo Falls. Life history, genetic, and ecological information indicate that the Big White Salmon and Klickitat River basins form part of a transitional zone between the two regions. At the time of the coastwide status reviews in the mid-1990s, there was considerable disagreement over the placement of populations within this transitional zone. New information, primarily on DNA microsatellite variation, underscores the transitional nature of populations in this area. The extirpation and potential alteration (via hatchery transfers) of some populations further cloud the issue of population assignment.

Within the transition zone it is relatively clear that the Hood River steelhead remain closely associated with Lower Columbia River steelhead populations. Given the relatively close proximity of the mouths of the Hood, Big White Salmon, and Klickitat Rivers, and the lack of definitive genetic information indicating that the populations are discrete, it would be reasonable to assign the Big White Salmon and Klickitat River steelhead populations to either the MCR steelhead DPS or to the Lower Columbia River steelhead DPS. The Fifteenmile Creek population, however, is clearly associated with the Interior Columbia steelhead lineage. The recent information underscores the transitional nature of the Big White Salmon and Klickitat River populations and the uncertainty associated with the Lower Columbia River and MCR steelhead DPS boundary highlighted in the previous review.

Membership of Hatchery Programs

In preparing this report, our management biologists reviewed the available information regarding hatchery membership of this DPS (Jones et al. 2011). They considered changes in hatchery programs that occurred since the last status review and made recommendations about the inclusion or exclusion of specific programs. They also noted any errors and omissions in the existing descriptions of hatchery population membership. NMFS intends to address any needed changes and corrections via separate rulemaking subsequent to the completion of these five-year status reviews.

The MCR steelhead DPS includes all naturally spawned populations of steelhead in streams from above the Wind River, Washington, and the Hood River, Oregon (exclusive), upstream to, and including, the Yakima River, Washington, excluding steelhead from the Snake River Basin (64 FR 14517; March 25, 1999). Seven artificial propagation programs are considered part of the DPS: the Touchet River Endemic, Yakima River Kelt Reconditioning Program (in Satus Creek, Toppenish Creek, Naches River, and Upper Yakima River), Umatilla River, and the Deschutes River steelhead hatchery programs. We have determined that these artificially propagated stocks are no more divergent relative to the local natural population(s) than what would be expected between closely related natural populations within the DPS (71 FR 834; January 5, 2006).

The MCR steelhead hatchery programs have not changed substantially from the previous ESA status review to suggest that their level of divergence relative to the local natural populations has changed (Jones et al. 2011).

2.2 Recovery Criteria

The ESA requires NMFS to develop recovery plans for each listed species. Recovery plans must contain, to the maximum extent practicable, objective measureable criteria for delisting the species, site-specific management actions necessary to recover the species, and time and cost estimates for implementing the recovery plan.

2.2.1 Does the species have a final, approved recovery plan containing objective, measurable criteria?

DPS Name	YES	NO
Middle Columbia River Steelhead	X	

2.2.2 Adequacy of recovery criteria

Based on new information considered during this review, are the recovery criteria still appropriate?

DPS Name	YES	NO
Middle Columbia River Steelhead	X	

Are all of the listing factors that are relevant to the species addressed in the recovery criteria?

DPS Name	YES	NO
Middle Columbia River Steelhead	X	

2.2.3 List the recovery criteria as they appear in the recovery plan

For the purposes of reproduction, salmon and steelhead typically exhibit a metapopulation structure (Schtickzelle and Quinn 2007, McElhany et al. 2000). Rather than interbreeding as one large aggregation, ESUs and DPSs function as a group of demographically independent populations separated by areas of unsuitable spawning habitat. For conservation and management purposes, it is important to identify the independent populations that make up an ESU or DPS. For recovery planning and development of recovery criteria, the Interior Columbia Technical Recovery Team (ICTRT) identified independent populations within the MCR steelhead DPS, and grouped them into genetically similar major population groups (MPGs) (ICTRT 2003). The DPS is composed of four MPGs: Cascades Eastern Slope Tributaries, John Day River, Umatilla/Walla Walla Rivers, and Yakima River (Figure 1).

Toole Declaration, Exhibit 6, page 17

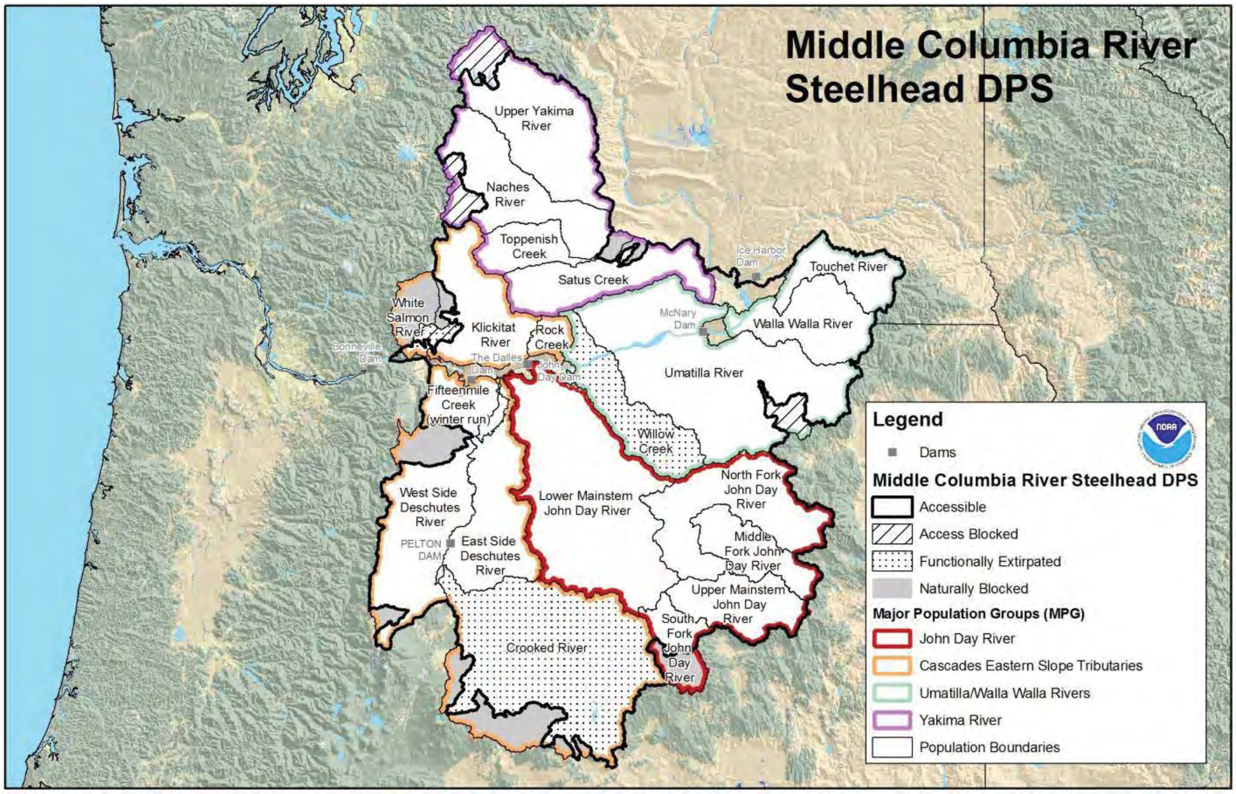

Figure 1. MCR Steelhead population structure[1]

The ICTRT (2007b) also developed specific biological viability criteria based on the VSP concept (McElhany et al. 2000) at the population, MPG, and DPS levels.

At the population level, the ICTRT recommended specific biological criteria based on the four viability components of VSP—abundance/productivity and spatial structure/diversity. These criteria are integrated to develop a total-population viability rating. The population viability ratings, in order of increasing risk, are highly viable, viable, moderate risk and high risk. A further bifurcation occurs at the moderate risk rating. Populations rated at moderate risk are candidates for achieving a "maintained" status. Additional criteria identified in the Recovery Plan must be met before a population at moderate risk can be considered "maintained." Populations that do not meet these additional criteria would remain rated at moderate risk and would generally not contribute to viability at the MPG level.

In 2009, we issued a final recovery plan (Plan) for MCR steelhead, which adopted the ICTRT viability criteria as biological delisting goals (NMFS 2009). The recovery strategies outlined in the Plan are targeted to achieve, at a minimum, the biological criteria for each MPG in the DPS. The criteria are "[t]o have all four major population groups at viable (low risk) status with representation of all the major life-history strategies present historically, and with the abundance,

[1] The map above generally shows the accessible and historically accessible areas for the MCR steelhead. The area displayed is consistent with the regulatory description of the boundaries of the MCR steelhead found at 50 CFR17.11, 223.102, and 224.102. Actions outside the boundaries shown can affect this DPS. Therefore, these boundaries do not delimit the entire area that could warrant consideration in recovery planning or determining if an action may affect this DPS for the purposes of the ESA.

productivity spatial structure and diversity attributes required for long-term persistence." The Plan recognizes that there may be several different combinations of population status that could satisfy the biological criteria for each MPG, and identifies the combinations most likely to result in achieving viability for each MPG (NMFS 2009; Ford et al. 2010). The Plan also recognizes a range of restoration objectives that go beyond the biological viability necessary for delisting (NMFS 2009). The following describes the combinations of population status most likely to achieve viability for each MPG.

Cascades Eastern Slope Tributaries MPG

The Klickitat River, Fifteenmile Creek, East Side Deschutes and West Side Deschutes populations should be viable; at least one of these populations should be highly viable. The Rock Creek population should be at maintained status.

John Day River MPG

The Lower Mainstem John Day River, the North Fork John Day River, and either the Middle Fork John Day River or the Upper Mainstem John Day River populations should be viable. One of these populations should be highly viable.

Yakima River MPG

Two of the four populations in the Yakima River MPG should be viable, including, at a minimum, either the Naches River or the Upper Yakima River population. The other two populations should at least be at maintained status.

Umatilla/Walla Walla Rivers MPG

Either the Walla Walla River or the Touchet River population should be viable, and the Umatilla River population should be highly viable.

2.3 Updated Information and Current Species' Status

In addition to recommending recovery criteria, the ICTRT also assessed the current status of each population within the DPS (ICTRT 2007b). Each population was rated against the biological criteria identified in the recovery plan and assigned a current viability rating.

2.3.1 Analysis of VSP Criteria (including discussion of whether the VSP criteria have been met)

Information provided in this section is summarized from Ford et al. (2010)—Status review update for Pacific salmon and steelhead listed under the Endangered Species Act: Northwest.

Abundance and Productivity

Cascades Eastern Slope Tributaries MPG

Abundance data are available for three (Fifteenmile Creek, East Side Deschutes, and West Side Deschutes) of the five extant populations in the Cascades Eastern Slope Tributaries MPG along with two years of estimates for a fourth population (Klickitat River). Total spawning abundance for the most recent five-year series (2005-2009) is below the levels reported in the last status review for the three populations. However, natural-origin spawner abundance is higher for the more recent estimates (for all three populations with more than two years of abundance estimates). Estimates of the proportion of natural-origin spawners were higher for all three (Fifteenmile Creek, East Side Deschutes, and West Side Deschutes) populations in the most recent brood cycle (Ford et al. 2010). Based on mark-recapture analysis during 2006-2007, an average of 1,450 natural and 1,670 hatchery steelhead passed upstream of the Klickitat Falls and into spawning reaches in the Klickitat River.

John Day River MPG

Total escapement and natural-origin escapement were down from the levels reported in the previous status review for four (Upper Mainstem, North Fork, Middle Fork, and Lower Mainstem) out of the five John Day populations. Both total and natural-origin spawning escapements in the South Fork John Day River were higher in the more recent brood cycle than in 1997-2001. Estimates of the fraction of natural-origin spawners were relatively unchanged for the upstream John Day populations, but had increased for the Lower Mainstem John Day River (Ford et al. 2010).

Yakima River MPG

Total and natural-origin escapement estimates were higher in the most recent brood cycle for all four of the Yakima River populations than in the cycle associated with the last status review. Steelhead escapements into the Upper Yakima River, although increased relative to the previous review, remain very low relative to the total amount of habitat available. The proportion of natural-origin fish remained high in the Yakima River Basin (estimated for aggregate run at Prosser Dam) (Ford et al. 2010).

Umatilla/Walla Walla Rivers MPG

Total spawning escapements have increased in the most recent brood cycle over the period associated with the last status review for all three populations in the Umatilla/Walla Walla Rivers MPG. Natural-origin escapements are higher for two populations (Umatilla River and Walla Walla River) while remaining at approximately the same level as in the prior review for the Touchet River (Ford et al. 2010).

Spatial Structure and Diversity

Cascades Eastern Slope Tributaries MPG

Access to 50 miles of habitat in the upper Klickitat River has been greatly enhanced with completion of the Castille Falls fishway. The new facility is expected to improve immigration, but its effectiveness is still being evaluated.

With completion of improved passage facilities at the Pelton Round Butte hydroelectric complex and subsequent release of fish into the upper basin since 2007, access to up-river habitats has substantially improved in the Deschutes River Basin (www.deschutespassage.com). These facilities are expected to result in a substantial increase in habitat available to steelhead. Previous risk ratings for the spatial extent or range of the population were moderate because of the blocked passages at Pelton Round Butte. While the new facilities are expected to improve passage, the effectiveness of those facilities is still being evaluated.

John Day River MPG

Spatial structure and diversity metrics have not changed since the completion of the 2008 ICTRT status assessments (Ford et al. 2010).

Yakima River MPG

Spatial structure and diversity metrics have not changed since the completion of the 2008 ICTRT status assessments (Ford et al. 2010).

Umatilla/Walla Walla Rivers MPG

Spatial structure and diversity metrics have not changed since the completion of the 2008 ICTRT status assessments (Ford et al. 2010).

Updated Risk Summary

Cascades Eastern Slope Tributaries MPG

The current status of two of the five populations in the Cascades Eastern Slope Tributaries MPG, Fifteenmile and the East Side Deschutes River , is rated as viable using the ICTRT criteria incorporated into the recovery plan.

The West Side Deschutes population remains rated at high risk because of relatively low estimates for current productivity and natural-origin abundance. The data series for the Klickitat River population is not sufficient to allow for a rating. However, available mark-recapture based estimates for two recent years indicate that the population may be functioning at, or near viable levels. Data are not available for the remaining extant population (Rock Creek), and the White Salmon River and Crooked River populations are both classified as extinct by the ICTRT.

John Day River MPG

The North Fork John Day population continues to be rated highly viable when data through the 2009 spawning year are incorporated into the assessment. The remaining four populations in the John Day River MPG remain rated as maintained status. Natural-origin abundance estimates (ten year geometric mean) are higher in the current assessments for four populations and lower for the Middle Fork John Day River. Productivity estimates (geometric mean of brood year spawner/spawner ratio at low to moderate parent escapements) were generally lower in the updated data series than the estimates generated for the ICTRT status reviews ending in spawning year 2005.

Yakima River MPG

The ratings for individual populations in the Yakima River MPG should be interpreted with caution given the basis for estimating population specific returns from Prosser Dam counts. The overall viability ratings improved from maintained status to viable for the Satus Creek and Toppenish Creek populations, but remained at maintained status for the Naches River and at high risk for the Upper Yakima River population. The changes in ratings reflect the relatively high annual returns in most years since 2001. Productivity estimates based on the return series updated through 2009 (previously through 2005) have increased or remained at approximately the same levels as estimated in the recovery plan/ICTRT status assessments.

Umatilla/Walla Walla Rivers MPG

The overall rating for the Umatilla River and Walla Walla River populations remain at maintained status after incorporating the updated abundance and productivity data. The current status of the Touchet River population remains at high risk, primarily driven by relatively low productivity. Natural-origin abundance estimates increased for the Umatilla River and the Walla Walla River populations relative to the levels reported in the recovery plan/ICTRT status assessments (through return year 2005). Productivity estimates for all three extant populations in this MPG are lower than in the previous reviews. The Willow Creek population is classified as extinct by the ICTRT.

DPS Summary

Although there have been improvements in the viability ratings for some of the component populations, none of the MPGs are meeting the recovery criteria and only 3 of the 17 extant populations are considered to be viable. Since the DPS-level recovery criteria require that all four MPGs be rated as viable, more progress must be made before this MCR steelhead DPS can be considered recovered.

Several factors cited in the previous status review (Good et al. 2005) remain concerns or key uncertainties. Natural-origin spawning estimates are highly variable relative to minimum abundance thresholds across the populations in the DPS. Some populations, such as the North Fork John Day, are rated highly viable and have consistently high abundance, while several other populations remain at high risk. Updated information indicates that straying levels into at least the Lower John Day River population are also high. Returns to the Yakima River Basin and to the Umatilla and Walla Walla rivers have been higher over the most recent brood cycle while natural-origin returns to the John Day River have decreased. Out-of-basin hatchery stray proportions, although reduced, remain very high in the Deschutes River Basin.

Overall, the new information considered does not indicate a change in the biological risk category since the time of the last status review. Although direct biological performance measures for this DPS indicate little realized progress to date toward meeting its recovery criteria, there is no new information to indicate that its extinction risk has increased significantly. The DPS remains well distributed throughout its historical range in the Middle Columbia River Basin and at least some populations are considered to be viable. The percentage of natural-origin spawners is relatively high (70-99 percent; Ford et al. 2010) and the estimates of total DPS abundance indicates that the DPS is not at immediate risk of extinction. New information considered during this review confirms that this DPS remains at moderate risk of extinction.

2.3.2 Five-Factor Analysis

Section 4(a)(1)(b) of the ESA directs us to determine whether any species is threatened or endangered because of any of the following factors: (1) the present or threatened destruction, modification, or curtailment of its habitat or range; (2) overutilization for commercial, recreational, scientific, or educational purposes; (3) disease or predation; (4) the inadequacy of existing regulatory mechanisms; or (5) other natural or human-made factors affecting its continued existence. Section 4(b)(1)(A) requires us to make listing determinations after conducting a review of the status of the species and taking into account efforts to protect such species. Below we discuss new information relating to each of the five factors as well as efforts being made to protect the species.

Present or threatened destruction, modification or curtailment of its habitat or range

Significant habitat restoration and protection actions at the Federal, state, tribal, and local levels have been implemented to improve degraded habitat conditions and restore fish passage. While these efforts have been substantial and are expected to benefit the survival and productivity of the targeted populations, we do not yet have evidence demonstrating that improvements in habitat conditions have led to improvements in population viability. The effectiveness of habitat restoration actions and progress toward meeting the viability criteria will be monitored and evaluated with the aid of newly implemented monitoring and evaluation programs. Generally, it takes one to five decades to demonstrate such increases in viability. Below, we summarize several noteworthy restoration and protection actions implemented since the last review. We also note areas where concerns about this DPS' habitat condition remain.

The implementation of the Federal Columbia River Power System (FCRPS) Biological Opinion (Opinion) (NMFS 2008a; NMFS 2010) has provided a number of actions that will result in survival improvements, reduced duration of outmigration to the estuary, improvements in juvenile survival and condition, and increased access to habitats. Some of the major milestones include the following:

Improvements in operations and fish passage at hydropower facilities and dams

Implementation of the FCRPS Opinion (NMFS 2008a; NMFS 2010) provides a number of new actions and continuation of existing programs that have and will likely continue to increase passage survival through the Columbia River passage corridor. In addition to increasing direct survival at the dams and through the project reservoirs, these actions reduce the duration of juvenile salmonid outmigration to the estuary, and increase access to habitat for adult migrants.

Since 2006, direct survival for juvenile salmonid outmigration in the Columbia River has likely increased because of installation of, or improvements to, juvenile passage structures at The Dalles Dam (spillway wall installed in 2010), John Day Dam (two surface passage weirs installed in 2008), and McNary Dam (surface passage routes and spillway weirs installed in 2007). Previously installed juvenile passage facilities are performing well at Bonneville Dam (corner surface collector installed in 2004). Mainstem dam juvenile passage facilities have been evaluated for passage survival and behavioral response, and testing continues. Survival and behavioral testing subsequently inform modifications to passage facility design and project operations, based on lessons learned and adaptive management.

Future improvements are anticipated as the FCRPS Opinion (NMFS 2008a; NMFS 2010) is implemented further. Some of the future improvements include adult PIT tag detectors at The Dalles Dam or John Day Dam; enhanced estuarine detection of PIT tagged adults; and development and evaluation of PIT tag detection at project spillways. These technological enhancements will increase the ability to detect and correct salmonid passage issues throughout the Columbia River Basin.

Deschutes Basin Passage Improvements include:

- Pelton Round Butte, Selective Water Withdrawal Facility: The first year of operations was in 2010. The facility and operations have improved the management of water flow and temperature to better resemble historical conditions. These improvements in flow and temperature management are primarily targeted to benefit Chinook populations; the expected benefits for Deschutes River steelhead are unknown. Habitat and passage improvements in Trout Creek, also part of the Pelton Round Butte re-licensing agreement, are expected to benefit the East Side Deschutes steelhead population.

- Fish Reintroduction: Outplants in the Wychus Creek, Crooked River and the Deschutes River of unfed fry from the Round Butte hatchery stock above Pelton-Round Butte are intended to re-establish an extirpated population. The capture of 7,700 steelhead smolts in 2010 at Pelton Round Butte suggests some near-term successes of these reintroduction efforts.

Management of Tributary Habitat

Since the last status review, numerous habitat projects have been completed. Recovery projects throughout the range of the DPS included: (1) improved fish passage and increased access to high quality habitat; (2) riparian vegetation restoration through fencing and planting; (3) instream habitat improvements; (4) screening of irrigation diversions; (5) land acquisitions to protect existing habitat; (6) removal or structural improvements of tributary dams (e.g., Roza on Yakima River, Hofer on Touchet River); (7) protection and enhancement of instream flows, groundwater recharge and water quality; and (8) design and/or implementation of watershed scale plans (e.g., Toppenish, Touchet).

Most of these projects were accomplished with cooperation and/or funding from the Washington Salmon Recovery Funding Board, the Pacific Coastal Salmon Recovery Fund, Habitat Conservation Plans, Bonneville Power Administration, Army Corps of Engineers, Bureau of Reclamation, the Oregon Watershed Enhancement Board, Conservation Districts, Federal, state, local landowners, and others.

Despite significant efforts to improve habitat conditions, much of the habitat in the range of MCR steelhead remains degraded. Restoring habitat to historic conditions may not be needed to attain viability, but considerable improvement is needed to restore habitat to levels that will support viable steelhead populations within the DPS. In particular, the poor status of the habitat and populations in the Yakima Basin is a major obstacle to achieving DPS viability. There are significant opportunities to adjust the operations of the Yakima Basin project to benefit populations in the Yakima River MPG. In the Yakima River and elsewhere in the range of the DPS, there are many opportunities to provide access to historically occupied habitats, preserve existing high quality habitats, and restore degraded habitats.

In addition, mainstem tributary flow remains a key concern, particularly within the Walla Walla River Basin, Umatilla River Basin, and portions of the Yakima River Basin. Late-season tributary flow management is also a concern in certain areas. Some reaches of small to mid-size tributaries providing key rearing habitat often are dry during the summer due to an over-allocation of surface water for irrigation and municipal purposes.

Non-Federal actions including agriculture, urbanization, and development throughout the Middle Columbia River Basin have likely resulted in stormwater inputs, pesticide and herbicide contamination, bank hardening and stabilization, sediment input, channel simplification, high stream temperatures and low stream flow. These types of impacts may further degrade habitat conditions. The net impact of such degradation in the context of habitat restoration efforts being implemented is unknown.

Federal Land Management

Federal land managers have taken a number of measures to protect and restore habitat throughout the range of the MCR steelhead DPS. According to the Forest Service and Bureau of Land Management, habitat improvement and benefits have been demonstrated on Federal lands through the implementation of PACFISH (USDA and USDI 1994), the Aquatic Habitat Restoration Activities Biological Opinion (ARBO), and other management efforts.

Monitoring results from the PACFISH Biological Opinion Monitoring Program (PIBO) provided by the Forest Service indicate that, within the range of the MCR steelhead, some trends in stream habitat attributes (large woody debris, streambank characteristics, etc.) are positive, some are negative, and others have no trend (Al-Chokhachy et al. 2010a). One notable improvement is an increase in the average number of large woody debris placed in streams across the range of the MCR steelhead DPS (Al-Chokhachy et al. 2010a).

Additional information from the PIBO monitoring program indicates that unmanaged or reference reaches (streams in watersheds with little to no impact from road building, grazing, timber harvest, and mining) on Federal lands in the Interior Columbia Basin are in better condition than managed streams (Al-Chokhachy et al. 2010b). In particular, managed watersheds with high road densities or livestock grazing tend to have stream reaches with worse habitat condition than streams in reference watersheds. When roads and grazing both occur in the same watershed, the presence of grazing has an additional significant negative effect on the relationship between road density and the condition of stream habitat (Al-Chokhachy et al. 2010b). These results indicate that legacy effects of historic management are still manifest in the current condition of streams on Federal lands in the Interior Columbia Basin, and ongoing management may still be affecting stream recovery rates. Forest Service researchers have concluded that the observed differences in average stream condition between reference and managed watersheds may indicate that recent management regulations (e.g, PACFISH) in combination with the legacy of previous management actions may not be sufficient to improve the status of streams within managed watersheds, particularly over relatively short time periods (10-20 years) (Al-Chokhachy et al. 2010b).

Significant progress in livestock grazing management on Federal lands has been made in the last 15 years, but the results of Al-Chokhachy et al. (2010b) indicate that further refinements to grazing management may be necessary in certain areas. In addition to these refinements, it is also essential to carry out adequate monitoring for livestock grazing. Without monitoring data, it will not be possible to tell if future refinements to grazing management are actually being carried out.

The Federal land managers are implementing several programs designed to restore the health of watersheds and improve aquatic habitat. The Forest Service's Legacy Road restoration program and identification of a minimum road system through implementation of Subpart A of the Travel Management Rule may help reduce the aquatic impacts of the transportation system. The Federal land managers have also developed aquatic restoration strategies. The Aquatic Restoration Strategy (Forest Service) and the 2015 Aquatic Strategy Plan (BLM) emphasize cooperative whole watershed-scale restoration. The actual realized benefits of these programs will depend on funding and the effectiveness of implementation.

Due to the vast acreage of Federal land throughout the range of MCR steelhead, conservation of this DPS' habitat on Federal land is a recovery priority. However, there is uncertainty over the future conservation of MCR steelhead on Federal lands. The level of protection afforded to this

DPS and its habitat will be determined by land management plans currently under development by the Forest Service and BLM. In August 2008, the Deputy Regional Directors for the Forest Service, BLM, NMFS, U.S. Fish and Wildlife Service, and Environmental Protection Agency developed "A Framework for Incorporating the Aquatic and Riparian Component of the Interior Columbia Basin Strategy into Bureau of Land Management and Forest Service Plan Revisions." The framework identifies six components to be included in the plan revisions: riparian management areas; protection of population strongholds; identification of restoration priorities; multi-scale analysis; development of management direction to identify desired outcomes of future conditions; and monitoring/adaptive management. The manner in which these components are implemented and integrated with the recovery plan will help determine the extent to which federal land management will contribute to recovery.

Inclusion of a comprehensive effectiveness monitoring program such as PIBO is an essential component of any future aquatic conservation strategy. Effectiveness monitoring data from a large-scale program such as PIBO allows managers to determine if current practices are allowing for the attainment of aquatic and riparian management objectives. It also allows managers to incorporate the additive effects of multiple land management activities when prescribing future management standards that will prevent further degradation of streams and begin to restore physical habitat (Al-Chokhachy et al. 2010b).

Significant opportunities exist for recovery and/or conservation actions on Federal lands as part of the ESA section 7(a)(1) responsibilities. NMFS will continue to work with the Forest Service and BLM to identify opportunities for restoration actions on Federal lands. We will also work with these agencies, to the degree possible, to provide technical assistance for projects that benefit the MCR steelhead DPS. Initiation and completion of consultation by Forest Service and BLM on all actions where consultation is required is also a conservation priority.

Habitat Factor Conclusion

New information available since the last status review indicates there is some improvement in freshwater and estuary habitat conditions due to restoration and additional habitat protection. In particular, changes to hydropower operations have increased juvenile survival rates through the mainstem Columbia River corridor. Improvements to fish passage and numerous tributary habitat restoration projects should result in improved survival for this DPS. We therefore conclude that the risk to the species' persistence because of habitat destruction or modification has improved slightly since the last status review. However, habitat concerns remain throughout the range of this DPS particularly in regards to water quality, water quantity, and riparian condition. There are numerous opportunities for habitat restoration or protection throughout the range of this DPS. It is likely that many additional habitat protection or restoration actions will be necessary to bring this DPS to viable status.

Overutilization for commercial, recreational, scientific, or educational purposes

Harvest

Over the past 5 years, harvest rates of MCR steelhead have remained relatively stable. The overall exploitation rate remained less than 10 percent for all fisheries combined, although higher rates of harvest are reported for some populations. The May 2008 *U.S. v. Oregon* Management Agreement (2008-2017) will, on average, reduce harvest impacts to this DPS (NMFS 2008b).

Research and Monitoring

Although the absolute quantity of take authorized for scientific research and monitoring has been relatively low, requests for authorization of take have increased over the past five years. Our records of take authorization under ESA sections 10(a)(1)(A) and 4(d) for this DPS reveal a steady increase in requests for take for the purposes of scientific research. We expect additional increases in take requests in the foreseeable future with implementation of the 2010 FCRPS Supplemental Biological Opinion (FCRPS Biological Opinion). This Opinion integrates the 2008 reasonable and prudent alternative, the Adaptive Management Implementation Plan, and Hatchery Genetic Management Plans. Handling impacts (e.g., direct mortality, delayed mortality, and sub-lethal effects) from research and monitoring activities (e.g., electroshocking, tagging, and marking) need to be better quantified.

New information available since the last ESA status review indicates harvest impacts have decreased slightly, but research impacts have increased. Impacts from these sources of mortality are not considered to be major limiting factors for this DPS. We conclude that the risk to the species' persistence because of overutilization remains essentially unchanged since the last status review.

Disease or predation

Although actions to reduce avian predation in the Columbia Basin have been ongoing with implementation of the FCRPS Biological Opinion, high levels of avian predation continue to significantly affect the MCR steelhead DPS. A Columbia Basin-wide assessment of avian predation on juvenile salmonids indicates that the most significant impacts to smolt survival occur in the Columbia River estuary (Collis et al. 2009). The combined consumption of juvenile salmonids by Caspian terns and double-crested cormorants nesting on East Sand Island is estimated to be between 7 and 16 million smolts annually. This represents approximately 10 percent of all the salmonid smolts that survive to the estuary in an average year. Estimated smolt losses to piscivorous colonial waterbirds that nest in the Columbia River estuary are more than an order of magnitude greater than those observed on the Mid-Columbia River.

Predation remains a concern due to a general increase in pinniped populations along the West Coast. California sea lion populations are growing rapidly, and there is potential that these predators could substantially reduce the abundance of several salmon and steelhead species. The available information clearly indicates that adult salmon contribute substantially to the diets of pinnipeds in the lower Columbia River and estuary, especially in the spring, late-summer, and fall seasons when Chinook salmon are most abundant (Scordino 2010). The effect of marine mammals on the productivity and abundance of Columbia River Basin ESA-listed salmon and steelhead populations has not been quantitatively assessed. The absolute number of animals preying on salmon and steelhead throughout the lower Columbia River and estuary is not known, the duration of time that they are present is uncertain, and the portion of their diet that is made up of listed species is unknown. We do have information to indicate that Steller sea lion abundance is increasing in the lower Columbia River and that predation by California sea lions at Bonneville Dam continues to increase (NMFS 2011).

A sport fishing reward program was implemented in 1990 to reduce the numbers of Northern pikeminnow in the Columbia Basin (NMFS 2010). The program continues to meet expected targets, which may reduce predation on smolts in the mainstem Columbia River.

Non- indigenous fish affect salmon and their ecosystems through many mechanisms. A number of studies conclude that many established non-indigenous species (in addition to smallmouth bass, channel catfish, and American shad) pose a threat to the recovery of ESA-listed Pacific salmon. Threats are not restricted to direct predation; non-indigenous species compete directly and indirectly for resources, significantly altering food webs and trophic structure, and potentially altering evolutionary trajectories (Sanderson et al. 2009; NMFS 2010).

Disease rates over the past five years are believed to be consistent with the previous review period. Climate change impacts such as increasing temperature may increase susceptibility to diseases. Recent reports indicate the spread of a new strain of infectious haematopoietic necrosis virus along the Pacific coast may increase disease related concerns for MCR steelhead in the future.

New information available since the last status review indicates there is an increase in the level of avian and pinniped predation on MCR steelhead. At this time we do not have information available that would allow us to quantify the change in extinction risk due to predation. We therefore conclude that the risk to the species' persistence because of predation has increased by an unquantified amount since the last status review.

Inadequacy of existing regulatory mechanisms

Various Federal, state, county and tribal regulatory mechanisms are in place to reduce habitat loss and degradation caused by human use and development. New information available since the last status review indicates that the adequacy of a number of regulatory mechanisms has improved. Examples include:

- Clean Water Act: The Federal Clean Water Act addresses the development and implementation of water quality standards, the development of total maximum daily loads (TMDLs), filling of wetlands, point source permitting, the regulation of stormwater, and other provisions related to protection of U.S. waters. State water quality standards are set to protect beneficial uses, which include several categories of salmonid use. States also develop water quality cleanup plans to address water quality limited streams and to establish limits on pollutants that can be discharged in the water body.

TMDLs address high steam temperatures and other water quality parameters identified as a limiting factor or threat for salmonid populations. TMDLs are subject to approval by EPA.

- The EPA has approved the following TMDLs within the Washington portion of the DPS**:**
    - Little Klickitat River Watershed temperature TMDL approved in 2003 and TMDL Implementation plan approved 2005;
    - Walla Walla River and Tributaries chlorinated pesticides and PCBs TMDL approved in 2006; fecal coliform, temperature, and pH and dissolved oxygen TMDLs approved in 2007; Implementation Plan for the four Walla Walla Basin TMDLs approved in 2008;
    - Within the Yakama River Basin the Naches River temperature TMDL approved in 2010; Selah Ditch fecal coliform and temperature TMDL approved in 2006; Teanaway temperature TMDL approved in 2002; Wilson and Cookie Creeks fecal coliform TMDL approved in 2005.

- The EPA approved Oregon's 2004/2006 Integrated 305(b) report and 303(d) list in February 2007. Oregon submitted its 2010 Integrated Report to EPA in May 2011.

- The EPA approved the following TMDLs within the Oregon portion of the DPS:
    - Walla Walla Subbasin temperature TMDL approved in 2005;
    - Willow Creek Subbasin temperature, pH, and bacteria TMDL approved in 2007;
    - John Day River Basin temperature, bacteria, DO, and biocriteria TMDL approved in 2010.

- Washington State Use-based (e.g., aquatic life use) Surface Water Quality Standards, Washington Administrative Code (WAC) 173-201A. The 2003 standards were amended in 2006 to provide additional spawning and incubation temperature criteria for salmon, trout, and char. The standards include an Antidegradation Policy, which was approved by Environmental Protection Agency (EPA) in May 2007. The EPA approved the Washington State's 2008 Water Quality Assessment 305(b) report and 303(d) list in January 2009. Washington's 2010 water quality report is scheduled for submission to EPA in the fall of 2011.

- Washington Shoreline Management Act, Ch. 90.58 RCW (SMA). In 1971 the Washington State Legislature passed the Washington Shoreline Management Act, adopted by public referendum in 1972. The purpose of the Act is "to prevent the inherent harm in an uncoordinated and piecemeal development of the state's shorelines" by requiring every county and many cities to develop a Shoreline Master Plan (SMP) to govern development in shoreline areas, including all wetlands, river deltas, and riparian areas associated with rivers, streams and lakes. The SMP for the Klickitat River and its tributaries, for example, designates various shorelines as "environments," which determine the level of protection that is warranted. Much of the Klickitat River is designated as either "Natural Environment" which prohibits most development within its shorelines or "Conservancy Environment," which allows a limited scope of development, subject to conditions (i.e., shoreline conditional use permit).

County and city shoreline master programs were originally adopted in the 1970's under Washington Administrative Code, Ch. 173-26. The Washington State Department of Ecology promulgated more protective shoreline requirements in 2003. All counties in Washington State, and the cities within those counties, are subject to these requirements and are updating their shoreline master programs pursuant to the update schedule specified in RCW 90.58.080. The statute requires shoreline master programs to be updated in Skamania County by December 1, 2012; in Kittitas and Benton counties by December 1, 2013; and in Klickitat and Walla Walla counties by December 1, 2014. The Washington State Department of Ecology approved the City of Kennewick's updated SMP in December 2009 and the updated Yakama County Regional SMP in January 2010.

- Washington Growth Management Act, Revised Code of Washington Ch. 36.70A (GMA) and Critical Areas Ordinance (CAO). As with the SMA, GMA also has an update process for city and county critical areas ordinances. Most critical areas ordinances were originally adopted following GMA's enactment in 1990/1991. While CAO are typically amended more often than shoreline master programs, GMA's update schedule for Eastern Washington counties started in December 2005, 2006, or 2007 (depending on the county), with extensions granted to slow-growth counties such as Klickitat, which updated its CAO in 2004 and has an update deadline of December 2013.

Stream Flows:

- Washington Administrative Code, Ch. 173-532, updated in 2007, protects instream flows in the Walla Walla Basin.
- Washington's Anadromous Fish Sanctuary statute (RCW 77.55.191) protects stream flows in the Klickitat and Rock Creek by restricting water diversions and dam construction.
- Oregon's Administrative Rules (OARs), updated in 2011, protect stream flows in the Deschutes Basin (OAR 690-505), the John Day Basin (OAR 690-506), and in the Umatilla Basin (OAR 690-506). The Deschutes River Water Management Rules (OAR 690-522), promulgated in 2010, are intended to operate in conjunction with the Deschutes Basin Ground Water Mitigation Rules (OAR 690-505) and the Deschutes Basin Mitigation Bank and Mitigation Credit Rules (OAR 690-521).

However, despite improvement in the adequacy of regulatory mechanisms within the DPS, there remain a number of concerns regarding existing regulatory mechanisms, including:

- Lack of documentation or analysis of the effectiveness of land-use regulatory mechanisms and land-use management plans.

- Contradictory policies and/or implementation of regulations by Federal agencies. For example, one agency may take actions to improve riparian vegetation and instream habitat in one area while a short distance away another Federal authority requires removal of vegetation and instream structures.
- Lack of reporting and enforcement for some regulatory programs.

We conclude that the risk to the species' persistence because of the adequacy of existing regulatory mechanisms has decreased slightly, based on the improvements noted above. However, many ongoing threats to steelhead habitat could be ameliorated by strengthening existing regulatory mechanisms.

Other natural or manmade factors affecting its continued existence

Climate Change

Current research by Mote and Salathé (2010), and other members of the University of Washington Climate Impacts Group, is providing insights to potential future climate change impacts for the Pacific Northwest region. Although the values or severity of these changes may be uncertain, and their biological impacts on salmonids have yet to be demonstrated, there is general scientific agreement regarding the impacts already evident in the last 40 years of climatological data and expected trends.

Expected climate change impacts for freshwater conditions and salmon and steelhead populations include:

- Increased water temperatures.
- Decreases in snow pack causing a shift of peak flows from summer to spring, and a decrease in summer flows. Shifts in the timing of peak flows will likely result in changes in outmigration timing, changes in survival, changes in distribution, and changes in the availability of spawning and rearing habitats.
- Peak flows will be flashier, likely resulting in channel scouring and increased risk of sedimentation.
- Likely increase in winter flooding events.
- Under future climate scenarios, higher elevation areas will likely continue to provide habitat conditions within the biological tolerances of salmonids. However, lower and transitional areas will experience increasing temperatures reducing the available spawning and rearing habitats, altering distribution, and diminishing survival.

Expected climate change impacts to ocean conditions include:

- Increasing ocean acidification (although there is uncertainty about the effects on marine food webs and salmonid survival in the ocean).

- Ocean temperatures will increase resulting in changes in the distribution and abundance of warm- and cold-water species. There is uncertainty about the effects on marine food webs and ocean survival of salmonids.
- Likely changes to a variety of processes such as the pattern and cycle of the Pacific Decadal Oscillation and the intensity and patterns of upwelling.

Over the past 40 years climate change has degraded environmental conditions for Pacific Northwest salmon and steelhead. The certainty in modeled climate change impacts has increased as has our understanding of likely impacts of these changes on salmonid populations. While climate change impacts remain a recovery concern over the long term, it is unknown whether climate change impacts have changed in the few years since the last review.

Hatchery Effects

Hatchery programs can provide short-term demographic benefits, such as increases in abundance during periods of low natural abundance. They also can help preserve genetic resources until limiting factors can be addressed. However, the long-term use of artificial propagation may pose risks to natural productivity and diversity. The magnitude and type of the risk depends on the status of affected populations and on specific practices in the hatchery program.

Within the MCR steelhead DPS, hatchery programs have not changed substantially since the previous ESA status review. Those programs that were considered to be part of the DPS continue to incorporate natural-origin adults into the broodstock and are operated to conserve genetic resources. Two non-endemic hatchery programs in the Walla Walla and Touchet Rivers were evaluated under the ESA and found to not jeopardize the continued existence or recovery of the DPS. The two programs that release Skamania stock summer and winter steelhead into the White Salmon River discontinued releases in 2010. Additional information is needed to assess the potential impact of hatchery-origin fish on natural production in the Klickitat Basin and the effects of hatchery strays on natural production in the Deschutes River system.

The Yakima Basin wild steelhead kelt program continues with up to 800 steelhead adults per year captured at the Prosser Diversion Dam. About 36 percent of the kelts reconditioned survive to spawn a second time.

New information available since the last status review indicates that there have not been significant changes to these natural or manmade factors or in our knowledge of the extent to which they present risks to the persistence of the MCR steelhead DPS.

Efforts being made to Protect the Species

When considering whether to list a species as threatened or endangered, section 4(b)(1)(A) of the ESA requires that NMFS take into account any efforts being made to protect that species. Throughout the range of salmon ESUs and steelhead DPSs, there are numerous Federal, state, tribal and local programs that protect anadromous fish and their habitat. The proposed listing determinations for West Coast salmon and steelhead (69 FR 33102) reviewed these programs in detail.

In the final listing determinations for salmon (70 FR 37160) and steelhead (71 FR 834), we noted that while many of the ongoing protective efforts are likely to promote the conservation of listed salmonids, most efforts are relatively recent, have yet to demonstrate their effectiveness, and for the most part do not address conservation needs at scales sufficient to conserve entire ESUs or DPSs. Therefore, we concluded that existing protective efforts did not preclude listing several ESUs of salmon and several DPSs of steelhead.

In our above five-factor analysis, we note the many habitat, hydropower, hatchery, and harvest improvements that occurred in the past five years. We currently are working with our Federal, state, and tribal co-managers to develop monitoring programs, databases, and analytical tools to assist us in tracking, monitoring, and assessing the effectiveness of these improvements.

2.4 Synthesis

The ESA defines an endangered species as one that is in danger of extinction throughout all or a significant portion of its range, and a threatened species as one that is likely to become an endangered species in the foreseeable future throughout all or a significant portion of its range. Under ESA section 4(c)(2), we must review the listing classification of all listed species at least once every five years. While conducting these reviews, we apply the provisions of ESA section 4(a)(1) and NMFS's implementing regulations at 50 CFR part 424.

To determine if a reclassification is warranted, we review the status of the species and evaluate the five factors, as identified in ESA section 4(a)(1): (1) the present or threatened destruction, modification, or curtailment of its habitat or range; (2) overutilization for commercial, recreational, scientific, or educational purposes; (3) disease or predation; (4) inadequacy of existing regulatory mechanisms; and (5) other natural or man-made factors affecting a species continued existence. We then make a determination based solely on the best available scientific and commercial information, taking into account efforts by states and foreign governments to protect the species.

The updated status review completed by our Northwest Fisheries Science Center indicates that while there have been improvements in the viability ratings for some of the component populations, the MCR steelhead DPS is not currently meeting the viability criteria in the recovery plan. None of the MPGs are currently considered to be viable. Several more populations in each MPG will need improved viability ratings in order to meet the criteria. While little improvement in DPS viability has been observed over the last five years, there is also no new information to indicate that the extinction risk has increased. The Science Center concluded, after reviewing the available new information, that the biological risk category for this DPS has not changed since the time of the last status review.

Our analysis of the ESA section 4(a)(1) factors indicates that the collective risk to the MCR steelhead's persistence has not changed significantly since our final listing determination in 2006. Improvements have been made to the operation of the FCRPS and numerous habitat restoration projects have been completed in many Middle Columbia River tributaries. Harvest rates remain relatively low and stable. The protection afforded by some regulatory mechanisms, such as implementation of TMDLs, has increased. Conversely, habitat problems are still common throughout the range of this DPS and more habitat improvements are likely needed to achieve DPS viability. Many existing regulatory mechanisms could be improved to better protect steelhead habitat. In addition, predation from an increase in pinniped populations and significant avian impacts remain a concern, as do the impacts that climate change poses to long-term recovery.

After considering the biological viability of the MCR steelhead DPS and the current status of its ESA section 4(a)(1) factors, we conclude that the status of the MCR steelhead DPS has not improved significantly since it was last reviewed in 2006. However, the implementation of sound management actions in hydropower, habitat, hatcheries, and harvest are essential to the recovery of the MCR steelhead DPS and must continue. The biological benefits of habitat restoration and protection efforts, in particular habitat restoration, have yet to be fully expressed and will likely take another five to 20 years to result in measurable improvements to population viability. By continuing to implement actions that address the factors limiting population survival and monitoring the effects of the action over time, we will ensure that restoration efforts meet the biological needs of each population and, in turn, contribute to the recovery of this DPS. The MCR Steelhead Recovery Plan is the primary guide for identifying future actions to target and address MCR steelhead's limiting factors and threats. Over the next five years, it will be important continue to implement these actions and monitor our progress.

2.4.1 DPS Delineation and Hatchery Membership

- Recent genetic analyses are inconclusive regarding the transitional boundary between the Lower Columbia River and MCR steelhead DPSs.
- The MCR steelhead hatchery programs have not changed substantially from the previous ESA status review to suggest that their level of divergence relative to the local natural populations has changed.

2.4.2 DPS Viability and Statutory Listing Factors

- The Northwest Fisheries Science Center's review of updated information does not indicate a change in the biological risk category since the time of the last status review. (Ford et al. 2010).
- Our analysis of ESA section 4(a)(1) factors indicates that the collective risk to the MCR steelhead's persistence has not changed significantly since our final listing determination in 2006.

3 ·Results

3.1 Classification

Listing status:

Based on the information identified above, we determine that no reclassification for the MCR steelhead DPS is appropriate, and therefore the MCR steelhead DPS should remain listed as threatened.

DPS delineation:

Available genetic and biogeographic information show that the Klickitat and Big White Salmon basins fall in a transition zone between the Interior Columbia and Coastal/Lower Columbia River Eco-regions. Given the lack definitive information to support adjusting the boundary of this DPS, we conclude that these populations should remain in the MCR steelhead DPS.

Hatchery membership:

The MCR steelhead hatchery programs have not changed substantially from the previous ESA status review to suggest that their level of divergence relative to the local natural populations has changed. Therefore, we conclude that no changes in hatchery membership for the MCR steelhead DPS are needed.

3.2 New Recovery Priority Number

There are no changes in the recovery priority number listed in Table 4 for the MCR Steelhead DPS.

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4 · Recommendations for Future Actions

In our review of the listing factors we identified several actions critical to improving the status of the MCR steelhead DPS. The most important actions to be taken over the next 5 years include implementation of the high-priority strategies and actions for the MPGs (Sections 7.2 and 7.3 of the recovery plan, November 2009), the 2008 Harvest Biological Opinion, the 2010 FCRPS Biological Opinion, and the completion of ESA consultations on the hatchery programs in the MCR steelhead DPS. We are currently in the process of identifying actions that address the factors contributing to the existing moderate or high risk rating for each population, since such actions have the greatest potential to improve VSP parameters at both the MPG and DPS levels.

We are directing our efforts at populations that need viability improvement according to DPS-, MPG-, and population-level recovery criteria, the best available scientific information concerning DPS status, the role of the independent populations in meeting DPS and MPG viability, limiting factors and threats, and the likelihood of action effectiveness to guide our recommendations for future actions. NMFS is coordinating with the Federal, state, tribal, and local implementing entities during this prioritization process to ensure that risk factors and actions identified in the recovery plan, and the actions identified in the Harvest Biological Opinion, the FCRPS Biological Opinion, and the ESA consultations on hatchery programs are addressed.

The greatest opportunity to advance recovery is to increase flows in the Yakima, Umatilla, Walla Walla, and John Day basins. Additional recommended actions include:

- NMFS and the Bureau of Reclamation completing the consultation on Bureau of Reclamation operations in the Yakima River Basin;
- Hatchery managers reducing the extent of spawning by hatchery fish, especially out-of-DPS hatchery fish, in natural spawning areas within the DPS;
- States, tribes, and private entities continuing to implement actions that restore historical passage to the upper Deschutes subbasin, including the Westside tributaries and Crooked River above Pelton Round Butte Dam (Confederated Tribes of the Warm Springs Indian Reservation of Oregon, ODFW, and PGE) the Yakima subbasin, and the White Salmon river above Condit Dam (Yakama Nation, WDFW, and PacifiCorp);
- U.S. Army Corps of Engineers and fisheries co-managers continuing to implement flow and passage improvements in the Walla Walla and Touchet Rivers;
- State and tribal fisheries co-managers continuing to develop annual estimates of wild steelhead escapement, and evaluate the effects of hatchery releases on the production of wild steelhead and implement measures as needed to reduce those impacts in Rock Creek, the Klickitat River, the Walla Walla River, the Touchet River, the Umatilla River Basin, the Naches River, Satus Creek, Toppenish Creek, and the Yakima River;

- State and tribal fisheries co-managers, and local agencies continuing to implement actions to reduce stream temperature in Rock Creek, the Umatilla River, the Walla Walla River, the Touchet River, the Naches River, Satus Creek, and the Yakama River.

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National Marine Fisheries Service
5-Year Review

Middle Columbia River Steelhead

Conclusion:
Based on the information identified above, we conclude:

- The Middle Columbia River Steelhead DPS should remain listed as threatened

REGIONAL OFFICE APPROVAL

Northwest Regional Administrator, NOAA Fisheries

Approve: William Stelle Date: *July 26, 2011*

Science, Service, Stewardship

5-Year Review:
Summary & Evaluation of
Upper Columbia River Steelhead
Upper Columbia River
Spring-run Chinook

National Marine Fisheries Service
Northwest Region
Portland, OR

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5-Year Review: Upper Columbia River Species

Species Reviewed	Evolutionarily Significant Unit or Distinct Population Segment
Chinook Salmon (*Oncorhynchus tshawytscha*)	*Upper Columbia River Spring-run Chinook*
Steelhead (*O. mykiss*)	*Upper Columbia River Steelhead*

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1 ▪ General Information

1.1 Introduction

Many West Coast salmon and steelhead (Oncorhynchus sp.) stocks have declined substantially from their historic numbers and now are at a fraction of their historical abundance. There are several factors that contribute to these declines, including: overfishing, loss of freshwater and estuarine habitat, hydropower development, poor ocean conditions, and hatchery practices. These factors collectively led to the National Marine Fisheries Service's (NMFS) listing of 28 salmon and steelhead stocks in California, Idaho, Oregon, and Washington under the Federal Endangered Species Act (ESA).

The ESA, under section 4(c)(2), directs the Secretary of Commerce to review the listing classification of threatened and endangered species at least once every five years. After completing this review, the Secretary must determine if any species should be: (1) removed from the list; (2) have its status changed from threatened to endangered; or (3) have its status changed from endangered to threatened. The most recent listing determinations for most salmon and steelhead occurred in 2005 and 2006. This document describes the results of the agency's 5-year status review for ESA-listed Upper Columbia River (UCR) salmon and steelhead species. These include: UCR Spring-run Chinook salmon and UCR steelhead.

1.1.1 Background on salmonid listing determinations

The ESA defines species to include subspecies and distinct population segments (DPS) of vertebrate species. A species may be listed as threatened or endangered. To identify distinct population segments of salmon species we apply the "Policy on Applying the Definition of Species under the ESA to Pacific Salmon" (56 FR 58612). Under this policy we identify population groups that are "evolutionarily significant units" (ESU) within their species. We consider a group of populations to be an ESU if it is substantially reproductively isolated from other populations, and represents an important component in the evolutionary legacy of the biological species. We consider an ESU as constituting a DPS and therefore a "species" under the ESA.'

To identify DPSs of steelhead, we apply the joint U.S. Fish and Wildlife Service-National Marine Fisheries Service DPS policy (61 FR 4722) rather than the ESU policy. Under this policy, a DPS of steelhead must be discrete from other populations, and it must be significant to its taxon.

Artificial propagation programs (hatcheries) are common throughout the range of ESA-listed West Coast salmon and steelhead. Prior to 2005, our policy was to include in the listed ESU or DPS only those hatchery fish deemed "essential for conservation" of a species. We revised that approach in response to a court decision and on June 28, 2005, announced a final policy addressing the role of artificially propagated Pacific salmon and steelhead in listing determinations under the ESA (70 FR 37204) (hatchery listing policy). This policy establishes criteria for including hatchery stocks in ESUs and DPSs. In addition, it (1) provides direction for considering hatchery fish in extinction risk assessments of ESUs and DPSs; (2) requires that hatchery fish determined to be part of an ESU or DPS be included in any listing of the ESU or DPS; (3) affirms our commitment to conserving natural salmon and steelhead populations and the ecosystems upon which they depend; and (4) affirms our commitment to fulfilling trust and treaty obligations with regard to the harvest of some Pacific salmon and steelhead populations, consistent with the conservation and recovery of listed salmon ESUs and steelhead DPSs.

To determine whether a hatchery program is part of an ESU or DPS and therefore must be included in the listing, we consider the origins of the hatchery stock, where the hatchery fish are released, and the extent to which the hatchery stock has diverged genetically from the donor stock. We include within the ESU or DPS (and therefore within the listing) hatchery fish that are derived from the population in the area where they are released, and that are no more than moderately diverged from the local population.

Because the new hatchery listing policy changed the way we considered hatchery fish in ESA listing determinations, we completed new status reviews and ESA-listing determinations for West Coast salmon ESUs and steelhead DPSs. On June 28, 2005, we issued final listing determinations for 16 ESUs of Pacific salmon (70 FR 37160). On January 5, 2006 we issued final listing determinations for 10 DPSs of steelhead (71 FR 834).

1.2 Methodology used to complete the review

On March 18, 2010, we announced the initiation of five year reviews for 16 ESUs of salmon and 10 DPSs of steelhead in Oregon, California, Idaho, and Washington (75 FR 13082). We requested that the public submit new information on these species that has become available since our listing determinations in 2005 and 2006. In response to our request, we received information from Federal and state agencies, Native American Tribes, conservation groups, fishing groups, and individuals. We considered this information, as well as information routinely collected by our agency, to complete these five year reviews.

To complete the reviews, we first asked scientists from our Northwest Fisheries Science Center to collect and analyze new information about ESU and DPS viability. To evaluate viability, our scientists used the Viable Salmonid Population (VSP) concept developed by McElhany et al. (2000). The VSP concept evaluates four criteria – abundance, productivity, spatial structure, and diversity – to assess species viability. Through the application of this concept, the Science Center considered new information on the four salmon and steelhead population viability criteria. They also considered new information on ESU and DPS boundaries. At the end of this process, the science teams prepared reports detailing the results of their analyses (Ford et al. 2010).

To further inform the reviews, we also asked salmon management biologists from our Northwest Region familiar with hatchery programs to consider new information available since the previous listing determinations. Among other things, they considered hatchery programs that have ended, new hatchery programs that have started changes in the operation of existing programs, and scientific data relevant to the degree of divergence of hatchery fish from naturally spawning fish in the same area. They produced a report (Jones et al. 2011) describing their findings. Finally, we consulted salmon management biologists from the Northwest Region who are familiar with hatchery programs, habitat conditions, hydropower operations, and harvest management. In a series of structured meetings, by geographic area, these biologists identified relevant information and provided their insights on the degree to which circumstances have changed for each listed entity.

In preparing this report, we considered all relevant information, including the work of the Northwest Fisheries Science Center (Ford et al. 2010;); the report of the regional biologists regarding hatchery programs (Jones et al. 2011); recovery plans for the species in question; technical reports prepared in support of recovery plans for the species in question; the listing record (including designation of critical habitat and adoption of protective regulations); recent biological opinions issued for UCR steelhead and Spring-run Chinook salmon; information submitted by the public and other government agencies; and the information and views provided by the geographically based management teams. The present report describes the agency's findings based on all of the information considered.

1.3 Background – Summary of Previous Reviews, Statutory and Regulatory Actions, and Recovery Planning

1.3.1 Federal Register Notice announcing initiation of this review

75 FR 13082; March 18, 2010

1.3.2 Listing history

In 1997, NMFS began listing UCR salmonid species under the ESA. By 1999, NMFS listed two species in this area as endangered, and later reclassified one as threatened (Table 1).

Table 1. Summary of the listing history under the Endangered Species Act for the Upper Columbia River salmonids.

Salmonid Species	ESU/DPS Name	Original Listing	Revised Listing(s)
Chinook Salmon (*O. tshawytscha*)	Upper Columbia River Spring-run Chinook Salmon	**FR Notice:** 64 FR 14308 **Date:** 3/24/1999 **Classification:** Endangered	**FR Notice:** 70 FR 37160 **Date:** 6/28/2005 **Classification:** Endangered
Steelhead (*O. mykiss*)	Upper Columbia River Steelhead	**FR Notice:** 63 FR 43937 **Date:** 8/18/1997 **Classification:** Endangered	**FR Notice:** 71 FR 834 **Date:** 1/5/2006 **Re-classification:** Threatened **FR Notice:** Legal Challenge **Date:** 1/13/2007 **Re-classification:** Endangered **FR Notice:** 74 FR 42605 **Date:** 8/24/2009 **Re-classification:** Threatened

1.3.3 Associated rulemakings

The ESA requires NMFS to designate critical habitat, to the maximum extent prudent and determinable, for species it lists under the ESA. Critical habitat is defined as: (1) specific areas within the geographical area occupied by the species at the time of listing, if they contain physical or biological features essential to conservation, and those features may require special management considerations or protection; and (2) specific areas outside the geographical area occupied by the species at the time of listing if the agency determines that the area itself is essential for conservation. We designated critical habitat for both UCR Spring-run Chinook salmon and UCR steelhead in 2005.

Section 9 of the ESA prohibits the take of species listed as endangered. The ESA defines take to mean harass, harm, pursue, hunt, shoot, wound, trap, capture, or collect, or attempt to engage in any such conduct. For threatened species, the ESA does not automatically prohibit take, but instead authorizes the agency to adopt regulations it deems necessary and advisable for species conservation including regulations that prohibit take (ESA section 4(d)). For threatened salmonids, NMFS has adopted 4(d) regulations that prohibit take except in specific circumstances. On January 5, 2006, we applied the 4(d) regulations to UCR steelhead (71 FR 834).

Table 2. Summary of rulemaking for 4(d) protective regulations and critical habitat for salmon and steelhead in the Upper Columbia River.

Salmonid Species	ESU/DPS Name	4(d) Protective Regulations	Critical Habitat Designations
Chinook Salmon (*O. tshawytscha*)	Upper Columbia River Spring-run Chinook Salmon	ESA section 9 applies	**FR Notice:** 70 FR 52630 **Date:** 9/2/2005
Steelhead (*O. mykiss*)	Upper Columbia River Steelhead	**FR Notice:** 71 FR 5178 **Date:** 2/1/2006	**FR notice:** 70 FR 52630 **Date:** 9/2/2005

1.3.4 Review History

Table 3 lists the numerous scientific assessments of the status of the UCR Spring-run Chinook salmon and UCR steelhead DPS. These assessments include status reviews conducted by our Northwest Fisheries Science Center and technical reports prepared in support of recovery planning for these species.

Table 3. Summary of previous scientific assessments for UCR salmon and steelhead.

Salmonid Species	ESU/DPS Name	Document Citation
Chinook Salmon (*O. tshawytscha)*	Upper Columbia River Spring-run Chinook Salmon	ICTRT 2007a ICTRT 2007b ICTRT and Zabel 2007 Good et al. 2005 McClure et al. 2005 ICTRT 2003 NMFS 1999 NMFS 1998a NMFS 1998b
Steelhead (*O. mykiss*)	Upper Columbia River Steelhead	ICTRT 2007a ICTRT 2007b ICTRT and Zabel 2007 Good et al. 2005 McClure et al. 2005 ICTRT 2003 NMFS 1997 NMFS 1996

1.3.5 Species' Recovery Priority Number at Start of 5-year Review Process

On June 15, 1990, NMFS issued guidelines (55 FR 24296) for assigning listing and recovery priorities. We assess three criteria to determine a species' priority for recovery plan development, implementation, and resource allocation: (1) magnitude of threat; (2) recovery potential; and (3) existing conflict with activities such as construction and development. Table 4 lists the recovery priority numbers for the subject species, as reported in the 2006-2008 Biennial Report to Congress on the Recovery Program for Threatened and Endangered Species (available at: http://www.nmfs.noaa.gov/pr/pdfs/laws/esabiennial2008.pdf).

1.3.6 Recovery Plan or Outline

Table 4. Recovery Priority Number and Endangered Species Act Recovery Plan for UCR Spring-run Chinook salmon and UCR steelhead.

Salmonid Species	ESU/DPS Name	Recovery Priority Number	Recovery Plan/Outline
Chinook Salmon (*O. tshawytscha*)	Upper Columbia River Spring-run Chinook Salmon	**1**	**Title:** Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan **Date:** 10/9/2007 Available at: http://www.nwr.noaa.gov/Salmon-Recovery-Planning/Recovery-Domains/Interior-Columbia/Upper-Columbia/Upper-Col-Plan.cfm **Type:** Final **FR Notice:** 72 FR 57303
Steelhead (*O. mykiss*)	Upper Columbia River Steelhead	**1**	**Title:** Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan Available at: http://www.nwr.noaa.gov/Salmon-Recovery-Planning/Recovery-Domains/Interior-Columbia/Upper-Columbia/Upper-Col-Plan.cfm **Date:** 10/9/2007 **Type:** Final **FR Notice:** 72 FR 57303

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2 · Review Analysis

In this section we review new information to determine whether the UCR species' delineations remain appropriate.

2.1 Delineation of Species under the Endangered Species Act

Is the species under review a vertebrate?

ESU/DPS Name	YES	NO
Upper Columbia River Spring-run Chinook Salmon	X	
Upper Columbia River Steelhead	X	

Is the species under review listed as an ESU/DPS?

ESU/DPS Name	YES	NO
Upper Columbia River Spring-run Chinook Salmon	X	
Upper Columbia River Steelhead	X	

Was the ESU/DPS listed prior to 1996?

ESU/DPS Name	YES	NO	Date Listed if Prior to 1996
Upper Columbia River Spring-run Chinook Salmon		X	n/a
Upper Columbia River Steelhead		X	n/a

Prior to this 5-year review, was the ESU/DPS classification reviewed to ensure it meets the 1996 ESU/DPS policy standards?

Not Applicable

2.1.1 Summary of relevant new information regarding the delineation of the UCR Spring-run Chinook salmon ESU and the UCR steelhead DPS

ESU/DPS Boundaries

This section provides a summary of information presented in Ford et al. 2010: Status Review update for Pacific salmon and steelhead listed under the Endangered Species Act: Northwest.

We found no new information that would justify a change in the boundaries of the UCR spring-run Chinook salmon ESU or the UCR steelhead DPS (Ford et al. 2010).

Membership of Hatchery Programs

In preparing this report, our management biologists reviewed the available information regarding hatchery membership of this ESU and DPS (Jones et al. 2011). They considered changes in hatchery programs that occurred since the last status review (e.g., some have been terminated while others are new) and made recommendations about the inclusion or exclusion of specific programs. They also noted any errors and omissions in the existing descriptions of hatchery population membership. NMFS intends to address any needed changes and corrections via separate rulemaking subsequent to the completion of these five-year status reviews.

They also identified five programs that are trending toward divergence from the ESU/DPS and need further evaluation before recommending for inclusion or removal from the ESU/DPS.

UCR Spring-run Chinook salmon

The UCR Spring-run Chinook ESU includes all naturally spawned populations of Chinook salmon in all river reaches accessible to Chinook salmon in Columbia River tributaries upstream of the Rock Island Dam and downstream of Chief Joseph Dam in Washington, excluding the Okanogan River (64 FR 14208: March 24, 1999). Six artificial propagations are considered to be part of the ESU: The Twisp River, Chewuch River, Methow Composite, Winthrop NFH, Chiwawa River, and White River spring-run Chinook hatchery programs. We have determined that these artificially propagated stocks are no more divergent relative to the local natural population(s) than what would be expected between closely related natural populations within the ESU (70 FR 37160).

We determined that the Spring-run Chinook salmon hatchery program at the Entiat National Fish Hatchery (not considered part of the ESU) was a threat to the ESU, and therefore discontinued the program in 2007. The last adult from the program returned to the Entiat River in 2010. In the Methow River, there are two hatchery programs that are considered to be part of the ESU. The Winthrop National Fish Hatchery, operated by the US Fish and Wildlife Service, and the Methow Fish Hatchery (Methow Composite), operated by the WDFW, both rely on a high percentage of hatchery-origin fish for broodstock in addition to using a composite stock of natural spawners (i.e., a combination of Methow and Chewuch River fish). These practices genetically homogenize Methow River Spring-run Chinook salmon, breaking down genetic differentiation and posing a continued risk to population diversity and productivity. Continued implementation of existing broodstock practices may result in a level of divergence that warrants reconsideration of ESU-membership for both Methow River Spring-run Chinook salmon hatchery programs. Jones et al. (2011) recommended further review of these programs.

UCR Steelhead

The UCR steelhead DPS includes all naturally spawned populations of steelhead in streams in the Columbia River Basin upstream from the Yakima River, Washington, to the U.S.-Canada border (62 FR 43937); August 18, 1997). Six artificial propagation programs are considered part of the DPS: the Wenatchee River, Wells Hatchery in the Methow and Okanogan rivers, Winthrop NFH, Omak Creek, and the Ringold steelhead hatchery programs. We have determined that these artificially propagated stocks are no more divergent relative to the local natural population(s) than what would be expected between closely related natural populations within the DPS (71 FR 834).

The Winthrop NFH, Wells Hatchery, and Ringold Hatchery (located in the lower portion of the Upper Columbia River) programs continue to use composite Methow and Okanogan natural-origin and hatchery-origin steelhead for broodstock. Only a portion of the Winthrop NFH program uses all natural-origin Methow River steelhead in the broodstock. If the Winthrop NFH, Wells Hatchery, and Ringold Hatchery program continue to use composite Methow and Okanogan natural-origin and hatchery-origin steelhead for broodstock, divergence would be expected, and membership in the DPS may warrant reconsideration. Jones et al. (2011) recommended further review of these programs.

2.2 Recovery Criteria

The ESA requires that NMFS develop recovery plans for each listed species. Recovery plans must contain, to the maximum extent practicable, objective measureable criteria for delisting the species, site-specific management actions necessary to recover the species, and time and cost estimates for implementing the recovery plan.

2.2.1 Do the species have final, approved recovery plans containing objective, measurable criteria?

ESU/DPS Name	YES	NO
Upper Columbia River Spring-run Chinook Salmon	X	
Upper Columbia River Steelhead	X	

2.2.2 Adequacy of recovery criteria.

Based on new information considered during this review, are the recovery criteria still appropriate?

ESU/DPS Name	YES	NO
Upper Columbia River Spring-run Chinook Salmon	X	
Upper Columbia River Steelhead	X	

Are all of the listing factors that are relevant to the species addressed in the recovery criteria?

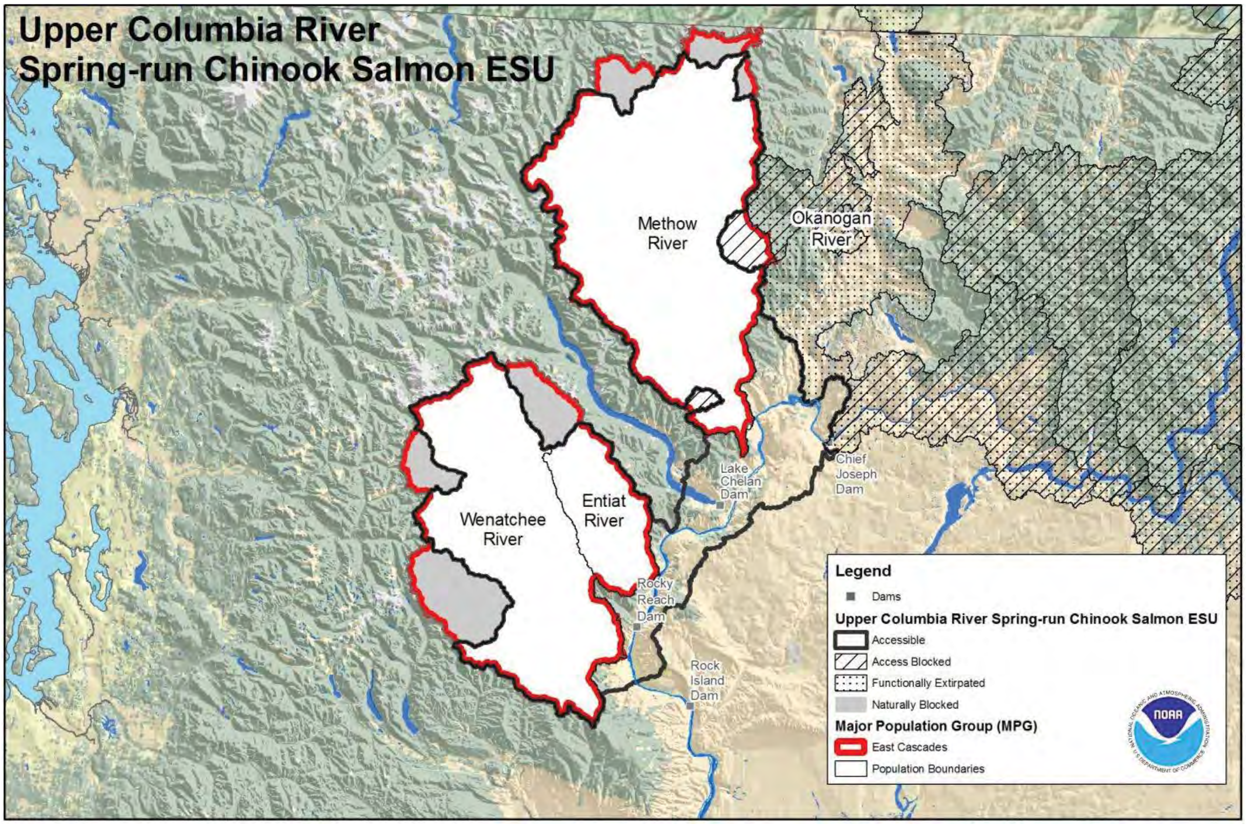
ESU/DPS Name	YES	NO
Upper Columbia River Spring-run Chinook Salmon	X	
Upper Columbia River Steelhead	X	

2.2.3 List the recovery criteria as they appear in the recovery plan

For the purposes of reproduction, salmon ESUs and steelhead DPSs typically display a metapopulation structure (Schtickzelle and Quinn 2007, McElhany et al. 2000). Rather than interbreeding as one large aggregation, ESUs and DPSs function as a group of largely independent populations separated by areas of unsuitable spawning habitat. For conservation and management purposes, it is important to identify the independent populations that make up an ESU or DPS. For recovery planning and development of recovery criteria, the Interior Columbia Technical Recovery Team (ICTRT) identified independent populations within the UCR spring-run Chinook salmon ESU and the UCR steelhead DPS, and grouped them into genetically similar major population groups (MPGs) (ICTRT 2003). Within the UCR Spring-run

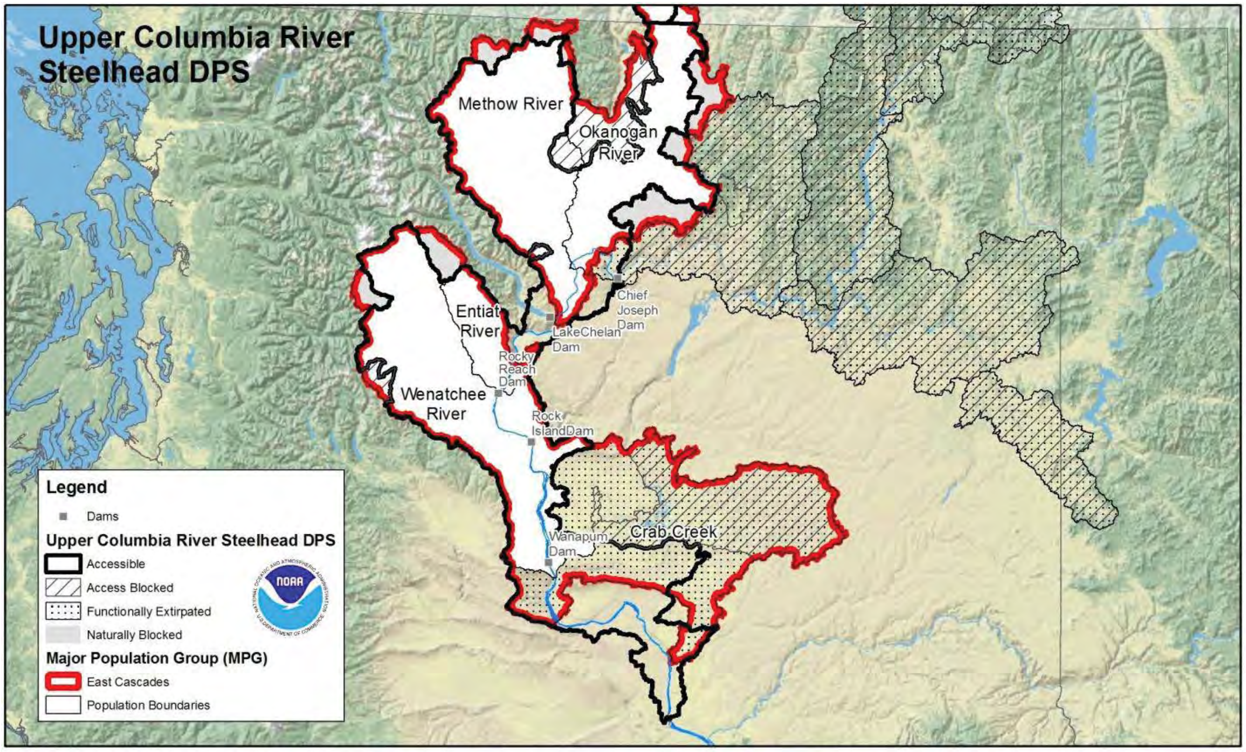
Chinook salmon ESU, there are four independent populations (three extant and one extinct) and all belong to one genetically similar MPG (Figure 1). Similarly, within the UCR steelhead DPS, there are four independent extant populations belonging to one genetically similar MPG (Figure 2).

Figure 1. UCR Spring-run Chinook salmon population structure[1]



[1] The maps in Figures 1 and 2 generally show the accessible and historically accessible areas for the UCR Spring-run Chinook salmon ESU and the UCR steelhead DPS. The areas displayed are consistent with the regulatory description of the boundaries of the UCR Spring-run Chinook salmon and UCR steelhead DPS found at 50 CFR17.11, 223.102, and 224.102. Actions outside the boundaries shown can affect this ESU/DPS. Therefore, these boundaries do not delimit the entire area that could warrant consideration in recovery planning or determining if an action may affect this ESU/DPS for the purposes of the ESA.

Figure 2. UCR steelhead population structure



The ICTRT (2007b) also developed specific biological viability criteria based on the VSP concept (McElhany et al. 2000) at the population, MPG, and ESU/DPS levels. At the population level, the ICTRT recommended specific biological criteria based on the four viability components of VSP—abundance/productivity and spatial structure/diversity. These criteria are integrated to develop a total population viability rating. The population viability ratings, in order of descending risk, are highly viable, viable, moderate risk and high risk.

In 2007, NMFS issued a final recovery plan (Plan) for the UCR Spring-run Chinook salmon ESU and the UCR steelhead DPS, which adopted the ICTRT 2007 viability goals as biological delisting criteria (UCSRB 2007). The recovery strategies outlined in the Plan are targeted to achieve, at a minimum, the biological criteria for each ESU/DPS.

UCR Spring-run Chinook Salmon Biological Recovery Criteria

Criterion 1: The 12-year geometric mean for abundance and productivity of naturally produced Spring-run Chinook salmon within the Wenatchee, Entiat, and Methow populations must reach a level that would have no more than a 5 percent extinction-risk (viability) over a 100-year period.

Criterion 2: At a minimum, the UCR Spring-run Chinook salmon ESU will maintain at least 4,500 naturally produced spawners and a spawner:spawner ratio greater than 1.0 distributed among the three populations.

Criterion 3, 4, and 5: The Recovery Plan identifies specific spatial structure and diversity metrics designed to restore the distribution of naturally produced UCR Spring-run Chinook salmon to previously occupied areas (where practical) and allow natural patterns of genetic and phenotypic diversity to be expressed.

UCR Steelhead Biological Recovery Criteria

Criterion 1: The 12-year geometric mean for abundance and productivity of naturally produced steelhead within the Wenatchee, Entiat, Methow, and Okanogan populations must reach a level that would have no more than a 5 percent extinction-risk (viability) over a 100-year period.

Criterion 2: At a minimum, the UCR steelhead DPS will maintain at least 3,000 spawners and a spawner:spawner ratio greater than 1.0 distributed among the four populations.

Criterion 3, 4, and 5: The Recovery Plan identifies specific spatial structure and diversity metrics designed to restore the distribution of naturally produced UCR steelhead to previously occupied areas (where practical) and allows natural patterns of genetic and phenotypic diversity to be expressed.

2.3 Updated Information and Current Species' Status

In addition to recommending recovery criteria, the ICTRT also assessed the current status of each population ESU/DPS (ICTRT 2007b). Each population was rated against the biological criteria identified in the recovery plan and assigned a current viability rating.

2.3.1 Analysis of Viable Salmonid Population (VSP) Criteria

UCR Spring-run Chinook Salmon ESU

Abundance & Productivity

Total spawning abundance, including both natural-origin and hatchery fish, has increased relative to the levels reported in the previous review. The geometric mean abundances of both natural-origin and hatchery spawners are higher for each population relative to the previous ESA status review and to the levels just prior to listing. The relative increase in hatchery-origin spawners in the Wenatchee and Methow River populations is disproportionately high, reflecting the large increase in releases from the directed supplementation programs in those two drainages.

The short term indices of population growth rate depict an upward trend in natural-origin returns since 1995 at a higher average rate than during the period leading up to the previous ESA status review (Ford et al. 2010). However, estimated population growth rates, assuming that hatchery-origin spawners and natural-origin spawners are contributing to natural production at the same rate, are below replacement for all three populations in this ESU. Possible contributing factors would include density dependent effects, differences in spawning distribution relative to habitat quality, and reduced fitness of hatchery-origin spawners. Overall abundance and productivity remains at High risk for each of the three extant populations in this MPG/ESU.

Spatial Structure & Diversity

Despite modest improvements in the distribution of fish within their historical range through replacement of culverts and removal of other passage barriers, the composite spatial structure/diversity metric for all three extant populations in this MPG/ESU remained the same, primarily because of the diversity component driven by chronically high proportions of hatchery-origin spawners in natural spawning areas and lack of genetic diversity among the natural-origin spawners (ICTRT 2008).

Updated Risk Summary

Overall abundance and productivity remains at high risk of extinction for each of the three extant populations in this MPG/ESU. The 10-year geometric mean abundance of adult natural-origin spawners has increased for each population relative to the levels for the 1981-2003 series, but the estimates remain below the corresponding thresholds identified by the ICTRT. Estimated productivity (spawner-to-spawner return rate at low to moderate escapements) was, on average, lower over the years 1987-2009 than for the previous 1981-2003 period. The combinations of current abundance and productivity for each population result in a high risk rating relative to the ICTRT viability curves.

The composite spatial structure/diversity (SS/D) risks for all three of the extant populations in this MPG/ESU are at high risk of extinction. The spatial structure component of the SS/D metric is at a low risk rating for the Wenatchee River and Methow River populations and at moderate risk rating for the Entiat River population. All three of the extant populations in this single MPG/ESU are at high risk of extinction for the diversity metric. Chronically high proportions of hatchery-origin spawners in natural spawning areas and lack of genetic diversity among the natural-origin spawners (ICTRT 2008) drive this diversity risk factor.

Based on the combined ratings for abundance/productivity and spatial structure/diversity, all three extant populations of UCR Spring-run Chinook salmon remain at an overall high risk of extinction.

ESU Summary

Although there has been an increase of abundance for all three UCR Spring-run Chinook salmon populations, overall productivity has decreased and the ESU remains at a high risk of extinction. Since the ESU-level recovery criteria require that all the extant populations within this single MPG be rated as viable for the ESU to be viable, more progress must be made before the UCR Spring-run Chinook salmon ESU can be considered recovered.

Several factors cited in the previous status review (Good et al. 2005) remain concerns or key uncertainties for all three extant populations. Increases in natural-origin abundance relative to the extremely low spawning levels observed in the mid-1990s are encouraging. However, average productivity levels remain extremely low. Large-scale directed supplementation programs are underway in the Wenatchee and Methow populations. These programs are intended to mitigate short-term demographic risks while actions to improve natural productivity and capacity are implemented. While these programs may provide short-term demographic benefits, there are significant uncertainties regarding the long-term risks of relying on high levels of hatchery influx to maintain natural populations.

Overall, the new information considered does not indicate a change in the biological risk category since the time of the last status review. The viability of the UCR Spring-run Chinook salmon ESU has likely improved somewhat, however the ESU remains at a moderate-to-high risk of extinction - none of the populations meet the ICTRT's 2007 biological recovery criteria (ICTRT 2007b).

UCR Steelhead DPS

Abundance & Productivity

The most recent estimates (five year geometric mean) of total and natural-origin spawner abundance are higher for all four independent populations of the DPS, and for the Priest Rapids Dam aggregate run, since the last status review. Annual returns since 2005 were all above the population-specific ranges reported in the previous review. In spite of the recent increases however, natural-origin returns remain well below target levels.

Hatchery-origin returns continue to constitute a high fraction of total spawners in natural spawning areas for this DPS. Estimates of natural-origin spawner abundance are higher for the most recent five year cycle. Current patterns in the proportion of natural-origin spawners among populations are similar to that reported in the previous status review. The proportions of natural-origin spawners are highest in the Wenatchee River, and remain at extremely low levels in the Methow and Okanogan Rivers.

Spatial Structure & Diversity

Although modest improvements in the distribution of fish within their historical range have been achieved through replacement of culverts and removal of other passage barriers, the spatial structure and diversity metrics have not changed since the completion of the 2008 ICTRT status assessments. The proportions of hatchery-origin returns in natural spawning areas remain extremely high across the DPS, especially in the Methow and Okanogan River populations, and continue to be a major concern.

Updated Risk Summary

All four populations of the UCR steelhead DPS remain at high risk of extinction since the last status review. The most recent estimates of natural-origin abundance (10-year geometric mean) and natural-origin productivity are at low to moderate parent abundance and remain well below the ICTRT-defined viability curve minimum for the DPS. Spawning escapements into natural areas, especially for the Methow and Okanogan populations, continue to show a high proportion of hatchery-origin fish. Productivity, assuming that the hatchery-origin and natural-origin spawners are contributing to natural production at the same effectiveness, is below replacement for all four populations (even at low to moderate spawning levels). Geometric mean natural-origin abundance and productivity estimates since the previous status review are the highest for the Wenatchee River population that contains the lowest relative proportion of hatchery spawners.

DPS Summary

Although there has been an increase in abundance and productivity for all four UCR steelhead populations, the improvement has been minor, and none of the populations meet the recovery criteria established in the UCR Recovery Plan. Since the DPS-level recovery criteria require that all four populations be viable, more progress must be made before the UCR steelhead can be considered recovered.

Several factors cited in the previous status review (Good et al. 2005) remain concerns or key uncertainties. UCR steelhead populations have increased in natural-origin abundance in recent years, but productivity levels continue to remain low. The proportion of hatchery-origin returns in natural spawning areas remains extremely high across the DPS, especially in the Methow and Okanogan River populations. Recent improvements in natural returns, although modest, are most likely the result of several years of relatively good ‘natural’ ocean and tributary habitat survival conditions.

Overall, the new information considered does not indicate a change in the biological risk category since the time of the last status review. Direct biological performance measures for this DPS indicate modest progress to date toward meeting viability criteria. New information considered during this review confirms that all populations within this DPS are at high risk and the DPS, as a whole, is not viable.

2.3.2 Five-Factor Analysis

Section 4(a)(1)(b) of the ESA directs us to determine whether any species is threatened or endangered because of any of the following factors: (1) the present or threatened destruction, modification, or curtailment of its habitat or range; (2) overutilization for commercial, recreational, scientific, or educational purposes; (3) disease or predation; (4) the inadequacy of existing regulatory mechanisms; or (5) other natural or human-made factors affecting its continued existence. Section 4(b)(1)(A) requires us to make listing determinations after conducting a review of the status of the species and taking into account efforts to protect such species. Below we discuss new information relating to each of the five factors as well as efforts being made to protect the species.

Present or threatened destruction, modification or curtailment of its habitat or range

Significant habitat restoration and protection actions at the Federal, state, and local levels have been implemented to improve degraded habitat conditions and restore fish passage. While these efforts have been substantial and are expected to benefit the survival and productivity of the targeted populations, we do not yet have evidence demonstrating that improvements in habitat conditions have led to improvements in population viability. The effectiveness of habitat restoration actions and progress toward meeting the viability criteria will be monitored and evaluated with the aid of new reporting techniques. Generally, it takes one to five decades to demonstrate such increases in viability. Below, we summarize several noteworthy restoration and protection actions implemented since the last review. We also note areas where concerns about this DPS' habitat condition remain.

The implementation of the Federal Columbia River Power System (FCRPS) Biological Opinion (Opinion) (NMFS 2008a; NMFS 2010) has provided a number of actions that will result in survival improvements, reduced duration of outmigration to the estuary, improvements in juvenile survival and condition, and increased access to habitats. Some of the major milestones include the following:

Improvements in Operations and Fish Passage at Hydropower Facilities and Dams

Implementation of the FCRPS Opinion (NMFS 2008a; NMFS 2010) provides a number of new actions and continuation of existing programs that have and will likely continue to increase passage survival through the Columbia River passage corridor. In addition to increasing direct survival at the dams and through the project reservoirs, these actions reduce the duration of juvenile salmonid outmigration to the estuary, and increase access to habitat for adult migrants.

Since 2006, direct survival for juvenile salmonid outmigration in the Columbia River has likely increased because of the installation or improvement of juvenile passage structures at The Dalles Dam (spillway wall installed in 2010), John Day Dam (two surface passage weirs installed in 2008), McNary Dam (surface passage routes and spillway weirs installed in 2007), Priest Rapids Dam (surface bypass prototype evaluated and design improvements from 2007-2010), and Wanapum Dam (surface bypass installed in 2008). Juvenile passage facilities continue to perform well at Rocky Reach Dam (surface collector installed in 2003), Rock Island Dam (array of notched surface spill gates), Wells Dam (surface collector) and Bonneville Dam (corner surface collector installed in 2004). Mainstem dam juvenile passage facilities have been evaluated for passage survival and behavioral response, and testing continues. Survival and behavioral testing subsequently inform modifications to passage facility design and project operations, based on lessons learned and adaptive management.

By 2001, juvenile project survival standard (93 percent survival for dam and reservoir passage) for juvenile UCR Spring-run Chinook salmon and juvenile UCR steelhead was only achieved at one of the five Middle Columbia PUD dams. As of 2010, four PUD hydroelectric projects achieved Spring Chinook salmon survival standards and the fifth project is within a percentage point. Four of the five PUD dams now have a permanent juvenile passage facility, and construction at the fifth dam is planned for 2011-2012. UCR steelhead survival performance standards are achieved at all PUD dams, but unresolved reservoir mortality issues have not allowed achievement of project survival standards at two of the five projects. Tests to identify reservoir mortality mechanisms are planned for 2011. Other recent hydroelectric project improvements include the construction of a new trap and handling facility at Priest Rapids Dam; ongoing installation of new turbines at Wanapum Dam; installation of PIT tag detection arrays in the Rocky Reach Dam juvenile bypass facility; improvements to Northern Pikeminnow removal programs; and enhanced avian predator deterrent programs (hazing and wire arrays).

Future improvements are anticipated as the FCRPS Opinion (NMFS 2008a; NMFS 2010) is implemented further. Some of the future improvements include adult PIT tag detectors at The Dalles Dam or John Day Dam; enhanced estuarine detection of PIT tagged adults; and development and evaluation of PIT tag detection at project spillways. These technological enhancements will increase the ability to detect and correct salmonid passage issues throughout the Columbia River Basin. Plans to study reservoir mortality are underway.

Management of Tributary Habitat

Since the last status review, numerous habitat improvement projects have been completed. Recovery projects throughout the range of the UCR Spring-run Chinook salmon ESU and the UCR steelhead DPS included: (1) improved fish passage and increased access to high quality habitat; (2) riparian vegetation restoration through fencing and planting; (3) reestablishment of off channel habitat; (4) significant flow improvements in several important tributary stream reaches; and (5) land protection through funds from Middle Columbia Habitat Conservation Plans, Grant County PUD, Washington Salmon Recovery Funding Board, Bonneville Power Administration, and the Pacific Coast Salmon Recovery Fund.

In Nason Creek, two restored oxbows now connect over one mile of habitat, thereby increasing habitat diversity and off-channel rearing and over-wintering habitat for salmon and steelhead. Additional off-channel areas have been created or enhanced throughout the Wenatchee watershed from Leavenworth downstream. Replacement of eighteen culverts in Chumstick

Creek provides year-round passage to all life stages of fish. Improved management at Leavenworth National Fish Hatchery enables steelhead to access roughly two additional miles of good quality habitat. In the Methow River Basin, the Forest Service has improved habitat conditions by fencing riparian areas where grazing occurs, replacing culverts in the Twisp watershed, and performing a minimum roads analysis in the Chewuch Watershed to help guide their road system. While these projects will likely improve salmonid rearing conditions and survival, habitat responses have yet to be adequately monitored. It is also important to note that habitat projects usually require more than five years to improve habitat conditions. Instream flows have been significantly improved in the Chewuch River, Twisp River, Beaver Creek and other tributaries as a result of publicly funded water conservation projects and court action. In the Okanogan Basin, fish passage and instream flows have been improved in several tributaries as well as in the mainstem Okanagon. Passage projects in the Okanogan are particularly important for steelhead in that portion of the mainstem within the U.S. where it is too warm to support year-round rearing.

Despite significant efforts to improve habitat conditions, much of the habitat in the range of UCR Spring-run Chinook salmon and UCR steelhead remains degraded. Restoring habitat to historic conditions may not be needed to attain viability, but considerable improvement is needed to restore habitat to levels that will support viable populations of both UCR steelhead and Spring-run Chinook salmon. In particular, the poor status of the habitat is a major obstacle to achieving UCR Spring-run Chinook salmon ESU and steelhead DPS viability. There are significant opportunities to improve habitat conditions in the Methow, Entiat, and Wenatchee basins. For example, in the Methow basin, sediment levels in the Chewuch River are very high. Yet, land managers have made little progress in reducing road densities and treating other sediment sources. Additional opportunities for habitat improvement include increasing flows in the lower eight miles of the Chewuch River and removing problematic irrigation push-up dams on the Twisp and Methow rivers.

The mainstems of the Wenatchee, Entiat, and Methow rivers and key reaches of larger tributaries of each are nearly devoid of large woody debris. State and Federal highway departments, railroad rights-of-way and power line corridors severely limit the expression of normative floodplain function and the extent of the channel migration zone of the Wenatchee River, Nason Creek, and Peshastin Creek. Residential development has severely limited channel migration in the Methow below the Lost River, and future residential development presents a substantial threat to normative habitat forming processes. In the dynamic reaches of the upper Methow, bank armoring at a single location can cause negative changes in habitat conditions for great distances both up and downstream. For this reason, much of the money available for habitat restoration in the Methow Basin has instead been dedicated to preventing the problems that would otherwise result from the type of residential development typically permitted there.

Federal and Non-Federal actions, including agriculture, urbanization, and development throughout the UCR basin have likely resulted in stormwater inputs, pesticide and herbicide contamination, bank hardening and stabilization, overwater structures, and low stream flow. In addition, the frequency of large fires and increases in disease and insect outbreaks also add uncertainty to the future condition of large areas of forested lands and their ability to maintain conditions suitable for anadromous fish. These types of impacts may further degrade habitat conditions. The net impact of such degradation in the context of considerable habitat restoration efforts is unknown.

Federal Land Management

Federal land managers have taken a number of measures to protect and restore habitat throughout the UCR basin. According to the Forest Service and Bureau of Land Management, habitat improvement and benefits have been demonstrated on Federal lands through the implementation of the Northwest Forest Plan (FEMAT 1993), PACFISH (USDA and USDI 1994), the Aquatic Habitat Restoration Activities Biological Opinion (ARBO), and other management efforts.

Monitoring results from the PACFISH Biological Opinion Monitoring Program (PIBO) provided by the Forest Service indicate that, within the range of the UCR steelhead and UCR Spring-run Chinook salmon, some trends in stream habitat attributes (large woody debris, streambank characteristics, etc.) are positive, some are negative, and others have no trend (Al-Chokhachy et al. 2010a). One notable improvement is an increase in the average number of large woody debris placed in streams across the range of the UCR steelhead DPS (Al-Chokhachy et al. 2010a).

Additional information from the PIBO monitoring program indicates that unmanaged or reference reaches (streams in watersheds with little to no impact from road building, grazing, timber harvest, and mining) on Federal lands in the Interior Columbia Basin are in better condition than managed streams (Al-Chokhachy et al. 2010b). In particular, managed watersheds with high road densities or livestock grazing tend to have stream reaches with worse habitat condition than streams in reference watersheds. When roads and grazing both occur in the same watershed, the presence of grazing has an additional significant negative effect on the relationship between road density and the condition of stream habitat (Al-Chokhachy et al. 2010b). These results indicate that legacy effects of historic management still manifest in the current condition of streams on Federal lands in the Interior Columbia Basin and ongoing management may still be affecting stream recovery rates. Forest Service researchers conclude that the observed differences in average stream condition between reference and managed watersheds may indicate that recent management regulations (e.g., PACFISH) in combination with the legacy of previous management actions may not be sufficient to improve the status of streams within managed watersheds, particularly over relatively short time periods (10-20 years) (Al-Chokhachy et al. 2010b).

Significant progress in livestock grazing management on Federal lands has been made in the last 15 years, but the results of Al-Chokhachy et al. (2010b) indicate that further refinements to grazing management may be necessary in certain areas. In addition to these refinements, it is also essential to carry out adequate monitoring for livestock grazing. Without monitoring data, it will not be possible to tell if future refinements to grazing management are actually being carried out.

The Federal land managers are implementing several programs designed to restore the health of watersheds and improve aquatic habitat. The Forest Service's Legacy Road restoration program and identification of a minimum road system through implementation of Subpart A of the Travel Management Rule may help reduce the aquatic impacts of the transportation system. The Federal land managers have also developed aquatic restoration strategies. The Aquatic Restoration Strategy (Forest Service) and the 2015 Aquatic Strategy Plan (BLM) emphasize cooperative whole watershed-scale restoration. The actual realized benefits of these programs will depend on funding and the effectiveness of implementation.

Due to the vast acreage of Federal land throughout the range of UCR steelhead and Spring-run Chinook salmon, conservation of this DPS'/ESU's habitat on Federal land is a recovery priority. However, there is uncertainty over the future conservation of UCR steelhead and UCR Spring-run Chinook salmon on Federal lands. The level of protection afforded to these species and their habitat will be determined by land management plans currently under development by the Forest Service and BLM. In August 2008, the Deputy Regional Directors for the Forest Service, BLM, NMFS, U.S. Fish and Wildlife Service, and Environmental Protection Agency developed "A Framework for Incorporating the Aquatic and Riparian Component of the Interior Columbia Basin Strategy into Bureau of Land Management and Forest Service Plan Revisions." The framework identifies six components to be included in the plan revisions: riparian management areas; protection of population strongholds; identification of restoration priorities; multi-scale analysis; development of management direction to identify desired outcomes of future conditions; and monitoring/adaptive management. The manner in which these components are implemented and integrated with the recovery plan will help determine the extent to which federal land management will contribute to recovery.

Inclusion of a comprehensive effectiveness monitoring program such as PIBO is an essential component of any future aquatic conservation strategy. Effectiveness monitoring data from a large-scale program such as PIBO allows managers to determine if current practices are allowing for the attainment of aquatic and riparian management objectives. It also allows managers to incorporate the additive effects of multiple land management activities when prescribing future management standards that will prevent further degradation of streams and begin to restore physical habitat (Al-Chokhachy et al. 2010b).

Significant opportunities exist for recovery and/or conservation actions on Federal lands as part of the ESA section 7(a)(1) responsibilities. NMFS will continue to work with the Forest Service and BLM to identify opportunities for restoration actions on Federal lands and to the degree possible, to provide funding and technical assistance for projects that benefit the UCR steelhead and Spring-run Chinook salmon.

New information available since the last status review indicates that many restoration and protection actions have been implemented in freshwater and estuary habitat but does not reveal overall trends in habitat quality, quantity, and function. In addition, we remain concerned with habitat conditions throughout the range of the UCR steelhead DPS and Spring-run Chinook salmon ESU, particularly in regards to water quality, water quantity, riparian condition, and floodplain function. We therefore conclude that the risk to the species' persistence because of habitat destruction or modification has not changed since the last status review.

Overutilization for commercial, recreational, scientific, or educational purposes

Harvest

New terminal fisheries targeted at hatchery-origin fish in the Hanford Reach and surrounding tributaries reduce hatchery surplus returns and minimize impact to natural-origin fish. The May 2008 U.S. v. Oregon Management Agreement (2008-2017) will, on average, reduce impacts of fisheries on the UCR Spring-run Chinook salmon ESU and UCR steelhead DPS (NMFS 2008b).

UCR Spring-run Chinook salmon migrate offshore in marine waters where impacts from ocean salmon fisheries are too low to be quantified. The only significant harvest occurs in the mainstem Columbia River in tribal and non-tribal fisheries directed at hatchery Spring-run Chinook salmon. Exploitation rates have increased in recent years but still remain relatively low, generally below 10 percent. The increase of exploitation rates are a result of record returns of hatchery Spring-run Chinook salmon to the Columbia River basin.

For UCR steelhead, total exploitation rates have been stable at around 5 percent. The majority of impacts on the summer run occur in tribal gillnet and dip net fisheries targeting the Spring-run Chinook salmon.

Research and Monitoring

Although the absolute quantity of take authorized for scientific research and monitoring has been relatively low, our records of take authorization under ESA sections 10(a)(1)(A) and 4(d) for the UCR species reveal a steady increase in requests for take. We expect additional increases in take requests in the foreseeable future with implementation of the 2010 FCRPS Supplemental Biological Opinion. This Opinion integrates the 2008 reasonable and prudent alternative and the Adaptive Management Implementation Plan (FCRPS Biological Opinion) and Hatchery Genetic Management Plans (HGMPs). Handling impacts (e.g., direct mortality, delayed mortality, and sub-lethal effects) from research and monitoring activities (e.g., electroshocking, tagging, and marking) need to be better quantified.

New information available since the last status review indicates harvest impacts have decreased somewhat, but research impacts have increased. We conclude that the absolute degree of change in either direction from these factors has not changed substantially since the last status review.

Disease or predation

Although actions to reduce avian predation in the Columbia Basin have been ongoing with implementation of the FCRPS Biological Opinion, high levels of avian predation continue to significantly affect the UCR Spring-run Chinook salmon ESU and steelhead DPS. A Columbia Basin-wide assessment of avian predation on juvenile salmonids indicates that the most significant impacts to smolt survival occur in the Columbia River estuary (Collis et al. 2009). The combined consumption of juvenile salmonids by Caspian terns and double-crested cormorants nesting on East Sand Island was estimated to be between 7 and 16 million smolts annually. This represents approximately 10 percent of all the salmonid smolts that survive to the estuary in an average year.

Predation remains a concern due to a general increase in pinniped populations along the West Coast. California sea lion populations are growing rapidly, and there is potential that these predators could substantially reduce the abundance of several salmon and steelhead ESUs/DPSs. The available information clearly indicates that adult salmon contribute substantially to the diets of pinnipeds in the lower Columbia River and estuary, especially in the spring, late-summer, and fall seasons when Chinook salmon are most abundant (Scordino 2010). The effect of marine mammals on the productivity and abundance of Columbia River basin ESA-listed salmon and steelhead populations has not been quantitatively assessed. The absolute number of animals preying upon salmon and steelhead throughout the lower Columbia River and estuary is not known, the duration of time that they are present is uncertain, and the portion of their diet that is made up of listed species is unknown. We do have information to indicate that Steller sea lion abundance is increasing in the lower Columbia River and that predation by California sea lions at Bonneville Dam continues to increase (NMFS 2011).

A sport fishing reward program was implemented in 1990 to reduce the numbers of northern pikeminnow in the Columbia basin (NMFS 2010). The program continues to meet expected targets, which may reduce predation on smolts in the mainstem Columbia River.

Non- indigenous fishes affect salmon and their ecosystems. A number of studies have concluded that many established non-indigenous species (in addition to smallmouth bass, channel catfish, and American shad) pose a threat to the recovery of ESA-listed Pacific salmon. Threats are not restricted to direct predation; non-indigenous species compete directly and indirectly for resources, significantly altering food webs and trophic structure, and potentially altering evolutionary trajectories. (Sanderson et al. 2009; NMFS 2010)

Disease rates over the past five years are believed to be consistent with the previous review period. Climate change impacts such as increasing temperature may increase susceptibility to diseases. Recent reports indicate the spread of a new strain of infectious haematopoietic necrosis virus along the Pacific coast may increase disease related concerns for UCR Spring-run Chinook salmon and UCR steelhead in the future.

New information available since the last status review indicates there is an increase in the level of avian and pinniped predation on UCR steelhead and UCR Spring-run Chinook salmon. At this time we do not have information available that would allow us to quantify the change in extinction risk due to predation. We therefore conclude that the risk to the species' persistence because of predation has increased by an unquantified amount since the last status review.

Inadequacy of existing regulatory mechanisms

Various Federal, state, county and tribal regulatory mechanisms are in place to reduce habitat loss and degradation caused by human use and development. New information available since the last status review indicates that the adequacy of a number of regulatory mechanisms has improved. Examples include:

- Washington State Use-based (e.g., aquatic life use) Surface Water Quality Standards, Washington Administrative Code (WAC) 173-201A. The 2003 standards were amended in 2006 to provide additional spawning and incubation temperature criteria of salmon, trout, and char. The standards include an Antidegradation Policy, which was approved by Environmental Protection Agency (EPA) in May 2007. The EPA approved the Washington State's 2008 Water Quality Assessment 305(b) report and 303(d) list in January 2009. Washington's 2010 water quality report is scheduled for submission to EPA in the fall of 2011.

- Washington Shoreline Management Act, Ch. 90.58 RCW (SMA). In 1971 the Washington State Legislature passed the Washington Shoreline Management Act, adopted by public referendum in 1972. The purpose of the Act is "to prevent the inherent harm in an uncoordinated and piecemeal development of the state's shorelines" by requiring every county and many cities to develop a Shoreline Master Plan (SMP) to govern development in shoreline areas, including all wetlands, river deltas, and riparian areas associated with rivers, streams and lakes. The Douglas County shoreline master program update was approved by the state on August 27, 2009. Chelan and Okanogan Counties are in the process of updating their Shoreline master programs.

- Washington Growth Management Act, Revised Code of Washington Ch. 36.70A (GMA) and Critical Areas Ordinance (CAO). As with the SMA, GMA also has an update process for city and county critical areas ordinances. Most critical areas ordinances were originally adopted following GMA's enactment in 1990/1991. While CAO are typically amended more often than shoreline master programs, GMA's update schedule for Eastern Washington counties started in December 2005, or 2006, or 2007 (depending on the county).

- Instream Flows: On December 11, 2007, amendments to Chapter 173-545 WAC (the Instream Resources Protection Program for the Wenatchee River Basin, WRIA 45) were adopted. The existing water management rule (adopted in 1983) was amended to guide water use planning and decision-making for future human domestic needs while maintaining enough water in streams to protect important fish species and existing water rights. The rule amendments were recommended by the Wenatchee Watershed Planning Unit. Specifically, the rule amendments:
    - Revise existing instream flow levels,
    - Establish a reservation of water for future use, and
    - Set maximum allocations above the instream flows for the Wenatchee River and its tributaries.

However, despite improvement in the adequacy of regulatory mechanisms within the UCR ESU/DPS, there remain a number of concerns regarding existing regulatory mechanisms, including:

- Lack of documentation or analysis of the effectiveness of land-use regulatory mechanisms and land-use management plans;
- Contradictory policies and/or implementation of regulations by Federal agencies. For example, one agency may take actions to improve riparian vegetation and instream habitat in one area while a short distance away another Federal authority requires removal of vegetation and instream structures;
- Lack of reporting and enforcement for some regulatory programs;

We conclude that the risk to the species' persistence because of the adequacy of existing regulatory mechanisms has decreased slightly, based on the improvements noted above. However, many ongoing threats to UCR salmon and steelhead habitat could be ameliorated by strengthening existing regulatory mechanisms.

Other natural or manmade factors affecting its continued existence

Climate Change

Current research by Mote and Salathé (2010), and other members of the University of Washington Climate Impacts Group, is providing insights to potential future climate change impacts for the Pacific Northwest region. Although the values or severity of these changes may be uncertain, and their biological impacts on salmonids have yet to be demonstrated, there is general scientific agreement regarding the impacts already evident in the last 40 years of climatological data and expected trends.

Expected climate change impacts for freshwater conditions and salmon and steelhead populations include:

- Increase water temperatures.
- Decreases in snow pack causing a shift of peak flows from summer to spring, and a decrease in summer flows. Shifts in the timing of peak flows will likely result in changes in outmigration timing, changes in survival, changes in distribution, and changes in the availability of spawning and rearing habitats.
- Peak flows will be flashier, likely resulting in channel scouring and increased risk of sedimentation.
- Likely increase in winter flooding events.
- Under future climate scenarios, higher elevation areas will likely continue to provide habitat conditions within the biological tolerances of salmonids. However, lower and transitional areas will experience increasing temperatures reducing the available spawning and rearing habitats, altering distribution, and diminishing survival.

Expected climate change impacts to ocean conditions include:

- Increasing ocean acidification (although there is uncertainty about the downstream effects on marine food webs and salmonid survival in the ocean).
- Ocean temperatures will increase resulting in changes in the distribution and abundance of warm and cold-water species. There is uncertainty about the effects on marine food webs and ocean survival of salmonids.
- Likely changes to a variety of processes such as the pattern and cycle of the Pacific Decadal Oscillation and the intensity and patterns of upwelling.

Over the past 40 years climate change has degraded environmental conditions for Pacific Northwest salmon and steelhead. The certainty in modeled climate change impacts has increased as has our understanding of likely impacts of these changes on salmonid populations. While climate change impacts remain a recovery concern over the long term, it is unknown whether climate change impacts have changed in the few years since the last review.

Hatchery Effects

Hatchery programs can provide short-term demographic benefits, such as increases in abundance during periods of low natural abundance. They also can help preserve genetic resources until limiting factors can be addressed. However, the long-term use of artificial propagation may pose risks to natural productivity and diversity. The magnitude and type of the risk depends on the status of affected populations and on specific practices in the hatchery program.

UCR Spring-run Chinook Salmon

Implementation of reforms and changes in hatchery management has occurred since the last status review, although the benefits have not yet been fully realized and documented. Improvements include the following to reduce the diversity risks to the ESU:

- Discontinuing the Entiat National Fish Hatchery (NFH) Spring-run Chinook salmon program;
- Phasing out the non-ESU Carson stock of the Methow River hatchery programs;
- Proposed hatchery reforms for the Wenatchee River programs (e.g., limiting hatchery fish on the spawning grounds based on the abundance of natural-origin returns;
- Increasing genetic resources in the White River to reduce risks to diversity and productivity for the Wenatchee Spring-run Chinook salmon population; and,
- Removing differentially marked Leavenworth hatchery fish at Tumwater Dam before escaping upstream to spawn in order to reduce the risk of naturally spawning Leavenworth NFH hatchery strays that originate from outside the ESU to the Wenatchee population.

New information available since the last status review indicates that although hatchery management has become less of a risk factor to the Wenatchee and Entiat River Spring-run salmon populations, hatchery practices in the Methow Basin have not changed the risk to diversity for the Methow River population. We conclude on balance, that the extent to which hatchery effects continue to present risks to the persistence of the UCR Spring-run Chinook salmon ESU remains unchanged.

UCR Steelhead

We anticipate that proposed hatchery reforms will likely reduce risks to diversity for the Wenatchee River steelhead population. There is no steelhead hatchery program in the Entiat River. However, new information since the last status review indicates that hatchery practices in the Methow River are posing an increased risk to population diversity and productivity.

Hatchery practices for the Wells Hatchery, Omak Creek Hatchery, and Ringold Hatchery are trending toward divergence from the local natural populations in the DPS. These programs continue to use composite Methow River and Okanogan River steelhead for broodstock and incorporate a low percentage of natural-origin fish for broodstock. These programs also are responsible for excessive levels of natural spawning by hatchery fish which poses risks to population diversity, productivity, and abundance (risks to abundance result primarily from competition and predation affects on natural fish). On average, hatchery fish comprise at least 85 percent of the natural spawners in the Methow River and are likely to result in decreased viability of the UCR steelhead DPS unless the above noted concerns are addressed.

New information since the last status review indicates that there have not been significant changes to these factors, and that these factors continue to present risks to the persistence of the UCR steelhead DPS.

Efforts being made to protect the species

When considering whether to list a species as threatened or endangered, section 4(b)(1)(A) of the ESA requires that NMFS take into account any efforts being made to protect that species. Throughout the range of salmon ESUs and steelhead DPSs, there are numerous Federal, state, tribal and local programs that protect anadromous fish and their habitat. The proposed listing determinations for West Coast salmon and steelhead (69 FR 33102) reviewed these programs in detail.

In the final listing determinations for salmon (70 FR 37160) and steelhead (71 FR 834), we noted that while many of the ongoing protective efforts are likely to promote the conservation of listed salmonids, most efforts are relatively recent, have yet to demonstrate their effectiveness, and for the most part address conservation needs at scales sufficient to conserve entire ESUs or DPSs. Therefore, we concluded that existing protective efforts did not preclude listing several ESUs of salmon and several DPSs of steelhead.

In our five factor-analysis above, we note the many habitat, hydropower, hatchery, and harvest improvements that occurred in the past five years. We currently are working with our Federal, state, and tribal co-managers to develop monitoring programs, databases, and analytical tools to assist us in tracking, monitoring, and assessing the effectiveness of these improvements.

2.4 Synthesis

The ESA defines an endangered species as one that is in danger of extinction throughout all or a significant portion of its range, and a threatened species as one that is likely to become an endangered species in the foreseeable future throughout all or a significant portion of its range. Under ESA section 4(c)(2), we must review the listing classification of all listed species at least once every five years. While conducting these reviews, we apply the provisions of ESA section 4(a)(1) and NMFS' implementing regulations at 50 CFR part 424.

To determine if a reclassification is warranted, we review the status of the species and evaluate the five risk factors, as identified in ESA section 4(a)(1): (1) the present or threatened destruction, modification, or curtailment of its habitat or range; (2) overutilization for commercial, recreational, scientific, or educational purposes; (3) disease or predation; (4) inadequacy of existing regulatory mechanisms; and (5) other natural or man-made factors affecting a species' continued existence. We then make a determination based solely on the best available scientific and commercial information, taking into account efforts by states and foreign governments to protect the species.

The updated status reviews completed by our Northwest Fisheries Science Center indicates that the viability ratings for all populations of UCR Spring-run Chinook salmon and UCR steelhead remain at high risk and do not meet the recovery criteria. Neither the UCR Spring-run Chinook salmon ESU or UCR steelhead DPS are viable, and, there is no new information to indicate that the extinction risk has changed for either UCR ESU/DPS. The Science Center concluded, after reviewing the available new information, that the biological risk category for the UCR Spring-run Chinook salmon ESU and the UCR steelhead DPS has not changed since the time of the last status review.

Our analysis of the ESA section 4(a)(1) factors indicates that the collective risk to the persistence of the Spring-run Chinook salmon ESU and steelhead DPS has not changed significantly since our final 2005 ESU and 2006 DPS listing determinations. Improvements have been made in operations and fish passage at tributary dams and at the FCRPS dams, and numerous habitat restoration projects have been completed in many Upper Columbia River tributaries. Conversely, habitat problems are still common throughout the region and many more habitat improvements are likely needed to achieve viability. Harvest rates remain relatively low and stable for both species. Changes in hatchery management are needed for both species to reduce the number of hatchery-origin fish used as broodstock and to reduce the number of hatchery fish allowed to spawn naturally. The protection afforded by some regulatory mechanisms, such as implementation of TMDLs, has increased, although existing regulatory mechanisms could be improved to better protect UCR steelhead and Spring-run Chinook salmon habitat. In addition, predation from an increase in pinniped populations and significant avian impacts remain a concern, as do the impacts that climate change poses to long-term recovery.

After considering the biological viability of the Upper Columbia River ESU/DPS and the current status of their ESA section 4(a)(1) factors, we conclude that the status of the UCR Spring-run Chinook salmon ESU and steelhead DPS has not improved significantly since the final listing determinations in 2005 and 2006, respectively. The implementation of sound management actions in hydropower, habitat, hatcheries, and harvest are essential to the recovery of the Upper Columbia River ESU/DPS and must continue. The biological benefits of habitat restoration and protection efforts, in particular habitat restoration, have yet to be fully expressed and will likely take another five to 20 years to result in measurable improvements to population viability. By continuing to implement actions that address the factors limiting population survival and monitoring the effects of the action over time, we will ensure that restoration efforts meet the biological needs of each population and, in turn, contribute to the recovery of these species. The UCR Recovery Plan is the primary guide for identifying future actions to target and address UCR Spring-run Chinook salmon and UCR steelhead limiting factors and threats. Over the next five years, it will be important continue to implement these actions and monitor our progress.

2.4.1 Upper Columbia River ESU and DPS Delineation and Hatchery Membership

The Northwest Fisheries Science Center's review (Ford et al. 2010) found that no new information has become available that would justify a change in boundaries of the Upper Columbia River ESU and DPS.

The Northwest Regional Office's review of new information to inform the ESU/DPS membership status of various hatchery programs (Jones et al. 2011) found that the UCR steelhead and Spring-run Chinook salmon hatchery programs have not changed substantially from the previous 2005 ESA status review. However, trends in current hatchery management, if continued, could lead to future changes in ESU and DPS memberships (Jones et al. 2011).

2.4.2 ESU/DPS Viability and Statutory Listing Factors

- The Northwest Fisheries Science Center's review of updated information does not indicate a change in the biological risk category for either UCR species since the time of the last status review (Ford et al. 2010).

- Our analysis of the ESA section 4(a)(1) factors indicates that the collective risk to the UCR salmon and steelhead's persistence has not changed significantly since our 2005 final listing determination for the Spring-run Chinook salmon ESU, and our 2006 final listing determination for the steelhead DPS.

3 · Results

3.1 Classification

Listing status:

Based on the information identified above, we determine that no reclassification for either the UCR steelhead DPS or the UCR Spring-run Chinook salmon ESU is appropriate, and therefore the UCR steelhead DPS should remain listed as threatened, and the UCR Spring-run Chinook salmon ESU should remain listed as endangered.

Hatchery membership:

The UCR steelhead and spring-run Chinook salmon hatchery programs have not changed substantially from the previous ESA status review. Therefore, we do not recommend any changes in hatchery membership for either the UCR steelhead DPS or UCR Spring-run Chinook salmon ESU.

Five hatchery programs that are part of the listed ESUs/DPS are trending toward divergence from the listed ESUs/DPS and should be reviewed in the future to determine if they should remain part of the ESUs/DPS.

Hatchery programs needing further review:

- The Winthrop NFH Spring-run Chinook Program (Methow Composite Stock)
- The Methow Composite Program (Spring-run Chinook salmon)(at Methow River)
- The Wells Hatchery summer steelhead program (Methow River program)
- The Wells Hatchery summer steelhead program (Okanogan River program)
- The Ringold Hatchery summer steelhead program (summer steelhead from Wells Hatchery)
- Winthrop NFH summer steelhead program (Methow River)

3.2 New Recovery Priority Number

There are no changes in the recovery priority number listed in Table 4 for either the UCR Spring-run Chinook salmon ESU or the UCR steelhead DPS.

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4 · Recommendations for Future Actions

In our review of the listing factors we identified several actions critical to improving the status of the UCR steelhead DPS and the Spring-run Chinook salmon ESU. The most important actions to be taken over the next 5 years include implementation of the high priority strategies and actions identified in the 2007 UCR Recovery Plan, the 2008 Harvest Biological Opinion, the 2010 FCRPS Biological Opinion, and the completion of ESA consultations on the hatchery programs in the UCR steelhead DPS and Spring-run Chinook salmon ESU. We are currently in the process of identifying actions that address the factors contributing to the existing high risk rating for each population, since such actions have the greatest potential to improve VSP parameters at both the MPG and ESU/DPS levels.

We are directing our efforts at populations that need viability improvement according to ESU/DPS-, MPG-, and population-level recovery criteria, the best available scientific information concerning ESU/DPS status, the role of the independent populations in meeting ESU/DPS and MPG viability, limiting factors and threats, and the likelihood of action effectiveness to guide our recommendations for future actions. NMFS is coordinating with the Federal, state, tribal, and local implementing entities during this prioritization process to ensure that risk factors and actions identified in the recovery plan, and the actions identified in the Harvest Biological Opinion, the FCRPS Biological Opinion, and the ESA consultations on hatchery programs are addressed.

Additional recommended actions include:

- Fisheries co-managers further evaluating the impacts of other hatchery releases (both anadromous and resident) on Spring-run Chinook salmon and steelhead.
- Federal and private dam operators further investigating causes of adult losses between hydro facilities by reach (particularly the Columbia River Estuary to Bonneville Dam; Bonneville Dam to McNary Dam; and, McNary Dam to Wells Dam).
- State and Tribal fisheries co-managers using pit tag detection on all harvested fish to better understand the sources of losses in conversion rates and improve the sophistication in harvest management.
- Federal and state management agencies estimating sea lion population (and predation rates on salmonids) in the Lower Columbia River.
- Fisheries co-managers improving estimates of catch and release harvest impacts.
- Federal, state, tribal and private entities improving estimates of research, monitoring, and evaluation handling (electrofishing, weirs, catch and release, tagging, marking, trapping, sorting) impacts.

- Federal, state, tribal and private entities identifying contributing factors for lower or greater hatchery fish reproductive success.
- Federal, state, tribal and private entities continuing focus and prioritization of recovery actions on limiting factors.
- Federal, state, tribal and private entities implementing Research Monitoring and Evaluation (RME) actions to address critical uncertainties

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National Marine Fisheries Service
5-Year Review

Upper Columbia River Spring-run Chinook Salmon
Upper Columbia River Steelhead

Conclusion:

Based on the information identified above, we conclude:

- The Upper Columbia River Spring-run Chinook salmon ESU should remain listed as endangered.
- The Upper Columbia River steelhead DPS should remain listed as threatened.

REGIONAL OFFICE APPROVAL

Northwest Regional Administrator, NOAA Fisheries

Approve: William Stelle Date: *July 26, 2011*