Collaborative Systemwide Monitoring and Evaluation Project (CSMEP)

Collaborative Systemwide Monitoring and Evaluation Project (CSMEP) – Year 5

Project No. 2003-036-00

Annual Report for FY 2008

COLUMBIA BASIN FISH AND WILDLIFE AUTHORITY

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Executive Summary

The Collaborative Systemwide Monitoring and Evaluation Project (CSMEP) is a coordinated effort to improve the quality, consistency, and focus of fish population and habitat data to answer key monitoring and evaluation questions relevant to major decisions in the Columbia River Basin. CSMEP was initiated by the Columbia Basin Fish and Wildlife Authority (CBFWA) in October 2003. The project is funded by the Bonneville Power Administration (BPA) through the Northwest Power and Conservation Council's Fish and Wildlife Program (NPCC). CSMEP is a major effort of the federal state and Tribal fish and wildlife managers to develop regionally integrated monitoring and evaluation (M&E) across the Columbia River Basin. CSMEP has focused its work on five monitoring domains: status and trends monitoring of populations and action effectiveness monitoring of habitat, harvest, hatcheries, and the hydrosystem. CSMEP's specific goals are to: 1) interact with federal, state and tribal programmatic and technical entities responsible for M&E of fish and wildlife, to ensure that work plans developed and executed under this project are well integrated with ongoing work by these entities; 2) document, integrate, and make available existing monitoring data on listed salmon, steelhead, bull trout and other fish species of concern; 3) critically assess strengths and weaknesses of these data for answering key monitoring questions; and 4) collaboratively design, implement and evaluate improved M&E methods with other programmatic entities in the Pacific Northwest.

Progress in FY2008

During FY2008 CSMEP biologists continued their reviews of the strengths and weaknesses (S&W) of existing subbasin inventory data for addressing monitoring questions about population status and trends at different spatial and temporal scales. Work was focused on Lower Columbia Chinook and steelhead, Snake River fall Chinook, Upper Columbia Spring Chinook and steelhead, and Middle Columbia River Chinook and steelhead. These FY2008 data assessments and others assembled over the years of the CSMEP project can be accessed on the CBFWA public website (www.cbfwa.org/committee_CSMEP.cfm). The CSMEP web database (http://csmep.streamnet.org/) houses metadata inventories from S&W assessments of Columbia River Basin watersheds that were completed prior to FY2008. These older S&W assessments are maintained by StreamNet, but budget cutbacks prevented us from adding the new FY2008 assessments into the database.

Progress was made in FY2008 on CSMEP's goals of collaborative design of improved M&E methods. CSMEP convened two monitoring design workshops in Portland (December 5 and 6, 2007 and February 11 and 12, 2008) to continue exploration of how best to integrate the most robust features of existing M&E programs with new approaches. CSMEP continued to build on this information to develop improved designs and analytical tools for monitoring the status and trends of fish populations and the effectiveness of hatchery and hydrosystem recovery actions within the Columbia River Basin. CSMEP did not do any new work on habitat or harvest effectiveness monitoring designs in FY2008 due to budget cutbacks. CSMEP presented the results of the Snake Basin Pilot Study to the Independent Scientific Review Panel (ISRP) in Portland on December 7, 2008. This study is the finalization of CSMEP's pilot exercise of developing design alternatives across different M&E domains within the Snake River Basin spring/summer Chinook ESU. This work has been summarized in two linked reports (CSMEP 2007a and CSMEP 2007b). CSMEP participants presented many of the analyses developed for the Snake Basin Pilot work at the Western Division American Fisheries Society (AFS) conference in Portland on May 4 to 7, 2008. For the AFS conference CSMEP organized a symposium on regional monitoring and evaluation approaches. A presentation on CSMEP's Cost Integration Database Tool and Salmon Viability

Monitoring Simulation Model developed for the Snake Basin Pilot Study was also given to the Pacific Northwest Aquatic monitoring Partnership (PNAMP) steering committee in Portland on August 28, 2008.

Further information on CSMEP strengths and weaknesses assessments and monitoring design products for FY2008 is presented in the main text and appendices of this Annual Report as well as being available on CBFWA's public website (http://www.cbfwa.org/committee_CSMEP.cfm).

CSMEP M&E Design Domain Subgroups:

1) Status and trends

In FY2008, the CSMEP Status and Trends Subgroup focused on refining the simulation model for evaluating alternative designs for monitoring the status and trends of at the population, Major Population Group (MPG) and Evolutionary Significant Unit (ESU) scales. The model incorporates the four data elements (abundance, productivity, spatial structure and diversity) required to make decisions on species delisting. The model uses misclassification rates to describe errors in assessing diversity and spatial structure metrics. It allows evaluation of the sensitivity of the viability criteria to changes in the quality of the data obtained from different M&E designs, and provides quantitative comparisons of the status quo monitoring and alternative designs to assess viability. In FY2008 the group finalized the coding of the viability monitoring simulation model, updated the spring/summer Chinook salmon population datasets for the Snake River Basin ESU, developed a user-friendly interface so the model can be used in other ESUs, and created a supporting user guide document. At this time the model uses the Interior Columbia Technical Recovery Team (ICTRT 2007) rule set to assess viability of populations, MPGs, and the ESU. To provide datasets for the extension of this model for viability assessments of Chinook and steelhead populations in other ESUs, the Status and Trends Subgroup extended their analyses of the strengths and weaknesses of Chinook and steelhead monitoring programs in other watersheds of the Basin.

2) Hydrosystem

In FY2008 CSMEP's Hydrosystem Subgroup finalized their designs for evaluating the survival of ESA listed Snake River and upper Columbia steelhead (both wild and hatchery) from smolt to adult and through the hydrosystem. The group worked through a formal process of evaluating the cost-precision tradeoffs represented by alternative designs (Status Quo, Low, Medium, and High) to address hydrosystem effectiveness questions. The four steelhead hydrosystem effectiveness questions evaluated by CSMEP in FY2008 were:

1. Are SARs sufficient to achieve NPCC and recovery goals?
2. Is transportation more effective than in-river passage?
3. Does the annual in-river survival of steelhead from Lower Granite Dam to Bonneville Dam meet the 2000 FCRPS BiOp performance standards?
4. Does the SAR of transported steelhead change during the migration season?

To date, neither NOAA and USFWS Biological Opinions, nor NPCC documents have specified limits on decision errors related to these hydrosystem questions. Therefore CSMEP's Hydro Subgroup used various models and statistical methods to examine *hypothetical* decision rules and the potential decision errors associated with these rules under different monitoring and evaluation designs. Decision errors were measured by a variety of metrics. Alternative designs included varying the number of PIT-tagged steelhead, and the level of accuracy and precision in data that are collected.

3) Habitat

CSMEP budget limitations in FY2008 precluded any further work by the Habitat Subgroup on analyses related to alternative designs for monitoring habitat action effectiveness.

4) Harvest

CSMEP budget limitations in FY2008 precluded further work by the Harvest Subgroup on analyses related to alternative designs for monitoring harvest action effectiveness.

5) Hatchery

The CSMEP Hatchery Subgroup focused on two primary tasks in FY2008 that completed the work begun in FY2007:

1. continued collaboration with the Ad Hoc Supplementation Work Group (AHSWG) developing approaches for basinwide evaluation of the long-term effects of hatchery supplementation, and
2. development of a statistical approach to calculate sample size requirements for relative reproductive success (RRS) studies.

The CSMEP Hatchery Subgroup placed the bulk of their FY2008 effort into fuller collaboration with the AHSWG, in order to capitalize on the greater interagency support available within that group. This joint AHSWG and CSMEP effort resulted in a comprehensive approach to assess the impacts of supplementation on the long and short-term abundance and productivity of targeted populations. This approach consists of three components:

1. standardizing monitoring approaches with respect to “viable salmonid population” (VSP) metrics for use in a large-scale treatment versus reference (T/R) analyses of supplemented versus un-supplemented populations;
2. implementation of a relative reproductive success (RRS) study in a representative subset of anadromous salmonid populations; and
3. identification of a number of small-scale studies aimed at identifying the mechanisms underlying observed fitness reductions in supplemented populations.

CSMEP’s Hatchery Subgroup also recognized the need to determine adequate juvenile sample sizes to conduct relative reproductive success (RRS) studies. In order to determine the sample size necessary to construct confidence intervals for RRS and evaluate the statistical power of the RRS estimates, CSMEP developed a statistical model to calculate the appropriate sample sizes.

6) Design Integration

Collaboration and coordination of monitoring within the Columbia Basin are important to develop cost effective monitoring and evaluation (M&E) programs for fish populations that cross multiple jurisdictions. A program that integrates status and trend with All-H action effectiveness monitoring will provide an economy of scale, prevent duplication of effort, and is cost effective. An integrated approach will help managers understand environmental stressors and sources of mortality throughout the anadromous and resident fish life cycle. In FY2008 CSMEP identified management decisions made either routinely or else infrequently by fish management agencies in the Columbia River Basin. The identification of common decisions by the various agencies throughout the Columbia River Basin allowed

CSMEP to highlight areas that require a coordinated inter-jurisdictional approach to develop a regional M&E plan in the Columbia River Basin. CSMEP used the following approach for this task:

1. Survey the management agencies for decisions made on a frequent basis (seasonally or annually) and those made on a more infrequent basis.
2. Identify those decisions which are primarily made under local jurisdiction versus those that may require collaboration or coordination with multiple managers.
3. Identify CSMEP work tasks, CBFWA Amendment Recommendations to the NPCC, and Federal Columbia River Power System Biological Opinion Reasonable and Prudent Alternatives (RPA) that address the monitoring needs for those decisions made in collaboration with multiple management agencies.

Identifying the priority decisions across monitoring domains (i.e., status & trends, harvest, hatchery, hydrosystem and habitat action effectiveness monitoring) represents a first step towards clearly defining the necessary performance measures for monitoring and the relevant spatial scale(s) of these data for varied subgroup monitoring needs. CSMEP has been exploring the integration of the individual M&E component parts within a larger monitoring framework (i.e., generation of improved efficiencies for capturing required performance measures through integrated designs). CSMEP has worked to ensure that analyses and monitoring designs explored as part of the project are consistent with the overarching objectives of Columbia River Basin monitoring agencies by continuing regular interactions with agency representatives throughout FY2008. Integration of M&E to address the suite of decisions identified by CSMEP in FY2008 will depend on the policy and management priorities of each monitoring domain and its constituent questions. Consequently, there is no “optimal” design that will exactly suit the preferences of all agencies. Therefore, program managers will need to iteratively review and collaboratively revise integrative strategies and designs. To assist this process CSMEP has developed an Integrated Costs Database Tool (ICDT) to calculate the costs of integrated monitoring, as well as a salmon viability monitoring model (SVMM) to evaluate the reliability of Chinook salmon and steelhead population assessments using alternative M&E designs. The cost database and viability models allow managers to assess trade-offs in statistical power, costs, sampling effort, accuracy and precision of the data of various M&E designs.

Table of Contents

List of Tables

List of Figures

1. Introduction

1.1 Background

The Collaborative Systemwide Monitoring and Evaluation Project (CSMEP) is a shared effort led by the members of the Columbia Basin Fish and Wildlife Authority (CBFWA). This project, now completing its 5^{th} year, focuses on the issue of Columbia River Basin systemwide monitoring and evaluation of fish status, addressing requirements of National Oceanographic and Atmospheric Administration Fisheries Service (NOAAF) and U.S. Fish and Wildlife Service (USFWS) biological opinions and recovery plans as well as the Northwest Power and Conservation Council (NPCC) Fish and Wildlife Program. CSMEP's goal is to demonstrate the benefits of systematic development and evaluation of alternative monitoring and evaluation (M&E) designs on a regional scale, for answering key questions related to fish and watershed management decisions in the Columbia Basin. It involves an integrated, collaborative effort by fisheries scientists and biometricians to fulfill seven objectives:

1. *Interact with federal, state and tribal programmatic and technical entities* responsible for monitoring and evaluation of fish and wildlife, to ensure that quarterly work plans developed and executed under this project are well integrated with ongoing work by these entities.
2. *Collaboratively inventory existing monitoring data* that bear on the problem of evaluating the status and trend of salmon, steelhead, bull trout and other species of regional importance across the U.S. portion of the Columbia Basin, and for selected parts of the Columbia River Basin in Canada which affect the status of key fish stocks in the U.S. portion of the Columbia River Basin (e.g., Okanagan sockeye).
3. *Work with existing entities (e.g., StreamNet, NOAAF) to make a subset of existing monitoring data available through the Internet,* recognizing the continuing evolution of data management in the Columbia Basin.
4. *Critically assess the strengths and weaknesses* of existing monitoring data and associated evaluation methods for answering key questions at various spatial scales concerning the state of ecosystems and fish habitat, as well as fish distributions, stock status and responses to management actions.
5. *Collaboratively design* improved monitoring and evaluation methods that will fill information gaps and provide better answers to these questions in the future, by providing state and tribal fish agency participation and work products for multi-agency development of regionally coordinated monitoring programs.
6. *Assist state and tribal participants* with regionally coordinated, multi-agency *implementation* of pilot projects or large scale monitoring programs.
7. *Participate in regional forums* to evaluate new monitoring program results, assess new ability to answer key questions, propose revisions to monitoring approaches, and coordinate proposed changes with regional monitoring programs.

Since project initiation in October 2003, CSMEP participants have developed work plans in close consultation with other programmatic and technical entities (Objective 1). For Objective 2 (data inventory), CSMEP began with a set of 16 specific M&E questions adapted from Jordan *et al*. (2002), and a set of 45 performance measures for viable salmonid populations, adapted from McElhany *et al*. (2000). To evaluate the range of data quality that exists within the Columbia River Basin, CSMEP selected pilot subbasins that included both data rich and data poor areas and were located across a range of Basin Ecoregions. For each of these pilot subbasins, StreamNet staff and CSMEP biologists jointly completed an inventory of the information available for each of the key performance measures for each of the target fish species. A CSMEP database (Objective 3) has been developed by StreamNet to allow access to the metadata recorded from these CSMEP inventories. For Objective 4, CSMEP biologists have reviewed the strengths and weaknesses of these data in watersheds throughout the Columbia River Basin for addressing status and trend and action effectiveness questions. CSMEP workshops have provided continuing opportunities for biologists and biometricians from across the region to meet and discuss recent advances in M&E approaches (e.g., sampling frames, results from pilot projects, Intensively Monitored Watershed strategies). CSMEP thus represents a unique forum for the cross-fertilization of M&E ideas among federal, state and tribal fish agency staff (Objective 7). Ideas expressed at these workshops have been incorporated into CSMEP's proposed alternative M&E designs for status and trend (S&T) and effectiveness monitoring (Objective 5). CSMEP's design work for their Snake River Basin Pilot Study provided input to the NOAAF/Bonneville Power Administration (BPA) Salmon River Subbasin Pilot Study and the Lemhi River Subbasin Habitat Conservation Plan (Objective 6). In FY2007 CSMEP finalized their alternative M&E designs for the pilot study in the Snake River Basin (CSMEP 2007a, 2007b). Our results of the pilot study were presented to the Independent Scientific Review Panel (ISRP) in FY2008. While these analyses were focused on the Snake River spring/summer Chinook ESU, the methodology and approach used can be transferred to other listed species in the Columbia River Basin and beyond to the larger Pacific Region. CSMEP's assessments and design efforts during this period have been primarily focused on improving monitoring programs across M&E domains for Chinook salmon and steelhead.

2. Summary of Progress on M&E Designs in FY2008

Overview

CSMEP has developed a set of strategies and general principles to meet the challenge of integrating multiple M&E objectives for the Basin:

1. involve federal, state, tribal and local entities in the collaborative development of M&E designs for multiple scales, questions and species, closely coordinating to ensure no duplication of effort;
2. survey managers and policy people to ascertain their relative priorities for different questions, scales, and species;
3. use *decisions* as the starting point for developing sampling, response and evaluation designs, rather than *questions*, which permits a more rigorous assessment of the exact inputs and level of precision required in monitoring data, and the risks of making different types of decision errors (Marmorek *et al*. 2005); and
4. recognize that M&E designs inevitably involve tradeoffs across a number of design objectives and evaluation criteria, and attempt to address these tradeoffs explicitly.

Two monitoring design workshops were undertaken in Portland by CSMEP participants in FY2008 (December. 5 and 6, 2008 and February 11 and 12, 2008) to further explore how best to integrate the strengths of existing monitoring with alternative approaches that help to deal with their weaknesses. The CSMEP design process is fully outlined in Proposed Evaluation and Design of Preliminary Design Templates (Parnell *et al*. 2005) available on the CSMEP website. CSMEP has continued in FY2008 with development of analyses and tools that build on the Snake River pilot work (CMSEP 2007a, 2007b). CSMEP had to defer any further work on habitat or harvest effectiveness monitoring designs due to budget reductions in FY2008 and concentrated design efforts on S&T monitoring, hatchery and hydrosystem effectiveness monitoring, and monitoring integration. Participants in CSMEP's design domain subgroups during FY2008 are listed in Table 2.1

CSMEP continued their outreach efforts to other M&E entities in the Basin. These efforts included a presentation to the ISRP of the Snake Basin Pilot Study. The ISRP compiled their favorable review of CSMEP's work in ISRP 2008-1 (2008; http://www.nwcouncil.org/library/isrp/isrp2008-1.pdf). CSMEP also organized a symposium on regional monitoring and evaluation approaches at the Western Division American Fisheries Society (AFS) conference in Portland May 4-7, 2008. CSMEP participants presented many of the analyses developed for the Snake Basin Pilot work at this symposium. A presentation on CSMEP's Cost Integration Database Tool (ICDT) and Salmon Viability Monitoring Model (SVMM) (both developed for the Snake Basin Pilot Study) was also given to the Pacific Northwest Aquatic Monitoring Partnership (PNAMP) steering committee in Portland on August 28, 2008. CSMEP participants attended meetings of PNAMP's Fish Population Monitoring Workgroup and provided input into Pacific Region fish population metadata inventories being developed by NOAAF. CSMEP's short easy-to-understand brochure with a description of CSMEP's approach and M&E products has been circulated regularly by CSMEP participants at conferences and other venues.

Table 2.1. Participants in each of the CSMEP design domain subgroups in FY2008.

I)	**Status and Trends** of Listed Species/Stocks for Extinction Risks and Recovery Evaluations: Alan Byrne (IDFG), Darcy Pickard (ESSA), Ken MacDonald (CBFWA), Tom Rien (ODFW), Eric Tinus (ODFW), Dan Rawding (WDFW), Paul Wilson (USFWS), Casey Baldwin (WDFW), Rick Orme (NP), Marc Porter (ESSA), John Arterburn (CTCR)
II)	Effects of **Habitat** Restoration Actions: CSMEP did not have a dedicated Habitat subgroup in FY2008 due to funding limitations
III)	Effects of **Hydrosystem** Operations: Charlie Petrosky (IDFG), Paul Wilson (USFWS), Tom Berggren (FPC), Katherine Wieckowski (ESSA) David Marmorek (ESSA)
IV)	Effects of **Hatchery** Operations: Chris Beasley (NP-Quantitative Consultants), Peter Galbreath (CRITFC), Lyman MacDonald (WEST), Jay Hesse (NP), Marc Porter (ESSA)
V)	Effects of **Harvest** Management Decisions CSMEP did not have a dedicated Harvest subgroup in FY2008 due to funding limitations
VI)	**Integration of Monitoring** Across Domains Ken MacDonald (CBFWA), Alan Byrne (IDFG), Jay Hesse (NP), Dan Rawding (WDFW), Tom Rien (ODFW), David Marmorek (ESSA), Marc Porter (ESSA), David Carr (ESSA)

2.1 Status and trends

Comparing alternative monitoring designs requires specific information about the populations within each ESU. A useful strategy is to describe the status-quo monitoring programs in each population and evaluate how accurately they are able to generate the four types of data required to assess viability: abundance, productivity (age-structure), spatial structure, and diversity (McElhany *et al*. 2000). It should then be possible to identify populations where insufficient data are available to adequately assess viability and suggest alternative monitoring activities that would overcome these insufficiencies. In populations with extensive monitoring it would be valuable to consider the consequences of reducing monitoring effort. Populations with physical limitations or other unusual characteristics should be noted. For example: some populations may not have a suitable location for a weir; or may have extensive overhead vegetation making aerial surveys impossible.

CSMEP's Status and Trends Subgroup has developed a simulation model that can be used for evaluating alternative designs for monitoring fish at the population, major population group (MPG) and Evolutionary Significant Unit (ESU) scales. Alternative monitoring designs can be compared in terms of accuracy, precision, and the probability of error in viability decisions that are associated with each design. To use the simulation model effectively it is important to have good qualitative and quantitative understanding of the strengths and weaknesses of the current monitoring in place (e.g., how accurate is a redd survey or a weir estimate for this population?). Given this information, the simulation model can be used to compare a number of alternative strategies helping managers understand the impact of different on-the-ground strategies to assess viability and associated listing decisions. CSMEP's simulation model provides a tool for assessing variability in data used to measure abundance, productivity, spatial structure, and diversity. By employing misclassification rates to describe errors in ascribed risk levels, it allows evaluation of the sensitivity of the IC-TRT viability criteria to changes in the quality of monitoring data employed, and provides quantitative comparisons of the reliability of status quo monitoring vs. alternative designs.

In FY2008 this simulation model was enhanced to be a more realistic, flexible, and user friendly tool. The input adult abundance data now has a known age-structure. The improved version of the model has options that allow the user to vary the monitoring effort related to assessing age-structure (which affects the assessment of productivity) in addition to abundance, spatial structure, and diversity. Each option smoothes the age-structure estimates across populations to a different degree (see Beamesderfer *et al*. 1997 for methodology and rule set):

1. Use a population specific age structure for each population in each year (requires a minimum of 20 samples per population per year). This is the preferred option.
2. Use a MPG specific age structure estimate by combining age information from populations within the MPG (requires a minimum of 20 samples per year from the MPG). This option is used if population specific data are not available.
3. Use the long term average age structure obtained from a population within the ESU and apply it to all populations (no sample size constraint). This is the least preferred option and is used only if there is no data to use option 1 or 2.

To apply the model to other Chinook and steelhead ESUs for viability assessments, the Status and Trends Subgroup completed analyses in FY2008 of the strengths and weaknesses of existing monitoring data for Chinook and steelhead ESUs in the Snake River Basin and the Upper, Middle and Lower Columbia River (see Section 3.2). These assessments provide the necessary information on the current monitoring infrastructure in place and the data available to allow the simulation model to be modified for viability assessments in other ESUs.

The viability monitoring simulation model itself was made more flexible by allowing users to vary monitoring designs year by year as well as by population. The model was also made flexible enough to work with other ESUs, although at this point it is limited to using only the IC-TRT decision rules. It is anticipated that additional modifications of the model will eventually be required to account for variation in decision rule sets that were developed for other recovery regions (e.g., Willamette/Lower Columbia). A graphical user interface (UI) was created to make it easier for users to work with the model to develop additional monitoring scenarios. A linked database was developed that stores all the input data scenarios and results. A user guide was developed to walk the user through application of the model. The viability simulation model and the associated user guide are now available for download from the CBFWA website.

2.2 Hydrosystem

CSMEP's Hydro Subgroup originally tackled a set of ten hydro management questions across several scales: individual projects, survival by different passage routes through the hydrosystem, and overall life cycle survival. These different scales related to a variety of decisions: operations at individual projects (e.g., spill, bypass, removable spillway weirs); overall operations (e.g., when to transport fish within season, compliance with hydrosystem biological opinions), longer term hydrosystem decisions (e.g., flow management, effectiveness of transportation over multiple years, system configuration); and adequacy of hydrosystem operations for stock recovery. Moving along these scales, the performance measures of interest change. Performance measures range from direct survival at and between dams, to smolt-to-adult survival rates (e.g., smolts leaving Lower Granite Dam to adults returning there 2-3 years later) to inferences about delayed mortality from contrasts in mortality patterns (contrasts in recruits/spawner or smolt-to-adult survival rates).

In FY2008 the Hydro group extended their work on these hydrosystem decisions to Snake River and Upper Columbia ESA listed steelhead. The four hydro effectiveness questions evaluated by CSMEP for steelhead in FY2008 are listed in Table 2.2. Analyses for these are described in detail in Appendix B.

Table 2.2. Steelhead hydrosystems effectiveness questions addressed by CSMEP in FY2008.

Steelhead Hydro Effectiveness Questions
1. Is SAR sufficient for a) NPCC goal and b) recovery goals?
2. Is transportation more effective than in-river passage?
3. How does annual in-river survival of steelhead (Lower Granite Dam (LGR) to Bonneville (BON)) compare to 2000 FCRPS BiOp performance standards?
4. How does effectiveness of transportation change over the course of the season?

To date, neither NOAA and USFWS Biological Opinions, nor NPCC documents have specified limits on decision errors related to the questions in Table 2.2. Therefore the Hydro Subgroup used various models and statistical methods to examine *hypothetical* decision rules and the potential decision errors associated with these hypothetical rules under different monitoring and evaluation designs. Decision errors were measured by a variety of metrics. Alternative designs included varying the number of PIT-tagged steelhead, and the level of accuracy and precision in data that are collected.

1. Determining whether SAR goals have been met under different M & E designs

Determination of whether the 2% SAR goal has been met does not appear to improve under the Medium and High design alternatives relative to the Status Quo, for hatchery steelhead. This result is a consequence of the annual SAR estimates being substantially less than the 2% SAR minimum. The benefit of a reduction in estimated uncertainty that is expected from an increase in tag numbers is therefore not realized under the condition of very low SARs. However, when the value of the annual SAR estimate is such that its Status Quo CI straddle 2% SAR, moving to a Medium or High design would allow compliance to be determined with greater frequency.

2. Determining transportation effectiveness under different M & E designs

In general, transport SARs were higher than in-river SARs in most years for Snake River wild steelhead (1997 to 2003). The low number of adult returns makes it difficult to determine with a high degree of confidence whether in a given year transportation improved overall survival of hatchery steelhead compared to leaving fish in-river (transportation effectiveness can only be determined in 2/7 years). The ability to definitively determine whether survival is higher for transported fish or in-river migrants is contingent on two things: 1) the degree of difference between the transport in-river ratio (TIR) estimate and the value of 1 (i.e., the closer the TIR estimate is to 1, the harder it is to distinguish which is better); and 2) the width of the 90 percent CI on the TIR estimate, coupled with whether the confidence interval straddles the value of 1. For wild steelhead it is not possible to increase tagging efforts because of the small population size; an action that if feasible, would help to decrease CI width. For hatchery steelhead, however, the increased PIT tagging of the Medium and High designs improves the ability to ascertain the relative survivals by alternative down-river routes relative to Status Quo.

3. Determine whether in river-survival rates meet 2000 BiOp performance standards under different M & E designs

The FCRPS BiOp set a performance standard of 50.6 percent for smolt survival from LGR to BON dam. During the period from 1997 to 2003, Status Quo monitoring made it possible to determine compliance with the BiOp standard in 3 of 7 years for both wild and hatchery steelhead. Increasing the number of PIT tags for hatchery steelhead would result in an increased ability to assess compliance (5 of 7 years under Medium and High alternatives).

4. How does effectiveness of transportation change over the course of the season?

SARs appear to be higher for wild steelhead collected and transported during all quartiles, compared to wild steelhead migrating in-river, given each season's in-river conditions duing the period of our analysis (1997 to 2003). Other in-river migration conditions could result in different in-season TIR ratios. Seasonal TIR estimates calculated annually and pooled over a multi-year period will likely be needed to assess whether seasonal TIR objectives are met within a target level of precision and accuracy. Increasing the number of PIT tags per year will improve the precision of annual and seasonal estimates, but for transportation evaluations a very large increase in tags would be required to make substantive improvements over the *Status Quo* design we evaluated. Adding more years of PIT tag observations, however, can significantly improve statistical precision. The ratio of transport SARs and in-river SARs, whether estimated on an annual basis or for discrete in-season timeframes, will be influenced by in-river migration conditions caused by manipulation of the hydrosystem, climatic conditions, or a combination of both. If in-river out-migration conditions vary from year to year, survival evaluations using multiple year estimates may hide important year to year differences in the relative effectiveness of transportation to recover and sustain populations

2.3 Habitat

CSMEP budget limitations in FY2008 precluded any further work by the Habitat Subgroup on analyses related to alternative designs for monitoring habitat action effectiveness.

2.4 Harvest

CSMEP budget limitations in FY2008 precluded any further work by the Harvest Subgroup on analyses related to alternative designs for monitoring habitat action effectiveness.

2.5 Hatchery

In FY2008 the CSMEP Hatchery Subgroup focused on continued collaboration with the AHSWG on developing regional-based hatchery designs and development of a statistical approach to calculate sample size requirements for RRS studies.

AHSWG Collaboration

The AHSWG gained significant momentum in FY2007, which continued into FY2008, and currently benefits from substantial collaboration with nearly all Columbia River Basin fish management entities. The CSMEP Hatchery Subgroup placed the bulk of their FY2008 effort into fuller collaboration with the

AHSWG, in order to capitalize on the greater interagency support available within that group. This joint AHSWG and CSMEP effort resulted in substantial progress in FY2008, generating a comprehensive "three-pronged" approach to assessing the impacts of supplementation on the long and short-term abundance and productivity of targeted populations (Galbreath *et al.* 2008). This approach consists of three components:

1. standardizing monitoring approaches with respect to "viable salmonid population" (VSP) metrics for use in a large-scale treatment versus reference (T/R) analyses of supplemented versus un-supplemented populations;
2. implementation of a relative reproductive success (RRS) study in a representative subset of anadromous salmonid populations; and
3. identification of a number of small-scale studies aimed at identifying the mechanisms underlying observed fitness reductions in supplemented populations.

Component 1 of the AHSWG approach satisfies the data requirements for the stray ratio design developed initially by CSMEP in FY2007. Additionally, within the AHSWG, we identified how components 1 (standardized T/R design) and 2 (RRS studies) could be viewed simultaneously to reduce the uncertainties associated with either approach when implemented independently.

Component 2 of the AHSWG design was initially based on the RRS design elaborated in the CSMEP FY2007 annual report (Marmorek *et al.* 2007). However, in FY2008 the groups diverged with regard to the statistical approach for selecting study populations. Briefly, the CSMEP relative reproductive success (RRS) design utilized a systematic random sample across the range of proportionate natural influence (PNI) scores observed for Columbia River Basin hatcheries. PNI provided a means to select populations for RRS studies. As the CSMEP and AHSWG projects collaborated to calculate project-specific PNI values for Columbia River Basin Hatcheries, it became clear that most programs exhibited substantial variance in PNI over time. Thus, the systematic random sample approach developed by CSMEP would require selected hatchery programs to limit variance in PNI over the course of the study.

Alternatively, the AHSWG elected to abandon PNI as a means to achieve a statistical sample of hatchery programs, and instead focused selection on programs that have consistently monitored VSP criteria since inception. Also, the AHSWG design includes a much larger sample of populations, which includes six stream-type Chinook salmon populations, similar to the CSMEP design, as well as six supplemented steelhead populations and two ocean-type Chinook salmon populations. Additionally, the AHSWG design recommends the cessation of supplementation in at least five or six stream-type Chinook salmon populations, several steelhead populations, and at least one ocean-type Chinook salmon population.

The primary tradeoff between the designs is the ability to apply the results to other hatchery programs. Because the CSMEP design proposed to utilize a statistical sample of populations, the results of that design could be extended to un-sampled populations in a statistically valid manner. Alternatively, because the selection of study populations in the proposed AHSWG design is non-random, the application of those results to un-sampled populations is not strictly statistically valid. However, given the much larger sample size included in the AHSWG design, the applicability of results from either design may be similar.

Sample size requirements for RRS studies

In CSMEP's FY2007 annual report (Marmorek *et al.* 2007) the CSMEP Hatchery Subgroup recognized the need to determine adequate juvenile sample sizes to conduct RRS studies. Three sources of sampling variation can be identified in RRS studies that are measured at the juvenile life stage: adult enumeration, juvenile enumeration and genotyping error (Galbreath *et al*. 2008). Current methods for estimation of

RRS are considered biased. A critical need exists for information on precision and confidence intervals for RRS or statistical power in RRS experiments. In order to evaluate the statistical power of RRS estimates a statistical model was constructed in FY2008 to correct for bias in estimation of RRS, as well as to calculate necessary sample sizes for determining RRS under a range of assumptions (see Appendix A). The model by the Hatchery subgroup provides sample size guidance for establishing required levels of precision in RRS studies where it is expected that offspring sampling will be incomplete. The basic method 'corrects the zeros' in studies of RRS. Point estimates of RRS for specific subsets of the data with standard errors and confidence intervals can be obtained using the R program 'manly.main' in conjunction with built-in R functions for bootstrap estimates. The program along with instructions for use and an example are given in Appendix A.

2.6 Synthesis and integration

Identification of common fishery management decisions in multiple agencies

Collaboration and coordination among agencies within the Columbia River Basin are important to develop cost effective monitoring and evaluation programs for fish populations that cross multiple jurisdictions. Monitoring programs need to support the reporting and decision making within individual state or tribal jurisdictions, as well as regional forums such as the Columbia Basin Fish and Wildlife Authority, Northwest Power and Conservation Council's Fish and Wildlife Program, the FCRPS, Biological Opinion (BiOp), harvest management through US *vs.* Oregon and the ocean fishery management forums, and the federal Endangered Species Act (ESA)

Status and trends monitoring of fish populations provides the foundation of a regional M&E program and provides information about the population trend and abundance. Action effectiveness monitoring of the hydrosystem, habitat, harvest, and hatcheries (All-H) provides information to assess management actions and fish population responses. A program that integrates status and trend with All-H action effectiveness monitoring can provide an economy of scale, prevent duplication of effort, and is cost effective (CSMEP 2007a). An integrated approach helps managers understand environmental stressors and sources of mortality throughout the anadromous and resident fish life cycle (Figure 2.1). An integrated regional M&E program allows fish managers to collaboratively recommend, implement, and modify monitoring efforts across jurisdictional boundaries within an adaptive management framework (Figure 2.2).

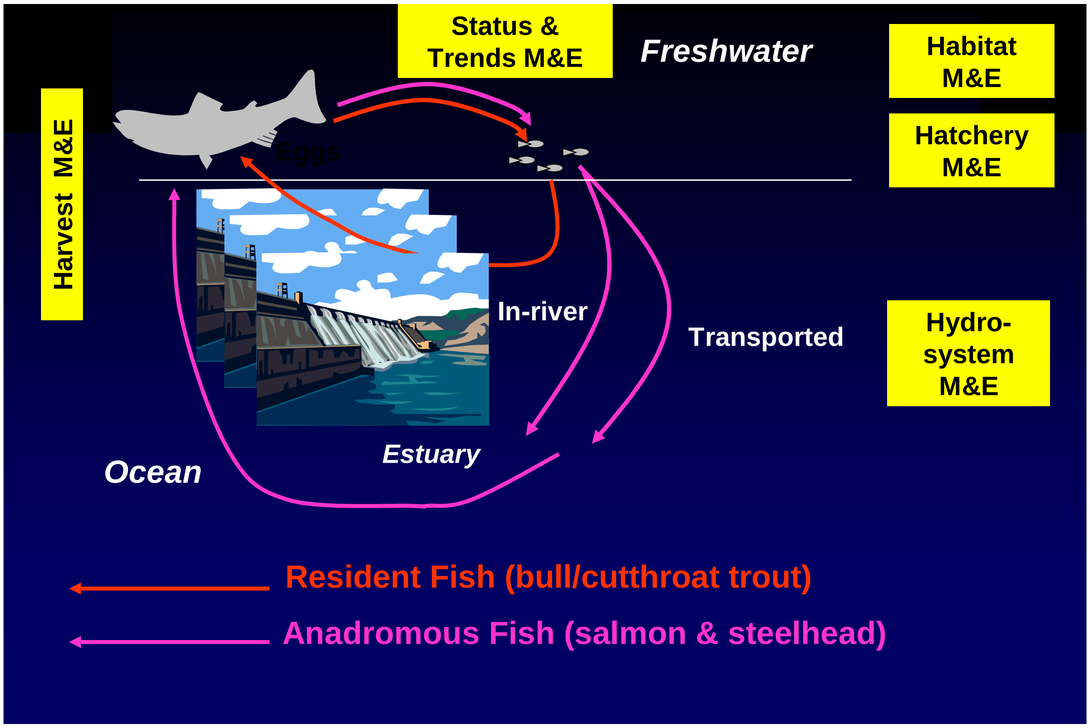

Figure 2.1. The life cycle monitoring context as it applies to fish populations in the Columbia River Basin.

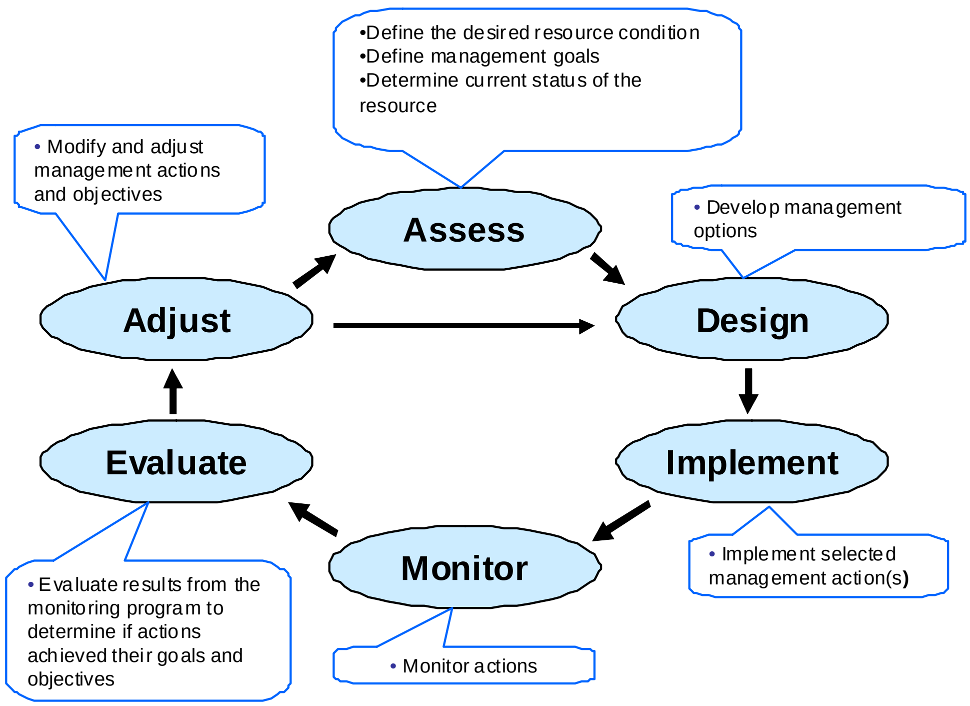

Figure 2.2. The adaptive management framework.

In FY2008 CSMEP identified management decisions that are made either routinely or infrequently by fish management agencies in the Columbia River Basin. The identification of common decisions by the various agencies throughout the Columbia River Basin allowed CSMEP to highlight areas that require a coordinated inter-jurisdictional approach to develop a regional M&E plan in the Columbia River Basin. CSMEP used the following approach for this task:

1. Survey the management agencies for decisions made on a frequent basis (seasonally or annually) and those made on a more infrequent basis.
2. Identify those decisions which are primarily made under local jurisdiction versus those that may require collaboration or coordination with multiple managers.
3. Identify CSMEP work tasks, with the CBFWA amendment recommendations to the NPCC Fish and Wildlife Program, and FCRPS Reasonable and Prudent Alternatives (RPA) to confirm if the identified tasks were still priorities to meet collaborative monitoring needs and identify additional areas where collaborative monitoring is needed (Appendix C).

Status and trends monitoring

Status and trends monitoring helps the managers determine the population status and trend relative to its desired condition or objective. Management decisions include: (1) what level of intensity and approach of monitoring is required to describe the condition of the resource and provide data needed for management?; (2) is the species viable and able to support a fishing season?; (3) if the species is not viable does it warrant protection under ESA?; (4) does a species require management intervention to achieve agency goals and should implementation of these actions be pursued?; and (5) for ESA listed species, can they be delisted? Many of these decisions are based on VSP criteria and limiting factors and threats analysis collected at the population scale that are then aggregated at the MPG and ESU or Distinct Population Segment (DPS) scale. Data to inform VSP metrics at the population scale must be collected annually with a viability assessment at the ESU/DPS scale conducted every five years.

Action effectiveness monitoring

Action effectiveness monitoring is used to assess, evaluate, and modify management actions and activities. Decisions within each category are listed and organized for each of the All-H’s (habitat, harvest, hatcheries, and hydrosystem).

Habitat Habitat actions can be defined as any activity designed to improve fish abundance or productivity (screening diversions, acquiring easements or water rights, in-stream alterations and structures, riparian plantings, fencing, etc.). Most of the habitat decisions involve coordination with land management agencies and private landowners. They can be summarized as:

1. Identify streams and sites for habitat actions.
2. Develop a habitat improvement or restoration plan for each site/stream.
3. Implement specific habitat actions.
4. Develop an M&E plan to assess results of the habitat actions.
5. Alter, adjust, and modify habitat actions and plans based on knowledge gained from M&E of habitat actions that were implemented.

Harvest Harvest is the arena in which most fisheries management agencies expend a lot of time and effort. Information is needed to inform the following management decisions:

1. Are expected adult returns sufficient to support harvest?
2. How to allocate harvest among all user groups?
3. Set fishing season (opening and closing dates).
4. Set location of fishery.
5. Set fishing regulations (gear, limits).
6. Develop and implement surveys to estimate harvest and incidental "take" of target and non-target species.
7. Adjust regulations "in-season" if necessary.
8. Post-season evaluation of the fishery. These include: were pre-season estimates of abundance accurate; were harvest objectives met; were wild escapement goals met; were hatchery broodstock goals met; were the impacts to non-target and wild fish acceptable?

Hatcheries All hatcheries have decisions for routine operation procedures including broodstock management, spawning procedures, culling eggs/fry, disease monitoring and treatment, diet and feeding, marking fish, release location and release dates. These decisions are made in the context of individual hatchery management programs and are not collaborative in nature; however they may be informed by broader scale harvest decisions and M&E needs.

Hatchery decisions that are made within broader regional context include:

1. Initiate a hatchery program.
2. Develop goals and objectives for a hatchery program consistent with regional goals.
3. Develop the hatchery operation plan consistent with regional goals.
4. Develop a marking and mark sampling plan (adipose clip, PIT-tagging, CWT) consistent with regional goals.
5. Determine release sites, numbers and life-stage for release.
6. Modify and adjust hatchery program based upon M&E if objectives are not being met.
7. Terminate a hatchery program.

Hydrosystem Fish management agencies do not operate the hydrosystem. However, they participate in multi-agency forums and recommend actions for operating the hydrosystem to benefit fish. The decisions include:

1. Develop hydrosystem operation plan (spill, transport, structural improvements).
2. Determine if salmon and steelhead juvenile and adult hydrosystem passage performance objectives are met.
3. Modify, adjust, and alter hydrosystem operations based on knowledge gained from M&E.

Status and trends and All-H monitoring programs need to inform local agency decisions as well as decisions made in broader regional forums. These programs should be integrated to the extent possible to be cost effective and prevent duplication of effort. For example, an integrated regional PIT-tag program can provide data to assess status and trends of wild populations, life-cycle survival, assessment of hydrosystem passage performance objectives, and estimate the number of returning hatchery adults thereby improving the ability of managers to craft fisheries and allocate harvest. An integrated regional monitoring program requires the collaboration and coordination among the many agencies that will implement the program and use the data to make decisions within the adaptive management framework.

Identifying the priority decisions across monitoring domains represents a first step towards clearly defining the necessary performance measures for monitoring and the relevant spatial scale(s) of these data for varied subgroup monitoring needs. CSMEP has been exploring the integration of the individual M&E component parts within a larger monitoring framework (i.e., generation of improved efficiencies for capturing required performance measures through integrated designs). Integration of monitoring effort across scales and subgroups, illustrated in Figure 2.3., is a challenge faced by all subbasins. To assist in the planning and associated costing of integrated designs CSMEP has developed an Integrated Costs Database Tool that will allow M&E designers to integrate monitoring costs for shared performance measures at a variety of spatial scales to achieve greater efficiencies across monitoring programs. CSMEP's Integrated Costs Database Tool and its associated user guide are available from the CBFWA web site (http://www.cbfwa.org/csmep/web/Content.cfm?ContextID=1).

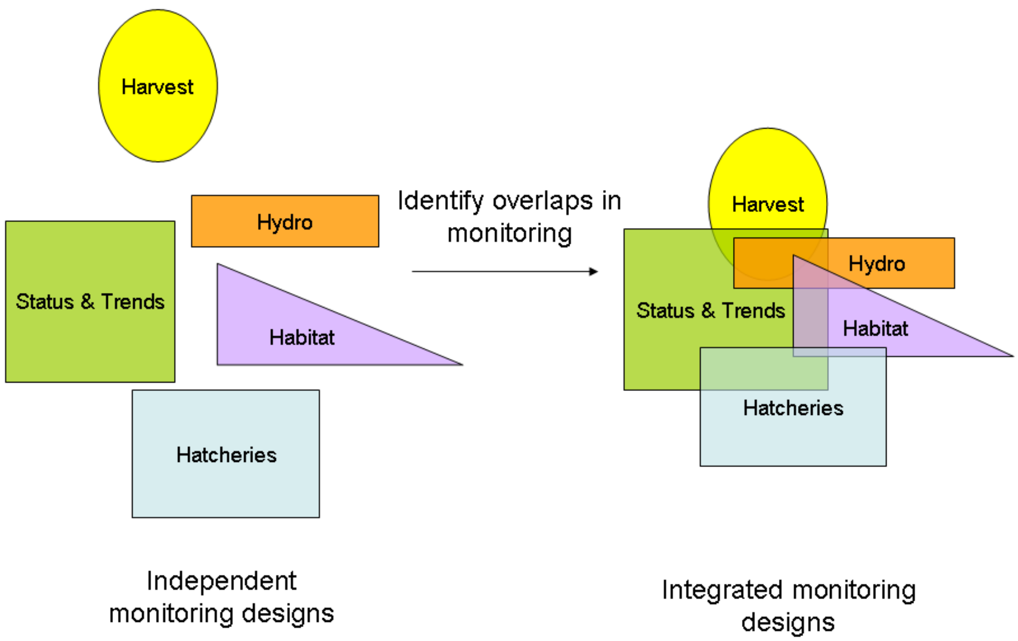

Figure 2.3. Conceptual illustration of integration of monitoring across M&E domains.

Table 2.3. CSMEP programmatic and technical interactions in FY2008.

Entity	Purpose of Interaction
Pacific Northwest Aquatic Monitoring Partnership (PNAMP)	Explain CSMEP workplan, continue to refine project / program descriptions, examine PNAMP and CSMEP workplans to prevent duplication of effort. Attended PNAMP meetings to promote ideas and receive feedback.
NOAAF	Provide support on NOAA inventory efforts
Technical Recovery Teams (TRTs) for the Interior and Lower Columbia, Willamette	Get input from TRT to inform S & T designs and simulation models
BiOP Remand groups	Get the Remand groups' input on CSMEP approaches to M&E designs (particularly for Hydrosystem) and simulation models
Ad Hoc Supplementation Group	Obtain assistance in gathering necessary datasets. get Ad Hoc groups' input on CSMEP approaches to M&E designs for hatchery questions
Independent Scientific Review Panel	Present the results of CSMEP's Snake River Basin Pilot Study

CSMEP is working to ensure that analyses and monitoring designs explored as part of the project are consistent with the overarching objectives of Columbia River Basin monitoring agencies. Table 2.3 provides a summary of CSMEP interactions with aquatic monitoring entities throughout FY2008.

CSMEP has begun to assess where elements of their separate subgroup designs may converge across monitoring domains (spatially, temporally, ecologically and programmatically). Identification of the common elements within the designs can provide the initial 'building blocks' to further develop a Columbia River Basin-wide integrated M&E program to address a larger suite of management questions. This will be an iterative learning process, through which agencies can identify workable strategies for simultaneously addressing multiple questions across domains.

Strategies for integration that CSMEP has explored include:

1. *Building on a Status & Trends foundation.* Layering of action effectiveness M&E alternatives on a consistent foundation of spatially representative Status and Trends monitoring.
2. *Integration within domains*. Evaluating how alternative designs could best address multiple questions within a particular M&E domain (i.e., Hydrosystem, Hatchery, Harvest, Habitat, or Status & Trends specific).
3. *Integration across domains*. Evaluating how alternative designs could best address multiple questions across M&E domains (e.g., what elements of each subgroup's designs can serve multiple functions).
4. *Maximizing benefits of monitoring techniques*. Evaluating how any particular monitoring technique can help address multiple questions across M&E domains (e.g., PIT tagging to address a suite of questions).
5. *Maximizing sampling efficiencies and minimizing redundancies in designs*. Evaluating shared costs and data gathering opportunities across overlapping designs.

Integration of M&E depends on the policy and management priorities of each domain and its constituent questions. Consequently, there is no “optimal” design that will exactly suit the preferences of all agencies. Therefore, program managers will need to iteratively review and collaboratively revise integrative strategies and designs. To assist this process CSMEP has continued to develop through FY2008 a suite of analytical tools and simulation models that will allow managers and scientists to jointly explore alternative M&E designs and associated trade-offs (i.e., statistical power, costs, sampling effort, etc.).

3. Subbasin Inventory and Evaluation

3.1 Subbasin inventory work

CSMEP's previous metadata inventories describe, in a systematic manner, the kinds of information currently available on the abundance, productivity, spatial distribution and diversity of salmon, steelhead and resident fish species of concern and are available at the StreamNet website (csmep.streamnet.org). CSMEP and StreamNet were unable to add new inventory metadata to the website in FY2008 due to budget cutbacks. Information collected in FY2008 included data on Chinook and steelhead from the Snake River and the Lower, Mid and Upper Columbia. This information has been summarized in the strengths and weaknesses assessments described in Section 3.2.

3.2 Strengths and weaknesses assessments

Throughout FY2008 CSMEP biologists continued with their evaluations of the strengths and weaknesses (S&W) of fish inventory data (Table 3.1) and applied the EPA Data Quality Objectives process (EPA 2000) to summarize M&E objectives and activities for each area. The strengths and weaknesses reviews identify areas where fish monitoring is currently being done well, in addition to uncovering inferential weaknesses and data gaps that will be important to address in agency monitoring designs. CSMEP's work for FY2008 was focused on Lower Columbia Chinook and steelhead, Snake River fall Chinook, Upper Columbia Spring Chinook and steelhead, and Middle Columbia River Chinook and steelhead. These FY2008 data assessments are available in Appendices D to J of this report, while others assembled over the years of the CSMEP project can be accessed on CBFWA's public website or in CSMEP Annual Reports from FY2004 to 2007 (Parnell *et al*. 2005; Porter *et al*. 2005; Marmorek *et al* 2006, 2007).

Table 3.1. Data strengths and weaknesses (S&W) assessments completed in FY2008 within Idaho, Oregon and Washington by ESU/DPS and species. The detailed S&W assessments are presented in Appendices D to J.

State	ESU / DPS	Species
Idaho	Snake	fall Chinook
Oregon	Mid Columbia	spring Chinook
Washington	Mid Columbia	spring Chinook
	Upper Columbia	spring Chinook steelhead)
	Lower Columbia (upstream of Bonneville Dam)	steelhead spring/fall Chinook

3.3 CSMEP public website and web data application

The CSMEP publicly accessible website is maintained by CBFWA. This site hosts the large body of CSMEP products (i.e., analyses, reviews, presentations, reports) that has been developed over the five years of the project.

CSMEP (with StreamNet's assistance) also continued to maintain their centralized web-based data application (managed by the regional StreamNet office in Portland) to store and allow access to CSMEP inventory metadata and data assessments (user name: CSMEP, password: CSMEP). No new inventory data was added in FY2008 due to CSMEP and StreamNet funding constraints. However, there were over 1,550 metadata records relating to fish population and fish habitat monitoring studies from across the Columbia River Basin that were previously entered.

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Appendix A.
A Correction of Bias and Necessary Sampling Effort for Estimation of Relative Reproductive Success

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Introduction

Current methods for estimation of Relative Reproductive Success are biased. A basic and apparently unsolved problem exists in the estimation of Relative Reproductive Success (RRS) (Chris Beasley, Quantitative Consultants, and Michael Ford, NOAA Fisheries, personal communications). RRS is defined as the ratio of offspring per hatchery parent spawning naturally to offspring per wild (natural spawned) parent spawning naturally (Hinrichsen 2003, Araki *et al*. 2008). Table A1 presents the form of a simple hypothetical data set for which one may wish to estimate the RRS. The problem stems from the fact that, e.g., a hatchery male (#2 in Table A1) may be known to have been on the spawning ground, because he was released above a weir or his carcass was seen on the spawning ground, however no offspring are observed in samples of parr, smolt, or returning adults. If the zero offspring for male #2 is left in the data set, the results are biased negatively for the fitness of hatchery males, because offspring could have been produced but none were observed in the samples of parr, smolt, or returning adults. If the zero for male #2 is removed from the data set, the results are biased positively for the fitness of hatchery males, because the average fitness of hatchery males with observed offspring is being estimated and there are likely some hatchery males that did fail to produce offspring.

Table A1. Matrix of data of interest for RRS studies.

sample	Sex of Parent M(0) F(1)	Number of offspring	origin	age	Weight (kg)
1	M	4	H	3	14
2	M	0	H	4	16
3	M	6	W	4	18
4	M	2	W	4	22
5	F	12	H	4	24
6	F	0	H	5	28
7	F	16	W	4	25
8	F	22	W	5	28
…					

As it is likely that data will contain substantial zero offspring cases for a given parent (male, female, hatchery or wild) it is crucial to explicitly model this portion of the population to avoid biases in the estimation of fitness.

A correction for bias in estimation of RRS

This method, conceived by Dr. Brian Manly, WEST, Inc., depends on the assumption or verification that an appropriate model is available for the probability distribution of the 'true' number of offspring for a given parent. These discrete probabilities are denoted $P_0, P_1, P_2, \ldots, P_n$, for the probabilities of 0, 1, 2, … n offspring for a given parent. We chose to first implement the Poisson distribution with inflated zeroes to model the number of offspring (Johnson, Kotz, and Kemp, 1992). The Poisson model by itself is appropriate for counts greater than zero for this type of data in most cases, however the zero inflated Poisson allows for an excess of zeros followed by the standard Poisson for positive counts. Other models such as the negative binomial are candidates, and tests for the goodness of fit of the basic model to be used are necessary parts of the analysis. At this point in time, only the zero inflated Poisson model is programmed into the R computer software programs in the Appendix A1. Other models that can be considered and programmed, with tests for which are appropriate, are the Poisson, negative binomial, and the zero inflated negative binomial.

Let Q be the sampling probability of the offspring (assumed known or estimated). For example, Q may be equal to 1.0 if all returning adults are observed at a weir leading to the spawning ground, or Q may be estimated as the proportion of smolts sampled in screw traps during out migration. The probability of observing 0 offspring for a given parent is the probability of 0 offspring, plus the probability of 1 offspring times the probability of not observing the offspring in the sample, plus the probability of 2 offspring times the probability of not observing either of the two in the sample, …, etc., … The sum is continued until the terms are sufficiently small. In symbols, this is written as

(1) $\Pr ob(0) = P_0 + P_1(1-Q) + P_2(1-Q)^2 + P_3(1-Q)^3 + ...$

Similarly, the probability of observing 1 offspring is

$\Pr ob(1) = P_1 Q + 2P_2 Q(1-Q) + 3P_3 Q(1-Q)^2 + ...$,

and the probability of i offspring is

$\Pr ob(i) = P_i Q^i + P_{i+1}\binom{i+1}{i}Q^i(1-Q) + P_{i+2}\binom{i+2}{i}Q^i(1-Q)^2 + ...$, i = 0, 1, 2, 3, …,

where $\binom{i+n}{i}$ denotes the number of ways $i+n$ items can be taken i at a time.

In the zero- inflated Poisson model, the P_i are written as

$P_i = 1-\pi+\pi e^{-\lambda}\, when\ i = 0\ and\ P_i = \pi\frac{e^{-\lambda}\lambda^i}{i!}, when\ i > 0$, $where\ 1-\pi$ is the probability of zero offspring and π is the probability of observing at least one offspring when excess zeros come from a different generating process than non-zero counts and λ is the mean of the non-zero counts.

The values of i are the observed number of offspring corrected for the fact that only Q(100)% are observed in the samples. The number of offspring observed, o, for a given parent is expanded by multiplication by the factor $\frac{1}{Q}$ to estimate i, i.e., i = o/Q, for a given parent. The likelihood (equation 2) of the data is then written as the product of the probabilities of the observed numbers, the $\Pr ob(i)$, and is then maximized to estimate the zero inflation Poisson parameters, (π, and λ) that give $P_0, P_1, P_2, ..., P_n$ for an adult parent. The function ‘optim’ in the statistical software program R is used to numerically maximize the likelihood.

(2) $L(P_0, P_1, ...P_n) = \prod_{i=1}^{n} \Pr ob(i).$

Having obtained the maximum likelihood estimates of $\pi\ and\ \lambda$ and the probabilities of occurrence of 0, 1, 2, … offspring, $P_0, P_1, P_2, ..., P_n,$ the expected number of offspring can then be calculated as the sum of the probabilities of occurrence times the number of offspring. For example, the probabilities would be estimated for a hatchery (H) female (F) parent and the expected number of offspring estimated by:

$$(3)\ E(number\ of\ offspring \mid H, F) = 0 \cdot \Pr ob_{hf}(0) + 1 \cdot \Pr ob_{hf}(1) + 2 \cdot \Pr ob_{hf}(2) + \ldots + i \cdot \Pr ob_{hf}(i) + \ldots$$

For a wild (W) female (F) parent the probabilities would be re-estimated and the expected number of offspring would be:

$$E(number\ of\ offspring \mid W, F) = 0 \cdot \Pr ob_{wf}(0) + 1 \cdot \Pr ob_{wf}(1) + 2 \cdot \Pr ob_{wf}(2) + \ldots + i \cdot \Pr ob_{wf}(i) + \ldots$$

An estimate of RRS for hatchery females relative to wild females is then calculated as the ratio,

$$(4)\ RRS_{hf/wf} = \frac{E(number\ of\ offspring \mid H, F)}{E(number\ of\ offspring \mid W, F)}.$$

Confidence intervals and standard errors for estimated RRS can be obtained by re-sampling procedures implemented in the R program, ‘manly.main’ via the R boot and boot.ci functions as shown in Appendix A1a. If sufficient data are available, this program can be used to estimate RRS for other subsets of the data. That is other attributes of the parent influencing RRS such as age and weight might be considered. An example might be the RRS of age 4 hatchery males and age 4 wild males confined to a certain weight class.

Determination of Adequate Sampling Effort

Three sources of sampling variation can be identified in relative reproductive success (RRS) studies which are measured at the juvenile life stage: adult enumeration, juvenile enumeration and genotyping error (Galbreath *et al* 2008). A critical need exists for information on precision and confidence intervals for RRS or statistical power in RRS experiments. In this paper, we consider the effect of different levels of smolt sampling intensity on acceptable levels of confidence in the assessment of significance of estimated RRS different from 1. For this stage of the work it has been assumed that adult enumeration is complete with 100 percent of adult escapement genetically sampled. It is also assumed that the assignment of offspring to their respective parents is without error.

Studies without a sufficient sample size, i.e., Q is too small, will result in a failure to detect a significant effect when it exists; however, there is often a high cost associated with field collection and genetic evaluation of large samples of parr, smolt and adults (Murdoch et al. 2007). This consideration makes sample size (power) a crucial step in designing RRS studies. One approach is to develop simulation models which would assist investigators in choosing adult and juvenile sample sizes that could be expected to attain a desired level of precision in the estimation of RRS. The models should be based on real data to reflect, actual expected data distributions, sampling rates, and hatchery – wild escapement conditions similar to those expected for the particular location or region of a proposed study (Berejikian et al. 2004). However users could create their own hypothetical input data to reflect alternative smolt abundance, fitness levels and adult covariate scenarios.

This report describes a method for examining alternative sample sizes, i.e., the proportion of parr, smolt, or returning adults, Q, to sample for parentage analysis. The objective is to meet precision and power requirements in RRS studies in which the number of offspring per hatchery parent is to be compared to the number of offspring per wild parent. The overall objective is to provide a flexible tool for researchers in RRS studies which would allow them to design experiments that would attain chosen levels of statistical power at optimal sampling rates of parr and smolt for genetic assignment. A proposal for future work is given at the conclusion of this report that would extend the boundaries and assumptions of current work to include adult enumeration variability, genotyping error and full development of computer programs as well as a Monte

Carlo study of potential fitness estimation bias and the effectiveness of the Manly program to correct for bias.

Determination of Q to meet precision requirements in RRS studies

We examine alternative sample sizes to meet precision requirements in RRS studies using the bootstrap percentile method or power simulation algorithm (Beran 1986), but without correction for estimation of non-zero offspring for cases in which the sampled data show zero offspring, i.e., without correcting the zeros. As we understand the current state of knowledge, researchers are analyzing their data without correcting the zeros. Also, our professional judgment is that recommendations for sample sizes to meet precision using this method will not vary much from recommendations that may be made when correcting the zeros. Future work would include determination of adequate sample sizes and sampling rates (Q) when correcting for zeros using the Manly model.

When there are adults which have not been sampled, the case of incomplete adult enumeration, the effect is similar to that of reducing Q, decreased power to detect RRS different from 1 . This is because progeny of the missing adults cannot be assigned to their respective parents. Thus the total number of assigned offspring is reduced and precision to estimate fitness is lower. If adults are sampled in an unbiased manner, e.g., genetic information is randomly collected on 50% of the adults, then Q will effectively be reduced by the sampling fraction. That is, if 50% of the adults are sampled then it will only be possible to identify the male parent (or the female parent) of approximately 50% of the sampled juveniles. In the case of random collection of genetic samples from the parents, this section can be used to help determine the proportion of juveniles for which parents can be determined, i.e., the effective value of Q. In the case of an experiment in which incomplete adult enumeration is expected, the sampling fraction, Q, could be increased to help offset the effects of the missing adults for which offspring will be unassigned. Use of the programs then could assist fisheries investigators in the design of an RRS experiment where errors in adult enumeration are expected by allowing them to set sampling rates sufficient to offset the lowered power due to missing parent fish.

The case of incomplete adult enumeration may or may not result in unbiased estimates of fitness and RRS. Certainly RRS would be more likely to be biased if adults were missing disproportionately by origin of adult or level of fitness.

The most general approach uses the superpopulation non-parametric bootstrap that takes into account the potential finite sampling nature of smolt collections for subsequent parentage assignment (Davison and Hinkley, 1997). The use of infinite population methods in finite sampling problems results in an overestimation of variance (Thompson, 2002; Davison and Hinkley, 1997). Thus offering a technique for handling the finite sampling case for studies in which Q is greater than 0.1 seems appropriate. If Q < 0.1, this step can be skipped and there will be a savings in required computer time. When Q > 0.1 there is an advantage of shorter confidence intervals. The finite nature of the sampling is mimicked by creating a bootstrap super-population, concatenating $\frac{1}{Q}$ copies of bootstrap re-samples from the original data. Adjustments are available for the case when $\frac{1}{Q}$ is not an integer (Davison and Hinkley, 1997). The bootstrap superpopulation is then sampled without replacement at the original sample size to achieve one bootstrap sample. RRS is computed from the re-sample datasets as well as a bootstrap standard error. The superpopulation bootstrap program plots standard errors against user selected alternative Q values (Figure A1). Suppose it was of interest to know the standard error of RRS at a value of Q equal to .30 when the original input data was collected under a sampling scheme that allowed a Q of only .10. The user would input these two values of Q when running the program along with the name of the dataset. The first step is to create a facsimile of the original population. In the case of Q = .10, 1/.1 or 10 copies of the original dataset are sampled with replacement from the original data and then concatenated to create the simulated version the original population that was sampled at Q = 0.10. A bootstrap sample for Q = 0.3 would then consist of re-sampling without replacement a sample .3/.1 or three times the size of the original data set from the simulated population data. Compared to the case where Q = .10, the Q = 0.3 bootstrap estimate having been made on samples three times larger than the Q = 0.1 case, will produce smaller standard errors for RRS.

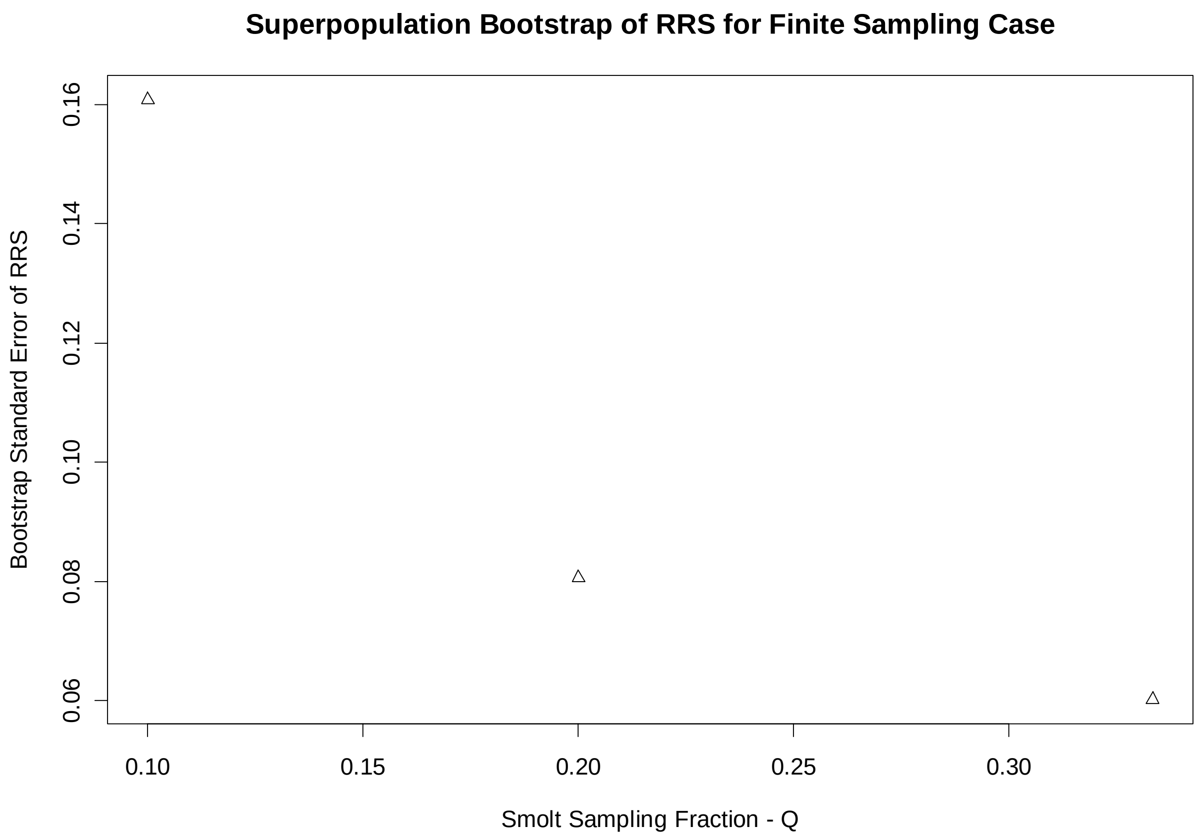

Figure A1. Bootstrap standard error of estimated RRS for Q = 0.1, 0.2 and 0.4 using the bootstrap super-population method which accounts for the finite sampling case where Q is the smolt detection probability. Data for hatchery offspring per parent and wild offspring per parent were generated from Poisson distributions with means of 15 and 20 respectively.

When these data are sampled at rates of less than 10% the difference in variance estimated using finite population methods from that when using methods which assume an infinite population becomes negligible. For example, when applying a finite population correction adjustment for a sampling fraction of $f = n / N$, a confidence interval for the mean offspring count is shortened by a factor $(1 - f)^{1/2}$. For Q = 0.07 this amounts to only .96. Thus for samples in which f is less than 0.1 the data may be considered to have been sampled from an infinite population without appreciable bias in variance estimation. Non parametric bootstrap methods which assume that the data are sampled from an infinite population include the percentile bootstrap or power simulation method.

The power simulation method employs a bootstrap null hypothesis distribution of RRS, the critical percentiles of which are then compared to the bootstrap alternative distribution to give a value of the power of rejecting a null hypothesis of RRS = 1, or equivalently that the difference between hatchery fitness and wild fitness equals 0. The effect size is the value of RRS computed from the original data without correcting the zeros and a significance level is chosen by the user. The bootstrap percentile method has the advantage of simulating the null distribution of RRS and providing statistical power without a distributional assumption. Using the R software program in appendix A1c., it is possible for the user to vary the sampling fraction, *Q*, to find associated power, Figure A2.

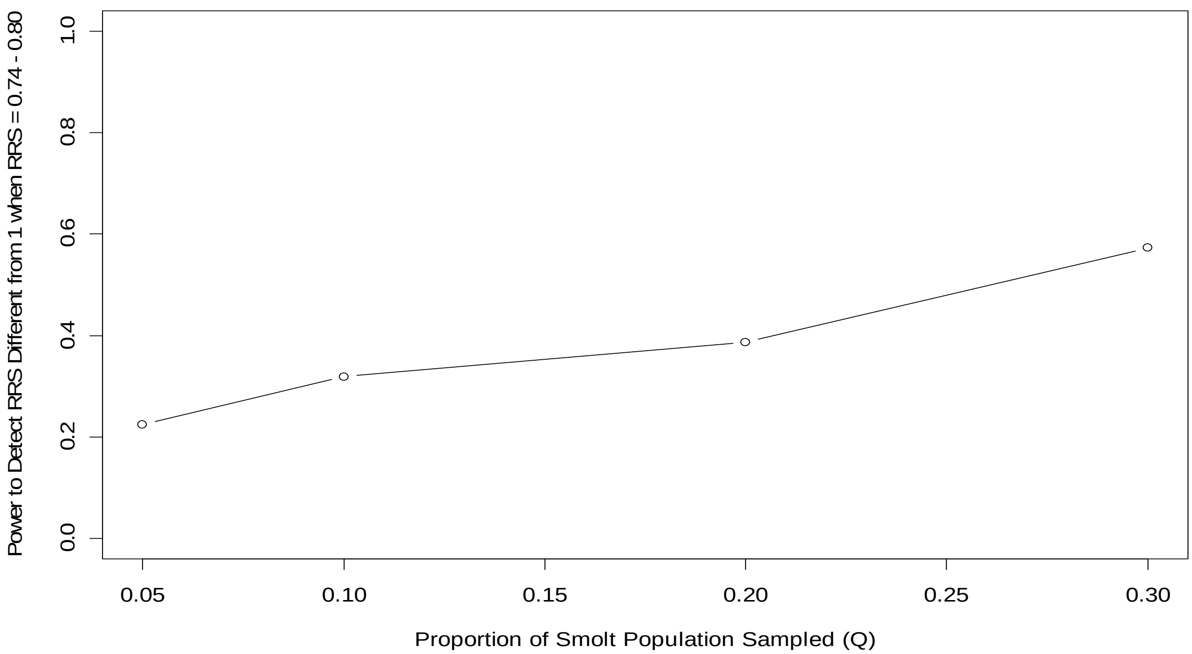

Figure A2. Power to detect RRS different from 1 and proportion of smolt population sampled.

Data were generated from zero-inflated Poisson distributions with the probability of a zero in the data equal to $\pi = 0.3$. Sample sizes for hatchery and wild offspring counts were 75 and 150 cases respectively. Data sets for Q = .3, .2, .1 and .05 were obtained by sampling from zero inflated Poisson distributions with π = 0.3 and hatchery and wild means of offspring equal to 30, 22.5 The R package VGAM was used to generate the four datasets.

Another use of the software is to investigate the effects of the proportion of zeros in the data on the power to reject the null hypothesis that the RRS = 1.0. Figure A3 contains an illustration of the type of power curves that can be developed using the R software programs in Appendix A1.

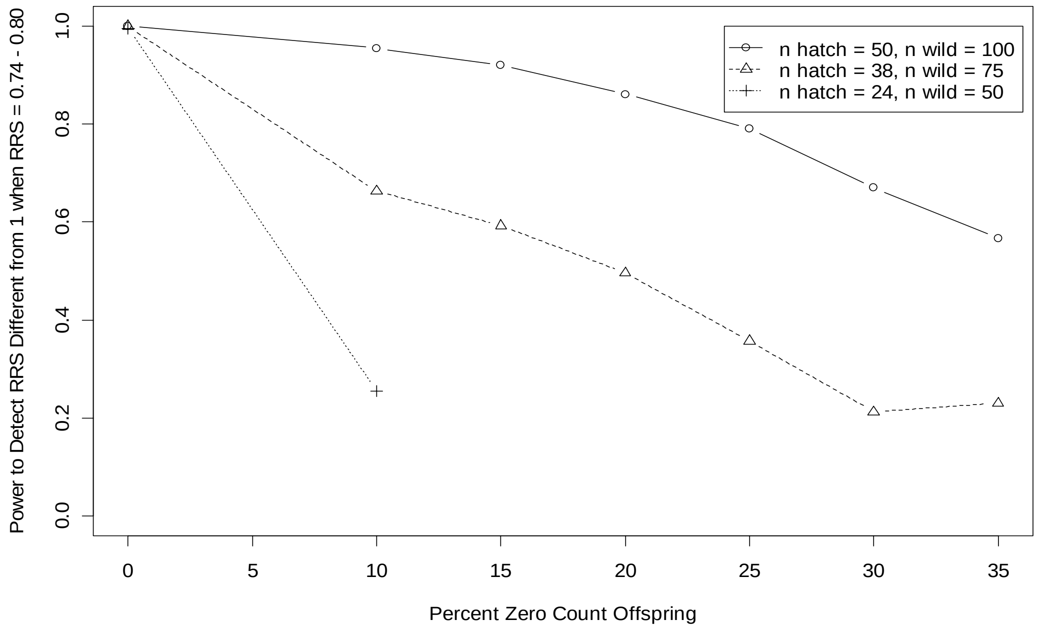

Figure A3. Power to detect RRS of 0.74-0.80 different from 1.0 for three sample sizes of hatchery smolt and wild smolt: 50, 100; 38, 75; and 25, 50 for Poisson simulated data having hatchery mean = 15 and wild offspring mean = 20 with frequencies of zero count offspring varying from 0.0 to 35 percent.

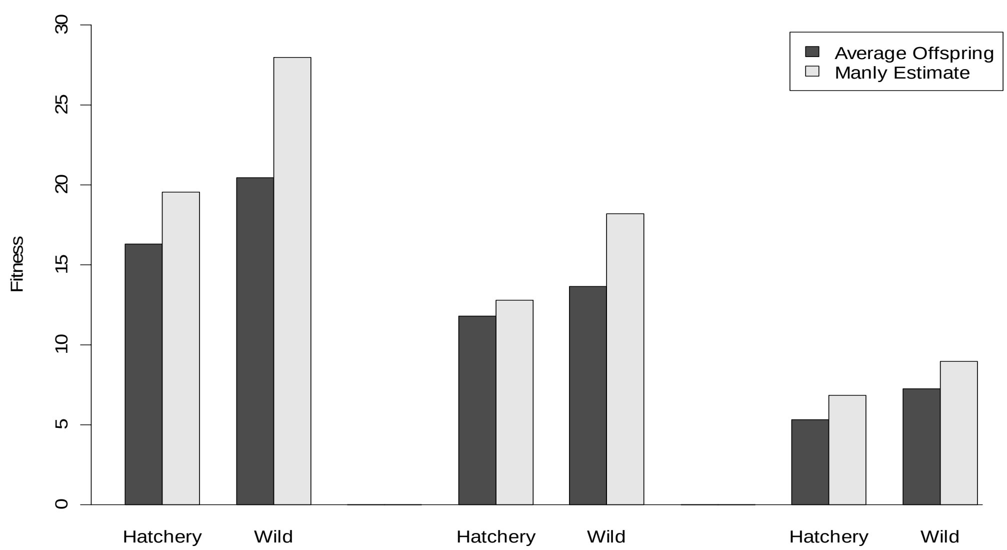

Figure A4. Expected fitness estimated by the manly.main R program and fitness using average offspring per parent for three data sets have 30 percent zero cases.

Algorithms

The R program, 'manly.main' calls two functions, 'manly.RRS.w' and 'manly.RRS.h' which compute the likelihood of the data as functions of the zero-inflated Poisson (zip) probabilities of occurrence of number of offspring per parent. The zip probabilities are functions of two parameters, π, the probability of a zero offspring and λ, the mean. The likelihood is then maximized via the R function 'Optim' in the main program, and maximum likelihood estimates of the parameters are returned; these are used in the estimate of hatchery fitness, wild fitness and RRS within the main program. The bootstrap simulation step is handled by the built-in R function 'boot' for which the user specifies the data, the above program, manly.main, the sampling fraction, Q, initial values for the parameters of the overall zip probability distribution function as well as the number of bootstrap replicates as arguments. Output of the boot function consists of the estimate of RRS, bootstrap standard error of RRS and an estimate of bias. Bootstrap confidence intervals can be obtained by using the built-in R function 'boot.ci' with the boot function output as an argument. The user may specify the type of confidence interval (percentile or bias corrected) as well as the confidence level as additional arguments to 'boot.ci.'

Brian Manly Model Based Maximum Likelihood Bootstrap Algorithm

1 expand the maximum value of both hatchery and wild offspring per parent in the data by a factor of 1/Q where Q is the estimate of the smolt sampling fraction to obtain an estimate of the maximum offspring per parent in the smolt population.

2 apply the zero-inflated Poisson (zip) probability function to the sequence 1:max(offspring) for each origin offspring maximum computed in 1 and index the
sequence by the letter j.
multiply the vector of probabilities of 1 through max offspring in 2 for each origin by a matrix of binomial probabilities, one matrix for each origin type. Create the two hatchery and wild binomial probability matrices as follows:

3

   a. the rows of the matrix are indexed by increasing i where i is a unique number of offspring per parent observed in the data. The row entries consist of i – 1 zeros followed by the sequence of binomial probabilities of i offspring where the number of binomial trials is i through max offspring and where p the probability of a sampled offspring equals Q and 1-p the probability of not sampling an offspring equals 1-Q.

4 compute an expression for the likelihood by writing the product of the entries of the vectors obtained in step 3. Do this for each origin type.

5 maximize the two likelihoods, one for each origin type, by separate calls to the R function Optim.

6 apply the zip parameters estimated in step 5 to the zip probability function to estimate the probabilities of the observed numbers of offspring for each origin type.

7 estimate fitness for each origin type by summing the products of the observed offspring numbers by their respective estimated probabilities.

8 estimate RRS as the ratio of estimated hatchery fitness to estimated wild fitness.

9 repeat steps 1-8, r = 1 through R times for R bootstrap datasets obtained by re-sampling with replacement from the original data.

10 compute the bootstrap mean fitness and bootstrap standard error as the empirical mean and standard error of the bootstrap estimates of RRS.

11 compute the bootstrap estimate of bias by subtracting the original estimate of RRS from the mean bootstrap estimate of RRS.

12 Compute the 1- alpha percent bootstrap percentile confidence interval by choosing the alpha/2 x 100 percentile and 1-alpha/2 x 100 percentile of the sorted bootstrap RRS estimates where 1-alph x 100 is the confidence level of interest. Divide the confidence interval by 2 to obtain a half-width confidence interval.

13 Note: Steps 10 – 12 are carried out by the R built-in functions boot and boot.ci.

Finite Sampling Superpopulation Bootstrap Algorithm (Davison and Hinkley 1997)

Description: The R program, 'RRS.superpop.boot.multq' in Appendix A1b. gives bootstrap estimates of standard error of RRS when input is a dataset formatted as in A1a. and a value of Q, the probability of observing a given offspring. This approach takes into consideration the finite-sampling effects of estimated variances when Q ranges from 0.1-0.5 (Davison and Hinkley 1997, pgs. 92-94)
For r = 1,..., R, and origin = Hatchery, Wild

1 generate a replicate superpopulation $Y^* = (Y_1^*, ..., Y_N^*)$ by sampling N times with replacement from $y_1, \ldots, y_n$ and concatenating these N samples of size n. Here $N \cong n/Q$.

2 generate a bootstrap sample $Y^* = (Y_1^*, ..., Y_n^*)$ by sampling n times without replacement from $Y^* = (Y_1^*, ..., Y_N^*)$, and set $RRS_r^* = rrs(Y_1^*, \ldots, Y_n^*)$.

3 calculate the empirical standard error and half-width confidence intervals of the R bootstrap RRS statistics.

4 repeat 1-3 for different datasets and variable Q or choose alternate values of Q with the original Q.

5 plot bootstrap standard errors and half-width confidence intervals against Q.

Calculating Statistical Power with the Percentile Bootstrap (Beran 1986, Hall and Wilson 1991) for Q < 0.1.

Description: The R program, 'RRS.power' in Appendix A1c, uses input data formatted as in Appendix A1a. , a significance level and the number of bootstrap replicates required. Output is the power of detecting a difference in fitness between hatchery origin adults and wild origin adults equal to that of the sample data (effect size).

1 center the hatchery and wild offspring counts on their respective means.

2 sample n_w times with replacement from the entire centered offspring vector and sample n_w times with replacement from the adult wild fish sample ids. Compute the fitness of the above bootstrap sample using the bootstrapped sample ids.

3 repeat 2, this time sampling n_h times with replacement from the entire centered offspring vector and sampling n_h times with replacement from the adult hatchery fish sample ids. Compute the fitness of the above bootstrap sample using the bootstrapped sample ids.

4 subtract the above hatchery fitness from the wild fitness. This difference is one bootstrap sample comprising the empirical null distribution (choose R = 500, 1000, …). The empirical null distribution will be centered on 0.

5 calculate the critical scores that correspond to the 2.5th and 97.5th critical alpha regions under the empirical null distribution: round ((.05/2)x(#bootstrap samples)) for lower percentile; and round ((1-(.05/2))x(#bootstrap samples)). Locate the scores that correspond to those percentiles.

6 generate the bootstrap alternative distribution:

A.) re-sample with replacement from wild portion of the data matrix offspring vector with replacement to generate a bootstrap sample of wild offspring with length equal to the original wild offspring sample size.

B.) re-sample with replacement from the hatchery portion of the data matrix offspring vector with replacement to generate a bootstrap sample of hatchery offspring with length equal to the original hatchery offspring sample size.

C.) calculate fitness for both wild bootstrap sample and hatchery bootstrap sample using respective adult sample ids.

D.) subtract the hatchery fitness from the wild origin fitness. This is one bootstrap difference representing the difference in fitness under the empirical alternate distribution. This difference is centered on the population difference under the alternate hypothesis.

7 Calculate the empirical power of the statistical test

A.) Using the upper and lower critical scores for the empirical null hypothesis calculated in step 5.), calculate the number of difference values in the empirical alternative sampling distribution that are as or more extreme than the critical scores under the null distribution.

B.) Take the count in step A.) and divide by the total number of bootstrap samples. This is the empirical power for the statistical test that tests no difference between hatchery fitness and wild fitness (or RRS different from 1) versus the alternative hypothesis that hatchery fitness is different from wild fitness for the value of Q given for the original data set at the specified value of alpha for the effect size equal to the original sample fitness of hatchery fish minus fitness of wild fish.

Notes: It should be possible and perhaps recommended that the finite-sampling super-population re-sampling approach be applied in Method 2 if Q is greater than 0.1, otherwise variances may be overestimated (Davison and Hinkley 1997).

Conclusion

Copies of this report and the computer software programs in the appendices are available for download on the West, Inc. web site.

The Manly method has been presented for point estimation of RRS while correcting for excess zeros in the data with measures of precision in the form of confidence intervals and standard errors for RRS. We also provide sample size guidance for establishing required levels of precision in RRS studies where it is expected that offspring sampling will be incomplete. For this stage of the work it has been assumed that adult enumeration is complete with 100 percent of escapement genetically sampled. It is also assumed that the assignment of offspring to their respective parents is without error. The basic method ‘corrects the zeros’ in studies of RRS. Point estimates of RRS for specific subsets of the data with standard errors and confidence intervals can be obtained using the R program ‘manly.main’ in conjunction with built-in R functions for bootstrap estimates. The programs along with instructions for use and an example are given in Appendix A1. Potential models for the numbers of observed offspring that have been programmed are the zero- inflated Poisson, and zero-inflated negative binomial. The zero-inflated Poisson program is available for use while the zero-inflated negative binomial requires further work.

Applying non-zero inflated models where the data are distributed according to a zero-inflated model when using traditional asymptotic likelihood ratio sample size (power) estimation approaches (Self, 1992), often results in an underestimate of sample size (Williamson *et al*. 2007). The Brian Manly model based likelihood bootstrap method models the excess zeros in the data as well as accounting for the probability of non-zero offspring for parent/offspring pairs having zero offspring in the original dataset. The bootstrap percentile method and the super-population finite sampling methods do not require a parametric assumption but may be biased when data have excess zeros.

The super-population bootstrap is a non-parametric approach for estimating RRS and has the advantage of taking into account the finite-sampling nature of offspring collections when the sampling fraction is greater than 0.1. This method creates a simulated population equal in size to the original population. Bootstrap samples are drawn without replacement from the simulated population data to mimic finite sampling from the real population of offspring. The method is simplified to be exchanged for the percentile bootstrap method when the sampling fraction Q is small, e.g., below 0.1. The advantage of the bootstrap percentile method is its easy implementation and intuitive approach as well as not having to adopt a parametric model for the data.

Appendix A1 displays the R computer programs for estimating RRS and an estimate of its precision by the Manly method as well as by the other two non parametric bootstrap methods. Sample sizes to achieve required precision in RRS studies in which parr, smolt, or adult stage offspring are assigned to a single parent fish are among the output. Instructions for running the programs are included in Appendix A1 as well as sample output.

Future work

Sample sizes for precision and power using the Manly method

The preferred approach for the study of power is unfortunately still under development. It would utilize the model based maximum likelihood method conceived by Brian Manly, WEST, Inc., and discussed above. The method involves an underlying parametric model in which a likelihood is constructed relating probabilities of observing a given number of offspring to the probability of occurrence of numbers of offspring/parent at values estimated from bootstrap re-samples of RRS data. The estimated probabilities are then used to estimate expected fitness for each origin group. The standard model for counts of the observed number of offspring per parent is the Poisson. However, if the data are over-dispersed such that the variance of the count variable is greater than the mean, then a negative binomial distribution may be used as it employs an additional parameter to describe the variance. If in addition the data are zero-inflated, a zero-inflated Poisson or zero-inflated negative binomial distribution may be appropriate. A useful R program would accommodate the above alternate distributions. A simulation is run by re-sampling data where sampling effort and juvenile capture probability, Q are set by the user.

The Manly method has the greatest potential of the models considered in this report, because it allows estimation of non-zero offspring for cases in which the sampled data show zero offspring and avoids bias if cases with zero observed offspring are dropped from the data set. As it is likely that data will contain substantial zero offspring cases for a given parent it may be crucial to explicitly model this portion of the population to avoid negative bias in the estimation of fitness. The zero-inflated Poisson distribution assumes that a subpopulation generates the zero counts; this distribution accounts for excess zeros by estimating a separate parameter for the probability of zero values. Sample size (power) calculations are especially important for zero-inflated models because a larger sample size is required to detect a significant effect with these models than with the standard Poisson or negative-binomial models (Williamson *et al*. 2007). Another objective is to include variability in the estimate of the sampling fraction, Q into the estimation of RRS within the Brian Manly model based program.

The theory for this method is well understood, however the R computer software program requires some additional work to identify and implement the appropriate alternative distributions where necessary. Output would consist of standard errors or half-width confidence intervals of RRS plotted against alternative values of Q to provide guidance in sample size selection. The program would employ score tests to determine which distribution is the most suitable for the data (van den Broek 1995; Ridout *et al*. 2001).

Incomplete adult enumeration, its Relationship to Q, and effect on power

When there are adults which have not been sampled, the case of incomplete adult enumeration, the effect is similar to that of reducing Q, decreased power to detect RRS different from 1 . This is because progeny of the missing adults cannot be assigned to their respective parents. Thus the total number of assigned offspring is reduced and precision to estimate fitness is lower. If adults are sampled in an unbiased manner, e.g., genetic information is randomly collected on 50% of the adults, then Q will effectively be reduced by the sampling fraction. That is, if 50% of the adults are sampled then it will only be possible to identify the male parent (or the female parent) of approximately 50% of the sampled juveniles. In the case of an experiment in which incomplete adult enumeration is expected, the sampling fraction, Q, could be increased to help offset the effects of the missing adults for which offspring will be unassigned. Use of the computer software provided in this report then could assist fisheries investigators in the design of an RRS experiment where errors in adult enumeration are expected by allowing them to set sampling rates sufficient to offset the lowered power due to incomplete collection of genetic information from the parents.

The case of incomplete adult enumeration may or may not result in unbiased estimates of fitness and RRS. Certainly RRS would be more likely to be biased if adults were missing disproportionately by origin of adult or level of fitness.

Incomplete adult enumeration and errors in assignment of offspring to parents

It is also necessary to extend the algorithms to experiments in which there is incomplete adult enumeration and assignment of offspring to parents is not without error. Guidelines are needed for the numbers or percentage of adult spawners to sample to provide acceptable power and precision for estimates of RRS. Similarly the effect of errors in assignment of offspring to parents on precision of estimates of RRS should be studied.

One way in which the effect of incomplete adult enumeration could be included into the analysis of RRS precision would be to allow the user to randomly eliminate cases (rows) from the data. The point estimate of RRS and bootstrap confidence interval obtained with the full data could be compared to the estimate and bootstrap confidence interval obtained from the data with the randomly missing adult/offspring cases to obtain an estimate of the effect of un-sampled adults which may have escaped collection at the weir.

Modeling the effect of assignment error

To simulate assignment error the program could be configured to allow the user to miss-match random cases of assignment of offspring to parent. Estimates from the mismatch computer run could then be compared to estimates from computer output from the original error-free data to investigate effects of assignment error on power and estimates of fitness and RRS.

Modeling the effect of covariates such as age and weight on RRS

It would also be of benefit to include covariates measured on parents in order to assess the effect of adult morphological and behavioral characteristics on fitness, RRS and estimates of their standard errors. This could be achieved by including these covariates in the zero-inflated Poisson probability function which is used in the Brian Manly model based bootstrap. Null model output would then be compared to covariate models to assess the effect of the covariate.

Comparison of RRS between studies or years

Extension of the programs and algorithms to enable statistical comparison of RRS estimates between studies or studies between years will be an important objective. Here the statistic to be bootstrapped would be the difference in RRS between the two studies or years.

Programming of additional distributions and tests of goodness of fit

Future work should also entail configuring the Brian Manly model based bootstrap to use distributions other than the zero-inflated Poisson distribution where appropriate. The zero-inflated negative binomial has been programmed but not yet tested. Other distributions would include the Poisson and negative binomial when excess zero data are not present. Score tests and or goodness of fit tests within the program would help to insure selection of the correct distribution to apply to the data.

Sensitivity of current estimation methods to the presence of zeros

Finally it is desirable to estimate and study the magnitude of the negative bias when estimating fitness for populations in which data contain excess zeros. The level of this bias in relation to sample size and data distributional properties should be explored. Monte Carlo methods can be applied to run sensitivity analyses to establish where bias exists and under which sampling conditions it attains unacceptable levels when the goal is accurate and precise estimation of RRS.

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Appendix A1: R Programs, instructions for use, data description, and sample output

The program R can be downloaded from the following site:
http://cran.r-project.org/bin/windows/base/old/

Appendix A1a. Brian Manly Model Based Maximum Likelihood Bootstrap
Program Name: manly.main
(Current program uses a zero-inflated Poisson distribution to model offspring counts.)

Instructions for use

1. Download R version 2.6.2 by going to the website above.
2. Open package boot by typing ‘library(boot)’ at the R prompt.
3. Set up an RRS dataset in EXCEL which should look like the following example header and first few lines:

sample	origin	offspring
1	h	15
2	h	14
3	h	19
.	.	.
.	.	.
51	w	23
52	w	19
53	w	13
.	.	.
.	.	.

Column ‘sample’ are numbers to identify an adult parent to its respective assigned number of sampled offspring in the ‘offspring’ column.

Save the dataset as a .csv file in a folder and directory of your choice.

4. Set the R directory to the same one where the data file is stored by clicking on ‘file’ then ‘change directory’ and selecting the appropriate directory and folder; click on ‘OK’.
5. Create a dataframe which the R program can use for input by typing the following at the R prompt: mydata<- read.csv(file = “mydata.csv”, header = TRUE, sep = “,”)
6. Highlight and paste the three R program, manly.main below, into R at the R prompt.
7. As an example, to obtain bootstrap estimates of RRS, type the following into the R prompt:

```
out.boot <- boot( data=mydata, stype='i', statistic=manly.main, q=.3, R=10, par=c(.7,80) )
```

notes on the arguments of the built-in R boot function:
Type ‘boot.out’ to see bootstrap estimates of RRS. Type ‘summary(boot.out)’ for a summary of program run. Type boot.out$t to see R bootstrap estimates of RRS. ‘help(boot)’ for more information on the function boot.
‘data’ is the dataframe you just created.

‘stype= i’ is the re-sample index for the data.
‘statistic’ is the R function or R program in which the statistic to be bootstrapped is computed.
‘par’ consists of initial values for the parameters of the zip distribution (i.e. Percent 0’s in your data set and maximum single offspring count for your data set’s offspring counts expanded by a factor of 1/Q.
‘q’ is the smolt sampling fraction.
‘R’ is the user selected number of bootstrap re-samples.

Notes: Currently the program takes a considerable amount of time, say several hours, to run R = 50 bootstrap replicates.
The current version of the code has a limit of max offspring of the expanded data of 160.
It may take more than one trial set of initial values to find one that allows convergence.
Type help(boot) for more information on how to use the R boot function.
The zero-inflated negative binomial distribution has been programmed but not tested.

8. To obtain bootstrap confidence intervals after having run the **boot** function , use the R built-in function **boot.ci** by entering the following code into the R prompt:
boot.ci.out<- **boot.ci**(boot.out, type="perc", conf=c(.80,.95))
The arguments of the **boot.ci** function are the output of the **boot** function in step 7.
‘type’ is the type of confidence interval, percentile in this case and ‘conf’ in which I have selected an 80% and 95% confidence interval to be output are the confidence levels.
After running the boot.ci function, type ‘boot.ci.out’ to see the results.
For more information on the R **boot.ci** function type help(boot.ci) at the R prompt.

Sample Output from Program manly.main

```
> boot.out
ORDINARY NONPARAMETRIC BOOTSTRAP
Call:
boot(data = dataset, statistic = manly.main, R = 10, stype = "i",
   par = c(0.7, 80), q = 0.3)
       Bootstrap Statistics :
    original      bias    std. error
t1* 0.6828665 -0.03847215  0.05328027

> boot.ci.out
BOOTSTRAP CONFIDENCE INTERVAL CALCULATIONS
Based on 10 bootstrap replicates
CALL :
boot.ci(boot.out = out, conf = c(0.8, 0.95), type = "perc")
Intervals :
Level     Percentile
80%   ( 0.5563,  0.7237 )
95%   ( 0.5519,  0.7275 )
```

Notes: The sample simulated data for the above program were generated from a zip distribution with parameters 0.30 probability of a zero offspring count and lambda (mean) for hatchery and wild offspring counts of 22.5 and 30 respectively. The sample sizes were 75 for hatchery and 150 for wild origin fish.

R Computer Program: manly.main for the Brian Manly Maximum Likelihood based Bootstrap

```
manly.main<-function(dataset,index,par,q)

{
   # This program calls two functions, manly.RRS.h and manly.RRS.w, which compute the likelihood for
probabilities of observing offspring/parent.
   # numbers in RRS data.
   # Likelihoods for hatchery and wild observed probabilities are maximized wrt the parameters of a zero-
inflated Poisson (zip) distribution.
   # Output is an estimate of RRS.
   # par - initial values for zero-inflated Poisson, c(theta, lambda), where theta is the proportion of zeros in
'dataset' and lambda is the mean offspring of the dataset/q.
   # q - is the capture probability of a smolt or the sampling fraction.
      dataset<- dataset[index,]                    # Set up bootstrap sample index.
      attach(as.data.frame(dataset))               # Attach to name data columns in program.
      n_h<- unique(dataset[origin=="h",]$offspring)  # Compute and sort unique numbers of observed
offspring/parent
      n_w<- unique(dataset[origin=="w",]$offspring)
      n_h<- sort(n_h)
      n_w<- sort(n_w)
      len_n_h<- length(n_h)
      len_n_w<- length(n_w)

#==============================================================================
==============================================================================
   manly.h<- function(par,...)
{
 # This function writes the negative loglikelihood of zero-inflated Poisson distribution data (mixture type) of
each of hatch and wild offspring count data
 # for the Brian Manly method of estimating simulated se of RRS when offspring data are zero-inflated
Poisson distributed.

 # Initial values for zero-inflated Poisson distribution of the hatchery offspring.
  #par<- rep(NA,2)
  theta_h<- par[1]
  lambda_h<- par[2]

 # The test smolt sampling fraction for the input dataset.
  Q<- q
 # dataset used for example.
  #dat<-dataset
  attach(as.data.frame(dataset))

 # Distinct values of numbers of offspring for each origin type.
      n_h<- unique(dataset[origin=="h",]$offspring)
      mean_h<- mean(dataset[origin=="h",]$offspring)
      n_h<- sort(n_h)
      len_n_h<- length(n_h)
```

```
 #write number of offspring as zero inflated poisson probabilities where 1-theta is the proportion of extra
zeros.


     offsprg_h<- rep(NA,len_n_h)
     offsprg_h<- round(n_h/Q,0)
     max_offsprg_h<- max(offsprg_h)

 # Set up vectors of probabilities of occurrence of 0,1,... offspring using parameters of zero-inflated Poisson
dist. which are to be estimated.
     p_h<- rep(NA,max_offsprg_h+1)

     p_h[2:(max_offsprg_h+1)]<- theta_h*(ppois(1:max_offsprg_h,lambda_h)-ppois(0:(max_offsprg_h-
1),lambda_h))
     p_h[1]<- (1 - theta_h) + theta_h*ppois(0,lambda_h)

     p_h<- as.vector(p_h)

     #print(length(p))

   # Set up, m, a matrix, the rows of which are observed probabilities expressed as a funtion of p and Q.
    m_h<- rep(NA,len_n_h*(max_offsprg_h+1))
    dim(m_h)<- c(len_n_h,(max_offsprg_h+1))

   # compute binomial terms containing Q for observed probabilities
  for (j in 2:len_n_h)       {

    m_h[j, 1:n_h[j]]<- rep( 0, n_h[j] )
    m_h[j,(n_h[j]+1):(max_offsprg_h+1)]<- dbinom( (n_h[j]+1),(n_h[j]+1):(max_offsprg_h+1),Q)

 }

    m_h[1,]<- (1-Q)^(0:max_offsprg_h)

  # Multiply the rows of m by the probabilities of occurrence to get the observed probabilities of 0,1,..
offspring per parent.
   prob_h<-m_h%*%p_h
   #print(sum(prob_h))
  # Write the negative loglikelihood as the product of the observed probabilities of 0,1,.. offspring/parent.
   print(prob_h)
  -log(prod(prob_h))

 }


#=============================================================================
=============================================================================
```

```
  manly.w<- function(par,...)
{
 # This function writes the negative loglikelihood of zero-inflated Poisson distribution data (mixture type) for wild offspring count data
 # for the Brian Manly method of estimating simulated se of RRS when offspring data are zero-inflated Poisson distributed.

 # Initial values for zero-inflated Poisson distribution of the hatchery offspring.
  #par<- rep(NA,2)
  theta_w<- par[1]
  lambda_w<- par[2]

 # The smolt test sampling fraction for the input dataset.
 Q<- q

 # dataset used for example.
 #dat<-dataset
 attach(as.data.frame(dataset))

 # Distinct values of numbers of offspring for each origin type.
     n_w<- unique(dataset[origin=="w",]$offspring)
     mean_w<- mean(dataset[origin=="w",]$offspring)

     n_w<- sort(n_w)

     len_n_w<- length(n_w)


 #write number of offspring as zero inflated poisson probabilities where 1-theta is the proportion of extra zeros.

     offsprg_w<- rep(NA,len_n_w)
     offsprg_w<- round(n_w/Q,0)
     max_offsprg_w<- max(offsprg_w)

 # Set up vectors of probabilities of occurrence of 0,1,... offspring using parameters of zero-inflated Poisson dist. which are to be estimated.
     p_w<- rep(NA,max_offsprg_w+1)

     p_w[2:(max_offsprg_w+1)]<- theta_w*(ppois(1:max_offsprg_w,lambda_w)-ppois(0:(max_offsprg_w-1),lambda_w))

     p_w[1]<- (1 - theta_w) + theta_w*ppois(0,lambda_w)

     p_w<- as.vector(p_w)

     #print(length(p))

   # Set up, m, a matrix, the rows of which are observed probabilities expressed as a funtion of p and Q.
    m_w<- rep(NA,len_n_w*(max_offsprg_w+1))
    dim(m_w)<- c(len_n_w,(max_offsprg_w+1))
```

```
  # compute binomial terms containing Q for observed probabilities
  for (j in 2:len_n_w)       {

    m_w[j, 1:n_w[j]]<- rep( 0, n_w[j] )
    m_w[j,(n_w[j]+1):(max_offsprg_w+1)]<- dbinom( (n_w[j]+1),(n_w[j]+1):(max_offsprg_w+1),Q)

 }

    m_w[1,]<- (1-Q)^(0:max_offsprg_w)

 # Multiply the rows of m by the probabilities of occurrence to get the observed probabilities of 0,1,..
offspring per parent.
   prob_w<- m_w%*%p_w
   #print(prob_w)
 # Write the negative loglikelihood as the product of the observed probabilities of 0,1,.. offspring/parent.
  #print(prob_h)
  -log(prod(prob_w))

 }

#==========================================================================
==========================================================================
  # Maximize the likelihood for hatchery offspring by calling the function manly.h.

  out.h<- optim(par,manly.h,factr=1e3,maxit=250, method = "L-BFGS-B",
     lower=c(.1, 10), upper=c(.99, 500))
  out<-optim(par,manly.w,factr=1e3,maxit=250, method = "L-BFGS-B",
     lower=c(.1, 10), upper=c(.99, 500))

  # Simulated Annealing
  #out.h <- optim(par,manly.h, method="SANN",
   #        control=list(maxit=200, temp=20))
  #out <- optim(par,manly.w, method="SANN",
   #        control=list(maxit=200, temp=20))


        # Maximize the likelihood for wild offspring by calling the function manly.RRS.w.

  thet_h<- out.h$par[1]                    # name estimated zip 0 probability parameter estimated by optim
above.
  lam_h<- out.h$par[2]                     # name estimated zip mean parameter estimated by optim above.
  lam_h<-lam_h*q                           # Scale zip mean parameter back to that of data.
  pr_h<- rep(NA,length(n_h))



  pr_h[2:len_n_h]<- thet_h*(ppois(n_h[2:len_n_h],lam_h)-ppois(n_h[1:(len_n_h-1)],lam_h)) # Compute
probabilites of occurrence of 0, 1, 2, … offspring.
  pr_h[1]<-  (1-thet_h) + thet_h*ppois(0,lam_h)                        # of offspring/parent.
```

```
  fitness_h<- t(pr_h)%*%n_h
                                    # Compute hatchery fitness by summing products of
sample numbers                              # of offspring/parent with their
respective probabilities.
                                    # of offspring/parent with their respective estimated
probabilities.
  thet_w<- out$par[1]
  lam_w<- out$par[2]
  lam_w<-lam_w*q
  pr_w<- rep(NA,length(n_w))

  pr_w[2:len_n_w]<-thet_w*(ppois(n_w[2:len_n_w],lam_w)-ppois(n_w[1:(len_n_w-1)],lam_w))
  pr_w[1]<-  (1-thet_w ) + thet_w*ppois(0,lam_w)
  fitness_w<- t(pr_w)%*%n_w



  RRS<- fitness_h/fitness_w                     # Compute RRS as ratio of hatchery to wild
fitness.

  return(RRS)

}
```

Appendix A1b. Finite-sampling superpopulation bootstrap

Program Name - RRS.superpop.boot.multq
Output – The output is a plot of bootstrap estimated standard errors of RRS versus user selected values of Q.

Instructions for Use – See comment lines in the RRS.boot.multi.q program below.

1. Download R using the website in Appendix A1a.
2. Format an RRS dataset, set R directory and create a dataframe by following steps 3-5 in Appendix A1a.
3. Copy the RRS.boot.multi.q program into R at the R prompt.
4. Type **RRS.boot.multi.q( )** at the R prompt and type in the following arguments separated by commas within the parentheses the arguments for the program:
    a. The name of your dataframe.
    b. The smolt sampling fraction
    c. A list of sampling fractions as in “c(.1, .2, .3333,..)”
    d. The number of bootstrap replicates.
    e. An example would be **RRS.boot.multi.q(mydata, .2, c(.1, .2, .3333), 99)**

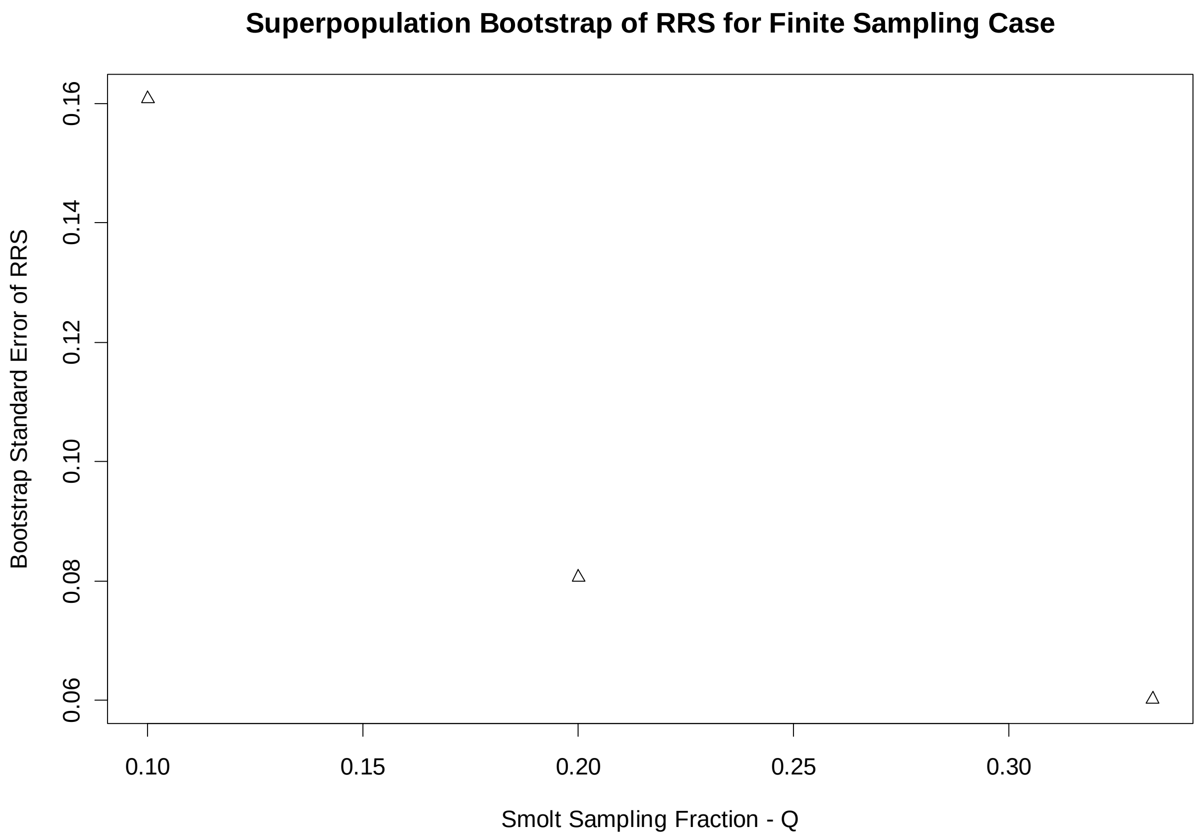
```
RRS.superpop.boot.multq<- function(data,q,fraction,iter)
{
  #This function implements a finite sampling superpopulation bootstrap for RRS, Davison and Hinckley
(1997) pgs.92-97.
  #The function plots bootstrap se's of RRS versus user input values of q.
  #user's values of q are in fraction.
  #q is the sampling fraction of original data.
  #iter is the number of bootstrap samples
  #store bootstrap RRS means and RRS standard errors
  RRS_values<- rep(NA,length(fraction))
  sd_RRS_multi_q<- rep(NA,length(fraction))
  #bootstrap RRS and it se for user's q values
 for ( k in 1:length(fraction) )
  {
  Q<- fraction[k]

  R<- iter
  dat<- data
  attach(dat)
  fitness_h<- rep(NA,R)
  fitness_w<- rep(NA,R)
 # concatenate 1/Q copies of the original data
  for ( i in 1: round(1/Q,0) )
  {
    dat_concat<- rbind(dat,dat)
  }
 # sample with replacement from expanded (1/Q times) data set a new data set of same dim
 # sample without replacement from above data set with length equal to original data
 # compute fitness by origin from above data set
  for ( r in 1:R ) {
    index<- sample(1:dim(dat_concat)[1],dim(dat_concat)[1], replace=TRUE )
```

```
    super_pop<- dat_concat[index,]
    index_2<- sample(1:dim(super_pop)[1],dim(dat)[1]*(Q/q),replace=FALSE)
    boot_samp<- super_pop[index_2,]
    attach(boot_samp)
  # sum no. of offspring by adult id and compute fitness
    boot_samp_adultID<- aggregate(boot_samp$offspring, list(boot_samp$sample,boot_samp$origin),sum)
    #boot_samp_adultID<- boot_samp
    names(boot_samp_adultID)<- c("sample","origin","offspring")
    attach(boot_samp_adultID)
    fitness_h[r]<- mean(as.numeric(boot_samp_adultID[origin=="h",]$offspring),na.rm=T)
    fitness_w[r]<- mean(as.numeric(boot_samp_adultID[origin=="w",]$offspring),na.rm=T)
    #print(fitness_h[r])
  }
   RRS<- fitness_h/fitness_
   sd_RRS_multi_q[k]<- sd(RRS )
   RRS_values[k]<- mean(RRS)
 }
   #print(length(sd_RRS_multi_q))
Par(cex=1.5)
   plot(fraction,sd_RRS_multi_q, xlab="Smolt Sampling Fraction - Q",ylab="Bootstrap Standard Error of
RRS",main="Superpopulation Bootstrap of RRS for Finite Sampling Case")
   attach(dat)
   sample_RRS<- mean(dat[origin=="h",]$offspring)/mean(dat[origin=="w",]$offspring)
   cat("Sample RRS =",sample_RRS)
 }
```

Example Run

```
>  RRS.superpop.boot.multq(zip_wh_.3_30_22.5_q.3,.333,c(.1,.2,.3333),10)
```

> Sample RRS = 0.7904855



<u>Sample data set for this example</u>:
Data used for this example were simulated from a zero-inflated Poisson distribution with probability of zero equal to 0.3 and hatchery and wild offspring mean offspring count of 22.5 and 30 respectively. Sample sizes for the hatchery and wild were 75 and 150 respectively.

Appendix A1c. Bootstrap Percentile Method (power simulation algorithm)

This R function outputs the power of a test of the difference in fitness between hatchery parents and wild parents (or RRS different from 1). Output includes the power of the test, p-value of the test, a bootstrap estimate of bias, and the bootstrap estimate of the standard error of estimated RRS.

Program Name: RRS.power

Instructions for use:

1. Download R from the website given in Appendix A1a. and follow steps 3. – 5. In Appendix A1a for setting an R directory and creating an RRS dataset and dataframe.
2. Type **RRS.power( )** at the R prompt.
3. In the parentheses enter the arguments for RRS.power:
   a. Your dataframe ('data') formatted as in Appendix A1a. Example - mydata
   b. A level of significance ('alpha') for the estimated power. Example – 0.05.
   c. The number of bootstrap replicates ('iter'). Example – 499.

<u>The R program – RRS.power</u>

RRS.power<- function(data,alpha,iter)

```
{
  dat<- data
  attach(dat)
  n_h<- length(dat[origin=="h",]$offspring)
  n_w<- length(dat[origin=="w",]$offspring)
  n_h.total<- sum(dat[origin=="h",]$offspring)
  n_w.total<- sum(dat[origin=="w",]$offspring)
 #Center hatchery data
  offspr_h_center<- dat[origin=="h",]$offspring - mean(dat[origin=="h",]$offspring)
 #Center wild data
  offspr_w_center<- dat[origin=="w",]$offspring - mean(dat[origin=="w",]$offspring)
 #stack data
  centered<- c(offspr_h_center,offspr_w_center)
  dat<-cbind(dat,centered)
  names(dat)<- c("sample","origin","offspring","cent_offspring")
  attach(dat)
 h0offspr_h<- matrix(sample(cent_offspring, n_h*iter,replace=T),nrow=iter)
 h0offspr_w<- matrix(sample(cent_offspring, n_w*iter,replace=T),nrow=iter)
 h0offspr_mean_h<-apply(h0offspr_h,1,mean)
 h0offspr_mean_w<-apply(h0offspr_w,1,mean)
 h0offspr_mean<- sort(h0offspr_mean_w - h0offspr_mean_h)
### Calculate critical cutoffs
critup<- quantile(h0offspr_mean,.975)
critlow<- quantile(h0offspr_mean,.025)
#### Calculate two-sided mean difference test probability for observed difference
diff.empirical<- mean(dat[origin=="w",]$offspring)-mean(dat[origin=="h",]$offspring)
RRS.empirical<- (mean(dat[origin=="h",]$offspring))/(mean(dat[origin=="w",]$offspring))
count<-length(h0offspr_mean[abs(h0offspr_mean)>=abs(diff.empirical)])
pvalue.empirical<-count/iter
# Sampling from H1: Sample wih replacement from centered offspring by origin
 #fitness_h<- rep(NA,iter)
 #fitness_w<- rep(NA,iter)
```

```
  #for (r in 1:iter ) {
   #index<- sample(1:dim(dat)[1],dim(dat)[1],replace=T)
  # boot_samp<- dat[index,]
    # sum no. of offspring by adult id and compute fitness
    #boot_samp_adultID<- aggregate(boot_samp$cent_offspring,
list(boot_samp$sample,boot_samp$origin),sum)
  #  boot_samp_adultID<- boot_samp
  #  names(boot_samp_adultID)<- c("sample","origin","offspring","cent_offspring")
  #  attach(boot_samp_adultID)
   # fitness_h[r]<- mean(as.numeric(boot_samp_adultID[origin=="h",]$cent_offspring),na.rm=T)
   # fitness_w[r]<- mean(as.numeric(boot_samp_adultID[origin=="w",]$cent_offspring),na.rm=T)
# }
  h1offspr_h<- matrix(sample(dat[origin=="h",]$offspring, n_h*iter,replace=T),nrow=iter)
  h1offspr_w<- matrix(sample(dat[origin=="w",]$offspring, n_w*iter,replace=T),nrow=iter)
  h1offspr_mean_h<-apply(h1offspr_h,1,mean)
  h1offspr_mean_w<-apply(h1offspr_w,1,mean)
     #### Sort and subtract fitness data vectors
    #    and accumulate into a fitness difference vector
    h1bvec<- sort(h1offspr_mean_w - h1offspr_mean_h)
    RRS.boot.mean<- mean(h1offspr_mean_h/h1offspr_mean_w)
    RRS.boot.se<- sd(h1offspr_mean_h/h1offspr_mean_w)
    boot.bias<-RRS.empirical-RRS.boot.mean
  ### Calculate the upper and lower cutoff percentiles for
  #   the lower and upper alpha criterion
   effectlow<-round((alpha/2)* iter)
   effectup<-round((1-alpha/2)* iter)
  #### Calculate Empirical Power
   countup<-length(h1bvec[h1bvec>=critup])
   countlow<-length(h1bvec[h1bvec<=critlow])
   power.twotail<-(countup+countlow)/iter
  ### Calculate fitness differences that correspond to the
  #   upper and lower alpha criterion cuttoffs
  h1.ci<-list(ci=c(h1bvec[effectlow], h1bvec[effectup]))
  ###Display Results
  cat("The number of hatchery parents and wild parents assigned offspring are respectively ", n_h)
  cat(" and ", n_w,"\n")
  cat("The number of hatchery offspring and wild offspring assigned parents are respectively ", n_h.total)
  cat(" and ", n_w.total,"\n")
  cat ("The power of the test is  ", power.twotail,"\n")
  cat ("for a difference in fitness between hatchery and wild parents of ",diff.empirical,"\n")
  cat("The empirical p-value is ", pvalue.empirical,"\n")
  print(“The bootstrap percentile confidence interval for the difference in fitness is: “)
  print(h1.ci)
  cat("The observed RRS is  ", RRS.empirical)
  cat(" and the bootstrap mean RRS is ",RRS.boot.mean,"\n")
  cat("The bootstrap estimate of bias is ", boot.bias,"\n" )
  cat("The bootstrap estimate of the standard error of RRS is ",RRS.boot.se,"\n")
}
```

Sample Output for Program RRS.power

```
>RRS.power(zip_wh_.3_30_22.5_q.3, .05, 499)
The number of hatchery parents and wild parents assigned offspring are respectively  75 and  150
```

The number of hatchery offspring and wild offspring assigned parents are respectively 1213 and 3069
The power of the test is 0.5831663
for a difference in fitness between hatchery and wild parents of 4.286667
The empirical p-value is 0.03406814
The bootstrap percentile confidence interval for the difference in fitness is
[1] 0.4733333 7.5600000

The observed RRS is 0.7904855 and the bootstrap mean RRS is 0.796873
The bootstrap estimate of bias is -0.006387487
The bootstrap estimate of the standard error of RRS is 0.08282443

Sample Data Set for this Example:
Data used for this example were simulated from a zero-inflated Poisson distribution with probability of zero equal to 0.3 and hatchery and wild offspring mean offspring count of 22.5 and 30 respectively. Sample sizes for the hatchery and wild were 75 and 150 respectively.

Appendix B.
Alternative M&E Designs for Addressing Steelhead Hydrosystem Effectiveness Questions

Introduction

Snake River and upper Columbia steelhead are listed under the US Endangered Species Act. Here we evaluate the status of steelhead, both wild and hatchery, with respect to four hydro effectiveness questions (see Table B1).

Table B1. Steelhead hydrosystems effectiveness questions addressed by CSMEP in FY2008.

Steelhead Hydro Effectiveness Questions
1. Is SAR sufficient for a) NPCC goal and b) recovery goals?
2. Is transportation more effective than in-river passage?
3. How does annual in-river survival of steelhead (Lower Granite Dam (LGR) to Bonneville (BON)) compare to 2000 FCRPS BiOp performance standards?
4. How does effectiveness of transportation change over the course of the season?

We developed some alternative M & E designs (Table B2), and evaluated the cost and statistical reliability of those designs relative to the Status Quo M & E. Alternative M & E designs for wild steelhead were not explored because we felt there are not presently enough wild fish to realistically increase the number of fish tagged. The purpose of this report is to describe the example M & E designs summarized in Table B2 and present results demonstrating the relative reliability of these designs with respect to the questions listed in Table B1.

Table B2. Description of alternative monitoring designs. Monitoring designs are described as High, Medium, and Low, in reference to the number of PIT tags and levels of accuracy and precision in data that are collected.

Description of Monitoring Design Alternatives				
Performance Measures	Status Quo	Low	Medium	High
SARs, TIRs, mainstem survival	*SR Hatchery Steelhead:* • # tags: Varies from year to year (26,000 to 36,000) *SR Wild Steelhead:* • Tagging is opportunistic, # of fish tagged varies annually	*SR Hatchery Steelhead:* • Same as Status Quo *SR Wild Steelhead:* • Tagging is opportunistic, # of fish tagged varies annually	*SR Hatchery Steelhead:* • # tags= 2x Status Quo *SR Wild Steelhead:* • Tagging is opportunistic, # of fish tagged varies annually	*SR Hatchery Chinook:* • # tags= 4x Status Quo *SR Wild Steelhead:* • Tagging is opportunistic, # of fish tagged varies annually

Methods

The wild PIT-tagged juvenile steelhead data used in the analyses presented here were obtained from all available marking efforts in the Snake River basin above Lower Granite Dam. Wild steelhead smolts from each tributary (plus fish tagged at the Snake River trap near Lewiston) were accounted for in the PIT-tag aggregates for migration years 1997 to 2003 (see Berggren 2006 – Table 15 for the number of fish tagged annually).

The methods used for these analyses are the same as those used for spring/summer Chinook and are described in section 4.2 of Marmorek *et al*. (2007).

Results

Annual SAR estimates and management targets

The annual time series of aggregate hatchery steelhead SARs were lower than the corresponding annual time series of aggregate wild steelhead SARs in all but one year between 1997 and 2003 (Figure B1); however, the SARs for hatchery fish were only significantly lower in 1999 based on non-overlapping 90% confidence intervals

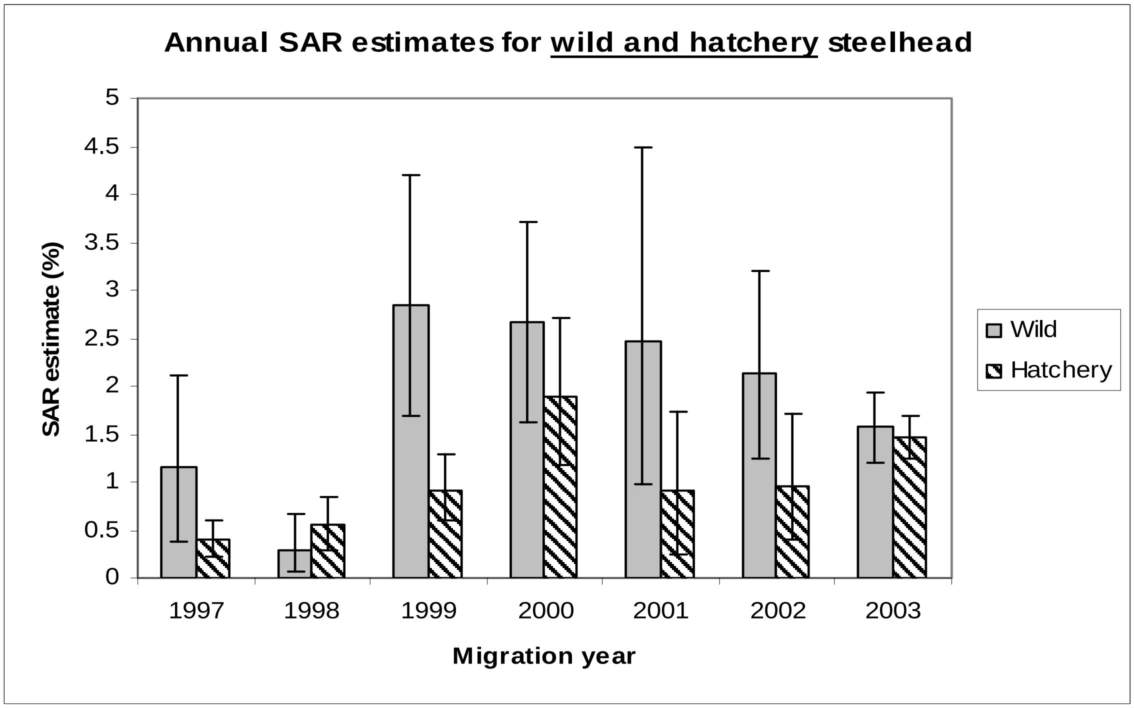


Figure B1. Trend in estimated annual SAR for hatchery and wild steelhead with 90% confidence intervals for migration years 1997 to 2003 (incomplete 2003 returns).

Wild steelhead

Annual estimates of $SAR_{LGR\text{-}to\text{-}LGR}$ for Snake River wild steelhead have dropped each year from the high estimated in 1999 of 2.86% to 1.57% estimated in 2003 (Figure B2, SAR_{Total} – striped bars). The observed pattern of decreasing estimated annual SAR_{Total} for wild steelhead is similar to that observed for the wild Chinook (see Section 4, Marmorek *et al*. 2007), the only difference being that the steelhead estimates are not dropping as rapidly over the period 1999 to 2003. The SAR estimates for wild steelhead in migration years 1999 to 2003 remained in the 2% vicinity for transported fish (T_0). SARs for in-river migrants (C_0) were significantly less than 2% in all years, excluding 2000, averaging around 0.71% SAR. Based on non-overlapping CIs between T_0 and C_0 classes, significant differences were observed for estimated SARs between transported and in-river migrants for migration years 2001 to 2003.

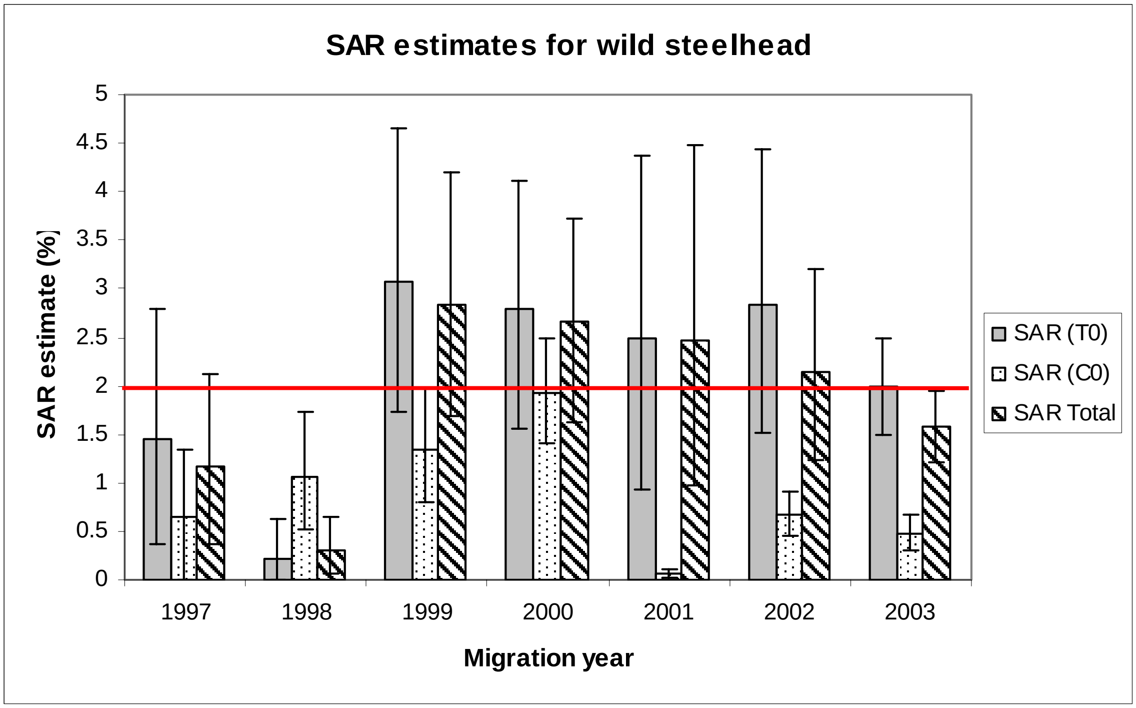


Figure B2. Estimated $SAR_{LGR\text{-}to\text{-}LGR}$ for wild steelhead in transport [$SAR(T_0)$] and in-river [$SAR(C_0)$] study categories, as well as the weighted SAR [SAR_{Total}] for migration years 1997 to 2003. The red horizontal line indicates the minimum NPCC interim goal of 2% SAR. Error bars are 90% CI.

Wild steelhead SAR_{Total} estimates are above the NPCC interim objective for a minimum SAR of 2% in 1999 to 2002 (Figure B3); however, they remain below the recommended average of 4% SAR (Berggren *et al*. 2006). Under Status Quo the 90% CIs overlap the 2% threshold in all years, with the exception of 1999 and 2003 where the 90% CIs were below the 2% interim goal (i.e., evaluation of compliance can be clearly assessed in 2 of 7 years).

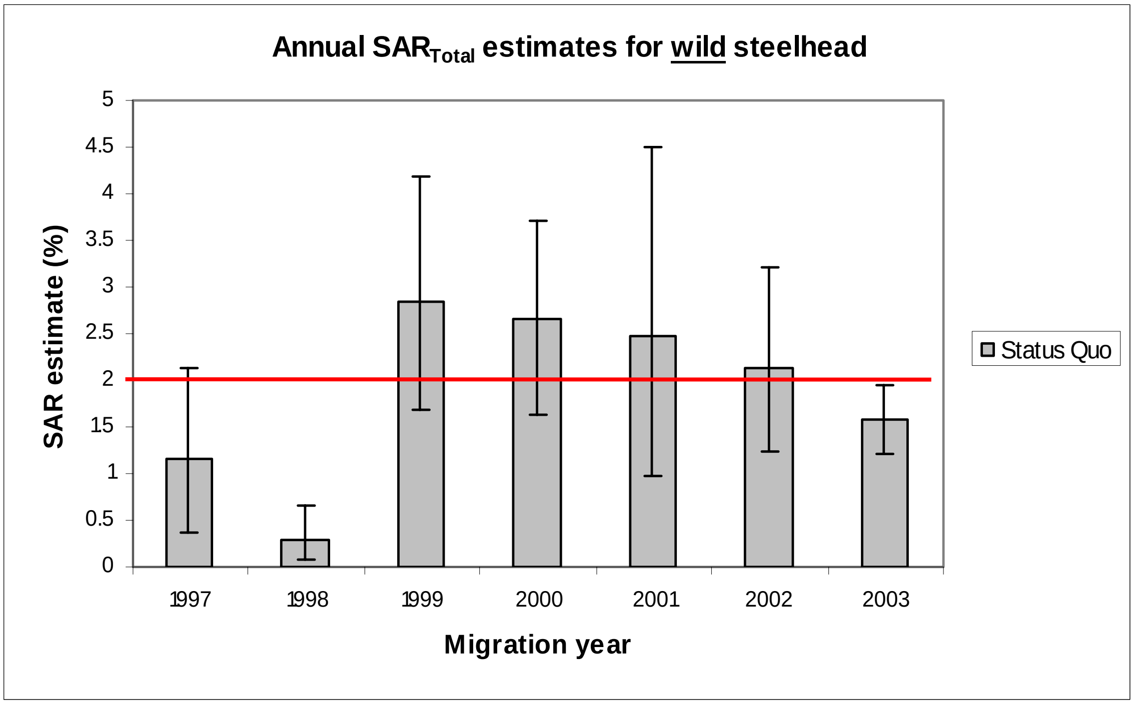
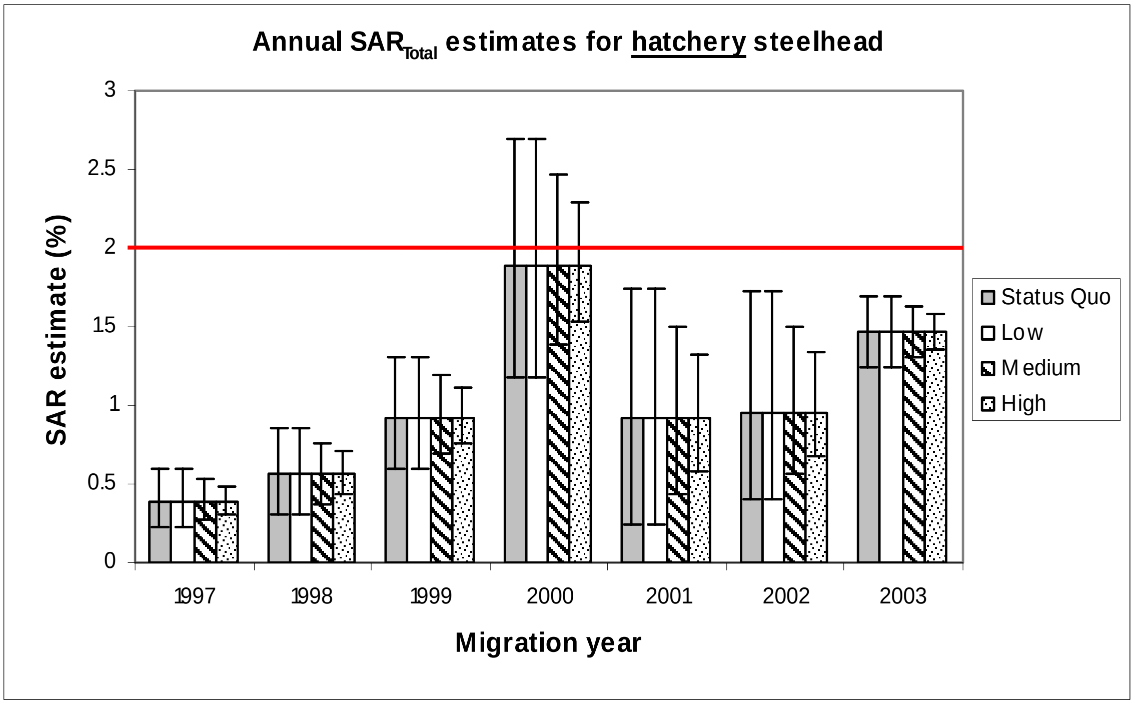


Figure B3. Estimated SAR$_{Total}$ for PIT-tagged wild steelhead for migration years 1997 to 2003 under Status Quo. Alternative tagging designs are not shown because the wild steelhead population is not large enough to allow increased tagging from Status Quo levels. i.e., Status Quo is already tagging as many wild fish as is opportunistically possible. The red horizontal line indicates the minimum NPCC interim goal of 2% SAR. Error bars are 90% CIs.

Hatchery steelhead

The 2003 estimate of SAR$_{Total}$ for Snake River hatchery steelhead was 1.46% (Figure B4). Although this is an improvement over 2001 and 2002 estimates, it is still below the 2% SAR interim goal set by NPCC. SAR$_{Total}$ estimates for hatchery steelhead have fallen below 2% SAR in all migration years for the period 1997 to 2003 (Figure B4). Evaluation of compliance with the 2% SAR threshold does not seem to improve under any of the alternative designs for hatchery steelhead at the Snake Basin level; compliance can be assessed in 6 of 7 years under Status Quo, Low, Medium, and High scenarios (see Figure B4). The lack of improvement is likely a result of SAR estimates lying so far below 2% in all years, except in 2000 where the SAR estimate is quite close to 2%.



FigureB4. Estimated SAR_{Total} for PIT-tagged hatchery steelhead for migration years 1997 to 2003 under alternative tagging designs. The red horizontal line indicates the minimum NPCC interim goal of 2% SAR. Error bars are 90% CIs.

Annual TIR estimates and management targets

Inter-annual variation in TIR estimates for both wild and hatchery steelhead may be large and can be expected to influence population viability if a large portion of fish are transported. In addition, sampling variance may also be substantial in parameter estimates of steelhead; this is in part a result of wild fish being opportunistically sampled because they tend to be available for capture and tagging in much lower numbers than hatchery fish. Sampling variance is inversely related to the number of adult returns, suggesting that the number of tagged smolts in each group of interest is a limiting factor for statistical inference of the differences in annual estimates of survival between groups. The confounding effect of this combined variation on inferences about these parameters can be seen in annual TIR estimates, where annual confidence bounds on TIR are wide and overlap the threshold value of 1.0 in a number of years. Combining data from multiple years may provide greater precision in the mean TIR estimate for wild steelhead via smaller CIs as is demonstrated in the analyses for wild Chinook (see Figure 4.12 in CSMEP *et al* 2007b).

Table B3. Estimated TIR ratios for wild and hatchery steelhead for 1997 to 2003 (with 90% CIs). Estimates calculated using data collected under Status Quo (Modified from Schaller *et al*. 2007). Estimates from 2001 are not included in the geometric mean, as this was a highly unusual year.

Year	TIR Estimates	
	Wild	Hatchery
1997	2.20 (0.00-8.16)	2.21 (0.99-5.66)
1998	0.20 (0.00-0.70)	0.58 (0.23-1.05)
1999	2.28 (1.15-4.38)	0.87 (0.48-1.41)
2000	1.45 (0.77-2.30)	2.20 (1.22-3.58)
2002	4.25 (2.12-7.67)	1.51 (0.38-3.33)
2003	4.13 (2.62-6.80)	2.65 (1.99-3.74)
Geometric mean	1.72 (0.18-16.73)	1.46 (0.43-4.93)
2001	37.0 (10.6-94.6)	59.7 (0.0-215.6)

Wild steelhead

The TIR estimates for wild steelhead, though based on small sample sizes, were generally greater than 1, with a geometric mean of 1.72 for 1997 to 2003, excluding 2001 (see Table B3; Figure B5). TIR estimates in 2001 were abnormally high as a consequence of the drought conditions which lead to exceptionally low in-river survival. The 1998 migration year was the only year with an estimated TIR below 1. A significant increase in the transport SAR over the in-river SAR is found when the lower limit of the 90% CI of the TIR ratio estimates is greater than one. This was observed in 4 of 7 years (1999 and 2001-2003; see Table B3).

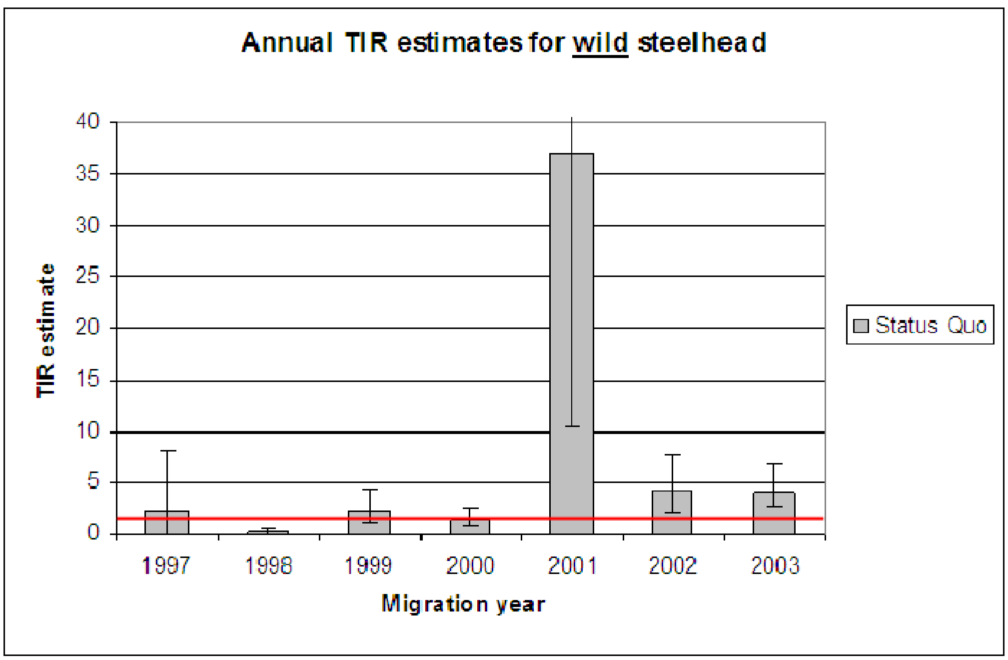


Figure B5. Estimated TIR for PIT-tagged wild steelhead for migration years 1997 to 2003 under Status Quo. Alternative tagging designs are not shown because the wild steelhead population is not currently large enough to allow increased tagging from Status Quo levels. i.e., Status Quo is already tagging as many wild fish as is opportunistically possible. The red horizontal line indicates the threshold of a 1:1 ratio of transported to in-river fish. Error bars are 90% CIs.

Hatchery steelhead

The TIR for hatchery steelhead, excluding 2001, ranged from 0.58 to 2.65 with a geometric mean of 1.46, excluding 2001 (Table B3). The TIR exceeded 1 in five of seven years (1997 and 2000 to 2003) (Figure B6; grey bars). TIRs were substantially larger than 1 in four of seven years (2000 to 2003) under Status Quo, however this may be partially the result of small sample sizes, particularly in 2001 (Schaller *et al*. 2007). Under Status Quo, TIRs were found to be significantly larger than 1 in 2 years (2000 and 2003; Table B3). In general, transport is beneficial to hatchery steelhead, although not as beneficial as it is for wild steelhead.

Whether transport SARs are significantly different than in-river SARs can be determined with increasing frequency under the Medium and High alternatives. Based on non-overlapping 90% CIs, the cumulative number of years that transportation effectiveness can be determined for hatchery steelhead is 2/7 years under the Low design and 4/7 years under the Medium and High designs (see Figure B6 for an annual breakdown; Table B4 for a summary). It is not currently possible to provide a breakdown of TIRs by hatchery. The benefit of increased tagging is highlighted by the smaller CIs under Medium and High scenarios where transportation effectiveness can be assessed in a greater number of years.

Table B4. Proportion of years where compliance with a transportation effectiveness threshold (i.e., TIR = 1) can be confidently determined for hatchery steelhead (1997 to 2003).

Hatchery	Existing Data	CSMEP M & E Alternatives		
	Status Quo	Low	Medium	High
Hatchery	2/7	2/7	4/7	4/7

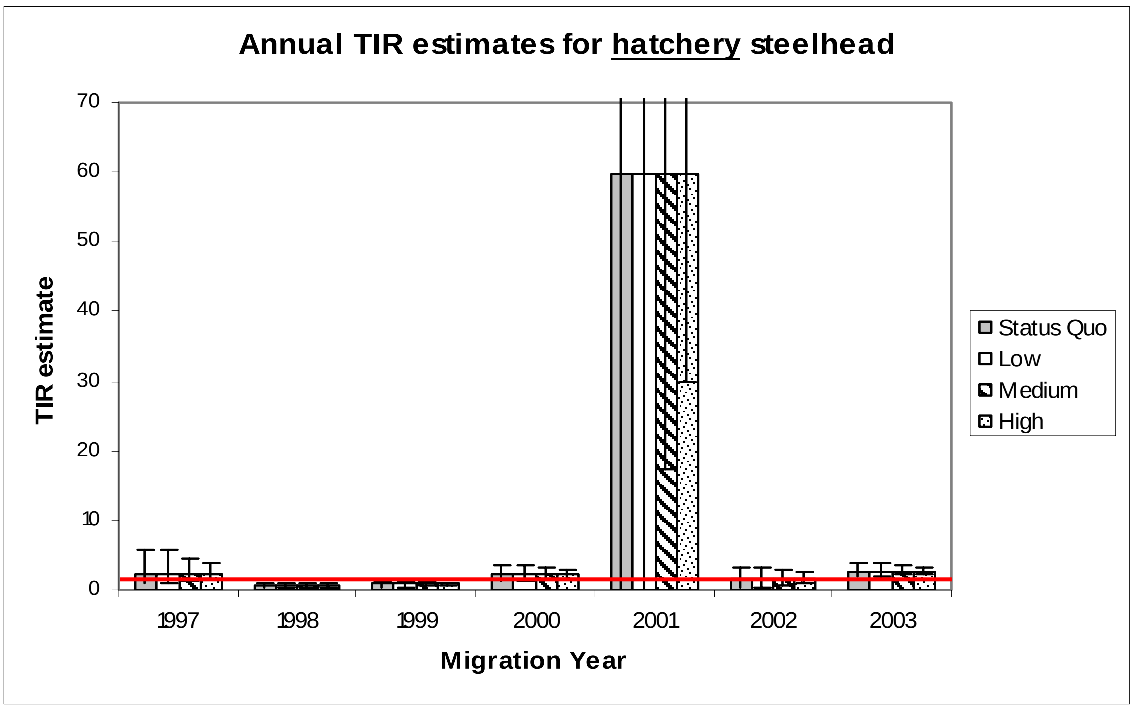


Figure B6. Estimated TIR for PIT-tagged hatchery steelhead for migration years 1997 to 2003 under alternative tagging designs. The red horizontal line indicates the threshold of a 1:1 ratio of transported to in-river fish. Error bars are 90% CIs.

Annual in-river survival and management targets

Table B5. Estimated S_R ratios for wild and hatchery steelhead for 1997 to 2003 with 90% CIs. Estimates calculated using data collected under Status Quo (modified from Schaller *et al*. 2007). Estimates from 2001 are not included in the geometric mean, as this was a highly unusual year.

Year	S_R Estimates	
	Wild	Hatchery
1997	0.52 (0.28-1.45)	0.40 (0.28-1.45)
1998	0.54 (0.48-0.62)	0.64 (0.47-1.02)
1999	0.45 (0.38-0.54)	0.45 (0.39-0.53)
2000	0.30 (0.28-0.35)	0.22 (0.19-0.26)
2002	0.52 (0.41-0.69)	0.37 (0.29-0.49)
2003	0.37 (0.31-0.44)	0.51 (0.43-0.62)
Geometric mean	0.44 (0.27-0.71)	0.41 (0.20-0.085)
2001	0.038 (0.027-0.059)	0.038 (0.023-0.088)

Annual trends in S_R over the period 1997 to 2003 are presented in Table B5 and Figure B7. The geometric mean of S_R for wild steelhead from 1997 to 2002, excluding 2001, was 0.44. During these same six years, the S_R estimate for wild Chinook had a geometric mean of 0.56, which was 27% higher than that for wild steelhead. The geometric mean of S_R for hatchery steelhead from 1997 to 2002, excluding 2001, was 0.41, similar to what was estimated for wild steelhead.

The BiOp standard for steelhead as laid out by the Federal Columbia River Power System (FCRPS) is a minimum of 50.6 percent smolt survival from LGR to BON dam. Using our example non-overlapping 90% CI compliance criteria, compliance with the BiOp standard under Status Quo can be assessed in 3 of 7 years for wild steelhead (Figure B7).

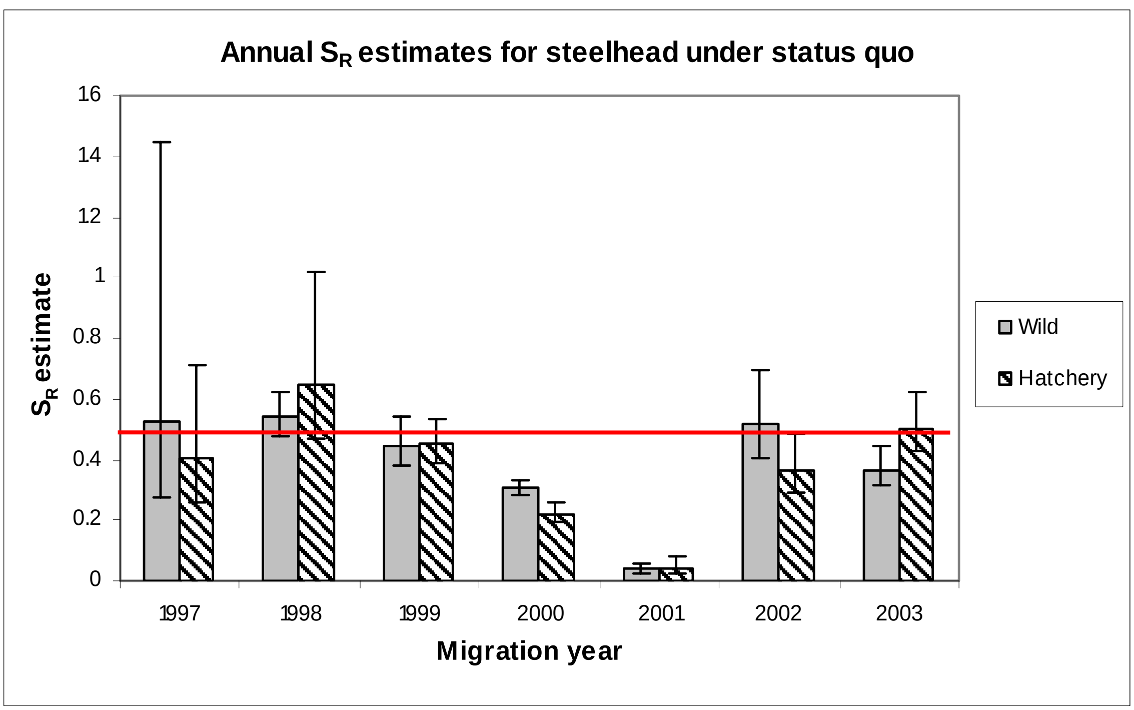


Figure B7. Estimated S_R for PIT-tagged steelhead for migration years 1997 to 2003 under status quo. The red horizontal line indicates the BiOp standard of 0.506 S_R. Error bars are 90% CIs.

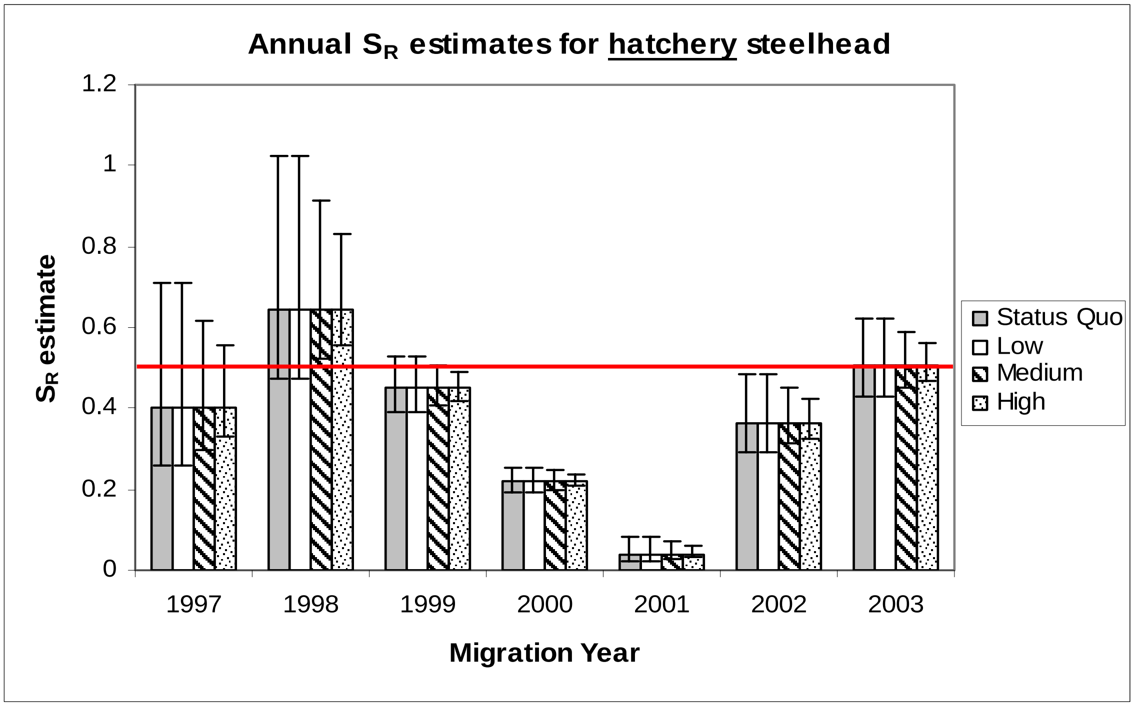


Figure B8. Estimated S_R for PIT-tagged hatchery steelhead for migration years 1997 to 2003 under alternative tagging designs. The red horizontal line indicates the BiOp standard of 0.506 S_R. Error bars are 90% CIs.

With respect to hatchery steelhead it is possible to determine compliance with the BiOp standard in 3 of 7 years under the Status Quo and Low alternatives. For the Medium and High alternatives it is possible to determine compliance in 5 of 7 years (Figure B8).

Within season variation in transportation of fish

TIRs can vary substantially over the season for both wild and hatchery steelhead (Table B6; Figure B9). The quartile TIR estimates for wild steelhead suggest that survival would be higher overall for smolts transported throughout the migration season compared to allowing them to outmigrate in-river dpending on each season's in-river conditions (i.e., TIR estimates are greater than 1 for all quartiles). The relative survival of in-river fish depends on the given in-river outmigration conditions for each year. With respect to hatchery steelhead, quartile TIR estimates suggest that survival of transported hatchery smolts would be highest if they were transported only during the last three quarters of the year; however in the first quartile the TIR estimate suggests that smolts fare equally well from both in-river outmigration and barge transport (i.e., TIR estimate is very close to 1 in first quartile).

Table B6. Mean TIRs by quartiles for hatchery and wild steelhead during the period 1997 to 2003. Ninety-five percent CIs are shown in brackets.

	Quartile			
	1	2	3	4
Wild steelhead TIRs	2.07 (1.83-2.32)	1.44 (1.24-1.66)	1.98 (1.69-2.29)	3.12 (2.52-3.79)
Hatchery steelhead TIRs	0.96 (0.77-1.15)	2.79 (2.38-3.23)	3.52 (2.96-4.11)	5.77 (4.75-6.92)

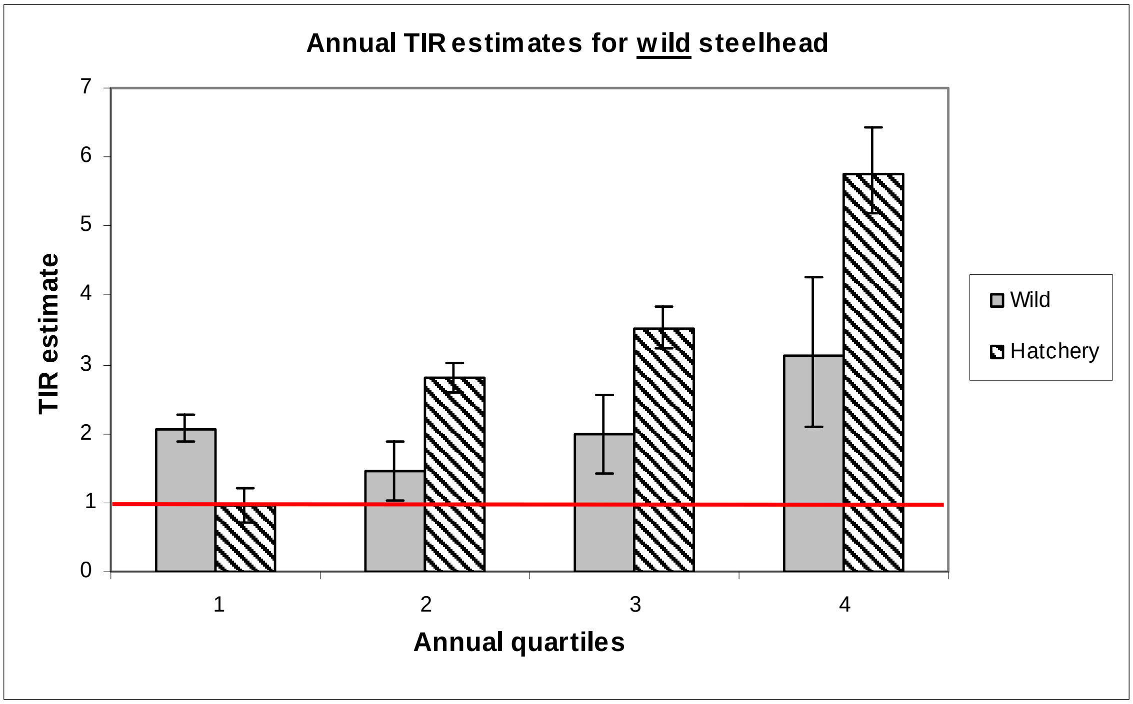


Figure B9. Estimated mean TIR by quartile for hatchery and wild steelhead during the period 1997 to 2003. Error bars are 95% CIs.

Summary of results

A summary of the results for SAR, TIR, and S_R estimates is given in Table B7.

Table B7. Evaluation of Monitoring Design Alternatives for Snake River steelhead.

Evaluation Criteria	Status Quo	Low	Med	High
Fraction of years for which definitive[1] evaluations can be made of achieving the SAR target[2]	Snake Basin level: wild: 2/7 years hatchery stocks: 6/7 years MPG level: *in prep*	Snake Basin level: hatchery stocks: 6/7 years MPG level: *in prep*	Snake Basin level: hatchery stocks: 6/7 years MPG level: *in prep*	Snake Basin level: hatchery stocks: 6/7 years MPG level: *in prep*
… of in-river survival target	wild: 3/7 years hatchery stocks: 3/7 years	hatchery stocks: 3/7 years	hatchery stocks: 5/7 years	hatchery stocks: 5/7 year
… whether transportation SARs > In-river SARs	wild: 5/7 years hatchery stocks: 2/7 years MPG level: *in prep*	hatchery stocks: 2/7 years MPG level: *in prep*	hatchery stocks: 4/7 years MPG level: *in prep*	hatchery stocks: 4/7 years MPG level: *in prep*

[1] "Definitive evaluations" are considered to occur when the 90% confidence interval for the estimate does not overlap the target. This is used as an example decision criterion.

[2] Source for Status Quo: Tables D19-20, D27-28, and E12-25 in Schaller et al. (2007)

Discussion and recommendations

Determining compliance with SAR goals under different M & E designs

Average SARs for wild steelhead during the period from 1997 to 2003 have been below the minimum 2% recommended in the NPCC Fish and Wildlife Program mainstem amendments in 3 of 7 years (NPCC 2003). While this target is primarily for wild populations, we can examine the performance of hatcheries against this same SAR goal. SARs for hatchery Snake River steelhead have been consistently below the 2% target in all years during 1997 to 2003.

Determination of whether the minimum 2% SAR goal has been met (with a high degree of confidence) does not appear to improve under the Medium and High design alternatives relative to the Status Quo, for hatchery steelhead. This result is a consequence of the annual SAR estimates being substantially less than the 2% SAR minimum, so much so that their upper 90% CIs generally fall well below 2% under Status Quo. The benefit of a reduction in estimated uncertainty that is expected from an increase in tag numbers (i.e., narrower CIs on SAR estimates under Medium and High alternatives) is therefore not realized under the condition of very low SARs. However, when the value of the annual SAR estimate is such that its Status Quo CI straddle 2% SAR, moving to a Medium or High design would allow determination of whether the SAR was met with greater frequency because of the narrower CI (except when the estimated SAR is very close to 2%).

Simulation results of annual SAR estimates and CIs under different tag number scenarios suggest that a longer time series, rather than increased annual tag numbers, is the primary driver behind narrowing CIs for long-term SAR mean values (see Section 4, Marmorek *et al.* 2007). This raises the question of whether the increased precision in annual SAR estimates for a single year is worth the substantial additional cost of tagging more fish. Getting the best possible estimates of SAR in individual years (by marking large numbers of fish) is useful for other purposes (e.g., understanding which covariates affect SARs), but not necessary for estimating long-term mean values. The tradeoff between annual cost and the increased certainty in annual SAR estimates is one that managers need to be aware of and consider when making management decisions regarding short versus long-term recovery objectives for steelhead.

Taking multiple-year SAR estimates is an alternative method to decrease the uncertainty in SAR estimates as shown in the analyses for spring/summer Chinook (see Marmorek *et al*. 2007). This particular method is valuable when it is not possible to increase tag numbers for budgeting or biological reasons (i.e., not enough funds or fish to tag). The latter is particular true in the case of wild steelhead populations.

Determining transportation effectiveness under different M & E designs

In general, transport SARs were higher than in-river SARs in most years for Snake River wild steelhead (1997 to 2003); the TIR for wild steelhead was significantly greater than 1 in 1999 and 2001 to 2003 (i.e., lower 90% CI > 1) and significantly less than 1 only in 1998 (i.e., upper 90% CI < 1). Transportation appeared to be of greatest benefit during the severe drought conditions of 2001. It is difficult to determine transportation effectiveness in 2 years (1997 and 2000) because of overlapping CIs. Small sample sizes limit the confidence that transportation has been beneficial in particular years (Schaller *et al*. 2007). The 10-year geometric mean (excluding 2001) TIR ratio was 1.72, while in 2001 the TIR was approximately 20-fold higher. This unweighted geometric mean does not take into account the magnitude of uncertainty of point estimates in the individual years. The low number of adult returns makes it difficult to determine with a high degree of confidence whether in a given year transportation improved overall survival of hatchery steelhead compared to leaving fish in-river (transportation effectiveness can only be determined in 2/7 years). Omitting 2001, which had an estimated TIR of 59.7, the 7-year geometric mean TIR was 1.46, indicating a higher transport benefit. In general, hatchery steelhead had a moderately increasing trend in TIR estimates; however, there was only minor demonstration of statistical significance indicating a benefit in just over half of the CSS study years.

The ability to definitively determine whether survival is higher for transported fish or in-river migrants is contingent on two things: 1) the degree of difference between the TIR estimate and the value of one (i.e., the closer the TIR estimate is to one, the harder it is to distinguish which is better); and 2) the width of the 90 percent CI on the TIR estimate, coupled with whether the CI straddles the value of one. For wild steelhead it is not possible to increase tagging efforts because of the small population size; an action that if feasible, would help to decrease CI width. That being said, given the current TIR estimates under Status Quo, increased tagging of wild fish would not substantially increase the number of years where compliance could be detected (i.e., compliance cannot be detected in only 2 of 7 years).

With respect to hatchery steelhead, the Low design yields the same as the Status Quo because the same number of hatchery fish are tagged. The Medium and High designs on the other hand, improve the ability to ascertain the relative survivals by alternative down-river route relative to Status Quo.

Simulation results of TIRs presented in Marmorek *et al*. (2007) suggest that increasing annual tag numbers does result in narrowed CIs of long-term estimates of TIRs. The increase in precision about the TIR estimate is likely due, at least in part, to the improvement in estimation of the correlation coefficient between transport and in-river SARs because of more reliable point estimates of the SARs. Similar to simulation results for SARs, accumulating years (i.e., longer time series) also has the benefit of decreasing uncertainty in TIR estimates. Simulations of different transportation decision rules also suggest that increased tag numbers lead to a higher probability of making the correct decision in a shorter amount of time, even when using an inappropriate rule. However, simulation results show that in the long run improvements in decision making from increased tag number are minimal compared to improvements in decision making as a result of longer time series.

This raises similar questions to those posed regarding increasing tag numbers and associated costs to improve SAR estimates. Is the cost of increased tagging worth the improved inter-annual decision making ability with respect to the transportation of fish? Again, this is something that managers need to be aware of and take into consideration when setting both short and long-term objectives.

Determine whether in river-survival rates meet 2000 BiOp performance standards under different M & E designs

The FCRPS BiOp set a performance standard of 50.6 percent for smolt survival from LGR to BON dam. Status Quo monitoring has PIT tags on about 26,000 hatchery steelhead, although numbers vary depending on strength of the run and hatchery objectives (e.g., can be as high as 36,000 PIT tags). Survival to LGL of the 26,000 tagged fish is generally low, and only about half of surviving fish are detected, leaving a much smaller number from which to calculate in-river survival estimates for steelhead.

During the period from 1997 to 2003, it is possible to determine compliance with BiOp standard in 3 of 7 years for both wild and hatchery steelhead. Increasing the number of PIT tags for hatchery steelhead would result in an increased ability to assess compliance (5 of 7 years under Medium and High alternatives).

How does effectiveness of transportation change over the course of the season?

SARs appear to be higher for wild steelhead collected and transported during all quartiles, compared to wild steelhead migrating in-river, given each season's in-river conditions.
These observations are based on the in-river conditions that occurred during the period of our analysis (1997 to 2003). Other in-river migration conditions could result in different in-season TIR ratios. Seasonal TIR estimates calculated annually and pooled over a multi-year period will likely be needed to assess whether seasonal TIR objectives are met within a target level of precision and accuracy. Multiple-year estimates can provide insights on whether survival objectives are met using a lower number of PIT-tagged fish, which permits analyses on smaller temporal scales (in-season patterns). Increasing the number of PIT tags per year will improve the precision of annual and seasonal estimates, but for transportation evaluations a very large increase in tags would be required to make substantive improvements over the *Status Quo* design we evaluated. For multiple-year estimates, statistical precision increases with increasing tag numbers up to 5,000 tags, but beyond this level, little further benefit is seen.

Adding more years of PIT tag observations can significantly improve statistical precision. Simulation results of annual SAR estimates and CIs under different PIT tag number scenarios suggest that a longer time series, rather than increased annual PIT tag numbers, is the primary driver behind narrowing CIs for long-term SAR mean values (see Section 4, Marmorek *et al.* 2007). Simulation results of TIRs presented in Marmorek *et al*. (2007) suggest that increasing annual PIT tag numbers results in narrowed CIs of long-term estimates of TIRs. This increase in precision of the TIR estimate is likely due to the improvement in the estimation of the correlation coefficient between transport and in-river SAR's because of more precise point estimates of the SAR's obtained when more fish are PIT tagged. This result for TIR estimates is similar to the simulation result for SARs -- a longer time series rather than an increase in annual PIT tag numbers is a better strategy to improve the accuracy and precision of these estimates.

With respect to costs of different M&E alternatives, there is likely to be a tradeoff between the intensity of annual monitoring and duration (number of years) over which consistent M&E is sustained. Additionally, the ratio of transport SARs and in-river SARs, whether estimated on an annual basis or for discrete in-season timeframes, will be influenced by in-river migration conditions caused by manipulation of the hydrosystem, climatic conditions, or a combination of both. If in-river out-migration conditions vary from year to year, survival evaluations using multiple year estimates may hide important year to year differences in the relative effectiveness of transportation to recover and sustain populations.

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Appendix C. Fishery Management Decisions

List of common fishery management decisions made by multiple agencies in the Columbia River Basin and their relation to the full funding level CSMEP FY08 work tasks, CBFWA amendments, and the FCRPS RPA's

Decision	Agencies involved	Information/Data Necessary	Spatial Scale	Time Scale	CSMEP FY08 task	CBFWA Amendment	FCRPS RPA
Status and Trend							
How to allocate resources to implement a monitoring program to collect VSP data for listed species	States, tribes, NOAA, USFWS, NPCC, BPA	Monitoring design, costs and benefits, trade-offs	Population, MPG, ESU/DPS	As needed.	5.1 (c); 5.6; 6.1; 7.1	2.1.5	3, 50; 51,73
How to allocate resources to implement a monitoring program to collect data for unlisted species	States, tribes, USFWS, NPCC	Monitoring design, costs and benefits, trade-offs	Population	As needed.	5.1 (c); 5.6; 6.1; 7.1	2.1.5; 2.2.5	NA
Does the M&E program need to be modified based on an evaluation of data collected (adaptive management).	States and tribes (federal agencies if species is listed)	Accuracy and precision of the data collected	Population, MPG, ESU	Annually	7.1	1.4; 1.5; 2.1.5; 2.2.5	3, 50
For ESA listed species is the ESU/DPS viable?	States, tribes, NOAA, USFWS	Adult abundance, productivity, spatial structure and diversity (VSP parameters)	Population, MPG, ESU/DPS	Assessment every 5 years. Data collected annually.	NA	1.4; 1.5; 2.1.5; 2.2.5	50
For listed and non-listed species are the agency management objectives being met?	States and tribes, NPCC (federal agencies if species is listed)	abundance, productivity, age structure, distribution, genetics	Population, MPG, ESU/DPS	Annually	NA	1.4; 1.5; 2.1.5; 2.2.5	50; 51; 71
Habitat							
Prioritize watersheds and sites for habitat improvement activities	states and tribes, NPCC, OWEB, SRFB, OSC, local recovery boards, land owners, land management agencies	habitat conditions, fish abundance and distribution. Limiting factors (physical, biological, hydrological)	Watersheds, Subbasin, local sites	Infrequently	5.3(b)	2.1.5.2	1, 34, 38, 56
Develop and implement specific habitat actions for each site.	states and tribes, land owners, land management agencies	limiting factors to address (site/stream specific)	watershed and site specific	Usually done once for each project.	NA	2.1.5.11	56

Decision	Agencies involved	Information/Data Necessary	Spatial Scale	Time Scale	CSMEP FY08 task	CBFWA Amendment	FCRPS RPA
How to allocate resources to design and implement a monitoring program to evaluate habitat restoration activities.	States, tribes, NOAA, USFWS, land owners, land management agencies	limiting factors, project goals, expected or desired results from the action(s), a M&E design to assess the restoration impacts	watershed and site specific	Usually done once for each project monitored. Intensive M&E of all projects may not be feasible, hence results from IMWs will need to be applied.	5.3(a)	2.1.5.11	56; 57
Did the habitat action achieve their objectives	States, tribes, NOAA, USFWS, land owners, land management agencies	fish abundance, productivity, distribution. Hydrological measures (% fine sediment, water temperature, water quality and quantity, riparian conditions)	Project specific based on the objective and action	Usually done once for each project monitored. Intensive M&E of all projects may not be feasible, hence results from IMWs will need to be applied.	NA	2.1.5.11; 2.1.5.2	35, 56; 57
Modify, adjust, alter habitat actions based on knowledge gained from M&E of previous habitat actions	states and tribes, land owners, land management agencies	Determine if habitat actions improved fish abundance and/or productivity, distribution, and did the habitat action improve the limiting factors (improved in-stream and/or riparian habitat, improve water quality and/or quantity)	Watersheds, local areas	As needed	NA	1.4; 1.5; 2.1.5.2	35, 56; 57
<u>Harvest</u>							
Is there enough Chinook salmon returning to the Columbia River to have a fishing season? (Yes or No)	TAC	Forecasted estimates of returns and stock composition, escapement targets and broodstock needs.	Columbia River Basin, subbasins, hatcheries	Annually. Done prior to the fishing season (Pre-season).	NA	NA	NA
Craft Chinook salmon fishing season, allocation, and regulations.	states and tribes with NOAA review	Forecasted estimates of returns and stock composition, escapement targets and broodstock needs.	Columbia River Basin, subbasins, hatcheries	Pre-season	NA	NA	NA

Decision	Agencies involved	Information/Data Necessary	Spatial Scale	Time Scale	CSMEP FY08 task	CBFWA Amendment	FCRPS RPA
Design and Implement surveys to monitor and estimate harvest and impacts of the fisheries.	states, tribes	re-assessment of predicted returns and re-adjustment of adult returns (Bonneville Dam counts), monitor fisheries to estimate catch and impacts on target and non-target species, hatchery rack returns	Columbia River Basin, subbasins, hatcheries	Pre-season and in-season	5.5(b); 5.6(c); 5.6(d); 5.6(e)	2.1.5.2; 2.1.5.3; 2.1.5.7; 2.1.5.10; 2.1.5.12	62
Do fishing regulations and season need adjustments based on in-season monitoring of the fishery.	states, tribes, TAC, NOAA	Updated run-size estimate, run timing, stock composition, estimates of harvest and impact on non-target species	Columbia River Basin, subbasins	In-season	NA	NA	NA
Allocation of enforcement personnel to ensure compliance of fishing rules and regulations.	States, tribes, NOAA, USFWS, USFS	availability of personnel, fishing rules and regulations	Columbia River Basin, subbasins	Pre-season and in-season	NA	NA	NA
Were the fishery management objectives achieved.	States, tribes, NOAA, USFWS	Post-season evaluations using indicators such as catches, escapement, hatchery returns, impacts on non-target species, fishing effort, and harvest rates.	Columbia River Basin, subbasins, hatcheries	Annually. Done post-season	NA	1.4; 1.5	NA
<u>Hatcheries</u>							
Initiate a hatchery program	states, tribes, USFWS	Local stock abundance. Fishery management goals for targeted area. Water quantity and quality. Cost.	Subbasin, Site specific	Infrequently	NA	NA	1, 39, 40, 41, 42
Establish goals and objectives for hatchery program	states, tribes, USFWS	Expected SAR's, expected adult returns, expected harvest amount and location of fisheries	Ocean, Columbia River Basin, Subbasin, Hatchery specific	Usually done when hatchery program initiated with annual review and revisions.	NA	NA	41, 42
Develop hatchery operation plan (broodstock, spawning, rearing, feeding, disease management, etc)	states, tribes, USFWS	spawning plan, number of eggs, juveniles, growth rate, disease monitoring	Hatchery specific	Annually, in-season.	NA	NA	39, 40
Develop a marking plan	states, tribes, USFWS, US <u>v</u> OR	fishery and M&E goals, US <u>v</u> OR agreement	Ocean, Columbia River Basin, Subbasin, Hatchery specific	Annually	5.4(b)	2.1.5.2; 2.1.5.3; 2.1.5.6; 2.1.5.7; 2.1.5.12	63; 64; 65

Decision	Agencies involved	Information/Data Necessary	Spatial Scale	Time Scale	CSMEP FY08 task	CBFWA Amendment	FCRPS RPA
Determine release sites, number of fish to release, life-stage of release, date of release	states, tribes, USFWS, US v OR	hatchery capacity, access to release locations, SAR of life-stage specific release groups, migration timing, smolt condition	Subbasin	Annually	NA	2.1.5.10	NA
Are hatchery objectives being met. How to modify and adjust hatchery program to achieve objectives if not being met.	states, tribes, USFWS, US v OR	Harvest Augmentation Hatcheries: hatchery returns, PNI, number of smolts released, SAR, contribution to fisheries (harvest), stray rates. Supplementation Hatcheries: Recruits per spawner for hatchery and natural fish, hatchery and natural adult abundance, hatchery and natural spawning distribution, SAR's, PNI, stray rates	Ocean, Columbia River Basin, Subbasin, Hatchery specific	Annually	5.4(b); 5.4(c)	1.4; 1.5	63; 64; 65
Terminate a hatchery program.	states, tribes, USFWS, US v OR	All of the above.	Subbasin, Hatchery specific	Infrequently	NA	NA	NA
Hydrosystem							
Develop hydrosystem operation plan (spill, transport, structural improvements)	States, tribes, NOAA, USACE, BPA	smolt and adult run-timing and duration, behavior of smolts and adults passing each project, projected flows	Columbia River Basin and Project specific	Annually and in-season	NA	2.1.5.4; 2.1.5.5; 2.1.5.8	1, 4, 5, 7, 10, 13 - 15, 18 - 33
Determine if salmon and steelhead juvenile and adult hydrosystem passage performance objectives are being met	States, tribes, NOAA, USACE, BPA	hydrosystem survival (adult and smolts), SAR, percent adult and juvenile mortality by project, TIR, Water Travel Time, spill, gas saturation, other water quality measures.	Columbia River Basin and Project specific	Annually and in-season	5.2; 5.6(c); 5.6(d); 5.6(e); 7.1	2.1.5.4; 2.1.5.5; 2.1.5.8	52; 53; 54
Modify, adjust, alter hydrosystem actions based on knowledge gained from M&E	States, tribes, NOAA, USACE, BPA	All hydrosystem data listed above.	Columbia River Basin and Project specific	Annually and in-season	NA	1.4; 1.5	6, 8, 9, 17, 55

Acronyms for Appendix C

BPA	Bonneville Power Administration
DPS	Distinct Population Segment
ESA	Endangered Species Act
ESU	Evolutionary Significant Unit
FCRPS	The Federal Columbia River Power System
IMW	Intensively Monitored Watershed
M&E	Monitoring and Evaluation
MPG	Major Population Group
NA	Not applicable
NOAA	National Oceanographic and Atmospheric Administration, Fisheries Service
NPCC	Northwest Power and Conservation Council
OCS	Idaho State Office of Species Conservation
OWEB	Oregon Watershed Enhancement Board
RPA	Reasonable and Prudent Alternative
SRFB	Washington State Salmon Recovery Board
TAC	Technical Advisory Committee
USACE	United States Army Corps of Engineers
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
US v OR	United States versus Oregon
VSP	Viable Salmonid Population

Appendix D. CSMEP Strengths and Weaknesses Assessment of current fall Chinook monitoring in the Snake River Fall Chinook MPG

R. Orme (Nez Perce Tribe Fisheries)

Table D1. Summary of monitoring activities used to assess fall Chinook viability in the Snake River ESU. x = monitoring occurs in the Major Spawning Area (SA) defined by the TRT.

			Snake River Fall Chinook ESU				
Data need	**Method/Description**		**Tucannon River SA**	**Clearwater River SA**	**Hells Canyon Lower SA**	**Hells Canyon Upper SA**	**Grande Ronde River SA**
Abundance of adults	A1		Redd expansion	Adult count at Lower Granite Dam for these four SA's combined; redd expansion within each SA.			
Abundance and distribution of redds	B1	Multiple pass counts	Ground count	Aerial Surveys	Aerial Surveys	Aerial Surveys	Aerial Surveys
Age structure of spawners	C1	Tags (CWT, PIT)	Carcass survey	Sub-sample at Lower Granite Dam			
	C2	Hard parts, scales	Carcass survey	Sub-sample at Lower Granite Dam			
	C3	Length at age	Carcass survey	Sub-sample at Lower Granite Dam			
Origin of spawners	D1		Carcass survey	Sub-sample at Lower Granite Dam			
Sex ratio of spawners	E1		Carcass survey	Sub-sample at Lower Granite Dam			
Abundance and spatial distribution of juveniles/smolts	F1	Juvenile trap (number)		2			
	F2	Beach seine			X	X	
	F3	Snorkel survey--random					
	F4	Snorkel survey--fixed					
	F5	Presence/absence					
Survival of juveniles/smolts	G1	Hatchery		X	X	X	X
	G2	Wild	X	X	X	X	

Age structure of juveniles/smolts	H1	Juvenile trap		X			
	H2	other in-river sampling					

Table D2. Summary of fall Chinook redd counts within each major spawning area (SA) by reach and survey method describing the number of redds observed, the length of the survey, and the number of surveys conducted for years 1995 through 2006. Data from Conner *et al*. 2007 and Milks *et al*. 2007.

	Reach	Data type	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Hells Canyon Upper Reach SA	Snake River air counts	# redds	28	49	20	109	226	188	306	647	675	686	665	455
		km surveyed	64.4	64.4	64.4	64.4	64.4	64.4	64.4	64.4	64.4	64.4	64.4	64.4
		# of surveys	7	7	8	8	9	9	10	7	7	8	8	6
	Snake River under water counts	# redds	5	7	4	28	77	42	90	115	168	282	207	148
		# of sites	41	23	51	39	62	50	55	47	35	54	29	40
	Imnaha River air counts	# redds	4	3	3	13	9	9	38	72	43	35	36	36
		km surveyed	15.8	6.1	6.1	22.5	31.4	31.4	31.4	31.4	31.4	31.4	31.4	31.4
		# of surveys	6	5	7	6	9	9	9	7	8	8	8	6
	Salmon River air counts	# redds	2	1	1	3	0	0	22	31	18	21	27	9
		km surveyed	168.9	140.0	215.6	168.9	154.5	154.5	168.9	168.9	168.9	168.9	168.9	168.9
		# of surveys	1	4	3	3	3	2	1	2	3	3	3	3
	Totals	**# redds**	**34**	**53**	**24**	**125**	**235**	**197**	**366**	**750**	**736**	**742**	**728**	**500**
		km surveyed	**249.1**	**210.5**	**286.1**	**255.9**	**250.2**	**250.2**	**264.7**	**264.7**	**264.7**	**264.7**	**264.7**	**264.7**
		redds/km	**0.14**	**0.25**	**0.08**	**0.49**	**0.94**	**0.79**	**1.38**	**2.83**	**2.78**	**2.80**	**2.75**	**1.89**
Hells Canyon Lower Reach SA	Snake River air counts	# redds	13	22	29	26	47	67	229	231	443	532	377	241
		km surveyed	95.8	95.8	95.8	95.8	95.8	95.8	95.8	95.8	95.8	95.8	95.8	95.8
		# of surveys	7	7	8	8	9	9	10	7	7	8	8	6
	Snake River under water counts	# redds	19	26	5	22	33	49	84	120	226	209	193	181
		# of sites	1	9	12	7	11	10	12	13	12	13	12	16
	Asotin Creek air counts	# redds									3	4	6	1
		km surveyed									12.5	12.5	12.5	12.5
		# of surveys									2	2	3	2
	Totals	**# redds**	**13**	**22**	**29**	**26**	**47**	**67**	**229**	**231**	**446**	**536**	**383**	**242**
		km surveyed	**95.8**	**95.8**	**95.8**	**95.8**	**95.8**	**95.8**	**95.8**	**95.8**	**108.3**	**108.3**	**108.3**	**108.3**
		redds/km	**0.14**	**0.23**	**0.30**	**0.27**	**0.49**	**0.70**	**2.39**	**2.41**	**4.12**	**4.95**	**3.54**	**2.23**

Table D2. Continued.

	Reach	Data type	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Clearwater River SA	Lower Clearwater River air counts	# redds	20	66	58	78	179	164	290	520	544	592	433	251
		km surveyed	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0	66.0
		# of surveys	3	4	9	5	10	11	8	9	9	10	10	6
	Upper Clearwater River air counts	# redds	0	0	0	0	2	8	16	4	19	36	54	6
		km surveyed	51.5	51.5	51.5	51.5	51.5	51.5	51.5	51.5	51.5	51.5	51.5	51.5
		# of surveys	2	1	7	5	8	11	4	3	9	2	3	2
	North Fork Clearwater River air counts	# redds	0	2	14	0	1	0	1	0	8	2	0	0
		km surveyed	2	2	2	2	2	2	2	2	2	2	2	2
		# of surveys	3	5	9	5	7	11	4	9	9	10	10	6
	South Fork Clearwater River air counts	# redds	0	1	0	0	2	1	5	0	0	0	0	0
		km surveyed	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.4	22.4
		# of surveys	1	3	7	5	8	6	7	3	3	2	1	1
	Middle Fork Clearwater River air counts	# redds	0	0	0	0	0	0	0	0	0		0	0
		km surveyed	37.0	37.0	37.0	37.0	37.0	37.0	37.0	37.0	37.0		37.0	37.0
		# of surveys	2	2	2	5	3	4	5	1	1	0	1	1
	Selway River air counts	# redds	0	0	0	0	0	0	0	0	0	0	0	0
		km surveyed	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0	30.0
		# of surveys	2	2	2	5	3	5	6	1	1	0	2	1
	Potlatch River ground counts	# redds					7	0	24	3	1	1		
		km surveyed					4.0	4.0	4.0	4.0	4.0	4.0		
		# of surveys					1	5	3	3	2	3		
	Totals	**# redds**	**20**	**69**	**72**	**78**	**191**	**173**	**336**	**527**	**572**	**631**	**487**	**257**
		km surveyed	**208.9**	**208.9**	**208.9**	**208.9**	**212.9**	**212.9**	**212.9**	**212.9**	**212.9**	**175.9**	**208.9**	**208.9**
		redds/km	**0.10**	**0.33**	**0.34**	**0.37**	**0.90**	**0.81**	**1.58**	**2.48**	**2.69**	**3.59**	**2.33**	**1.23**

Table D2.. Continued.

	Reach	Data type	**1995**	**1996**	**1997**	**1998**	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**
Grande Ronde Rive SA	Grande Ronde River air counts	# redds	18	20	55	24	13	8	197	111	93	162	129	41
		km surveyed	72.9	85.3	85.3	85.3	85.3	85.3	85.3	85.3	85.3	85.3	85.3	131.9
		# of surveys	3	4	8	6	7	7	9	7	8	8	9	6
		redds/km	0.25	0.23	0.64	0.28	0.15	0.09	2.31	1.30	1.09	1.90	1.51	0.31
Tucannon River SA	Tucannon River ground counts	# redds	29	43	27	40	21	19	65	183	143	111	61	
		km surveyed	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	25.1	25.1	25.1	
		# of surveys	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	7	7	
		redds/km	1.16	1.71	1.08	1.59	0.84	0.76	2.59	7.29	5.70	4.42	2.43	

Table D3. Summary of fall Chinook hatchery releases in each Major Spawning Area (SA) by life stage describing the number released by mark type, the number unmarked, the proportion of releases receiving a mark, the number of PIT tags released within each group, and the proportion of the release group that received PIT tags. Ad = Adipose fin clip; CWT = Coded Wire Tag; VIE = Visual Implant Tag. Data from Bill Arnsburg (NPT) personal communication.

Spawning Area	Release Year	Life Stage	Adipose Clip	CWT	Ad + CWT	VIE with/wo AD,CWT	Unmarked	Total Released	Proportion Marked	# PIT Tagged	Proportion PIT Tagged
Clearwater River	1997	subyearling	3,543		233,756		15,406	252,705	0.94		
		yearling	3,059		189,181		7,159	199,399	0.96		
	1998	yearling	1,792		58,986		394	61,172	0.99		
	1999	subyearling		195,231			151,874	347,105	0.56	1,997	0.006
		yearling	1,844	1,784	225,980		0	229,608	1.00	12,182	0.053
	2000	subyearling					890,474	890,474	0.00	1,014	0.001
		yearling	743	531	130,032		0	131,306	1.00	7,424	0.057
	2001	subyearling		196,507			660,461	856,968	0.23	4,522	0.005
		yearling	188	94	112,933		0	113,215	1.00	7,499	0.066
	2002	subyearling		197,763			803,126	1,000,889	0.20	5,016	0.005
		yearling	1,455	529	157,488		0	159,472	1.00	14,964	0.094
	2003	subyearling		652,797			359,669	1,012,466	0.64	19,078	0.019
		yearling	1,665	3,449	140,217		0	145,331	1.00	7,494	0.052
	2004	subyearling		362,020			281,132	643,152	0.56	5,107	0.008
		yearling		270	106,657		0	106,927	1.00	4,982	0.047
	2005	subyearling	2,150	399,059	338,375		639,942	1,379,526	0.54	2,498	0.002
		yearling	1,683	72,842	63,039		1,945	139,509	0.99	4,988	0.036
	2006	subyearling	4,314	445,900	296,364		441,136	1,187,714	0.63	68,350	0.058
		yearling	1,965	59,465	66,732		1,636	129,798	0.99	5,036	0.039
	2007	subyearling	2,128	389,425	297,796		522,156	1,211,505	0.57		
		yearling		77,220	67,891		10,369	155,480	0.93		
	Clearwater River Total		**26,529**	**3,054,886**	**2,485,427**		**4,786,879**	**10,353,721**	**0.54**	**172,151**	**0.017**
Grande Ronde River	2005	subyearling	8,050	610	191,868		281,932	482,460	0.42		
	2006	subyearling	3,467	335	196,630		208,733	409,165	0.49		
	Grande Ronde River Total		**11,517**	**945**	**388,498**		**490,665**	**891,625**	**0.45**		

Table D3. Continued.

Spawning Area	Release Year	Life Stage	Adipose Clip	CWT	Ad + CWT	VIE with/wo AD,CWT	Unmarked	Total Released	Proportion Marked	# PIT Tagged	Proportion PIT Tagged
Upper Snake River	1996	yearling	64		113,977		258	114,299	1.00		
	1997	yearling	2,673		134,693		9,950	147,316	0.93		
	1998	yearling	1,702		135,858		4,254	141,814	0.97		
	1999	yearling	3,401	4,501	134,983		0	142,885	1.00	9,943	0.070
	2000	subyearling					400,156	400,156	0.00	1,001	0.003
		yearling	1,298		133,411		0	134,709	1.00	7,477	0.056
	2001	subyearling	115,220	197,182			176,888	489,290	0.64	1,974	0.004
		yearling		761	102,980		0	103,741	1.00	7,503	0.072
	2002	subyearling	171,120	199,965			199,693	570,778	0.65	3,539	0.006
		yearling	672	2,687	156,372		0	159,731	1.00	7,545	0.047
	2003	subyearling	531,472	189,782			210,401	931,655	0.77	15,527	0.017
		yearling	1,733	2,195	136,455		0	140,383	1.00	7,492	0.053
	2004	subyearling	14,920		160,475		197,687	373,082	0.47	22,424	0.060
		yearling	186	1,488	143,257		186	145,117	1.00	4,983	0.034
	2005	subyearling	595,809		385,278		0	981,087	1.00	12,465	0.013
		yearling	279	79,701	69,598		1,128	150,706	0.99	4,997	0.033
	2006	subyearling	544,700		361,589		1,993	908,282	1.00	48,131	0.053
		yearling	2,516	77,644	66,987		2,410	149,557	0.98	4,993	0.033
	2007	subyearling	1,117	98,046	97,668		204,093	400,924	0.49		
		yearling	128	72,805	70,969		2,781	146,683	0.98		
	Upper Snake River Total		**1,989,010**	**926,757**	**2,404,550**		**1,411,878**	**6,732,195**	**0.79**	**159,994**	**0.024**

Table D3. Continued.

Spawning Area	Release Year	Life Stage	Adipose Clip	CWT	Ad + CWT	VIE with/wo AD,CWT	Unmarked	Total Released	Proportion Marked	# PIT Tagged	Proportion PIT Tagged
Lower Snake River	1998	yearling	1,572		130,728		905	133,205	0.99		
	1999	subyearling					322,928	322,928	0.00	2,046	0.006
		yearling	816	1,444	154,750		0	157,010	1.00	2,493	0.016
	2000	subyearling		388,193			504,654	892,847	0.43	1,001	0.001
		yearling	138	138	131,048		0	131,324	1.00	2,489	0.019
	2001	subyearling					575,374	575,374	0.00	76,243	0.133
		yearling	505	1,010	100,461		0	101,976	1.00	2,518	0.025
	2002	subyearling		367,439			781,984	1,149,423	0.32	102,940	0.090
		yearling		4,463	155,692		0	160,155	1.00	2,487	0.016
	2003	subyearling	1,315	385,636	96,073		508,165	991,189	0.49	59,125	0.060
		yearling	1,430	2,502	147,987		0	151,919	1.00	2,497	0.016
	2004	subyearling		192,649			308,090	500,739	0.38	2,493	0.005
		yearling		192	150,569		0	150,761	1.00	4,985	0.033
	2005	subyearling	23,868	89,825	277,565		548,050	939,308	0.42	6,959	0.007
	2006	subyearling	8,929	100,704	502,006		307,661	919,300	0.67	34,649	0.038
		yearling	490	78,156	70,185		2,291	151,122	0.98	4,884	0.032
	2007	subyearling	1,456	99,212	99,107		314,798	514,573	0.39		
		yearling	112	78,588	69,180		10,619	158,499	0.93		
	Lower Snake River Total		**40,631**	**1,790,151**	**2,085,351**		**4,185,519**	**8,101,652**	**0.48**	**307,809**	**0.038**

Table D3. Continued.

Spawning Area	Release Year	Life Stage	Adipose Clip	CWT	Ad + CWT	VIE with/wo AD,CWT	Unmarked	Total Released	Proportion Marked	# PIT Tagged	Proportion PIT Tagged
Tucannon River	1995	yearling	908		347,675		541	349,124	1.00		
	1996	fry					83,183	83,183	0.00		
		yearling	405		406,694		404	407,503	1.00	2,997	0.007
	1997	yearling	1,744		435,604		19,428	456,776	0.96	3,009	0.007
	1998	yearling	6,753		408,603		3,636	418,992	0.99	2,420	0.006
	1999	subyearling	1,301	4,299	198,594		0	204,194	1.00	1,566	0.008
		yearling	2,026	6,368	423,772		0	432,166	1.00	983	0.002
	2000	subyearling	2,435	6,083	188,125		0	196,643	1.00	1,487	0.008
		yearling	2,971	11,317	442,113		0	456,401	1.00	986	0.002
	2001	subyearling					3,994	3,994	0.00		
		yearling	1,648	10,440	326,669		0	338,757	1.00	991	0.003
	2002	subyearling	2,335	3,373	188,874		0	194,582	1.00	1,499	0.008
		yearling	4,509	6,612	421,390		0	432,511	1.00		
	2003	subyearling	1,727	4,517	193,848		0	200,092	1.00	1,504	0.008
		yearling	4,546	14,503	499,387		0	518,436	1.00		
	2004	subyearling	4,279	2,209	195,046		0	201,534	1.00		
		yearling	18,376	2,397	425,316		266	446,355	1.00		
	2005	subyearling	3,870	934	195,367		0	200,171	1.00	1,498	0.007
		yearling	250	35,120	37,535	380,036	259	453,200	1.00		
	2006	subyearling	789	789	200,369		71,263	273,210	0.74		
		yearling	16	23,005	16,710	409,835	435	450,000	1.00		
	2007	subyearling	6,000	1,810	191,436		1,446	200,692	0.99		
		yearling	1,499	11,763	5,199	436,100	48,600	503,161	0.90		
	Tucannon River Total		**68,387**	**145,539**	**5,748,326**	**1,225,971**	**233,455**	**7,421,677**	**0.97**	**18,940**	**0.003**
Grand Total			**2,136,074**	**5,918,278**	**13,112,152**	**1,225,990**	**11,108,396**	**33,500,890**	**0.67**	**658,894**	**0.020**

Hatchery and wild fall Chinook PIT-tagged

Table D4. Summary of the number hatchery fall Chinook PIT-tagged and released and the resulting detections from each spawning population in the Snake River in smolt migration years (MY) 2000-2007. All collection methods combined.

Spawning Population and/or Release Site	2000	2001	2002	2003	2004	2005	2006	2007
Number of PIT Tags Released								
Clearwater River	18,630	35,645	12,498	18,194	10,089	53,276	185,595	21,272
Grande Ronde River							25,357	
Lower Snake River	3,489	4,516	105,504	61,564	7,475	127,941	263,784	7,335
Upper Snake River	23,383	98,053	26,496	37,934	17,395	20,926	65,505	17,824
Lions Ferry Hatchery	2,466	991	1,499	1,504		1,498	12,095	1,500
Ice Harbor Dam	17,803		28,979	33,707		1,547	4	
Lower Granite Dam		24	424	1	2,557	4	454	296
Total	65,771	139,229	175,400	152,904	37,516	205,192	552,794	48,227
Number of PIT Tags Detected								
Clearwater River	8,297	13,364	6,267	10,220	6,097	7,424	46,475	5,441
Grande Ronde River							6,349	
Lower Snake River	2,296	3,273	26,333	42,282	5,197	28,270	67,404	2,880
Upper Snake River	6,522	35,514	7,533	20,616	8,944	11,545	37,370	6,685
Lions Ferry Hatchery	838	636	546	690		641	3,108	307
Ice Harbor Dam	9,163		12,162	21,101		1,528	2	
Lower Granite Dam		23	424	0	2,004	3	165	65
Total	27,116	52,810	53,265	94,909	22,242	49,411	160,873	15,378

Table D5. Summary of the number wild fall Chinook PIT-tagged and released and the resulting detections from each spawning population in the Snake River in smolt migration years (MY) 2000-2007. All collection methods combined.

Spawning Population and/or Release Site	2000	2001	2002	2003	2004	2005	2006	2007
Number of PIT Tags Released								
Clearwater River					2,019	1,875	1,547	1,682
Grande Ronde River				3				
Lower Snake River				2,931	4,305	6,542	1,208	3,101
Upper Snake River				1,809	1,229	2,757	946	995
Tucannon River	555	419	630					300
Ice Harbor Dam							40	
Lower Granite Dam	1		4	8		4	88	39
Total	556	419	634	4,752	7,553	11,178	3,829	6,117
Number of PIT Tags Detected								
Clearwater River					368	145	177	65
Grande Ronde River				1				
Lower Snake River				1,426	2,319	1,381	334	669
Upper Snake River				578	250	627	346	129
Tucannon River	212	87	250					47
Ice Harbor Dam							12	
Lower Granite Dam	0		0	5		3	21	17
Total	212	87	250	2,010	2,937	2,156	890	927

The assessment fall Chinook monitoring in the Snake River ESU was based on the viability criteria developed by the Interior Columbia Technical Review Team (TRT). The criteria include abundance, productivity, and twelve spatial and diversity metrics that were used in their population viability assessments of each population.

Abundance and productivity metrics

The ICTRT analyzed abundance and productivity for two time series, brood years 1977-2001 brood and 1990-2001. By definition the longer series captures more of the potential year-to-year variations in survival rates, but it also bridges across two distinctly different sets of in-river conditions and hydropower operations. The more recent period (1990-2001) corresponds to a period of relatively consistent harvest and hydropower operations with reduced impacts on Snake River fall Chinook. The ICTRT found it difficult to separate variations in ocean survivals from potential changes in hydropower impacts without comparative measures of juvenile passage survivals under current operations or a representative measure of ocean survival rates.

Spatial and diversity metrics

A.1 Maintain natural distribution of spawning areas

Factor A.1.a. Number and spatial arrangement of spawning areas.
Factor A.1.b. Spatial extent or range of population.
Factor A.1.c. Increase or decrease in gaps or continuities between spawning areas.

Current monitoring of adults will provide the necessary data for these metrics. Current redd surveys cover areas that currently are not occupied by adult spawners. Continued monitoring at the current level will provided information on the number of spawning areas, the increase or decrease in spatial range within each spawning area, and the continuity between spawning areas.

B.1 Maintain natural patterns of phenotypic and genotypic expression

Factor B.1.a. Major life history strategies: For adults, run-timing information is available for the MPG through window counts at Ice Harbor, Little Goose, and Lower Granite Dams. Spawn timing for each major spawning area can be inferred from multiple pass redd surveys. Timing of the smolt migration through the Columbia and lower Snake rivers is possible, on a yearly basis, from PIT tagged hatchery release groups within each major spawning area. Timing of wild/natural smolts is limited to areas that capture and PIT tag will fall Chinook. These include the lower Clearwater River (screw traps and beach seining) and the lower and upper reach of the Snake River in Hells Canyon (beach seine).
Factor B.1.b: Phenotypic variation. This metric can be assessed for all spawning populations above Lower Granite Dam through sub-sampling live adults. For the Tucannon River, limited carcass data is available. Phenotypic traits of juveniles can be assessed from screw traps and beach seining but sample sizes will be small.

Factor B.1.c: Genetic variation. Sampling of adult fall Chinook has occurred at Lower Granite Dam which covers the majority of the MPG. A limited number of carcasses are available from the Tucannon River. This data can provide a baseline to assess results of future genetic sampling.

B.2: Maintain natural patterns of gene flow

Factor B.2.a.1. Proportion of natural spawners that are out-of-DPS spawners.

Factor B.2.a.2. Proportion of natural spawners that are out-of-MPG spawners.

Factor B.2.a.3. Proportion of hatchery origin natural spawners derived from a within MPG brood stock program, or within population (not best practices) program.

Factor B.2.a.4. Proportion of hatchery origin natural spawners derived from a local (within population) brood stock program using best practices.

These metrics require sampling adult spawners and determining their origin. For hatchery adults, origin can be determined from marks (CWT, ad clipped, VIE) from a sub-sample of adults at Lower Granite Dam and from carcass recoveries in the Tucannon River. However, a proportion of hatchery releases are not marked and therefore scale analysis is required to determine wild/hatchery origin on unmarked adults. A run reconstruction based on marks and scale analysis from the known proportion of adults sampled at Lower Granite Dam is necessary to determine the actual wild/hatchery proportion for the MPG. The wild/hatchery proportion within each spawning population (excluding the Tucannon River) must be inferred from the proportions calculated at Lower Granite Dam. For the Tucannon River wild/hatchery proportions can be calculated from carcass recoveries however sample size is small.

B.3 Maintain occupancy in a variety of available habitat

Factor B.3.a. Distribution of population across habitat types:

An assessment is possible using the adult aerial redd count surveys that are done yearly in each Major Spawning Area.

B.4 Maintain integrity of natural systems

Factor B.4.a. Change in natural processes or impacts

Some of the information necessary for this metric is collected from adult redd counts and juvenile beach seining surveys. However, there has not been a coordinated effort to identify data needs for this metric hence information needs to do an assessment is incomplete.

DQO STEPS	SNAKE RIVER FALL CHINOOK	Policy Inputs[1] (✓)
1. State the Problem		
Problem:	Delisting of Snake River Fall Chinook	
Stakeholders:	States—Washington, Oregon, Idaho Tribes—NPT, SBT, CTUIR, CTWSR, YIN Federal—NOAA, USFWS, USFS, BPA, USACOE Intergovernmental—Columbia River Compact, CBFWA, CRITFC, PFMC, PSC, NPCC Other—Idaho Power, conservation groups, fishers (tribal, commercial, sport), landowners, upland land users (ranchers, farmers, municipalities, state and county governments), water users (agricultural, industrial, municipal)	
Non-technical Issues:	Interagency coordination, fiscal constraints, legal constraints, land ownership and access	
Conceptual Model:	Life history models	
2. Identify the Decision		
Principal Questions:	What is the ESA listing status for Snake River fall Chinook?	
Alternative Actions:	• If status is "listed," then recovery strategies (i.e., more restrictive management strategies at one or more points in the life history model). • If status is "delisted," then recovery or sustainable harvest strategies. • If status is "recovered," then sustainable harvest strategies	✓
Decision Statements:	• Has there been sufficient improvement in population status of Snake River fall Chinook ESU to justify delisting and allow removal of ESA restrictions? • Are additional management actions required for regional, ESA recovery and NPCC SAR goals?	✓
3. Identify the Inputs		
Information Required:	Abundance Productivity Spatial structure Diversity Abundance of spawners ✓ ✓ ✓ Abundance/distribution of redds ✓ ✓ ✓ ✓ Origin of spawners ✓ ✓	

DQO STEPS	SNAKE RIVER FALL CHINOOK	Policy Inputs[1] (✓)
	Age-structure of spawners ✓ ✓ ✓ Sex ratio of spawners ✓ ✓ Abundance/distribution of juveniles ✓ Juvenile survival ✓	
Sources of Data:	State, tribal, and federal programs and NGSs identified in CSMEP metadata inventories.	
Quality of Existing Data:	• Abundance of spawners: Counts made at Ice Harbor, Little Goose, and Lower Granite Dams provide a good estimate of the total number of hatchery and wild fall Chinook adults for the ESU. Aerial redd count surveys are available for each individual spawning population. • Abundance/distribution of redds: Current redd counts provide excellent information on the abundance and distribution of redds for each spawning population. • Origin of spawners: Not all hatchery releases are marked. Therefore, the determination of wild and hatchery origin of unmarked fall Chinook relies on scale analysis. Using scale analysis and run reconstruction and estimates of the proportion of wild and hatchery spawners is available for the entire ESU through adult sampling at Lower Granite Dam and from carcass recoveries in the Tucannon River. • Age-structure of spawners: Estimated from scale samples and known marks of hatchery releases are obtained from sub-samples at Lower Granite Dam and from carcass recoveries in the Tucannon River for the entire ESU. • Sex ratio of spawners: same as for age-structure data • Abundance/distribution of juveniles: Abundance and distribution information of	

DQO STEPS	SNAKE RIVER FALL CHINOOK	Policy Inputs[1] (✓)
	juveniles is limited. Abundance information of wild juveniles is not available for any spawning population. Distribution information is available for the Clearwater River and for the upper and lower Snake River through beach seining. • Survival of juveniles: PIT tags implanted in hatchery release groups can provide survival information. Survival information for PIT tagged wild juveniles is limited to the Clearwater River and the upper and lower Snake River spawning populations.	
New Data Required:	• Additional sampling of wild juvenile fish may be necessary for spatial structure and diversity metrics.	
Analytical Methods:	IC-TRT rules and criteria for combining measures of abundance, productivity, spatial structure, and diversity.	✓
4. Define the Boundaries		
Target Populations:	Snake River Fall Chinook	
Spatial Boundaries (study):	There is only one extant population in the Snake River fall Chinook salmon ESU, the Lower Snake River Mainstem population. It includes five MaSAs: (1) Hells Canyon upper reach - Hells Canyon Dam to the mouth of the Salmon River, including the lower mainstem of the Imnaha and Salmon Rivers; (2) Hells Canyon lower reach - mouth of the Salmon River to the upper end of Lower Granite Reservoir; (3) Clearwater River; (4) Grand Ronde River; and (5) Tucannon River.	✓
Temporal Boundaries (study):		✓
Practical Constraints:	Not all hatchery fish are marked hence identifying wild/natural adults requires additional handling and sampling. Wild juvenile abundance and survival is not well estimated due to lack of juvenile sampling and the small number of Pit-tags applied to wild fish. Inability to recovery carcasses on the spawning ground for age analysis.	✓
Spatial Boundaries (decisions):	Delisting decision made at f the ESU level.	
Temporal Boundaries (decisions):	IC-TRT rules for abundance and productivity require historical data, and 10 year series of annual data. IC-TRT rules require spatial structure and diversity data collected at unspecified intervals.	
5. Decision Rules (IC-TRT Rules)		
Critical Components and Population Parameters:	Two metrics (A/P and SS/D) are used to assess the status of each population. A/P combines abundance and productivity VSP criteria using a viability curve. SS/D integrates 12 measures of spatial structure and diversity.	✓
Critical Action Levels (Effect Sizes):	Risk categories are assigned at the population level for A/P using a 5% risk criterion to define viable populations. Populations scored as moderate or high risk in A/P criteria cannot meet viable standards, while populations at high risk for the 12 SS/D measures cannot be considered viable.	✓
If-Then Decision Rules: IC-TRT Draft	**MPG-level Viability Criteria:** Low risk (viable) MPGs meet the following six criteria: 1. One-half of the populations historically within the ESU (with a minimum of two populations) must meet minimum viability standards. 2. All populations meeting viability standards within the DPS cannot be in the minimum viability category; at least one population must be categorized as meeting more than minimum viability requirements. 3. The populations at high viability within an MPG must include proportional representation from populations classified as “Large” or “Intermediate” based on their intrinsic potential. 4. Populations not meeting viability standards should be maintained with sufficient	✓

DQO STEPS	SNAKE RIVER FALL CHINOOK	Policy Inputs[1] (✓)
	productivity that the overall MPG productivity does not fall below replacement (i.e. these areas should not serve as significant population sinks). 5. Where possible, given other MPG viability requirements, some populations meeting viability standards should be contiguous AND some populations meeting viability standards should be disjunct from each other. 6. All major life history strategies (i.e. adult “races,” A-run/B-run, resident and anadromous) that were present historically within the MPG must be present and viable. . **DPS-level Viability Criteria:** 1. All extant MPGs and any extirpated MPGs critical for proper functioning of the ESU must be at low risk. 2. ESU’s that contained only one MPG historically must meet the following criteria: a. Two-thirds or more of the populations within the MPG historically must meet minimum viability standards; AND b. Have at least two populations categorized as meeting more than minimum viability requirements.	
Consequences of Decision Errors:	Incorrectly concluding that delisting criteria have been achieved: • Decisions to relax ESA restrictions increase risks to the ESU Incorrectly concluding that delisting criteria have not been achieved: • Minimal biological impact given that decisions do not relax ESA restrictions • May over-invest in intensity of monitoring efforts • Unnecessary listing and restrictive measures • Loss of harvest opportunity	

[1]**Policy Inputs -** indicate with a check steps where group really needs policy feedback, presentation will elaborate on what feedback is required

Appendix E. CSMEP Strengths and Weaknesses Assessment of current spring Chinook monitoring in the Upper Columbia Spring Chinook ESU, North Cascades MPG

Casey Baldwin (WDFW) and John Arterburn (Colville Tribes)

Table E1. Summary of monitoring activities used to assess spring Chinook salmon viability in the Upper Columbia DPS.

			Upper Columbia spring Chinook			
Data need		**Method/Description**	**Wenatchee**	**Entiat**	**Methow**	**Okanogan (extirpated)**
Abundance of adults	A1	census weir (number)	x2		x?	x?
	A2	weir w/Mk. Recap. (number)				
	A3	weir w/o MR (number)				
	A4	MR survey, no weir				
Abundance and distribution of redds	B1	Index-multi	x	x	x	
	B2	Index-once				?
	B3	Index-multi + expanded probabalistic				
Age structure of spawners	C1	Tags (CWT, PIT)	x	x	x	?
	C2	Hard parts, scales	x	x	x	?
	C3	Length at age	x	x	x	?
	C4	Basinwide estimate	x	x	x	
Origin of spawners	D1	Marks , weirs (number)	x2		x?	
	D2	marks, remote sense	?	a	?	
	D3	marks, carcasses	x	x	x	
Sex ratio of spawners	E1	Carcass survey	x	x	x	
	E2	Weirs (number)	x		x	?
	E3	Remote sense	a	a		
Abundance and spatial distribution of juveniles/smolts	F1	Juvenile trap (number)	x4	x1	x2	?
	F2	Electrofish	x	x	x	
	F3	Snorkel survey--random	x	x	x	?
	F4	Snorkel survey--fixed	x	x	x	?
	F5	Presence/absence	x	x	x	?
Survival of juveniles/smolts	G1	mark-recapture				
	G2	egg deposition to smolt trap	x	x	x	

Age structure of juveniles/smolts	H1	Juvenile trap	x	x	x	?
	H2	other in-river sampling	x	x	x	

a = possible from PIT tags scanned at weirs / dams; however, sample size may be too small for precise estimates
b= from CWT recoveries of hatchery adults at weirs and as carcasses
c = hatchery fish only
? = there is some monitoring but its incomplete or inadequate
x = in at least 1 MaSA

Narrative for Table E1 for CSMEP monitoring strengths and weaknesses assessment.

Upper Columbia spring Chinook ESU

Wenatchee Spring Chinook

A1. Census at Tumwater Dam has been ongoing for many years and the hatchery monitoring programs (PUD funded) should be covering 100% census counts at Tumwater Dam for the length of their license. Its not MSA specific but it does capture all 5 MaSA (captures 85% of historic intrinsic potential production areas, even more based on current production). Reproductive success study intends to continue through at least 2012. There is also a weir in lower Chiwawa River, but it does not provide a census.

B1. Spring Chinook redd surveys have been conducted by CPUD and WDFW in index areas since the 1950s. Surveys were expanded to cover ~ 100% of potential spawning areas in the late 1990s.

C1-4. Data collected at Tumwater Dam and additional CWT information collected from carcasses.

D1. Tumwater Dam has provided mark identification on 100% of the spring Chinook and is planned to continue via the HCP hatchery monitoring programs. Chiwawa weir also provides information for one MaSA.

D2. PIT tag detection arrays have recently been installed in Peshastin Creek, Tumwater Canyon, two in the Chiwawa River, and two in Nason Creek. This method is still very new in the Upper Columbia and there is uncertainty regarding the protocols, tag retention rates, tag detection rates, longevity, data analysis and reporting.

D3. Carcass surveys have been conducted along with redd surveys. Efforts were substantially improved in 2001 and we now consistently recover greater than 20% of the spawn escapement.

E1-3. See information for C and D.

F1. Smolt traps are operated in the lower Wenatchee (RM 7), Nason Creek, Chiwawa River, White River, and in the Upper Wenatchee River just below the Lake.

F2-5. Conducted as part of USFS monitoring in some areas. ISEMP expanded that effort in 2004 and includes both fixed and random sites. CPUD/BioAnalysts extensive surveys in the Chiwawa since the early 1990s.

G2. Egg-to-smolt survival estimated from egg deposition and out migrating smolts.

H1. See F1.

H2. Estimated from scale analysis.

Entiat Spring Chinook

B1. The WDFW surveyed an index reach (RM 21.3-28.9) from 1957-1991. Expanded spring Chinook redd surveys have been conducted by USFWS throughout entire potential spawning area since 1994. Not sure what happened in 92 and 93?

C1-4 The USFWS has conducted spawning ground carcass recoveries since 1994. Started to PIT tag natural origin parr and smolts in recent years, it is unlikely that sample size will be adequate to provide population level information without additional effort at Priest Rapids.

D2. Starting in 2007-2008, PIT tag detection arrays were installed at RM ~1, near the mouth of the Mad River, and at the lower end of the Stillwater reach (~RM 16). This method is still very new in the Upper Columbia and there is uncertainty regarding efficiency, longevity, etc.

D3. The USFWS has conducted spawning ground carcass recoveries since 1994.

E1 & 3. See C1-4 and D2.

F1. The USFWS operates a trap in the lower Entiat (rkm 2) in 2007 and 2008. From 2003-2008 there has been a trap at rkm 11. They have at least one more year of running both traps and then will determine if they can go with one or the other or if they need both.

F2-5. Conducted by USFWS and ISEMP.

G2. Egg-to-smolt survival estimated from egg deposition and out migrating smolts.

H1. See F1.

H2. Estimated from scale analysis.

Methow Spring Chinook

A1. Census at Wells Dam, but the trap is not operated 24/7 and trap avoidance is apparent. Right now, its safe to assume zero natural production from the Okanogan. As Okanogan re-introduction efforts ramp up there will be more uncertainty and Wells Dam will be less effective for monitoring population specific parameters, particularly as they relate to hatchery fish.

B1. Spawning ground surveys have occurred throughout the vast majority of potential spawning areas since 1991. Historic data on index reaches since 1960 (SASI 1993). From 2003 to the present, WDFW has conducted those surveys (see reports by M. Humling and C. Snow) as part of the Wells Dam settlement agreement with Douglas County Public Utility District.

C1-4. From 1987 to 2002 the Yakama Nation conducted comprehensive spawning ground surveys that included biological sampling of salmon carcasses. From 2003 to the present, WDFW has conducted those surveys (see reports by M. Humling and C. Snow) as part of the Wells Dam settlement agreement with Douglas County Public Utility District.

D1. Wells Dam serves as a weir and information is collected for a subset of the population. Success of the Okanogan program will reduce the ability of using Wells Dam to monitor Methow spring Chinook. A weir is operated on the Twisp River, providing pretty good coverage for one MaSA. There are plans to improve the ability of Foghorn Dam to capture fish in the Upper Methow.

D2. PIT tag detection arrays have recently been installed on Beaver, Gold, and Libby Creeks. None of the spring Chinook MaSAs are currently covered. Plans are underway to wire the Twisp and lower Methow mainstem, which would provide coverage for one MaSA and for the whole population.

D3. See information for C1-4

E1&2. See C1-4 and D1.

F1. A smolt trap has been operated by WDFW in the lower Methow (rkm 30; McFarland Ck Bridge) since 2004. A smolt trap has been operated by WDFW in the lower Twisp River (rkm 3) since 2005. Previously to 2004, the Yakima Nation operated a smolt trap in various locations for various time periods, however, due to the inconsistencies that data set is not included with the more recent sites or in Table A. Additionally, CRITFC operated a smolt trap for 2 years in the lower Methow as part of a study that was testing the feasibility of a monitoring technique for summer Chinook. That effort was not continued so it is also not included in Table A.

F2-5. SRFB effectiveness monitoring does some at selected sites. Other effectiveness monitoring snorkeling will occur by USGS / USBR in 2008 and in out years. USFS covers various fish bearing streams on a 10-year rotating panel as part of their Stream Inventory.

G2. Egg-to-smolt survival estimated from egg deposition and out migrating smolts.

H1. See F1.

H2. Estimated from scale analysis.

Okanogan Spring Chinook

Spring Chinook in the Okanogan Basin are considered an experimental population that is composed of mostly excess Carson hatchery stock. Monitoring does not occur across the entire population in order to establish status and trend but instead is conducted sporadically to measure effectiveness only. Monitoring occurs at Wells Dam but the number of fish destined for the Okanogan from the counts cannot be parsed out using current data. In the future some method for determining the percentage destined for the Okanogan will be important due to the increase in hatchery production associated with the Chief Joseph Hatchery.

A1. Within the Okanogan Basin spring Chinook adults began being collected at the Omak Creek weir in 2004. These adults are the result of acclimation efforts conducted since 2003. Other less consistent releases have occurred throughout the mainstem Okanogan River but these returns are currently not monitored. Video Monitoring at Zosel dam could monitor spring Chinook returns but would have to first establish cut-off dates to differentiate from Summer Chinook (i.e. July 15th). However, spring Chinook life history within the Okanogan River basin is unknown.

B2. Multiple redd surveys have been conducted in likely spawning areas of Omak Creek over the last couple of years but these surveys have not been done consistently, nor do they follow a standardized protocol, and these efforts have resulted in very few redds being identified.

C1. The Pit tag array and trap in Omak Creek provides opportunity to interrogate spring Chinook. However, these data have only sporadically been collected since 2004 and many issues with standardizing these efforts remain to be worked out.

C2 and C3. Scales and length data have been collected sporadically at the Omak Creek trap since 2004. However, only limited data have been collected and sample sizes are too small to provide for meaningful analysis.

E2. These values could be calculated from data collected at the Omak Creek trap since 2004 but they have not been calculated to date because consistent data collection has not occurred, and due to a very small sample size.

F1. Smolt traps are in operation on Omak Creek and the Okanogan River near Malott, WA. Both traps could collect data on Spring Chinook. However, the trap on Omak Creek has only been in operation since 2006 and these data have not been made available publicly. The rotary trap data collected on the Okanogan River primarily focuses on sampling sub-yearling summer Chinook. Differentiating yearling summer Chinook from spring Chinook has proven to be difficult because of the very small number of naturally produced yearling Chinook.

F3, F4 & F5. The OBMEP monitoring project conducts snorkel surveys at randomly selected sites throughout the Okanogan River basin following standardized protocols however, it is extremely difficult to differentiate spring and summer Chinook stocks. Chinook counted in tributary streams would be considered spring Chinook and have only been identified in Omak Creek while yearling Chinook in mainstem habitats are impossible to classify without genetic data. Omak Creek has both random sites used in status and trend monitoring and fixed sites that are part of ongoing habitat effectiveness monitoring. Presence and absence of Chinook has been well established but no certainty in these data currently exists specific to spring Chinook.

H1. Age structure data could be collected at existing smolt traps. Smolt trap data from Omak Creek could be assumed to represent spring Chinook but age data collected from the Okanogan River screw trap would have far less certainty because of difficulties in identifying spring Chinook from summer Chinook.

Table E2. Summary of monitoring activities in the Major Spawning Area (MaSA) and Minor Spawning Area (MiSA) used to assess spring Chinook salmon and steelhead viability in the Upper Columbia ESU/DPS.

Major Population Group									
Population						Redd count surveys			
Major or Minor (m) Spawning Area	Number of Screw Traps	Fixed snorkel surveys	Random snorkel surveys	Number of hatchery weirs	Number of Temporary Weirs	index-multi	index-one	random, probabalistic, or rotating panel	periodic-spot check
Spring Chinook, North Cascades									
Wenatchee									
Lower Mainstem (population level)	1(double)			1					
Chiwawa	1	yes	yes	1		yes			
Nason Creek	1	3	yes			yes			
White River	1		yes			yes			
Upper Wenatchee Mainstem	1	1	yes	1		yes			
Little Wenatchee		1	yes			yes			
Chumstick Creek (m)		1	yes						
Peshastin Creek (m)		1	yes			?	?		
Mission Creek (m)			yes						
Icicle Creek (m)		2	yes	1		?	?		
Entiat									
Entiat (includes the Mad River)	2	yes	yes			yes			
Methow									
Lower Mainstem (population level)	1(double)								
Chewuch		yes				yes			
Upper Methow		yes				yes			
Twisp	1	yes			1	yes			
Middle Methow		yes		1		yes			
Methow (Twisp to Beaver Ck.) (m)		yes							
Okanogan									
Omak Creek	1	yes	yes	1		yes			

Wild Spring Chinook PIT tagged. Data not available so its not part of this assessment for the Upper Columbia.

The assessment of spring Chinook monitoring in the Upper Columbia ESU was based on the viability criteria developed by the Interior Columbia Technical Review Team (ICTRT 2007). The criteria include abundance, productivity, and twelve spatial structure and diversity metrics that were used in the population viability assessments of each population.

Abundance and Productivity:

Wenatchee spring Chinook: Since 1987, redd counts in the Wenatchee River basin have been based on multiple surveys and include most of the available spawning habitat (Beamesderfer *et al*., 1997). Age structure is determined from carcass recoveries on the spawning grounds where increased effort since 2002 has consistently provided greater than 20% recovery rate (A. Murdoch, personal communication). Sex ratio is determined from wild fish captured for broodstock (and other stock assessments) at Tumwater Dam (since 2004). Efforts to monitor Wenatchee spring Chinook abundance and productivity are very good and sustaining the current efforts should be the focus for this population. However, the Upper Columbia Regional Technical Team identified validation of redd surveys using mark-recapture techniques as a Tier 1 data gap (UCRTT 2008).

Entiat spring Chinook: The spatial coverage of redd surveys in the Entiat expanded several times during the 1990's (Beamesderfer *et al*. 1997). In recent years, up to 6 km of the Mad River and 30 km of the Entiat River have been surveyed (Hamstreet and Carie 2004) providing essentially complete coverage of the potential spawning areas in the Entiat River. Since 1994, fish per redd expansions have been 2.4, with the exception of 2002 when 3.3 was used (Hamstreet and Carie 2004). This value of 2.4 is used based on information from Mullen *et al*. (1992). The validity of this expansion multiplier should be evaluated. With no trapping facility for natural origin spring Chinook in the Entiat there is uncertainty in the appropriate fish per redd expansion multiplier. Mark recapture methods, such as PIT tags, should be evaluated as a potential method to provide this critical information. Current efforts to recover carcasses are adequate to provide age structure of the spawning population.

Methow Spring Chinook: Since 1987, redd counts in the Methow River basin have been based on multiple surveys and include most of the available spawning habitat (Beamesderfer *et al*., 1997). Age structure is determined from carcass recoveries on the spawning grounds where increased effort since 2003 has consistently provided greater than 20% recovery rate (Humling and Snow 2004, 2005, 2006; Snow *et al*. 2007). Since 2005, sex ratio has been determined from wild fish captured for broodstock at Wells Dam. Efforts to monitor Methow spring Chinook abundance and productivity are very good and sustaining the current efforts should be the focus for this population. However, the Upper Columbia Regional Technical Team identified validation of redd surveys using mark-recapture techniques as a Tier 1 data gap (UCRTT 2008). Additionally, if efforts to re-establish spring Chinook in the Okanogan Basin are successful, Wells Dam will no longer be a suitable location for evaluation of natural origin Methow spring Chinook sex ratio.

Spatial Structure and Diversity:
A.1. Maintain natural distribution of spawning areas: All listed Upper Columbia spring Chinook populations have redd surveys that cover the Major Spawning Areas and will allow for status assessments of the associated spatial structure metrics.

B1. Maintain natural patterns of phenotypic and genotypic expression:

Factor B.1.a. Major Life History Strategies: Current and planned PIT tag detection arrays should provide adequate data for juvenile movement patterns. Additional effort to remotely tag natural origin parr will most likely be needed in order to obtain adequate sample size.

Factor B.1.b. Phenotypic variation: Current monitoring programs associated with HCP hatchery programs include sufficient measurements to characterize current conditions for these metrics in the Wenatchee and Methow. In the Entiat, sufficient data should be available as long as the smolt trap operation and adult carcass recovery monitoring continues. A reference condition for the phenotypic variation metric is needed for all populations in the Upper Columbia (UCRTT 2008). Neither the ICTRT nor the Salmon Recovery Plan established what the baseline (or reference) condition is for each of the phenotypic traits. Without a reference condition it will not be possible to determine the level of deviation and therefore the level of risk.

Factor B.1.c. Genotypic variation: Current monitoring programs associated with HCP hatchery programs include sufficient measurements to characterize current conditions for these metrics in the Wenatchee and Methow. Genetic monitoring of Entiat spring Chinook is not conducted as part of any ongoing, funded, monitoring programs. However, the USFWS does collect and archive tissue samples from spring Chinook encountered during smolt trap and carcass recovery surveys. A reference condition for genotypic variation is needed for all populations in the Upper Columbia (UCRTT 2008).

B.2. Maintain natural patterns of gene flow:
Factor B.2.a. Spawner Composition: Current monitoring programs associated with HCP hatchery programs include sufficient measurements to characterize current conditions for these metrics in the Wenatchee and Methow. Likewise, carcass surveys in the Entiat conducted by the USFWS will provide the needed information to assess spawner composition.

B.3. Maintain occupancy in a variety of available habitat: All listed Upper Columbia spring Chinook populations have redd surveys that cover the Major Spawning Areas and will allow for status assessments associated with this metric.

B4. Maintain integrity of natural systems (Avoid selectivity in anthropogenic activities): The baseline information related to phenotypic traits is collected for each population and many of the potentially selective influences have been identified; however, the mechanisms and magnitude of each selective influence on the phenotypic traits are not understood. Additional input from the TRT, RIST, or other entity is needed to understand what data are needed to adequately rate this metric.

DQO STEPS	UPPER COLUMBIA SPRING CHINOOK	Policy Inputs[1] (✓)
1. State the Problem		
Problem:	Delisting of Upper Columbia Spring Chinook ESU	
Stakeholders:	States—Washington Tribes—Colville, Yakama Federal—NOAA, USFWS, USFS, BPA, USACOE Intergovernmental—Columbia River Compact, CBFWA, CRITFC, PFMC, PSC, NPCC Other—Grant, Chelan, and Douglas County PUDs, conservation groups, fishers (tribal, commercial, sport), landowners, upland land users (ranchers, farmers, municipalities, state and county governments), water users (agricultural, industrial, municipal)	
Non-technical Issues:	Interagency coordination, fiscal constraints, legal constraints, land ownership and access	
Conceptual Model:	Life history models	
2. Identify the Decision		
Principal Questions:	1) What is the ESA listing status for Upper Columbia Spring Chinook? 2) What is the current status and risk level for each population compared to ICTRT defined viability? Note: The recovery plans also require knowledge about the status of habitat conditions and limiting factors, which requires monitoring an entirely different set of variables that are not covered in this strength and weakness assessment.	
Alternative Actions:	If status is "listed," then recovery strategies (i.e., more restrictive management strategies at one or more points in the life history model). If status is "delisted," then recovery or sustainable harvest strategies. If status is "recovered," then sustainable harvest strategies	✓
Decision Statements:	Has there been sufficient improvement in population status of Upper Columbia Spring Chinook ESU to justify delisting and allow removal of ESA restrictions? Are additional management actions required for regional, ESA recovery and NPCC SAR goals?	✓
3. Identify the Inputs		
Information Required:	Information required Abundance Productivity Spatial Structure Diversity Abundance of spawners ✓ ✓ Abundance/distribution of redds ✓	

DQO STEPS	UPPER COLUMBIA SPRING CHINOOK	Policy Inputs[1] (✓)
	✓ ✓ ✓ Origin of spawners ✓ ✓ ✓ Age-structure of spawners ✓ ✓ ✓ Sex ratio of spawners ✓ ✓ ✓ Abundance/distribution of juveniles ✓ ✓ ✓ ✓ Juvenile survival ✓ ✓ ✓	
Sources of Data:	State, tribal, PUD, and federal programs currently collecting monitoring data within the Upper Columbia ESU.	
Quality of Existing Data:	o All listed Upper Columbia spring Chinook populations have redd surveys that cover the Major Spawning Areas and allow for status assessments associated with several VSP metrics.	

DQO STEPS	UPPER COLUMBIA SPRING CHINOOK	Policy Inputs[1] (✓)
	o Current monitoring programs associated with HCP hatchery programs include sufficient measurements to characterize current conditions for spawner composition in the Wenatchee and Methow (carcass surveys). Likewise, carcass surveys in the Entiat conducted by the USFWS will provide the needed information to assess spawner composition. o Current monitoring of the experimental population within the Okanogan River basin is limited to Omak Creek but is inadequate to provide population scale information.	
New Data Required:	Validation of redd surveys using mark-recapture techniques is needed. With no trapping facility for natural origin spring Chinook in the Entiat there is uncertainty in the appropriate fish per redd expansion multiplier. Mark recapture methods, such as PIT tags, should be evaluated as a potential method to provide this critical information. Genetic monitoring of Entiat spring Chinook is not conducted as part of any ongoing, funded, monitoring programs. Additional effort to remotely tag natural origin parr will most likely be needed in order to obtain adequate sample size to evaluate phenotypic traits and life history characteristics. A reference condition for the phenotypic variation metric is needed for all populations in the Upper Columbia A reference condition for the genotypic variation metric is needed for all populations in the Upper Columbia	
Analytical Methods:	IC-TRT rules and criteria for combining measures of abundance, productivity, spatial structure, and diversity.	✓
4. Define the Boundaries		
Target Populations:	Upper Columbia Spring Chinook; Wenatchee, Entiat, Methow	
Spatial Boundaries (study):	Population, MPG, and ESU levels for Spring Chinook within the Upper Columbia basin. One MPG, and one extirpated (Okanogan) within the extant portion of the ESU. Note: the ESU also includes the extirpated populations and MPGs above Grand Coulee Dam.	✓
Temporal Boundaries (study):	Status data evaluated over generations from annual abundance data and generational productivity data, summarized as 10-12 year geometric means. Spatial structure and diversity data collected and summarized at various intervals, depending on the metric.	✓
Practical Constraints:	Legal and logistical issues with access, permits, and interagency coordination across jurisdictional boundaries.	✓
Spatial Boundaries (decisions):	Delisting decision made at level of ESU, but is dependent on information from each of the component populations.	✓
Temporal Boundaries (decisions):	IC-TRT rules for abundance and productivity require historical data, and 10-year series of annual data. IC-TRT rules require spatial structure and diversity data collected at various intervals.	
5. Decision Rules (IC-TRT Rules)		
Critical Components and Population Parameters:	Two metrics (A/P and SS/D) are used to assess the status of each population. A/P combines abundance and productivity VSP criteria using a viability curve. SS/D integrates 12 measures of spatial structure and diversity.	✓
Critical Action Levels (Effect Sizes):	Risk categories are assigned at the population level for A/P using a 5% risk criterion to define viable populations. Populations scored as moderate or high risk in A/P criteria cannot meet viable standards, while populations at high risk for the 12 SS/D measures cannot be considered viable.	✓

DQO STEPS	UPPER COLUMBIA SPRING CHINOOK	Policy Inputs[1] (✓)
If-Then Decision Rules: IC-TRT Draft	**MPG-level Viability Criteria:** Low risk (viable) MPGs meet the following six criteria: 1. One-half of the populations historically within the ESU (with a minimum of two populations) must meet minimum viability standards. 2. All populations meeting viability standards within the ESU cannot be in the minimum viability category; at least one population must be categorized as meeting more than minimum viability requirements. 3. The populations at high viability within an MPG must include proportional representation from populations classified as “Large” or “Intermediate” based on their intrinsic potential. 4. Populations not meeting viability standards should be maintained with sufficient productivity that the overall MPG productivity does not fall below replacement (i.e. these areas should not serve as significant population sinks). 5. Where possible, given other MPG viability requirements, some populations meeting viability standards should be contiguous AND some populations meeting viability standards should be disjunct from each other. 6. All major life history strategies (i.e. adult “races,” A-run/B-run, resident and anadromous) that were present historically within the MPG must be present and viable. . **ESU-level Viability Criteria:** 1. All extant MPGs and any extirpated MPGs critical for proper functioning of the ESU must be at low risk. 2. ESU’s that contained only one MPG historically must meet the following criteria: a. Two-thirds or more of the populations within the MPG historically must meet minimum viability standards; AND b. Have at least two populations categorized as meeting more than minimum viability requirements. *Note: The Upper Columbia Recovery Plan (UCSRB 2007) rejected the ICTRT technical criteria that 2 populations within the MPG needed to be at highly viable status. The policy objective was to reach viable status in all populations.	✓
Consequences of Decision Errors:	Incorrectly concluding that delisting criteria have been achieved: • Decisions to relax ESA restrictions increase risks to the ESU Incorrectly concluding that delisting criteria have not been achieved: • Minimal biological impact given that decisions do not relax ESA restrictions • May over-invest in intensity of monitoring efforts • Unnecessary listing and restrictive measures • Loss of harvest opportunity	

[1]**Policy Inputs** - indicate with a check steps where group really needs policy feedback, presentation will elaborate on what feedback is required

Appendix F. CSMEP Strengths and Weaknesses Assessment of current summer steelhead monitoring in the Upper Columbia Steelhead DPS, North Cascades MPG

Casey Baldwin (WDFW) and John Arterburn (Colville Tribes)

Table F1. Summary of monitoring activities used to assess steelhead viability in the Upper Columbia DPS.

			Upper Columbia steelhead				
Data need		**Method/Description**	Wenatchee	Entiat	Methow	Okanogan	Crab Creek (functionally extirpated?)
Abundance of adults	A1	census weir (number)	x?			x5	
	A2	weir w/Mk. Recap. (number)	x	x	x	x	x
	A3	weir w/o MR (number)					
	A4	MR survey, no weir					
Abundance and distribution of redds	B1	Index-multi		x		x	x
	B2	Index-once				x	
	B3	Index-multi + expanded probabilistic	x		x		
Age structure of spawners	C1	Tags (CWT, PIT)	x	a	c	c	
	C2	Hard parts, scales	x	a	c	x	x
	C3	Length at age	x	a	c	x	x
	C4	Basinwide estimate	x	a	c	?	
Origin of spawners	D1	Marks , weirs (number)	x1		x?	x5	
	D2	marks, remote sense	a	a	a	a	
	D3	marks, carcasses				?	x
Sex ratio of spawners	E1	Carcass survey					x
	E2	Weirs (number)	x		?	x5	x
	E3	Remote sense	x	a	a		
Abundance and spatial distribution of juveniles/smolts	F1	Juvenile trap (number)	x4	x1	x2	x2	x
	F2	Electrofish	x	x	x		x
	F3	Snorkel survey--random	x	x	x	x	
	F4	Snorkel survey--fixed	x	x	x	x	
	F5	Presence/absence	x	x	x	x	
Survival of juveniles/smolts	G1	mark-recapture				c?	
	G2	egg deposition to smolt trap	x	x	x	?	x

Age structure of juveniles/smolts	H1	Juvenile trap	x	x	x	x	x
	H2	other in-river sampling	x	x	x		x

a = possible from PIT tags scanned at weirs / dams; however, sample size may be too small for precise estimates
b= from CWT recoveries of hatchery adults at weirs and as carcasses
c = hatchery fish only
? = there is some monitoring but its incomplete or inadequate
x = in at least 1 MaSA

Narrative for Table F1 for CSMEP monitoring strengths and weaknesses assessment.

Upper Columbia Steelhead DPS / MPG

Wenatchee Steelhead

A1. Dryden dam trap samples an unknown portion of the population and is not adequate for a census. Tumwater Dam does provide a census, but only for 4 of 7 MaSA and 0 of 8 MiSA.

A2. To date, the abundance estimates for all populations have been based on dam counts apportioned to populations using radio telemetry data (English *et al*. 2003). Radio tracking was only conducted in 1999 and 2001 leaving considerable uncertainty regarding the extrapolation of those data to other years. The further in time we get from those studies the less certain we are in the extrapolation.

B3. There have been steelhead redd surveys in index areas since 2001. ISEMP added probabilistic sites in a rotating panel in 2004. Minor spawning areas downstream of the Wenatchee Subbasin were only sampled 2005-2007 with no planned continuation.

C1-4. Some data are collected at Priest Rapids Dam, limited ability to get population specific data from PIT tags on natural origin fish. Age information on spawners is also collected at Dryden Dam. Spatially, it is low enough in the basin to capture all of the major spawning areas but there is uncertainty regarding whether or not it provides an unbiased representative sample for basinwide estimates.

D1. See response for C1-4.

D2. PIT tag detection arrays are installed at Peshastin Creek, Tumwater Canyon, two in the Chiwawa River, and two in Nason Creek. This method is still very new in the Upper Columbia and there is uncertainty regarding the protocols, efficiency, longevity, tag retention, tag detection rates, data analysis and reporting.

F1. Smolt traps are operated in the lower Wenatchee (RM 7), Nason Creek, Chiwawa River, White River, and in the Upper Wenatchee River just below the Lake.

F2-5. Conducted as part of USFS monitoring in some areas. ISEMP expanded that effort in 2004 and includes both fixed and random sites. CPUD/BioAnalysts extensive surveys in the Chiwawa since the early 1990s.

G2. Egg-to-smolt survival estimated from egg deposition and out migrating smolts.

H1. See F1.

H2. Estimated from scale analysis.

Entiat Steelhead

A2. To date, the abundance estimates for all populations have been based on dam counts apportioned to populations using radio telemetry data (English *et al*. 2003). Radio tracking was only conducted in 1999 and 2001, leaving considerable uncertainty regarding the extrapolation of data to other years. The further in time we get from those studies the less certain we are of the extrapolation.

B1. The USFS has surveyed the Mad River since 1997 and the USFWS has surveyed the mainstem Entiat since 2003. The USFWS expanded their temporal coverage of redd surveys to the lower Entiat Mainstem in 2005. Only index surveys are conducted regularly, no probabilistic sampling of other areas that could / might have spawning, except for 2008. In 2008, WDFW / NOAA Fisheries surveyed the upper mainstem, above Box Canyon (RM 28-34) and the Upper Mad River (RM 11-16) as a test to see if steelhead were using areas that appeared suitable via GIS modeling techniques (ICTRT intrinsic potential).

C1-4. It may be possible with ongoing or expanded PIT tag studies. 2008 was the first year for the lower Entiat PIT tag detection array. It is still uncertain how effective it will be. Even with good efficiency, the sample size of PIT tags might need to be increased by tagging more juveniles in basin and tagging natural origin adults at Priest Rapids Dam. Biological data collected for C1-4 at Priest Rapids Dam would have to be applied to the fish that entered and stayed in the Entiat. A major assumption would be that those fish are a representative sample of Entiat spawners.

D2. Starting in 2007-2008, PIT tag detection arrays were installed at RM ~1, near the mouth of the Mad River, and at the lower end of the Stillwater reach (~RM 16). This method is still very new in the Upper Columbia and there is uncertainty regarding efficiency, longevity, etc.

E3. See C1-4.

F1. The USFWS operates a trap in the lower Entiat (rkm 2) in 2007 and 2008. From 2003-2008 there has been a trap at rkm 11. They have at least one more year of running both traps and then will determine if they can go with one or the other or if they need both.

F2-5. Conducted by USFWS and ISEMP.

G2. Egg-to-smolt survival estimated from egg deposition and out migrating smolts.

H1. See F1.

H2. Estimated from scale analysis.

Methow Steelhead

A2. To date, the abundance estimates for all populations have been based on dam counts apportioned to populations using radio telemetry data (English *et al*. 2003). Radio tracking was only conducted in 1999 and 2001 leaving considerable uncertainty regarding the extrapolation of that data to other years. The further in time we get from those studies the less certain we are in the extrapolation.

B3. WDFW has conducted spawning ground surveys since 2001. Index and expanded index areas are surveyed multiple times. A rotating panel is used to survey other areas once every five years. The rotating panel is not probabilistic, the five streams are fixed and systematically surveyed once every 5 years. Within a year, the results are expanded within the rotating panel areas.

C1-4. Wells Dam provides information for Methow and Okanogan, but individual natural origin returns cannot be assigned to one population or the other. A weir is operated on the Twisp River, providing partial coverage for one MaSA during WDFW broodstocking activities. There are plans to improve the ability of Foghorn Dam to capture fish in the Upper Methow. It is unclear to what extent this improvement will be sufficient for providing data on natural origin fish. It is likely that additional efforts such as PIT tags and weirs on smaller tributaries will also be needed.

D1. See C1-4.

D2. PIT tag detection arrays are installed on Beaver, which is a MaSA and Gold, and Libby creeks, which are MiSAs. Plans are underway to wire the Twisp and lower Methow mainstem, which would provide coverage for one additional MaSA and for the whole population.

E2. See C1-4

E3. See D2.

F1. The USFWS operates a trap in the lower Entiat (rkm 2) in 2007 and 2008. From 2003-2008 there has been a trap at rkm 11. They have at least one more year of running both traps and then will determine if they can go with one or the other or if they need both.
F2-5. See F1.

G2. Egg-to-smolt survival estimated from egg deposition and out migrating smolts.

H1. See F1.

H2. Estimated from scale analysis.

Okanogan Steelhead

A1. Current monitoring includes collection of Adult escapement data at Wells Dam, Omak Creek, Bonaparte Creek, Inkaneep Creek, and Zosel Dam. Video enumeration at both Wells and Zosel dams represent counts of fish passing these locations and can not be directly applied as spawning adults due to unknown prespawn mortality, fall back, harvest, and other issues. However, we do believe that minus the harvest impacts which are measurable and can be subtracted that the other issues combined are likely to account for no more than a 5% difference between the counts and the actual number of spawners. Data collected at the sub-watershed traps is considered highly applicable to spawner abundance due to the proximity to the spawning areas. Data comparing with redd surveys with trap counts in Omak Creek have been almost identical (Arterburn *et al*. 2005).

A2. To date, the abundance estimates for all populations have been based on dam counts apportioned to populations using radio telemetry data (English *et al*. 2003). Radio tracking was only conducted in 1999 and 2001 leaving considerable uncertainty regarding the extrapolation of that data to other years. The further in time we get from those studies the less certain we are in the extrapolation.

B1. Multiple redd surveys are conducted throughout the United States portion of the Okanogan River. Redd surveys cover all suitable main-stem spawning habitats within the United States portion of the Okanogan River basin and as such is considered a census survey. Redd surveys have been completed since 2005 as part of OBMEP and will continue over the foreseeable future. These data are collected using a standardized protocol and are publicly available http://nrd.colvilletribes.com/obmep/default.htm.

B2. All tributaries within the United States portion of the Okanogan River are surveyed on a one time basis because they are small and easily surveyed. The entire length of these streams below the known anadromous fish barriers (Arterburn *et al*. 2007) is surveyed annually. When time allows multiple surveys are completed but the small size of these streams make one-time surveys highly accurate and cost effective.

C1-4. Wells Dam provides information for Methow and Okanogan, but individual natural origin returns cannot be assigned to one population or the other. In recent years, the Wells data have been considered representative of steelhead spawning in the mainstem Okanogan and Similkameen Rivers. However, as recovery efforts progress and the proportion of hatchery fish on the spawning grounds decreases this assumption will be less valid and other means of collecting these data will be needed. An adult trap has been operated on Omak Creek since 2004, Bonaparte Creek and Inkaneep Creek since 2006 where more specific data can be collected and is utilized to be representative of other similarly sized watersheds. Only hatchery fish are currently being pit or CWT tagged. A basin wide estimate for length at age could be potentially developed over time but is currently not available specifically for the Okanogan River.

E1-3. Spawner and sex ratio data are collected from adult traps in Omak Creek, Bonaparte Creek, and Inkaneep Creek based upon visual inspection of this, presence of marks, and tags, and the presence or absence of the adipose fin. These data are used to represent other tributaries of similar size. Visual indicators can be used to collect this information at Wells and Zosel dams using underwater video. Data collected during broodstock collection at Wells dam is also genetically verified and used to represent the mainstem habitats of the Okanogan and Similkameen Rivers. Data collected at Zosel dam is used to represent the Canadian portion of the watershed.

F1. Two smolt trap sites are operated within the Okanogan River subbasin and have been since 2006. Population estimates are currently only being developed for the main-stem site located near Malott, WA as the portion of the population represented by Omak Creek is currently unknown. Main stem trap data are collected using standardized protocols and are publicly available at www.cbr.washington.edu/dart/trap_com.html. Omak Creek data are not publicly available and are being collected primarily for effectiveness monitoring purposes.

F3-5. Status and trend monitoring of the population is conducted through OBMEP using standardized protocols and making these data publicly available at: http://nrd.colvilletribes.com/obmep/default.htm. The OBMEP protocols use a randomized EMAP design for selecting snorkel sites throughout the Okanogan River. Effectiveness monitoring is conducted using fixed sites and presence and absence is determined a by product of these productivity monitoring efforts.

G1-2. Adult spawner and smolt data are being collected, which will allow these indicators to be calculated in the future but are not currently being calculated. Egg to smolt survival can be estimated based upon average fecundity of hatchery broodstock. However, this indicator is not directly monitored.

H1. Scale and length data are currently being collected at both smolt traps but an index has not been developed at this time. With additional data, age structure can be determined with more certainty.

Table F2. Summary of monitoring activities in the Major Spawning Area (MaSA) and Minor Spawning Area (MiSA) used to assess spring Chinook salmon and steelhead viability in the Upper Columbia ESU/DPS.

Major Population Group									
Population									
Major or Minor (m) Spawning Area						Redd count surveys			
	Number of Screw Traps	Fixed snorkel surveys	Random snorkel surveys	Number of hatchery weirs	Number of Temporary Weirs	index-multi	index-one	random, probabilistic, or rotating panel	periodic-spot check
Steelhead, North Cascades									
Wenatchee									
Lower Mainstem (population level)	1(double)		yes	1		yes			
Chiwawa	1	yes	yes			yes			
Icicle Creek		2	yes			yes			
Nason Creek	1	3	yes			yes			
White/Little Wenatchee Rivers	1	1	yes			yes			
Chumstick Creek		1	yes					yes	
Upper Wenatchee Mainstem		1	yes			yes			
Peshastin Creek		1	yes			yes			
Mission Creek (m)		0	yes					yes	
Johnson (m)									yes
Quilomene/Brushy (m)									yes
Skookumchuck (m)									yes
Tekison (m)									yes
Rocky Coulee (m)									
Colockum (m)									yes
Squilchuck (m)									yes
Entiat									
Entiat (includes the Mad River)	2	yes	yes			yes			
Swakane Canyon (m)									
Methow									
Chewuch		yes				yes			
Upper Methow		yes				yes			
Twisp	1	yes			1	yes			
Beaver		yes				yes			

Major Population Group									
Population									
Major or Minor (m) Spawning Area						Redd count surveys			
	Number of Screw Traps	Fixed snorkel surveys	Random snorkel surveys	Number of hatchery weirs	Number of Temporary Weirs	index-multi	index-one	random, probabilistic, or rotating panel	periodic-spot check
Middle Methow		yes		1		yes			
Gold (m)		yes						yes	
Lower Methow (m)	1 (double)					yes			
Libby (m)		yes						yes	
French (m)								yes	
Antoine (Columbia) (m)									
Okanogan*									
Omak	1		yes	1			yes		
Salmon			yes		1				
Similkameen**			yes			yes			
Upper U.S. Okanogan			yes			yes			
Inkaneep-Canada**			yes		1	yes			
Lower U.S. Okanogan (m)**	1		yes			yes			
Loup Loup (m)			yes				yes		
Bonaparte (m)			yes	1			yes		
Tunk (m)**			yes				yes		
Vassuex-Canada (m)**			yes						
Lower Canada Okanogan (m)**			yes		1				
*Monitoring in the Okanogan is limited to summer Steelhead only.									
** Major or minor spawning area determined by empirical data collect since 2005 by the Okanogan Basin Monitoring and Evaluation Program (OBMEP)									

Wild steelhead PIT tagged. Data not available so its not part of this assessment for the Upper Columbia.

The assessment of summer steelhead monitoring in the Upper Columbia ESU was based on the viability criteria developed by the Interior Columbia Technical Review Team (ICTRT 2007). The criteria include abundance, productivity, and twelve spatial structure and diversity metrics that were used in the population viability assessments of each population.

Abundance and Productivity: The ICTRT (2007) and the local recovery plan (UCSRB 2007) used similar methods to estimate steelhead abundance and productivity throughout the MPG. Abundance estimates were based on dam counts apportioned to populations using radio telemetry data (English *et al*. 2003). Specifically, the number of natural origin returns to Priest Rapids Dam was apportioned to each of the populations based on the average proportion that returned to each basin during radio telemetry studies in 1999 and 2001 (English *et al*. 2003). Subsequently, redd surveys have been conducted in all of the basins but there has not been a standard or unified effort to determine if, when, and how to estimate abundance and productivity using redd surveys for steelhead. Nor has there been an analysis to determine which method is more accurate or precise or what the consistencies and differences are between the two methods. Redd surveys probably chronically underestimate total abundance and likely need a mark-recapture type of methodology as a complement and to provide an alternative method when redd observation conditions are too unreliable due to flow conditions in certain years. As the radio tracking data gets older there is increased uncertainty in its applicability and it seems less logical to rely on it without periodic or systematic updates. It is possible that with the increased PIT tagging effort throughout the Upper Columbia region that an ongoing mark-recapture effort for validating redd surveys may be available. However, summarized PIT tag data is not currently available for each population. Once data from PIT tag detection arrays at the lower end of each population is available, an effort will need to be undertaken to do the analysis and determine the feasibility of using it for population level abundance and productivity.

Wenatchee steelhead: The ICTRT (2007) and the local recovery plan (UCSRB 2007) used similar methods to estimate steelhead abundance and productivity for Wenatchee steelhead. Abundance estimates were based on dam counts apportioned to populations using radio telemetry data (English *et al*. 2003).

Steelhead redd surveys were initiated in the Wenatchee Basin in 2001. Starting in 2004, ISEMP expanded the spatial coverage of steelhead redd surveys beyond the initial index sites by adding additional probabilistic sites and surveying 25, one km reaches per year.

Entiat steelhead: The ICTRT (2007) and the local recovery plan (UCSRB 2007) used similar methods to estimate steelhead abundance and productivity for Entiat steelhead. Abundance estimates were based on dam counts apportioned to populations using radio telemetry data (English *et al*. 2003).

Steelhead redd surveys were initiated in the Entiat Basin in 2000 (Mad River) and 2003 (Entiat River)(Archibald 2008). Initially, the lower Entiat mainstem was not well spatially or temporally covered. Starting in 2005, surveys were expanded to cover the entire Entiat River mainstem with a multiple pass survey design (USFWS unpublished data). The USFS and USFWS surveys cover the majority of known steelhead spawning, though several small tributaries (i.e. Roaring and Tillicum creeks) that consistently support steelhead spawning are not always surveyed through the potential anadromous zone due to funding limitations (Archibald *et al*. 2008).

Methow steelhead:
The ICTRT (2007) and the local recovery plan (UCSRB 2007) used similar methods to estimate steelhead abundance and productivity for Methow steelhead. Abundance estimates were based on dam counts apportioned to populations using radio telemetry data (English *et al*. 2003).

Steelhead redd surveys were initiated in the Twisp River in 2001 and expanded to the mainstem Methow, Chewuch River, and select small tributaries in 2002 (Humling and Snow 2001; Jateff and Snow 2002). Further spatial coverage expansions were implemented in 2003-2004 including the establishment of a rotating panel design for covering 16 small tributaries on a four-year basis.

Okanogan steelhead:
The ICTRT (2007) and the local recovery plan (UCSRB 2007) used similar methods to estimate steelhead abundance and productivity for Okanogan steelhead. Abundance estimates were based on dam counts apportioned to populations using radio telemetry data (English *et al*. 2003).

Steelhead redd surveys were initiated in the Okanogan Basin in 2005. Starting in 2005, OBMEP began census redd surveys of all accessible habitat within the United States. A combination of sampling methods is used to produce the most precise and accurate spawner abundance estimates possible based on a preponderance of the evidence approach. Multiple pass redd surveys are conducted on all main-stem habitats annually, whereas tributary habitats are monitored by single pass redd surveys unless a trap is located at the downstream extent of the sub-population segment in which case the enumeration at the weir is used in combination with a redd survey between the trap location and confluence with the Okanogan River. All fish passing into Canada are enumerated at the Zosel Dam counting facility minus the spawner estimates from redd surveys conducted on Tonasket and Nine mile Creeks. All these inputs are summed to produce a population level spawner estimate that is validated against the ICTRT methodology and both methods have remained reasonably consistent. A comparison of results is provided in Arterburn *et al*. (2007).

Spatial Structure and Diversity:

A.1. Maintain natural distribution of spawning areas: All listed Upper Columbia steelhead populations have redd surveys that cover the Major Spawning Areas and will allow for status assessments of the associated spatial structure metrics. The Wenatchee population has some disconnected minor spawning areas in small tributaries that drain directly into the Columbia, between the Wenatchee and Crab Creek. Though not critical for contribution to abundance and productivity, these creeks do have relevance for spatial structure metrics and should be monitored periodically as part of a spatially balanced rotating panel design.

B1. Maintain natural patterns of phenotypic and genotypic expression:

Factor B.1.a. Major Life History Strategies: Current and planned PIT tag detection arrays should provide adequate data for juvenile movement patterns. Additional effort to remotely tag natural origin parr will most likely be needed in order to obtain adequate sample size. Little is known about the current or historic genetic and demographic contribution of resident redband rainbow trout to Upper Columbia River anadromous steelhead (UCRTT 2008). It is not clear how this data gap would affect the status assessment for this metric.

Factor B.1.b. Phenotypic variation: Current monitoring programs associated with HCP hatchery programs include sufficient measurements to characterize current conditions for adult and juvenile phenotypic characteristics in the Wenatchee and Methow. Throughout the MPG, increased efforts to establish PIT tag detection arrays at the downstream ends of the populations and the mouths of major spawning areas as well as tagging more natural origin juvenile steelhead will help reduce uncertainty in evaluating this metric.

Throughout the Upper Columbia, sufficient data should be available for juveniles as long as smolt-trapping operations continue and PIT tag efforts increase. MPG level run timing in the mainstem and spawn timing based on redd surveys are the only phenotypic traits that can currently be assessed for natural origin adults. A method of determining other phenotypic characteristics (sex ratio, age structure, physical characteristics, etc.) of the adult steelhead populations needs to be implemented in all populations except for the Wenatchee. In the Methow and Okanogan, hatchery broodstock collection could be used if a locally adapted strategy were adopted as part of hatchery reforms. Data collected at tributary sites could then be extrapolated to the larger population or at least other similar sized watersheds. Another possibility, and an option for the Entiat (where no broodstock collections are needed) would be to PIT tag natural origin steelhead at the Priest Rapids trap. Once a PIT tagged fish was detected in a tributary location the associated phenotypic information previously collected at Priest Rapids could be assigned to that population. Additionally, a reference condition for the phenotypic variation metric is needed for all populations in the Upper Columbia (UCRTT 2008). Neither the ICTRT nor the Salmon Recovery Plan established what the baseline (or reference) condition is for each of the phenotypic traits. Without a reference condition it will not be possible to determine the level of deviation and therefore the level of risk.

Factor B.1.c. Genotypic variation: Current monitoring programs associated with HCP hatchery programs include sufficient measurements to characterize current conditions for genotypic variation throughout most of the MPG, with the Okanogan being the exception. A reference condition for genotypic variation is needed for all populations in the Upper Columbia (UCRTT 2008). Neither the ICTRT nor the Salmon Recovery Plan established what the baseline (or reference) condition is for genotypic variation. Without a reference condition it will not be possible to determine the level of deviation and therefore the level of risk. Parental origin studies currently underway in the Okanogan at Omak Creek and Wenatchee basins will provide sufficient baseline data to establish bench marks in 2 of the 4 upper Columbia populations. These studies will also provide data in the fitness of hatchery fish and viability for reintroducing kelt steelhead to increase diversity.

B.2. Maintain natural patterns of gene flow:

Factor B.2.a-d. Spawner Composition: The ability to assess spawner composition for steelhead is more difficult than spring Chinook because carcasses cannot be recovered during spawning ground surveys. The ability to evaluate spawner composition and the hatchery management practices vary by population.

> **Wenatchee:** Dryden and Tumwater Dam collection facilities offer an opportunity to determine the spawner composition for the Wenatchee population.

> **Entiat:** There has not been a method of determining spawner composition in the Entiat. In 2008, a PIT tag detection array was installed in the lower Entiat, which could potentially provide the necessary information for this metric. The efficiency of this method is uncertain and the need for increased tagging of both juveniles and returning adults (at Priest Rapids) needs to be considered.

> **Methow:** Previous efforts to evaluate spawner composition have had to rely on Wells Dam as an interrogation site, which provides a conglomerate analysis of the Methow and Okanogan populations. A population specific method of determining spawner composition is needed (such as PIT tag detections or radio tracking).

> **Okanogan:** Previous efforts to evaluate spawner composition have had to rely on Wells Dam as an interrogation site, which provides a conglomerate analysis of the Methow and Okanogan populations. However, since 2004 traps on small tributaries and the operation of a counting facility at Zosel Dam have greatly expanded our ability to determine origin and spawner

composition in the Okanogan. Additional traps and video arrays are planned in the next few years as part of an expanded OBMEP effort. These efforts will allow the collection of data from multiple major and minor spawning areas to be covered.

B.3. Maintain occupancy in a variety of available habitat: All Upper Columbia steelhead populations have redd surveys that cover the Major Spawning Areas and will allow for status assessments associated with this metric.

B4. Maintain integrity of natural systems (Avoid selectivity in anthropogenic activities): The baseline information related to phenotypic traits is collected for each population and many of the potentially selective influences have been identified; however, the mechanisms and magnitude of each selective influence on the phenotypic traits are not understood. Additional input from the TRT, RIST, or other entity is needed to understand what data are needed to adequately rate this metric.

DQO STEPS	UPPER COLUMBIA STEELHEAD	Policy Inputs[1] (✓)
1. State the Problem		
Problem:	Delisting of Upper Columbia Steelhead DPS	
Stakeholders:	States—Washington Tribes—Colville, Yakima Federal—NOAA, USFWS, USFS, BPA, USACOE Intergovernmental—Columbia River Compact, CBFWA, CRITFC, PFMC, PSC, NPCC Other—Grant, Chelan, and Douglas County PUDs, conservation groups, fishers (tribal, commercial, sport), landowners, upland land users (ranchers, farmers, municipalities, state and county governments), water users (agricultural, industrial, municipal)	
Non-technical Issues:	Interagency coordination, fiscal constraints, legal constraints, land ownership and access	
Conceptual Model:	Life history models	
2. Identify the Decision		
Principal Questions:	1) What is the ESA listing status for Upper Columbia Steelhead? 2) What is the current status and risk level for each population compared to ICTRT defined viability? • Note: The recovery plans also require knowledge about the status of habitat conditions and limiting factors, which requires monitoring an entirely different set of variables that are not covered in this strength and weakness assessment.	
Alternative Actions:	• If status is "listed," then recovery strategies (i.e., more restrictive management strategies at one or more points in the life history model). • If status is "delisted," then recovery or sustainable harvest strategies. • If status is "recovered," then sustainable harvest strategies	✓
Decision Statements:	• Has there been sufficient improvement in population status of Upper Columbia Steelhead DPS to justify delisting and allow removal of ESA restrictions? • Are additional management actions required for regional, ESA recovery and NPCC SAR goals?	✓
3. Identify the Inputs		
Information Required:	Information required Abundance Productivity Spatial Structure Diversity Abundance of spawners ✓ ✓ Abundance/distribution of redds ✓ ✓ ✓	

DQO STEPS	UPPER COLUMBIA STEELHEAD	Policy Inputs[1] (✓)
	✓ Origin of spawners ✓ ✓ ✓ Age-structure of spawners ✓ ✓ ✓ Sex ratio of spawners ✓ ✓ ✓ Abundance/distribution of juveniles ✓ ✓ ✓ ✓ Juvenile survival ✓ ✓ ✓	
Sources of Data:	State, tribal, PUD, and federal programs currently collecting monitoring data within the Upper Columbia ESU.	
Quality of Existing Data:	• The Entiat, Methow, and Okanogan do not have population specific empirical measures of sex ratio, origin, and age structure. Wells Dam does provide composite information for Methow and Okanogan and the trap sites within each basin provide some MaSA level estimates. • Recent attempts to estimate spawn escapement have used radio-tracking data from 1999 and 2001 to apportion natural origin adults into each subbasin. Subsequently,	

DQO STEPS	UPPER COLUMBIA STEELHEAD	Policy Inputs[1] (✓)
	redd surveys have been conducted in all of the basins but there has not been a standard or unified effort to determine if, when, and how to estimate abundance and productivity using redd surveys for steelhead. Nor has there been an analysis to determine which method is more accurate or precise or what the consistencies and differences are between the two methods. Redd surveys probably chronically underestimate total abundance and would benefit from a mark-recapture type of methodology as a complement or alternative when redd observation conditions are compromised by run-off patterns in certain years. As the radio tracking data gets older there is increased uncertainty in its applicability and it seems less logical to rely on it without periodic or systematic updates. Methods for conducting periodic or systematic updates of radio tracking data would improve this issue. Mark/recapture methods using pit tags to apportion wild fish by population could produce estimates with greater accuracy and precision. • Studies in Crab Creek have very recently begun. ICTRT classified the population as functionally extirpated. If ongoing monitoring shows otherwise then we will have to include an additional strengths and weaknesses analysis for that population.	
New Data Required:	• Population specific steelhead data needed includes sex ratio, origin, and age structure for the Entiat, Methow and Okanogan. • PIT tag recovery analysis as a mark-recapture complement to redd surveys. • Power analysis of PIT tag mark rate to determine if more PIT tags are needed to provide reliable results. • Once data from PIT tag detection arrays at the lower end of each population (and MSA) are available, an effort will need to be undertaken to do the analysis and determine the feasibility of using it for population level abundance and productivity. • Additional effort to remotely tag natural origin parr will most likely be needed in order to obtain adequate sample size. • If PIT tag data are not adequate for mark-recapture compliment to redd surveys then re-visiting radio tracking may need to occur. • A reference condition for genetic variation for steelhead is needed so that we can determine what the goal is and how to track progress towards it. • A reference condition for the phenotypic variation metric is needed. • Assess the genetic and/or demographic contribution of resident redband rainbow trout to UCR anadromous steelhead	
Analytical Methods:	IC-TRT rules and criteria for combining measures of abundance, productivity, spatial structure, and diversity.	✓
4. Define the Boundaries		
Target Populations:	Upper Columbia Steelhead	
Spatial Boundaries (study):	Population, MPG, and DPS (Distinct Population Segment) levels for Steelhead within the Upper Columbia basin. One MPG, and one functionally extirpated (Crab Creek).	✓
Temporal Boundaries (study):	• Status data evaluated over generations from annual abundance data and generational productivity data, summarized as 10-12 year geometric means. Spatial structure and diversity data collected and summarized at various intervals, depending on the metric.	✓
Practical Constraints:	Legal and logistical issues with access, permits, and interagency coordination across jurisdictional boundaries.	✓
Spatial Boundaries (decisions):	Delisting decision made at level of DPS, but is dependent on information from each of the component populations.	✓
Temporal Boundaries (decisions):	IC-TRT rules for abundance and productivity require historical data, and 10-year series of annual data. IC-TRT rules require spatial structure and diversity data collected at	

DQO STEPS	UPPER COLUMBIA STEELHEAD	Policy Inputs[1] (✓)
	various intervals.	
5. Decision Rules (IC-TRT Rules)		
Critical Components and Population Parameters:	Two metrics (A/P and SS/D) are used to assess the status of each population. A/P combines abundance and productivity VSP criteria using a viability curve. SS/D integrates 12 measures of spatial structure and diversity.	✓
Critical Action Levels (Effect Sizes):	Risk categories are assigned at the population level for A/P using a 5% risk criterion to define viable populations. Populations scored as moderate or high risk in A/P criteria cannot meet viable standards, while populations at high risk for the 12 SS/D measures cannot be considered viable.	✓
If-Then Decision Rules: IC-TRT Draft	**MPG-level Viability Criteria:** Low risk (viable) MPGs meet the following six criteria: 1. One-half of the populations historically within the DPS (with a minimum of two populations) must meet minimum viability standards. 2. All populations meeting viability standards within the DPS cannot be in the minimum viability category; at least one population must be categorized as meeting more than minimum viability requirements. 3. The populations at high viability within an MPG must include proportional representation from populations classified as "Large" or "Intermediate" based on their intrinsic potential. 4. Populations not meeting viability standards should be maintained with sufficient productivity that the overall MPG productivity does not fall below replacement (i.e. these areas should not serve as significant population sinks). 5. Where possible, given other MPG viability requirements, some populations meeting viability standards should be contiguous AND some populations meeting viability standards should be disjunct from each other. 6. All major life history strategies (i.e. adult "races," A-run/B-run, resident and anadromous) that were present historically within the MPG must be present and viable. **DPS-level Viability Criteria:** 1. All extant MPGs and any extirpated MPGs critical for proper functioning of the DPS must be at low risk. 2. DPS's that contained only one MPG historically must meet the following criteria: a. Two-thirds or more of the populations within the MPG historically must meet minimum viability standards; AND c. Have at least two populations categorized as meeting more than minimum viability requirements. *Note: The Upper Columbia Recovery Plan (UCSRB 2007) rejected the ICTRT technical criteria that 2 populations within the MPG needed to be at highly viable status. The policy objective was to reach viable status in all populations.	✓
Consequences of Decision Errors:	Incorrectly concluding that delisting criteria have been achieved: • Decisions to relax ESA restrictions increase risks to the DPS Incorrectly concluding that delisting criteria have not been achieved: • Minimal biological impact given that decisions do not relax ESA restrictions • May over-invest in intensity of monitoring efforts • Unnecessary listing and restrictive measures • Loss of harvest opportunity	

[1]**Policy Inputs -** indicate with a check steps where group really needs policy feedback, presentation will elaborate on what feedback is required

Appendix G. CSMEP Strengths and Weaknesses Assessment of Monitoring in Washington's Lower Columbia River Steelhead DPS above Bonneville Dam, Draft

Dan Rawding (WDFW)

Table G1. Summary of monitoring activities used to assess steelhead viability in the Lower Columbia River Steelhead DPS above Bonneville Dam. x = monitoring occurs in at least one Spawning Area defined by the TRT; a = possible from PIT-tags scanned at weirs; b = from CWT recoveries of hatchery adults at hatchery weirs.

		P0PULATION	**Wind River Summers**	**Upper Gorge Winters**			
Data need	**Method/Description**		Wind River Summers	Wind River Winters	Rock Creek	Dog Creek	Other Small Tributaries
Abundance of adults	A1	census weir (number)					
	A2	weir/trap w/MR (number)	2	1			
	A3	weir/trapw/o MR (number)					
	A4	MR survey, no weir					
Abundance and distribution of redds	B1	Index-multi		1			
	B2	Index-once					
Age structure of spawners	C1	Tags (CWT, PIT)	a,b	a,b			
	C2	Hard parts, scales	x	x			
	C3	Length at age	x	x			
	C4	Basinwide estimate	x	x			
Origin of spawners	D1	Marks , weirs (number)	2	1			
	D2	marks, remote sense	1				
	D3	marks, carcasses					
Sex ratio of spawners	E1	Carcass survey					
	E2	Weirs (number)	2	1			
Abundance and spatial distribution of juveniles/smolts	F1	Juvenile trap (number)	4	1			
	F2	Electrofish	sometimes	sometimes			
	F3	Snorkel survey--random					
	F4	Snorkel survey--fixed	sometimes				
	F5	Presence/absence	yes				
Survival of juveniles/smolts	G1	mark-recapture	5				
Age structure	H1	Juvenile trap	4				

of juveniles/smolts	H2	other in-river sampling						

Table G2. Summary of monitoring activities used to assess steelhead viability in Washington's Lower Columbia River steelhead DPS above Bonneville Dam.

Gorge Strata							
Population	Number Screw traps	Fixed snorkel surveys	Random snorkel surveys	Number Hatchery weirs	Number Traps in Fish Ladders	Redd count surveys index-multi	index-one
Wind River Summers	4				2		
Wind River Winters	1				1	yes	
Rock Creek Winters							
Dog Creek Winters							
Other Small WA Tributaries Winters							

Wild steelhead PIT-tagged in the Washington's portion of the Lower Columbia River DPS above Bonneville Dam

Table G3. Summary of the number wild steelhead PIT-tagged in each Population the Lower Columbia River DPS above Bonneville Dam. All collection methods combined.

Strata and Population	Life Stage	1999	2000	2001	2002	2003	2004	2005	2006	2007	Average
Gorge											
Wind	parr	289	1461	1155	2005	2737	4116	3373	2722	313	2019
	smolts	0	21	0	0	1351	2113	2105	1319	2723	1070
	adults	0	0	0	0	0	0	0	0	276	31
	Total	*289*	*1482*	*1155*	*2005*	*4088*	*6229*	*5478*	*4041*	*3312*	*3120*

Table G4. Summary of all wild steelhead smolt detections for the Lower Columbia River DPS at Bonneville and in the estuary in smolt migration years (MY) 2000-2007. All interrogation methods combined.

Strata and Population	Life Stage	MY1999	MY2000	MY2001	MY2002	MY2003	MY2004	MY2005	MY2006	MY2007	Average
Gorge											
Wind	parr	0	0	0	88	19	47	20	39	25	26
	smolts	0	0	1	0	0	260	136	192	124	79
	Total	*0*	*0*	*1*	*88*	*19*	*307*	*156*	*231*	*149*	*106*

The assessment steelhead monitoring in Washington's portion of the Lower Columbia River DPS above Bonneville Dam was based on the viability criteria developed by the Willamette Lower Columbia Technical Recovery Team (TRT). The criteria include abundance, productivity, spatial structure, diversity, juvenile outmigrant, and habitat metrics that were used in their population viability assessments of each population.

Abundance, productivity, and Juvenile Outmigrant metrics

The TRT was only able to assess the abundance and productivity (A/P) for the Wind River summer steelhead population because data was lacking for other Gorge populations. Current monitoring may provide abundance and productivity estimates for the Wind River winter subpopulation in the future (obtained from mark-recapture and redd counts) (Rawding and Cochran 2008). Redd surveys are traditional used to assess steelhead abundance and could be applied to the remaining tributaries. Another promising methodology to gathering A/P data for Lower and Middle Columbia River winter steelhead populations above Bonneville is the use of mark-recapture (mark/tag at Bonneville and recover adults at tributary traps in Wind, Hood, and Klickitat Rivers for a population estimate) and genetic stock identification (GSI) of these same tagged adults sampled at Bonneville Dam. A baseline dataset for these populations has been assembled. It should be possible to test the feasibility and accuracy of this method as soon as funding becomes available. Other possible methods to estimate abundance include (1) PIT or radio tag wild adult steelhead at Bonneville Dam and track them to their natal stream, (2) use of sonar technology throughout the basin, and/or estimate winter steelhead abundance for remaining population through subtraction of individual winter populations estimates (Wind, Hood, and Klickitat Rivers) from the Bonneville Dam winter steelhead population estimate (Rawding *et al*. 2008). The monitoring of juvenile outmigrants is recommended in one population per strata and the current monitoring on the Wind River meets this requirement for Gorge steelhead populations.

Spatial structure and diversity metrics

Current monitoring of adults will not provide the necessary data for spatial structure in the Wind River due to difficulties in determining race from redd surveys and the inability to safely and accurately survey high gradient canyon sections of river. Since monitoring of adult spawners is not feasible under these conditions, juvenile monitoring by deployment of multiple screw traps has provided presence/absence and abundance data that could be used to infer adult spawning in populations. Redd surveys may provide adequate spatial structure in Washington's smaller tributaries or spatial structure may be inferred from juvenile snorkel or electrofishing surveys, but this may be complicated by not distinguishing resident rainbows.

The diversity metric includes estimates of run timing for adults and juveniles, spawning time, age structure, origin of spawners, and genetic diversity. For adults, run-timing information is not available except for a few tributaries where weirs or fish ladder traps can be operated, such as the Wind River. Run-time data for adults through the Bonneville Dam and at the population scale may be obtained through mainstem and in-river PIT tag interrogation systems. The timing of the smolt migration through the Columbia River is possible, on a yearly basis, from streams that have screw traps and PIT-tag sufficient juvenile steelhead to obtain adequate number of detections at the Bonneville Dam and the Columbia River estuary. For juveniles, migration patterns can be obtained at the screws traps however these traps are currently operating in the Wind River and its tributaries. Spawning time may be determined using redd surveys but these are currently only conducted on the lower Wind River for winter steelhead

There are only a few trap sites where adults are handled, hence age structure cannot be accurately assessed with the possible exception of the Wind River or through PIT tagging of juveniles from other populations. The diversity metric requires sampling adult spawners to determine their origin, which occurs on the Wind River. For natural origin fish this requires: (1) physically handling the fish; and (2) relying on GSI techniques to assign them to their natal stream. For hatchery adults, origin can be determined from marks such as a missing adipose fin, tags (CWT, PIT-tag), and/or GSI. Current monitoring could assess origin based on marks (adipose fin, CWT, PIT-tags) at traps, which are few. Alternate methods include representative PIT tagging of hatchery and wild juveniles, and in-river PIT detectors below major spawning areas to determine origin.

Genetic samples of adult steelhead from the Lower Columbia River and the Columbia portion of the Southwest Washington DPS were collected from 2004 to 2006. In populations where adult abundance was low and it was difficult and not cost-effective to capture adults, steelhead smolts were collected. One major gap in this sampling includes the Lower and Upper Gorge winters steelhead populations. This data can provide a baseline to assess results of future genetic sampling, along with portioning of winter steelhead by race at Bonneville Dam from mixture analysis.

Habitat

There has not been a coordinated effort to standardize habitat survey techniques and collect this information, although some monitoring forums are working toward this goal. The use of remotely sensed data may be a balanced cost-effective alternative to collect this data. The LCFRB's recently developed research, monitoring, and evaluation program provides a framework and strategy for habitat monitoring in the Lower Columbia but has not been fully implemented due to budgetary constraints.

References

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Rawding. D. and P.C. Cochran. 2008. Wind River Winter and Summer Steelhead Adult and Smolt Population Estimates from Trapping Data, 2007. Washington Department of Fish and Wildlife, Vancouver, WA. 24pp.

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DQO STEPS	WASHINGTON'S LOWER COLUMBIA RIVER STEELHEAD DPS ABOVE BONNEVILLE DAM	Policy Inputs[1] (✓)
1. State the Problem		
Problem:	Delisting of the Lower Columbia River Steelhead DPS	
Stakeholders:	States—Washington, Oregon Tribes- CTWSR, YIN Federal—NOAA, USFWS, USFS, BPA, USACOE Intergovernmental—Columbia River Compact, CBFWA, CRITFC, PFMC, NPCC Other—Lower Columbia River Fish Recovery Board (LCFRB), conservation groups, fishers (tribal, commercial, sport), landowners, upland land users (ranchers, farmers, municipalities, state and county governments), water users (agricultural, industrial, municipal)	
Non-technical Issues:	Interagency coordination, fiscal constraints, legal constraints, land ownership and access	
Conceptual Model:	Life history models	
2. Identify the Decision		
Principal Questions:	What is the ESA listing status for Lower Columbia River Steelhead?	
Alternative Actions:	• If status is "listed," then recovery strategies (i.e., more restrictive management strategies at one or more points in the life history model). • If status is "delisted," then recovery or sustainable harvest strategies. • If status is "recovered," then sustainable harvest strategies	✓
Decision Statements:	• Has there been sufficient improvement in population status of Lower Columbia River Steelhead DPS to justify delisting and allow removal of ESA restrictions? • Are additional management actions required for LCFRB goals, ESA recovery, and NPCC goals?	✓
3. Identify the Inputs		
Information Required:	Information required Abundance Productivity Spatial structure Diversity Abundance of Spawners ✓ ✓ ✓ Abundance/distribution of redds ✓ ✓ ✓ ✓	

DQO STEPS	WASHINGTON'S LOWER COLUMBIA RIVER STEELHEAD DPS ABOVE BONNEVILLE DAM	Policy Inputs[1] (✓)
	Origin of spawners ✓ ✓ Age-structure of spawners ✓ ✓ ✓ Sex ratio of spawners ✓ ✓ Abundance/distribution of juveniles ✓ Juvenile survival ✓	
Sources of Data:	State, tribal, and federal programs and NGSs identified in CSMEP metadata inventories.	
Quality of Existing Data:	Data varies in level of precision and bias. Major issues: • Abundance of spawners: The Wind River summer and winter steelhead are the only populations monitored for adult abundance. Abundance estimates above Shipherd Falls are based on tagging at a trap in the fish ladder and multiple recaptures surveys. The data quality of this program is excellent. No adult abundance surveys currently occur in the remaining Columbia River tributaries, which are small and probably support few steelhead. • Abundance/distribution of redds: Redd surveys are conducted in the Lower Wind River below Shipherd Falls to estimate abundance of winter steelhead. They are not practical in a significant portion of the Wind due to the inability to safely and accurately survey high gradient canyon reaches. As an alternative, distribution is obtained from the deployment of 4 screw traps and abundance estimates are determined from this mark-recapture program. No redd surveys occur in Upper	

DQO STEPS	WASHINGTON'S LOWER COLUMBIA RIVER STEELHEAD DPS ABOVE BONNEVILLE DAM	Policy Inputs[1] (✓)
	Gorge tributaries. • Origin of spawners: Proportion of wild and hatchery adults is estimated at the Shipherd Falls and Hemlock Dam traps and through adult snorkel surveys in the Wind River. Origin estimates are excellent for steelhead in the Wind but unavailable for other populations. • Age-structure of spawners: Age structure of adults and juveniles is available for the Wind River population based on scale analysis and PIT tagging. • Sex ratio of spawners: sex ratio data are available for Wind River steelhead. However, the quality of the data is unknown because the fish are sexually immature and distinguishing male from female can be difficult. • Abundance/distribution of juveniles: Fixed site snorkel surveys in the mainstem Wind River for adults and the presence/absence of juveniles is noted. Wind River juvenile snorkel and electrofishing surveys have been done to estimate abundance but the scope has been substantially reduced during the last few years due to budget limitations. Screw traps are operated at four locations in the Wind River and over 2,000 smolts have been PIT or CWT annually. Parr collected at the screw traps and during electroshocking surveys are also PIT tagged. The screw trap data provides both abundance and limited distribution for four key subwatersheds within the Wind River; snorkel data are imprecise for abundance but provide finer scale information on distribution. • Survival of juveniles: PIT-tags survival estimates but sample sizes should be increased to provide more accurate survival estimates.	
New Data Required:	• All information needed to assess status with the exception of habitat is available for Wind River steelhead. However, almost no information is available for Washington's Upper Gorge population. Adult abundance and distribution data could be collected using traditional methods such as redd surveys. However, redd surveys do not allow sampling of fish, so diversity metrics would be unavailable. Alternative methods of estimating abundance such as mark-recapture of adult winter steelhead at Bonneville Dam, along with radio or PIT tagging, or Genetic stock identification are capable of providing an abundance estimate for the combined Washington & Oregon Upper Gorge population. Sampling of juvenile fish would provide information on the spatial structure, diversity, and habitat metrics.	
Analytical Methods:	WLC-TRT rules and criteria for combining measures of abundance, productivity, spatial structure, diversity, juvenile outmigrant, and habitat.	✓
4. Define the Boundaries		
Target Populations:	Lower Columbia River Steelhead	
Spatial Boundaries (study):	Population, Strata, and DPS (Distinct Population Segment) levels for Steelhead within the Lower Columbia River and Tributaries. A total of 23 historical populations (eighteen winter and five summer populations) were found in this DPS. A total of 19 populations are found in Washington. One extirpated or functionally extirpated summer population occurred in the NF Lewis River above Merwin Dam with possible extirpated populations in the Cowlitz above Mayfield Dam. However, this study area is restricted to steelhead in Washington tributaries above Bonneville Dam and below the White Salmon River. In this area, there is one summer steelhead population (Wind River) and one winter steelhead population (Upper Gorge), which is shared with Oregon.	✓
Temporal Boundaries (study):	Status data evaluated over generations from annual abundance data, generational productivity, spatial structure and diversity data collected at unspecified intervals. Data on historical abundance, distribution, and productivity at the population scales are	✓

DQO STEPS	WASHINGTON'S LOWER COLUMBIA RIVER STEELHEAD DPS ABOVE BONNEVILLE DAM	Policy Inputs[1] (✓)
	lacking.	
Practical Constraints:	Legal and logistical issues with access, interagency coordination across jurisdictional boundaries. Inability to accurately sample adults using traditional methods.	✓
Spatial Boundaries (decisions):	Delisting decision made at level of DPS and viability at the population scale.	
Temporal Boundaries (decisions):	Technical Recovery Team (TRT) rules for abundance and productivity require historical data, and time series of annual data. TRT rules also require spatial structure and diversity data collected at unspecified intervals.	
5. Decision Rules (TRT Rules)		
Critical Components and Population Parameters:	Six metrics (Abundance (A), Productivity (P), Spatial Structure (SS), Diversity (D), Juvenile Outmigrants (JOM), and Habitat (H)) are used to assess the status of each population. A and P combines abundance and productivity VSP criteria using a viability curve. JOM is an assessment of juvenile abundance based on outmigrant trapping. SS and D integrate measures of spatial structure and diversity. H is an assessment of habitat to support viable populations.	✓
Critical Action Levels (Effect Sizes):	Population viability is based on the scoring of A, P, JOM, SS, D, and H measures.	✓
Decision Rules: WLC-TRT Draft and LCFRB recovery plan	**Population-level Viability Criteria:** The method used to capture each panel member persistence rating for each population attribute is similar to the method used by the NOAA Fisheries Biological Review Team to make initial listing evaluations and based on an approach developed by FEMAT. Each panel member has ten votes to allocate into the persistence levels (0–4) for that attribute according to the criteria and evaluation guidelines provided in each attribute section. Scores of 0 indicated low persistence levels (<40%) for A & P, and scores of 4 indicate very high persistence levels (>99%) for A & P. The attribute mean and vote distribution describe the population attribute status. Persistence levels for the population attribute would be calculated from the combined votes from all panel members. Additionally, panel members consider the quality of data utilized to determine the attribute status. Data quality would be scored from 0 to 4, 4 being high-quality data with little measure error. If the panel determined that the data quality was especially poor (0, 1, or 2), they could decide to reduce the population attribute mean as a precautionary measure. The amount of the reduction would be directly related to the data quality score. The population persistence score (0-4) is based on the sum of all attribute scores. The attribute scores are weighted as follows 1/3 from the abundance and productivity curves, and 1/6 each for juvenile outmigrants, spatial structure, diversity, and habitat attribute scores. **ESU/DPS-level Viability Criteria:** The WLC-TRT partitioned the populations in an ESU into a number of different strata, and then specified a risk evaluation system for deciding how many populations within each stratum should be at what status. The strata are defined based on two factors: (1) major life-history differences and (2) ecological zones. The partitioning based on ecological zones also results in a partitioning based on spatial distribution. If the ESU contains populations in each stratum, it will have a relatively low extinction risk from catastrophic events, correlated environments, and loss of diversity. In addition, the ESU will have some semblance of its historical structure, which increases confidence in ESU viability. At least two populations per strata must be at high or high plus viability levels, and the average viability score for the strata must be above moderate persistence level. Details regarding population level and ESU/DPS level viability criteria, along with recovery goals are found in the Lower Columbia Salmon and	✓

DQO STEPS	WASHINGTON'S LOWER COLUMBIA RIVER STEELHEAD DPS ABOVE BONNEVILLE DAM	Policy Inputs[1] (✓)
	Steelhead Recovery Plan (LCFRB 2004).	
Consequences of Decision Errors:	Incorrectly concluding that delisting criteria have been achieved: • Decisions to relax ESA restrictions increase risks to the DPS Incorrectly concluding that delisting criteria have not been achieved: • Minimal biological impact given that decisions do not relax ESA restrictions • May over-invest in intensity of monitoring efforts • Unnecessary listing and restrictive measures • Loss of harvest opportunity	

[1]**Policy Inputs -** indicate with a check steps where group really needs policy feedback, presentation will elaborate on what feedback is required.

Appendix H.
CSMEP Strengths and Weaknesses Assessment of Monitoring in Washington's Lower Columbia River Chinook ESU above Bonneville Dam, Draft

Dan Rawding (WDFW)

Table H1. Summary of monitoring activities used to assess Chinook salmon viability in the Lower Columbia River Chinook ESU above Bonneville Dam. x = monitoring occurs in at least one Spawning Area defined by the TRT; a = possible from PIT-tags scanned at weirs; b = from CWT recoveries of hatchery adults at hatchery weirs.

		P0PULATION	**Upper Gorge/Wind**						**White Salmon**		
Data need	**Method/Description**		Wind River Tules (Listed)	Wind Brights (Not Listed)	Wind Springs (not listed)	Drano Springs (Not Listed)	Drano Tules (Listed)	Drano Brights (Not Listed)	White Salmon Tules (Listed)	White Salmon Brights (Not Listed)	White Salmon Springs (Not Listed)
Abundance of adults	A1	census weir (number)									
	A2	weir w/MR (number)									
	A3	weir w/o MR (number)									
	A4	MR survey, no weir			1						
Abundance and distribution of redds/fish	B1	Index-multi			1						
	B2	Index-once									
	B3	AUC-Lives			1						
	B4	Peak Count Expansion									
	B5	Peak Count	1	1		1		1	1	1	1
Age structure of spawners	C1	Tags (CWT, PIT)	b	b	b	b	b	b	b	b	b
	C2	Hard parts, scales	b	b	b	b	b	b	b	b	b
	C3	Length at age	b	b	b	b	b	b	b	b	b
	C4	Basinwide estimate	x	x	x			x	x	x	x
Origin of spawners	D1	Marks , weirs (number)									
	D2	marks, remote sense									
	D3	marks, carcasses	x	x	x	x	x	x	x	x	x
Sex ratio of spawners	E1	Carcass survey	x	x	x	x	x	x	x	x	x
	E2	Weirs (number)									
Abundance and	F1	Juvenile trap (number)	1	1	1				1	1	1

spatial distribution of juveniles/smolts	F2	Electrofish	sometimes	sometimes	sometimes						
	F3	Snorkel survey--random									
	F4	Snorkel survey--fixed									
	F5	Presence/absence									
Survival of juveniles/smolts	G1	mark-recapture									
Age structure of juveniles/smolts	H1	Juvenile trap	1	1	1				1	1	1
	H2	other in-river sampling									

Table H2. Summary of monitoring activities used to assess Chinook salmon viability in Washington's Lower Columbia River Chinook ESU above Bonneville Dam.

Gorge Strata										
Population	Number Screw traps	Fixed snorkel surveys	Random snorkel surveys	Number Hatchery weirs	Number Temporary weirs	Redd count surveys		Fish count surveys		
						index-multi	index-one	AUC	Peak Count	Minimum Count
Wind Springs	2					1		1	1	
Wind Tules	1								1	
Wind Brights	1								1	
Drano Springs				1						1
Drano Tules				1						sometimes
Drano Brights				1					1	
White Salmon Springs	1						1		1	
White Salmon Tules	1								1	
White Salmon Brights	1								1	

Wild Chinook PIT-tagged in the Washington's portion of the Lower Columbia River ESU above Bonneville Dam

Currently there is no program to PIT tag naturally produced Chinook salmon juveniles in this portion of the ESU.

The assessment Chinook monitoring in Washington's portion of the Lower Columbia River ESU above Bonneville Dam was based on the viability criteria developed by the Willamette Lower Columbia Technical Recovery Team (TRT). The criteria include abundance, productivity, spatial structure, diversity, juvenile outmigrant, and habitat metrics that were used in their population viability assessments of each population. Chinook salmon origin in this portion of the ESU is believed to have changed substantially over the past 100 years. First, the White Salmon spring Chinook salmon population was extirpated shortly after the construction of Condit Dam in the early 1900's and subsequent failure of adult passage facilities. Release of non-native hatchery spring Chinook salmon in the White Salmon have occurred during the last ¼ century for harvest opportunity but releases for the purpose of re-introduction are scheduled to occur within the next decade. Second, historically there were no spring Chinook salmon in the Wind River, but the culture and releases of Carson Stock spring Chinook salmon have occurred over the last ½ century for harvest opportunity. Finally, releases of Upriver Bright Fall Chinook Salmon hatchery stocks in the portion of the ESU, primary from Little White Salmon and Bonneville Hatcheries, have potentially lead to the establishment of naturally sustaining Upriver Bright populations in some locations. Therefore, Chinook salmon monitoring is not confined to listed populations for recovery but includes other populations for fisheries management and to assess genetic and ecological risks between historical populations and recently established populations.

Abundance, productivity, and Juvenile Outmigrant metrics
The TRT was only concerned with assessment of historical Tule populations in the Wind and White Salmon River. These populations were assessed for abundance and productivity. Other Chinook salmon populations, which are not part of the ESU, were not assessed by the TRT but are assessed by WDFW (WDF *et al*. 1993, and WDFW 2003). Current monitoring provides population abundance estimates of the three Wind River Chinook salmon populations, two White Salmon River populations, and the Upriver Bright population in Drano Lake/Little White Salmon River. Spring Chinook surveys are intermittent in the White Salmon since this population was extirpated and hatchery releases have been discontinued. Tule abundance in Drano Lake is usually low and surveys are intermittent depending on funding. Spring Chinook salmon surveys in Drano Lake consist of a minimum count, which is a single count of pre-spawning fish below the Little White Salmon Hatchery.

The peak count expansion method is used to estimate abundance for Wind River Tule, Wind River Bright, White Salmon Tule, White Salmon Bright, and Drano Bright fall Chinook populations (WDFW 2003). A single peak count expansion factor was developed during the 1960's and 1980's for these populations (Stockley 1966, Stockley 1967, and Hymer 1991). Briefly, the carcasses were marked and recovered during the spawning period through out the spawning area. Population abundance was estimated using the Jolly-Seber model. The peak count expansion factor was estimated by dividing the Jolly-Seber abundance estimate by the peak count of live and dead Chinook salmon. Spring Chinook abundance estimates on the Wind River have been estimated using mark-recapture (Rawding and Cochran 2008) and before that using a single redd count and expansion factor based on professional judgment (Pettit 2003). When hatchery salmon were released into the White Salmon River, abundance was estimated using redd surveys.

The single peak count expansion factors for Tule and Upriver Bright populations are between 20 and 40 years old and should be updated with multiple abundance surveys to develop a mean peak count expansion factor and/or estimates of residence time and observer efficiency for use in estimating abundance through the Area-Under-the-Curve (AUC) method (Rawding *et al*. 2006), which is more precise than peak count expansion method for estimating Chinook Salmon abundance (Parken *et al*. 2003). Also the level of monitoring is proposed to increase as spring Chinook salmon are re-introduced in the White Salmon after the removal of Condit Dam but funding sources have not been confirmed for this additional monitoring. Juvenile monitoring of Chinook salmon outmigrants in the portion of the ESU is problematic because the lower most effective juvenile trapping sites are above a significant portion of the spawning area especially in the Wind and Little White Salmon Rivers. The White Salmon River is the best of these sites and is currently monitored for juvenile outmigrants (Allen and Connolly 2006).

Spatial structure and diversity metrics

Current monitoring of adults provides information for spatial structure and diversity metrics. Data are collected by index reach, from which raw and expanded spatial structure is produced. Carcass surveys occur in all streams on all surveys (Jenkins 2007). All carcasses, that are not too decomposed, are sampled for CWT, and a percentage of the sample is more intensively sampled. This bio-sampling requires length, scale, sex, and spawn success for female data to be collected. Therefore, these spawning ground surveys provide information on spawning timing, age structure, and origin of spawners. The current collection of this data is generally limited from 1 to 3 surveys near the peak abundance. If origin, age structure, and distribution are different between the peak and non-peak abundance period, assessments of diversity and spatial structure may be biased and should be investigated. Since 1 to 3 spawning ground surveys usually occur it is possible to determine peak abundance, and possibly peak spawning time but difficult to determine the temporal patterns of spawning. Additional surveys would allow a better description of spawning time and allow. If PIT tagging programs are implemented adult and juvenile run timing information at BON could be obtained. Genetic structure for these populations have been summarized in Marshall *et al*. (1995) and scale data, currently being collected, could be used for future genetic analysis.

Habitat

There has not been a coordinated effort to standardize habitat survey techniques and collect this information, although some monitoring forums are working toward this goal. The use of remotely sensed data may be a balanced cost-effective alternative to collect this data. The LCFRB's recently developed research, monitoring, and evaluation program provides a framework and strategy for habitat monitoring in the Lower Columbia but has not been fully implemented due to budgetary constraints.

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DQO STEPS	WASHINGTON'S LOWER COLUMBIA RIVER CHINOOK SALMON ESU ABOVE BONNEVILLE DAM	Policy Inputs[1] (✓)
1. State the Problem		
Problem:	Delisting of the Lower Columbia River Chinook Salmon ESU	
Stakeholders:	States—Washington, Oregon Tribes- CTWSR, YIN Federal—NOAA, USFWS, USFS, BPA, USACOE Intergovernmental—Columbia River Compact, CBFWA, CRITFC, PFMC, NPCC Other—Lower Columbia River Fish Recovery Board (LCFRB), conservation groups, fishers (tribal, commercial, sport), landowners, upland land users (ranchers, farmers, municipalities, state and county governments), water users (agricultural, industrial, municipal)	
Non-technical Issues:	Interagency coordination, fiscal constraints, legal constraints, land ownership and access	
Conceptual Model:	Life history models	
2. Identify the Decision		
Principal Questions:	What is the ESA listing status for Lower Columbia River Chinook?	
Alternative Actions:	• If status is "listed," then recovery strategies (i.e., more restrictive management strategies at one or more points in the life history model). • If status is "delisted," then recovery or sustainable harvest strategies. • If status is "recovered," then sustainable harvest strategies	✓
Decision Statements:	• Has there been sufficient improvement in population status of Lower Columbia River Chinook ESU to justify delisting and allow removal of ESA restrictions? • Are additional management actions required for LCFRB goals, ESA recovery, and NPCC goals?	✓
3. Identify the Inputs		

DQO STEPS	WASHINGTON'S LOWER COLUMBIA RIVER CHINOOK SALMON ESU ABOVE BONNEVILLE DAM	Policy Inputs[1] (✓)
Information Required:	Information required Abundance Productivity Spatial structure Diversity Abundance of Spawners ✓ ✓ ✓ Abundance/distribution of redds ✓ ✓ ✓ ✓ Origin of spawners ✓ ✓ Age-structure of spawners ✓ ✓ ✓ Sex ratio of spawners ✓ ✓ Abundance/distribution of juveniles ✓	

	Juvenile survival	

DQO STEPS	WASHINGTON'S LOWER COLUMBIA RIVER CHINOOK SALMON ESU ABOVE BONNEVILLE DAM	Policy Inputs[1] (✓)
Sources of Data:	State, tribal, and federal programs and NGSs identified in CSMEP metadata inventories.	
Quality of Existing Data:	Data varies in level of precision and bias. Major issues: • Abundance of spawners: All listed Chinook salmon populations in portion of the ESU are monitored along with most other introduced Chinook salmon populations. Abundance estimates include mark-recapture in the Wind River for spring Chinook salmon, peak count expansion for fall Chinooks salmon in the Wind and White Salmon Rivers along with Drano Bright Fall Chinook, and minimum and intermittent abundance estimates for Drano spring and Tule Chinook populations. The data quality of this program is could be improved through the development of more recent peak count expansion factors and/or the use of Area-Under-the-Curve method. Due to the high percentage of salmon and steelhead dip-ins the use of weirs, mark-recapture, or sonar may prove to be difficult. • Abundance/distribution: Raw and expanded estimates of Chinook salmon are collected and summarized by reach. Distribution may be obtained from the abundance estimates or redd data. However, in years of high abundance, accurate redd counts may be difficult to obtain. • Origin of spawners: The number of hatchery adults are estimated for all populations based on CWT recoveries expanded by sample rate and tagging rate for each age class. The number of naturally produced fish is estimate by subtraction of the hatchery estimate from the total estimate. • Age-structure of spawners: Age structure of adults is available for all Chinook Salmon populations based on scale analysis and for hatchery populations based on CWT. • Sex ratio of spawners: sex ratio data are available for all Chinook Salmon populations. • Abundance/distribution of juveniles: Chinook salmon in this portion of the ESU are often ocean type, and spend a limited time in freshwater after emergence. Therefore, estimates of juvenile distribution may be more reflective of the time of the survey and observer of collection efficiency. Screw trapping in the White Salmon River has the ability to estimate juvenile Chinook abundance but to be most useful three separate race estimates should be made. Techniques that could prove useful in this include timing/growth models and genetic analysis. • Survival of juveniles: Since naturally produced juvenile are not tagged there is no estimate of juvenile survival. Hatchery Chinook salmon are PIT tagged and have been used as an index of survival for naturally produced Chinook salmon.	
New Data Required:	• All information needed to assess status with the exception of habitat is available for ESA listed Chinook Salmon populations. However, the quality of Chinook salmon abundance data can be improved through: 1) multi-year mark-recapture studies to better determine peak count expansion factor from more recent and variable survey conditions, and/or 2) estimates of residence time and observer efficiency for use in estimating abundance through the Area-Under-the-Curve (AUC) method, which is more precise than peak count expansion method for estimating Chinook Salmon abundance. Sampling of juvenile fish would provide information on the spatial structure, diversity, and habitat metrics.	
Analytical Methods:	WLC-TRT rules and criteria for combining measures of abundance, productivity, spatial structure, diversity, juvenile outmigrant, and habitat.	✓

DQO STEPS	WASHINGTON'S LOWER COLUMBIA RIVER CHINOOK SALMON ESU ABOVE BONNEVILLE DAM	Policy Inputs[1] (✓)
4. Define the Boundaries		
Target Populations:	Lower Columbia River Chinook Salmon	
Spatial Boundaries (study):	Population, Strata, and ESU (Evolutionary Significant Unit) levels for Chinook Salmon within the Lower Columbia River and Tributaries. A total of 31 historical populations (nine spring and twenty-two fall populations) were found in this ESU. A total of 22 populations are found in Washington. All of Washington's Spring Chinook Salmon populations are either extirpated or maintained by hatchery supplementation. This study area is restricted to Chinook Salmon populations in Washington tributaries above Bonneville Dam and below the Klickitat River. In this area, there are two fall Chinook populations, Upper Gorge (Wind), and White Salmon, and one spring Chinook Salmon population, White Salmon, which was extirpated when passage was terminated at Condit dam in the early 1900's.	✓
Temporal Boundaries (study):	Status data evaluated over generations from annual abundance, generational productivity, and spatial structure and diversity data collected at unspecified intervals. Data on historical abundance, distribution, and productivity at the population scales are lacking.	✓
Practical Constraints:	Legal and logistical issues with access, interagency coordination across jurisdictional boundaries. Inability to accurately sample adults using traditional methods.	✓
Spatial Boundaries (decisions):	Delisting decision made at level of ESU and viability at the population scale.	
Temporal Boundaries (decisions):	Technical Recovery Team (TRT) rules for abundance and productivity require historical data, and time series of annual data. TRT rules also require spatial structure and diversity data collected at unspecified intervals.	
5. Decision Rules (TRT Rules)		
Critical Components and Population Parameters:	Six metrics (Abundance (A), Productivity (P), Spatial Structure (SS), Diversity (D), Juvenile Outmigrants (JOM), and Habitat (H)) are used to assess the status of each population. A and P combines abundance and productivity VSP criteria using a viability curve. JOM is an assessment of juvenile abundance based on outmigrant trapping. SS and D integrate measures of spatial structure and diversity. H is an assessment of habitat to support viable populations.	✓
Critical Action Levels (Effect Sizes):	Population viability is based on the scoring of A, P, JOM, SS, D, and H measures.	✓

DQO STEPS	WASHINGTON'S LOWER COLUMBIA RIVER CHINOOK SALMON ESU ABOVE BONNEVILLE DAM	Policy Inputs[1] (✓)
Decision Rules: WLC-TRT Draft and LCFRB recovery plan	**Population-level Viability Criteria:** The method used to capture each panel member persistence rating for each population attribute is similar to the method used by the NOAA Fisheries Biological Review Team to make initial listing evaluations and based on an approach developed by FEMAT. Each panel member has ten votes to allocate into the persistence levels (0–4) for that attribute according to the criteria and evaluation guidelines provided in each attribute section. Scores of 0 indicated low persistence levels (<40%) for A & P, and scores of 4 indicate very high persistence levels (>99%) for A & P. The attribute mean and vote distribution describe the population attribute status. Persistence levels for the population attribute would be calculated from the combined votes from all panel members. Additionally, panel members consider the quality of data utilized to determine the attribute status. Data quality would be scored from 0 to 4, 4 being high-quality data with little measure error. If the panel determined that the data quality was especially poor (0, 1, or 2), they could decide to reduce the population attribute mean as a precautionary measure. The amount of the reduction would be directly related to the data quality score. The population persistence score (0-4) is based on the sum of all attribute scores. The attribute scores are weighted as follows 1/3 from the abundance and productivity curves, and 1/6 each for juvenile outmigrants, spatial structure, diversity, and habitat attribute scores. **ESU/DPS-level Viability Criteria:** The WLC-TRT partitioned the populations in an ESU into a number of different strata, and then specified a risk evaluation system for deciding how many populations within each stratum should be at what status. The strata are defined based on two factors: (1) major life-history differences and (2) ecological zones. The partitioning based on ecological zones also results in a partitioning based on spatial distribution. If the ESU contains populations in each stratum, it will have a relatively low extinction risk from catastrophic events, correlated environments, and loss of diversity. In addition, the ESU will have some semblance of its historical structure, which increases confidence in ESU viability. At least two populations per strata must be at high or high plus viability levels, and the average viability score for the strata must be above moderate persistence level. Details regarding population level and ESU/DPS level viability criteria, along with recovery goals are found in the Lower Columbia Salmon and Steelhead Recovery Plan (LCFRB 2004).	✓
Consequences of Decision Errors:	Incorrectly concluding that delisting criteria have been achieved: • Decisions to relax ESA restrictions increase risks to the DPS Incorrectly concluding that delisting criteria have not been achieved: • Minimal biological impact given that decisions do not relax ESA restrictions • May over-invest in intensity of monitoring efforts • Unnecessary listing and restrictive measures • Loss of harvest opportunity	

[1]**Policy Inputs** - indicate with a check steps where group really needs policy feedback, presentation will elaborate on what feedback is required.

Appendix I. CSMEP Strengths and Weaknesses Assessment of Monitoring in Washington's Middle Columbia River Spring Chinook ESU, Draft

Dan Rawding (WDFW)

Table I1. Summary of monitoring activities used to assess spring Chinook salmon status and trends for Mid Columbia ESU populations in Washington.

			Mid Columbia spring Chinook in Washington			
Data need		**Method/Description**	**Klickitat**	**Upper Yakima**	**Naches**	**American**
Abundance of adults	A1	census weir (number)		1	x(1)	x(1)
	A2	weir w/Mk. Recap. (number)				
	A3	weir w/o MR (number)				
	A4	MR survey, no weir	1			
Abundance and distribution of redds	B1	Index-multi	X	X	X	X
	B2	Index-once				
Age structure of spawners	C1	Tags (CWT, PIT)	X	X	X	X
	C2	Hard parts, scales	X	X	X	X
	C3	Length at age	X	X	X	X
	C4	Basinwide estimate	X	X	X	X
Origin of spawners	D1	Marks , weirs (number)	X			
	D2	marks, remote sense				
	D3	marks, carcasses	X	x	x	X
Sex ratio of spawners	E1	Carcass survey	X	x	x	X
	E2	Weirs (number)	1	1		
	E3	Remote sense				
Abundance and spatial distribution of juveniles/smolts	F1	Juvenile trap (number)	3	1	x(1)	x(1)
	F2	Electrofish				
	F3	Snorkel survey--random				
	F4	Snorkel survey--fixed				
	F5	Presence/absence				
Survival of juveniles/smolts	G1	mark-recapture	X	x	x(1)	X(1)
	G2	egg deposition to smolt trap		x	x	X
Age structure of juveniles/smolts	H1	Juvenile trap	X	x	x	X
	H2	other in-river sampling				

Table I2. Summary of monitoring activities in Washington's Middle Columbia spring Chinook Salmon ESU.

Population	Number of Screw Traps	Fixed snorkel surveys	Random snorkel surveys	Number of hatchery weirs	Number of Fish Ladders/ Traps	Redd Surveys	
						index-multi	index-one
<u>Spring Chinook, Washington Mid Columbia</u>							
Klickitat	3			1	2	yes	
Upper Yakima	1			0	1	yes	
Naches				0	1	yes	
American				0	1	yes	

Wild spring Chinook salmon PIT-tagged in the Yakima Basin

Table I3. Summary of the number of wild spring Chinook salmon PIT-tagged in the Yakima Basin, migration years 2000 - 2007.

Release location	2000	2001	2002	2003	2004	2005	2006	2007	Average
Lower Yakima (3-population aggregate)	5864	4220	3022	9333	5729	4998	3311	1591	4759
Upper Yakima/Roza	2106	2179	8717	7803	3951	1733	2333	1200	3753
Basin total:	*7,970*	*6,399*	*11,739*	*17,136*	*9,680*	*6,731*	*5,644*	*2,791*	*8,511*

Table K4. Summary of the number of wild spring Chinook salmon PIT-tagged from the Yakima Basin, migration years 2000 – 2007 detected at Prosser(PRJ) and Columbia River Dams.

Release location	Det Site	MY2000	MY2001	MY2002	MY2003	MY2004	MY2005	MY2006	MY2007	Average
Lower Yakima (3-population aggregate)	PRJ	2862	3044	1498	5421	4215	3342	1525	707	2827
	COL	3001	4088	1887	4978	3004	1708	1459	813	2617
Upper Yakima/Roza	PRJ	650	634	1378	1859	991	441	143	96	774
	COL	1966	657	1767	1915	1010	354	362	341	1047
Basin total:		*8,479*	*8,423*	*6,530*	*14,173*	*9,220*	*5,845*	*3,489*	*1,957*	*6,218*

The assessment of spring Chinook monitoring in Washington's Middle Columbia River ESU was completed as part of the NOAA status review for Chinook salmon (Myers *et al*. 1998). WDFW periodically reviews status for individual Washington populations in the Salmonid Stock Inventory (SaSI) (WDF *et al*. 1993, WDFW 2003). Because the populations are not ESA-listed, the more formal and quantitative VSP assessment methods applied by the ICTRT (2005) have not been used for these populations.

Abundance and Productivity:

Klickitat River: Spring Chinook salmon abundance in the Klickitat has been estimated using redd surveys since the 1970's using area, redd, and visibility expansion factors (Pettit 2003). Redd surveys used for trend analysis include the index area from the Klickitat Salmon Hatchery to Twin Bridges, a distance of about 26 miles (WDFW 2003). As part of the Mitchell Act, an adult fish passage facility was constructed at Castile Fall (RM 64). The effectiveness of this facility in passing spring Chinook salmon was believed to be low, and recent improvements are believed to improve passage at this site. Recently, redd surveys have been expanded to include the area above Castile Falls. However, poor visibility in the mainstem Klickitat River can be problematic for redd surveys due to annual discharge patterns (Rich Pettit, WDFW pers. comm.). In addition, to the normal caveats about redd surveys, the Klickitat programs make assumptions regarding the broad spatial and temporal distribution and the overlap between spring, summer/Tule, and Upriver Bright Chinook salmon stocks in this basin. It is unclear how these assumptions influence abundance estimates from redd surveys.

Mark-recapture abundance estimates were first calculated for spring Chinook salmon in 2005 and the methods are described in Gray (2006). All Chinook salmon captured at the Lyle Falls trap at River Mile (RM) 2 were enumerated and were Floy tagged. Fish returning to the Klickitat Hatchery were classified as tagged or untagged. Abundance was estimated using a simple or pooled Petersen estimator (Gray 2006). This program has been continued by WDFW (Gray 2007) and more recently by the Yakama Nation biologists currently working in the Klickitat River (Joe Zendt, pers. comm.). YN staff are currently evaluating escapement estimates from the redd surveys and spring Chinook mark-recapture programs. In the interim, co-managers have recommended the mark-recapture program continue because it is likely to provide abundance estimates that are less biased than those generated by redd surveys. Double Floy tagging should continue and tests for tag loss, sex and size selectivity, equal mixing, and equal proportions should be conducted annually. Furthermore, modifications that use physical traits, timing, or PIT tags should be instituted so that separate population estimates by race can be made. Proposed improvements to the Lyle Falls fish ladder (YN and WDFW 2004), could allow improved precision and testing of the above assumptions. Since complete spatial coverage of the spawning distribution can be problematic in some years, population differentiation through genetic analysis of carcasses or fish trapped at Lyle Falls, or others methods should be pursued. Redd surveys, although limited in scope, provide important spatial structure in surveyed areas and have great value in monitoring the effectiveness of adult fish passage projects (Mendel *et al*. 2006).

Yakima River: Significant resources have been allocated to the Yakima basin to rebuild spring Chinook populations through supplementation. An extensive RM&E program accompanies this effort. Three fish ladders with separate video cameras are operated at Prosser Dam located at RM 46 on the Yakima River. Video images are reviewed by Yakama Nation (YN) fisheries technicians to obtain daily counts of hatchery and wild Chinook Salmon (Bosch and Fast 2006). Fish counts are updated one to two times per week and posted at the Yakima Klickitat Fisheries Project website (www.ykfp.org) and Data Access in Real Time (DART). Hatchery fish are identified based on the absence of the adipose fin. A total of three spring Chinook populations have been identified (WDFW 2003) and include the Upper Yakima, American, and Naches populations. The Prosser Dam counts are believed to provide a precise and accurate aggregate Chinook abundance estimate as long as the assumptions that fish detectability during turbid water is high or passage is low, and passage outside the count facility is negligible. Dam counts may overestimate abundance if fall back is significant and may underestimate abundance if water conditions allow fish to migrate upstream without using ladders.

A second dam located at Roza allows for enumeration of Upper Yakima spring Chinook salmon population, since most of the spawning for this population occurs above Roza Dam. Most counts occur during trapping and sampling operations but when the trap is not in operation counts are derived from video observations. Similar assumptions exist at this facility regarding fall back, turbidity, and bypass. Juvenile tagging and monitoring occurs at Roza and Chandler including the use of PIT tags. The Roza facility provides information about the Upper Yakima population, while the Chandler facility provides data for the combination of the three Yakima spring Chinook populations,

Winans *et al*. (2000) provided a study design and analysis to estimate steelhead composition at Bonneville Dam using non-lethal genetic sampling, which was implemented by WDFW to estimate stock aggregates at Bonneville Dam (Kassler *et al*. 2005). These methods may be applied to the genetic sampling of Chinook salmon at Prosser Dam coupled with dam counts to provide stock specific abundance, productivity, diversity, and spatial structure. The current Yakima River redd survey program provides spatial structure and abundance data but redd detection may be variable between years depending on covariates such as flow and turbidity. Because environmental condition are better in the late summer and fall than in the spring, spring Chinook redd surveys are believed to provide better estimates of abundance than steelhead redd surveys in this basin which have been documented as problematic (Bosch and Fast 2006).

Spatial Structure and Diversity:

Current monitoring of adults provides information for spatial structure and diversity metrics. Data are collected by index reach, from which raw and expanded spatial structure is produced. Carcass surveys occur in all streams on all surveys. All carcasses, that are not too decomposed, are sampled for CWT, and a percentage of the sample is more intensively sampled. This bio-sampling requires length, scale, sex, and spawn success for female data to be collected. Therefore, these spawning ground surveys provide information on spawning timing, age structure, and origin of spawners. VSP diversity data such as length, entry timing, and origin are also collected from the dam counts and the trapping of Chinook at Prosser and Roza Dams on the Yakima River. An extensive PIT tagging program has been implemented on the Yakima River. The tagging and interrogation of both adults and juveniles at mainstem Columbia and Yakima River facilities provide both adult and juvenile run timing information and survival.

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DQO STEPS	WASHINGTON"S MIDDLE COLUMBIA RIVER SPRING CHINOOK SALMON ESU	Policy Inputs[1] (✓)
1. State the Problem		
Problem:	• Ensure native spring Chinook salmon populations within Washington's Middle Columbia River ESU are healthy. • Protect, restore, and enhance the productivity, production, and diversity, of wild salmonids and their ecosystems to sustain ceremonial, subsistence, commercial, and recreational fisheries, non-consumptive fish benefits, and other related cultural and ecological values.	
Stakeholders:	States— Washington, Oregon. Tribes—Confederated Tribes of the Warms Springs Reservation of Oregon (CTWSRO), Confederated Tribes of the Umatilla Indian Reservation, Yakama Nation (YN). Federal—NOAA, USFWS, USFS, BLM, BOR, BPA, USACE, USDA Intergovernmental—Columbia River Compact Agencies of Oregon and Washington, CBFWA, CRITFC, PFMC, PSC, NPCC. Other—Conservation groups, fishers (tribal, commercial, sport), landowners, upland land users (ranchers, farmers, municipalities, state and county governments), water users (agricultural, industrial, municipal), watershed councils.	
Non-technical Issues:	Interagency coordination, fiscal constraints, legal constraints, land ownership and access.	
Conceptual Model:	Life history models.	
2. Identify the Decision		
Principal Questions:	Does the population still exist ***and*** is it healthy?	
Alternative Actions:	If status is "healthy", then continue appropriate management and restoration/rebuilding strategies. If status is "not healthy", then recovery strategies (i.e., more restrictive management strategies at one or more points in the life history that remove key limiting factors and threats).	✓
Decision Statements:	Is population status of Middle Columbia River Spring Chinook in Washington sufficient given current management? Are additional management actions required to meet Washington, regional, and NPCC SAR goals and other status and trends metrics?	✓
3. Identify the Inputs		
Information Required:	Information required Abundance Productivity Spatial Structure Diversity Abundance of spawners ✓ ✓ Abundance/distribution of redds ✓	

DQO STEPS	WASHINGTON"S MIDDLE COLUMBIA RIVER SPRING CHINOOK SALMON ESU	Policy Inputs[1] (✓)
	✓ ✓ ✓ Origin of spawners ✓ ✓ ✓ Age-structure of spawners ✓ ✓ ✓ Sex ratio of spawners ✓ ✓ ✓ Abundance/distribution of juveniles ✓ ✓ ✓ Juvenile survival ✓ ✓	
Sources of Data:	State, tribal, and federal programs currently collecting monitoring data on wild spring Chinook salmon production from the Klickitat and Yakima Rivers.	
Quality of Existing Data:	o All existing wild Mid Columbia spring Chinook populations in Washington have redd surveys that cover the majority of spawning areas and allow for status and trend assessments associated with several VSP metrics. In addition, monitoring at Prosser and Roza Dams in the Yakima River provide	

DQO STEPS	WASHINGTON"S MIDDLE COLUMBIA RIVER SPRING CHINOOK SALMON ESU	Policy Inputs[1] (✓)
	accurate abundance estimates from fish counts. Recently, WDFW and YN have used mark-recapture based on tagging in the Lyle Falls trap, and recovery of fish from the Klickitat Hatchery to estimate hatchery and wild spring Chinook abundance in the Klickitat River. o Juvenile out-migrants in the Yakima basin have been PIT tagged since the late 1990's at Roza and Chandler facilities to estimate collection efficiencies and calculate smolt-to-adult return rates (SARs) for the upper Yakima populations and an aggregate lower Yakima population.	
New Data Required:	There is uncertainty in the appropriate fish per redd expansion multiplier used to estimate escapement in the American and Naches Rivers. Mark recapture methods using as PIT or radio tags, or genetic data, could be evaluated as potential methods to provide better estimate Yakima River populations. A PIT tagging effort is needed for the Klickitat River population if SARs are to be monitored with higher accuracy and precision. Estimates of Columbia mainstem harvest rates are not population-specific. Providing samplers with PIT tag detectors, and genetic stock identification may be used to develop ESU or mpg estimates. A sampling program for juvenile abundance is needed in the Klickitat.	
Analytical Methods:	IC-TRT rules and criteria for combining measures of abundance, productivity, spatial structure, and diversity.	✓
4. Define the Boundaries		
Target Populations:	Mid Columbia Spring Chinook: Klickitat River, Naches River, American River, and Upper Yakima River populations.	
Spatial Boundaries (study):	Population, MPG, and ESU levels for Spring Chinook within the Klickitat and Yakima basins. Mainstem Columbia River, estuary, and ocean for survival monitoring.	✓
Temporal Boundaries (study):	Status data evaluated over generations from annual abundance, productivity, spatial structure, diversity and juvenile data collected and summarized at various intervals, depending on the metric.	✓
Practical Constraints:	Legal and logistical issues with access, permits, and interagency coordination across jurisdictional boundaries.	✓
Spatial Boundaries (decisions):	Decisions made at level of populations and the ESU, but are dependent on information from each of the component populations.	✓
Temporal Boundaries (decisions):	IC-TRT rules for abundance and productivity require historical data, and 10-year series of annual data. IC-TRT rules require spatial structure and diversity data collected at various intervals.	
5. Decision Rules (IC-TRT Rules)		
Critical Components and Population Parameters:	Two metrics (A/P and SS/D) are used to assess the status of each population. A/P combines abundance and productivity VSP criteria using a viability curve. SS/D integrates 12 measures of spatial structure and diversity.	✓
Critical Action Levels (Effect Sizes):	Risk categories are assigned at the population level for A/P using a 5% risk criterion to define viable populations. Populations scored as moderate or high risk in A/P criteria cannot meet viable standards, while populations at high risk for the 12 SS/D measures cannot be considered viable.	✓
If-Then Decision Rules: IC-TRT Draft	**MPG-level Viability Criteria:** Low risk (viable) MPGs meet the following six criteria: 1. One-half of the populations historically within the ESU (with a minimum of two populations) must meet minimum viability standards. 2. All populations meeting viability standards within the ESU cannot be in the minimum viability category; at least one population must be categorized as meeting more than minimum viability requirements.	✓

DQO STEPS	WASHINGTON"S MIDDLE COLUMBIA RIVER SPRING CHINOOK SALMON ESU	Policy Inputs[1] (✓)
	3. The populations at high viability within an MPG must include proportional representation from populations classified as "Large" or "Intermediate" based on their intrinsic potential. 4. Populations not meeting viability standards should be maintained with sufficient productivity that the overall MPG productivity does not fall below replacement (i.e. these areas should not serve as significant population sinks). 5. Where possible, given other MPG viability requirements, some populations meeting viability standards should be contiguous AND some populations meeting viability standards should be disjunct from each other. 6. All major life history strategies (i.e. adult "races," A-run/B-run, resident and anadromous) that were present historically within the MPG must be present and viable. **ESU-level Viability Criteria:** 1. All extant MPGs and any extirpated MPGs critical for proper functioning of the ESU must be at low risk. 2. ESU's that contained only one MPG historically must meet the following criteria: a. Two-thirds or more of the populations within the MPG historically must meet minimum viability standards; AND d. Have at least two populations categorized as meeting more than minimum viability requirements. *Note: These populations are not ESA-listed, and formal ICTRT VSP analyses have not been conducted as were done for the ESA-listed populations in the Interior Columbia Domain (IC-TRT 2005).	
Consequences of Decision Errors:	Incorrectly concluding that conservation criteria are being achieved: • Decisions to relax management restrictions increase risks to the ESU Incorrectly concluding that conservation criteria have not been achieved: • Minimal biological impact given that decisions do not relax management restrictions • May over-invest in intensity of monitoring efforts • Unnecessary restrictive management measures • Loss of harvest opportunity	

[1]**Policy Inputs** - indicate with a check steps where group really needs policy feedback.

Appendix J. CSMEP Strengths and Weaknesses Assessment of recent and current spring Chinook monitoring in the Oregon Mid Columbia Stock Management Unit

Eric Tinus (ODFW)

Table J1. Summary of monitoring activities used to assess spring Chinook salmon status and trends in the Oregon Mid Columbia spring Chinook stock management unit.

			Mid Columbia spring Chinook in Oregon			
Data need		**Method/Description**	**Deschutes**	**Middle Fork John Day**	**Upper Mainstem John Day**	**North Fork John Day**
Abundance of adults	A1	census weir (number)	X(1)			
	A2	weir w/Mk. Recap. (number)				
	A3	weir w/o MR (number)				
	A4	MR survey, no weir				
Abundance and distribution of redds	B1	Index-multi	?	X	X	X
	B2	Index-once	?	X	x	x
	B3	Index-multi + expanded probabilistic	?	x	x	x
Age structure of spawners	C1	Tags (CWT, PIT)	a	X	X	X
	C2	Hard parts, scales	X	X	X	X
	C3	Length at age	X	X	X	X
	C4	Basinwide estimate		X	X	X
Origin of spawners	D1	Marks , weirs (number)	X(1)			
	D2	marks, remote sense	b	b	b	B
	D3	marks, carcasses		x	x	X
Sex ratio of spawners	E1	Carcass survey	?	x	x	X
	E2	Weirs (number)	X(1)			
	E3	Remote sense				
Abundance and spatial distribution of juveniles/smolts	F1	Juvenile trap (number)	X(1)	X(1)	X(1)	
	F2	Electrofish	?	x	x	X
	F3	Snorkel survey--random	?	X	x	X
	F4	Snorkel survey--fixed	?	x	x	X
	F5	Presence/absence	?	x	x	X
Survival of juveniles/smolts	G1	mark-recapture	c	x	x	X
	G2	egg deposition to smolt trap	?	x	x	X

Age structure of juveniles/smolts	H1	Juvenile trap	X	x	x	X
	H2	other in-river sampling	?	x	x	X

a = hatchery fish only.
b= from past radio telemetry studies by University of Idaho.
C = to estimate trap efficiency

Deschutes Spring Chinook

A1. A hatchery program was established on the Warm Springs River in the 1970’s. A barrier dam is operated to collect hatchery broodstock and unmarked fish and Warm Springs hatchery-origin stock are enumerated and passed upstream to spawn naturally. The majority of natural spawning occurs upstream of the barrier. Nominal spawning occurs in Shitike Creek, a small Deschutes River tributary upstream of the Warm Springs River.

B1. Spring Chinook redd surveys have been conducted by CTWSRO in the Warm Springs River and Shitike Creek concurrently with operation of Warm Springs National Fish Hatchery (WSNFH). In the Warm Springs River, surveys are conducted both below WSNFH barrier and upstream. Whether they are conducted multiple times was not investigated yet.

C1-C3. Unmarked fish released upstream of WSNFH are sampled for biological information.

D1. Only unmarked fish and known origin hatchery (Warm Springs stock) are released upstream of WSNFH.

D2. University of Idaho (Chris Peery) has conducted radio telemetry studies that provide some information on straying of salmon and steelhead into the Deschutes River.

E1-E2. Biological information is collected from fish released upstream of WSNFH. Whether carcasses are sampled during spawning ground surveys was not investigated yet.

F1-F5. A smolt trap has been operated annually in the lower Warm Springs River since the 1970’s and more recently one in Shitike Creek.

G1-G2. Egg-to-smolt survival could be estimated from egg deposition estimated for spawners upstream of WSNFH and abundance of out migrating smolts estimated at the trap.

H1-H2. *See* F1-F5.

Middle Fork John Day Spring Chinook

B1-B3. Single-pass ground spawning surveys have been conducted in index areas since 1959. Lindsay *et al*. (1986) conducted extensive investigations of John Day Basin spring Chinook salmon, 1978 – 1985, that included surveying multiple times and in areas beyond the index areas. Beginning in 1998, surveys of areas beyond the historical index areas and times were resumed. Contemporary surveys represent an area census of known spawning habitat, are conducted multiple times each year, and additional survey sites are randomly selected along the periphery of known spawning habitat (Wilson *et al*. 2008).

C1-C4. Age structure is determined by analyzing scales collected from carcasses during spawning ground surveys. Information from PIT tag interrogations at main stem Columbia dams could also be used to estimate age structure. Lengths of carcasses are measured and recorded at the population level.

D2-D3. Starting in 2007-2008, PIT tag detection arrays were installed near the mouth of the lower John Day River.

E1. *See* C1-C4.

F1. A rotary screw trap has been operated on the Middle Fork John Day River since 2002 at river kilometer (rkm) 24. Fish are measured for length, age is estimated, information to monitor a condition factor is collected, and PIT tags are applied. Trap efficiency is routinely estimated by releasing marked fish upstream of the trap and monitoring numbers of recaptures.

F2-F5. Snorkel and electrofishing surveys have been conducted following an EMAP sampling protocol since 2004 (James *et al*. 2007).

G1-G2. Egg-to-smolt survival could be estimated from eggs per redd assumptions and out migrating smolt abundance estimates, 1978-1982 and 1999 to present.

H1. *See* F1-F5.

H2. Seining has been used to sample juvenile out-migrants since 1999 downstream of the confluence of the North Fork and the mainstem John Day River. This sampling is not population-specific. Unless fish were previously marked upstream, the information collected represents the three populations in aggregate.

Upper Mainstem John Day Spring Chinook

B1-B3. Single-pass ground spawning surveys have been conducted in index areas since 1959. Lindsay *et al*. (1986) conducted extensive investigations of John Day Basin spring Chinook salmon, 1978 – 1985, that included surveying multiple times and in areas beyond the index areas. Beginning in 1998, surveys of areas beyond the historical index areas and times were resumed. Contemporary surveys represent an area census of known spawning habitat, are conducted multiple times each year, and additional survey sites are randomly selected along the periphery of known spawning habitat (Wilson *et al*. 2008). In recent years, permission to access privately owned spawning habitat has been denied, making it difficult to estimate the season total level of spawning activity.

C1-C4. Age structure is determined by analyzing scales collected from carcasses during spawning ground surveys. Information from PIT tag interrogations at main stem Columbia dams could also be used to estimate age structure. Lengths of carcasses are measured and recorded at the population level.

D2-D3. Starting in 2007-2008, PIT tag detection arrays were installed near the mouth of the lower John Day River.

E1. *See* C1-C4.

F1. Two rotary screw traps have been operated on the upper mainstem of the John Day River since 2004 at rkm 352.

F2-F5. Snorkel and electrofishing surveys have been conducted following an EMAP sampling protocol since 2004 (James *et al*. 2007).

G1-G2. Egg-to-smolt survival could be estimated from egg deposition and out migrating smolts, 1978-1982 and 1999 to present.

H1. *See* F1-F5.

H2. Seining has been used to sample and PIT tag juvenile out-migrants since 1999 downstream of the confluence of the North Fork and the mainstem John Day River. This sampling is not population-specific. Unless fish were previously marked upstream, the information collected represents the three populations in aggregate.

North Fork John Day Spring Chinook

B1-B3. Single-pass ground spawning surveys have been conducted in index areas in the Granite Creek system (tributary to North Fork John Day River) since 1959 and in the mainstem of the North Fork since 1964. Lindsay *et al*. (1986) conducted extensive investigations of John Day Basin spring Chinook salmon, 1978 – 1985, that included surveying multiple times and in areas beyond the index areas. Beginning in 1998, surveys of areas beyond the historical index areas and times were resumed. Contemporary surveys represent an area census of known spawning habitat, are conducted multiple times each year, and additional survey sites are randomly selected along the periphery of known spawning habitat (Wilson *et al*. 2008).

C1-C4. Age structure is determined by analyzing scales collected from carcasses during spawning ground surveys. Information from PIT tag interrogations at main stem Columbia dams could also be used to estimate age structure for the three populations in aggregate. Lengths of carcasses are measured and recorded at the population level.

D2-D3. Starting in 2007-2008, PIT tag detection arrays were installed near the mouth of the lower John Day River.

E1. *See* C1-C4.

F1. Juvenile out-migrants were sampled and PIT tagged in 2006 at rkm 26.

F2-F5. Snorkel and electrofishing surveys have been conducted following an EMAP sampling protocol since 2004 (James *et al*. 2007).

G1-G2. Egg-to-smolt survival could be estimated from egg deposition and out migrating smolts, 1978-1982 and 1999 to present.

H2. Seining has been used to sample and PIT tag juvenile out-migrants since 1999 downstream of the confluence of the North Fork and the mainstem John Day River. This sampling is not population-specific.

Table J2. Summary of monitoring activities in the Oregon Mid Columbia spring Chinook Stock Management Unit.

Population	Number of Screw Traps	Fixed snorkel surveys	Random snorkel surveys	Number of hatchery weirs	Number of Temporary Weirs	Redd count surveys			
						index-multi	index-one	random, probabalistic, or rotating panel	periodic-spot check
<u>Spring Chinook, Oregon Mid Columbia</u>									
Deschutes									
Warm Springs	1	?	?	1	?	?	?		
Shitike Creek		?	?		1	?	?		
Middle Fork John Day River	1		yes	0	0	yes	yes	Yes (area census)	Yes
Upper Mainstem John Day River	1 (double)		yes	0	0	yes	yes	Yes (area census)	Yes
North Fork John Day River	1		yes	0	0	yes	yes	Yes (area census)	Yes

Wild spring Chinook salmon PIT-tagged in the John Day Basin

Table J3. Summary of the number of wild spring Chinook salmon PIT-tagged in the John Day Basin, migration years 2000 - 2007.

Release location	2000	2001	2002	2003	2004	2005	2006	2007	Average
Mainstem seining (3-population aggregate)	1,852	3,893	4,000	6,106	2,893	2,499	926	1,533	--
Middle Fork trap	--	--	--	--	599	1,407	1,154	927	--
Upper Mainstem traps	--	--	--	--	856	1,795	836	1,447	--
North Fork trap	--	--	--	--	--	--	494	--	--
South Fork trap	--	--	--	--	87	93	8	149	--
Basin total:	*1,852*	*3,893*	*4,000*	*6,147*	*4,435*	*5,749*	*3,418*	*4,056*	*4,194*

The assessment of spring Chinook monitoring in Oregon's Mid Columbia Stock Management Unit was based on an Oregon Native Fish Status Report completed in 2005 (URL: http://www.dfw.state.or.us/fish/ONFSR/). At the time, an interim set of criteria to assess the conservation status of wild fish populations in Oregon, pursuant to direction provided by Oregon's Native Fish Policy was used. The criteria are generally similar to the ICTRT metrics (Interior Columbia Basin Technical Recovery Team, 2005). Because the populations are not ESA-listed, the more formal and quantitative VSP assessment methods applied by the ICTRT have not been used yet for these populations.

Abundance and Productivity:

Deschutes River spring Chinook: Abundance is based on 30 years of trapping data at WSNFH. Some spawning occurs downstream of WSNFH and Shitike Creek, but at relatively low levels. Ground spawning surveys are conducted both upstream and downstream of the dam. Age structure is determined from scale samples collected from fish passed upstream of the hatchery barrier dam. Sex ratio is also determined. Efforts to monitor Deschutes River spring Chinook abundance and productivity are very good. A potential weakness in estimating adult recruits to the spawning grounds is how well known prespawning mortality is between upstream passage and spawning. As spring Chinook salmon reintroduced upstream of Round Butte Dam begin to return, the ability to distinguish those fish from wild lower Deschutes River fish will be important to monitor spawner origin and recruitment numbers in the basin. Deschutes population SAR monitoring outside the Deschutes River to adjust Spawner to Spawner estimates for an A/P viability dataset does not occur. SARs for the Warm Springs have been estimated using juvenile and adult trap observations in the Warm Springs River with relatively wide confidence intervals (personal communication, Bob Spateholts, CTWSRO). Establishing and continuing PIT tagging of juvenile out-migrants would result in life cycle survival estimates with higher precision and accuracy. Hatchery fish are coded-wire tagged and SARs for hatchery fish could potentially be developed.

Middle Fork John Day spring Chinook:

Trends in abundance have been monitored through spawning ground surveys. Index spawning ground surveys have been conducted since 1960. Surveys were expanded both spatially and temporally, 1978 – 1985, and again since 1995. Results of recent surveys are considered to represent a complete redd count. All know spawning habitat is surveyed multiple times and peripheral areas are randomly surveyed annually. A direct count of spawning adults is unavailable because hatchery weirs are not used in the John Day Basin. Previous stock-recruitment assessments have assumed a three fish per redd average expansion factor or variable fish per redd rates from other populations in the Snake River Basin or in the Deschutes River (e.g., Lindsay *et al*. 1986; Jonasson and Albaladejo, 1999; Schultz *et al*. 2008; Wilson *et al*. 2008). Redd densities (redds per mile) have also been used to track abundance and productivity (ODFW 2005). Trends in recruitment rely on carcass sampling during spawning ground surveys to determine age and hatchery fraction. Abundance monitoring of redds is considered good. Spawner abundance relies on out-of-basin or assumed fish per redd ratios. PIT tagging has provided SAR estimates that could be used to adjust spawner to spawner estimates, but the time series is relatively short.

Upper Mainstem John Day spring Chinook:

Trends in abundance have been monitored through spawning ground surveys. Index spawning ground surveys have been conducted since 1959. Surveys were expanded both spatially and temporally, 1978 – 1985, and again in 1995 and since 1998. Results of recent surveys are considered to represent a complete redd count. All know spawning habitat is surveyed multiple times and peripheral areas are randomly surveyed annually. A direct count of spawning adults is unavailable because hatchery weirs are not used in the John Day Basin. Previous stock-recruitment assessments have assumed a three fish per redd average expansion factor or variable fish per redd rates from other populations in the Snake River Basin or in the Deschutes River (e.g., Lindsay *et al*. 1986; Jonasson and Albaladejo, 1999; Schultz *et al*. 2008; Wilson *et al*. 2008). Redd densities (redds per mile) have also been used to track abundance and productivity (ODFW 2005). Trends in recruitment rely on carcass sampling during spawning ground surveys to determine age and hatchery fraction. Abundance monitoring of redds is considered good. Spawner abundance relies on out-of-basin or assumed fish per redd ratios. In recent years, lack of access to privately owned spawning habitat has hampered the ability to estimate total numbers of redds. PIT tagging has provided SAR estimates that could be used to adjust spawner to spawner estimates, but the time series is relatively short.

North Fork John Day spring Chinook:

Trends in abundance have been monitored through spawning ground surveys. Index spawning ground surveys have been conducted in Granite Creek since 1959 and in the mainstem since 1964. Surveys were expanded both spatially and temporally, 1978 – 1985, and again in 1995 and since 1998. Results of recent surveys are considered to represent a complete redd count. All know spawning habitat is surveyed multiple times and peripheral areas are randomly surveyed annually. A direct count of spawning adults is unavailable because hatchery weirs are not used in the John Day Basin. Previous stock-recruitment assessments have assumed a three fish per redd average expansion factor or variable fish per redd rates from other populations in the Snake River Basin or in the Deschutes River (e.g., Lindsay *et al*. 1986; Jonasson and Albaladejo, 1999; Schultz *et al*. 2008; Wilson *et al*. 2008). Redd densities (redds per mile) have also been used to track abundance and productivity (ODFW 2005). Trends in recruitment rely on carcass sampling during spawning ground surveys to determine age and hatchery fraction. Abundance monitoring of redds is considered good. Estimating spawner abundance relies on out-of-basin or assumed fish per redd ratios. PIT tagging has provided SAR estimates that could be used to adjust spawner to spawner estimates, but the time series is relatively short.

Spatial Structure and Diversity:

A.1. Maintain natural distribution of spawning areas: All of these Mid Columbia spring Chinook populations have redd surveys that cover the known spawning habitat that will allow for status assessments of the spatial structure metrics. The historical and recent information should be adequate to assess the number and spatial arrangement of spawning areas; the spatial extent or range of the populations; and any increase or decrease in gaps or continuities between spawning areas. However, for these unlisted populations, major and minor spawning areas have not been formally defined as was done by the ICTRT for ESA-listed salmon and steelhead populations in the Interior Columbia Domain (NOAA Fisheries, 2008; Carmichael 2006).

B1. Maintain natural patterns of phenotypic and genotypic expression:

Factor B.1.a. Major Life History Strategies: The potential exists to compare some of the observations of Lindsay *et al*. (1986) with monitoring observations from 1998 to present (e.g., Jonasson and Albaladejo, 1999; Schultz *et al*. 2008; Wilson *et al*. 2008) including timing and distribution of adult holding and spawning, juvenile rearing behavior, migration timing within the John Day Basin and the Columbia River, age at out-migration and return, etc. If information prior to Lindsay *et al*. (1986) is required to establish an historical state, then assessing changes from historical to present status would likely need to be inferred from habitat modeling as was done for ESA-listed Oregon Mid Columbia steelhead and Snake River spring/summer Chinook salmon populations (NOAA Fisheries, 2008; Carmichael 2006).

Factor B.1.b. Phenotypic variation: Current monitoring programs should provide adequate information about returning adults at a population scale. The juvenile traps and seining activities are not all population-specific in the John Day Basin and trap operation has not been continuous in Shitike Creek in the Deschutes Basin. If ongoing monitoring is supposed to reveal potential trends, some type of reference condition needs to be established.

Factor B.1.c. Genotypic variation: By management design, hatchery-origin fish are allowed to spawn only at pre-determined numbers and proportions with the Warm Springs wild population in the Deschutes Basin (recently at rates less than 10%). Carcass sampling in the John Day Basin yields CWT or other tag information on the rate of straying by hatchery fish, as long as the juvenile external mark rate (clipped adipose or other fins) is sufficiently high. The observed rate of straying in the John Day Basin is very low (less than 1-2% over past multiple generations).

B.2. Maintain natural patterns of gene flow:

Factor B.2.a. Spawner Composition: Handling and sampling adults at WSNFH and conducting carcass sampling in the John Day Basin provide information on presence of hatchery-origin fish.

B.3. Maintain occupancy in a variety of available habitat: Spawning ground surveys cover the distribution of spawning adults. Continuation of the EMAP sampling of juvenile fish and their habitat in the John Day Basin will provide information for this metric. Implementing this approach and making effective use of recent monitoring data require a sustained commitment to annual monitoring over a long term.

B4. Maintain integrity of natural systems (Avoid selectivity in anthropogenic activities): Selectivity could result from management of the Columbia River hydrosystem, harvest practices, hatchery management, and habitat modification. Life cycle monitoring, particularly continuing PIT tag studies could track this metric, although changes in population status and trends need to be linked to the limiting factors and threats.

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DQO STEPS	INTERIOR COLUMBIA WILD UNLISTED SPRING CHINOOK SALMON IN OREGON	Policy Inputs[1] (✓)
1. State the Problem		
Problem:	• Ensure native populations within Oregon Stock Management Units are "Not At Risk" (*see* Oregon Native Fish Conservation Policy, OAR 635-007-0507 and OAR 635-007-0505 (6) & (7); http://www.dfw.state.or.us/fish/nfcp/ • Maintenance of naturally produced fish in order to provide substantial ecological, economic and cultural benefits to the citizens of Oregon. • Sustenance of opportunities for fisheries consistent with the conservation of naturally produced fish and responsible use of hatcheries.	
Stakeholders:	States—Oregon. Tribes—Confederated Tribes of the Warms Springs Reservation of Oregon (CTWSRO), Confederated Tribes of the Umatilla Indian Reservation. Federal—NOAA, USFWS, USFS, BLM, BOR, BPA, USACE, USDA Intergovernmental—Columbia River Compact Agencies of Oregon and Washington, CBFWA, CRITFC, PFMC, PSC, NPCC. Other—Conservation groups, fishers (tribal, commercial, sport), landowners, upland land users (ranchers, farmers, municipalities, state and county governments), water users (agricultural, industrial, municipal), watershed councils.	
Non-technical Issues:	Interagency coordination, fiscal constraints, legal constraints, land ownership and access.	
Conceptual Model:	Life history models.	
2. Identify the Decision		
Principal Questions:	Does the population still exist ***and*** is it not at risk of extinction in the near future? Do the naturally produced members of a population occupy at least 50% of the predevelopment habitat in at least three of the last five years? Is the number of naturally-produced fish that survive to spawn greater than 25% of average abundance of naturally-produced spawners over the last 30 years in at least three of the last five years? Is the intrinsic rate of population increase at least 1.2 naturally-produced adult offspring (that survive to spawn) per natural spawner in three of the last five years when total abundance was less than the average abundance of naturally-produced spawners over the last 30 years?	
Alternative Actions:	If status is "Not at Risk", then continued conservation management and potential for in-basin harvest. If status is "Potentially at Risk" or "At Risk", then recovery strategies (i.e., more restrictive management strategies at one or more points in the life history that remove key limiting factors and threats).	✓
Decision Statements:	Is population status of Interior Columbia Wild Unlisted Spring Chinook in Oregon sufficient to justify in-basin harvest? Are additional management actions required to meet Oregon, regional, and NPCC SAR goals and other status and trends metrics?	✓
3. Identify the Inputs		

DQO STEPS	INTERIOR COLUMBIA WILD UNLISTED SPRING CHINOOK SALMON IN OREGON	Policy Inputs[1] (✓)
Information Required:	Information required Abundance Productivity Spatial Structure Diversity Abundance of spawners ✓ ✓ Abundance/distribution of redds ✓ ✓ ✓ ✓ Origin of spawners ✓ ✓ ✓ Age-structure of spawners ✓ ✓ ✓ Sex ratio of spawners ✓ ✓ ✓ Abundance/distribution of juveniles ✓	

DQO STEPS	INTERIOR COLUMBIA WILD UNLISTED SPRING CHINOOK SALMON IN OREGON	Policy Inputs[1] (✓)
	✓ ✓ Juvenile survival ✓ ✓	
Sources of Data:	State, tribal, and federal programs currently collecting monitoring data on wild spring Chinook salmon production from the Deschutes and John Day subbasins.	
Quality of Existing Data:	All existing wild Mid Columbia spring Chinook populations in Oregon have redd surveys that cover the majority of spawning areas and allow for status and trend assessments associated with several VSP metrics. Juvenile out-migrants in the John Day Basin have been PIT tagged since 1998 at sufficient levels (average 4,200 per year) to calculate smolt-to-adult return rates (SARs) for three populations in aggregate. No direct abundance measurements are done in the John Day Basin because spring Chinook salmon populations are managed as wild populations with no artificial production. The wild Deschutes River population is managed in tandem with an integrated hatchery program, and abundance of natural-origin fish is monitored at an efficient adult trap near the down-most extent of natural spawning habitat.	
New Data Required:	With no trapping facilities for natural origin spring Chinook in the John Day Basin there is uncertainty in the appropriate fish per redd expansion multiplier. Mark recapture methods, such as PIT tags, could be evaluated as a potential method to provide this information. A PIT tagging effort is needed for the Deschutes River population if SARs are to be monitored with higher accuracy and precision. Estimates of Columbia mainstem harvest rates are not population-specific. The EMAP sampling program for juvenile abundance, distribution, and habitat condition needs to continue and be better supported in the John Day Basin.	
Analytical Methods:	IC-TRT rules and criteria for combining measures of abundance, productivity, spatial structure, and diversity.	✓
4. Define the Boundaries		
Target Populations:	Mid Columbia Spring Chinook: Deschutes River, Middle Fork John Day, Upper Mainstem John Day, and North Fork John Day populations.	
Spatial Boundaries (study):	Population, MPG, and ESU levels for Spring Chinook within the Deschutes and John Day basins. Mainstem Columbia River, estuary, and ocean for survival monitoring.	✓
Temporal Boundaries (study):	Status data evaluated over generations from annual abundance data and generational productivity data, summarized as 20 and 10-year geometric means. Spatial structure and diversity data collected and summarized at various intervals, depending on the metric. Abundance and distribution of juveniles and habitat condition sampled annually in the John Day Basin.	✓

DQO STEPS	INTERIOR COLUMBIA WILD UNLISTED SPRING CHINOOK SALMON IN OREGON	Policy Inputs[1] (✓)
Practical Constraints:	Legal and logistical issues with access, permits, and interagency coordination across jurisdictional boundaries.	✓
Spatial Boundaries (decisions):	Decisions made at level of populations and the ESU, but are dependent on information from each of the component populations.	✓
Temporal Boundaries (decisions):	IC-TRT rules for abundance and productivity require historical data, and 10-year series of annual data. IC-TRT rules require spatial structure and diversity data collected at various intervals.	
5. Decision Rules (IC-TRT Rules)		
Critical Components and Population Parameters:	Two metrics (A/P and SS/D) are used to assess the status of each population. A/P combines abundance and productivity VSP criteria using a viability curve. SS/D integrates 12 measures of spatial structure and diversity.	✓
Critical Action Levels (Effect Sizes):	Risk categories are assigned at the population level for A/P using a 5% risk criterion to define viable populations. Populations scored as moderate or high risk in A/P criteria cannot meet viable standards, while populations at high risk for the 12 SS/D measures cannot be considered viable.	✓
If-Then Decision Rules: IC-TRT Draft	**MPG-level Viability Criteria:** Low risk (viable) MPGs meet the following six criteria: 1. One-half of the populations historically within the ESU (with a minimum of two populations) must meet minimum viability standards. 2. All populations meeting viability standards within the ESU cannot be in the minimum viability category; at least one population must be categorized as meeting more than minimum viability requirements. 3. The populations at high viability within an MPG must include proportional representation from populations classified as “Large” or “Intermediate” based on their intrinsic potential. 4. Populations not meeting viability standards should be maintained with sufficient productivity that the overall MPG productivity does not fall below replacement (i.e. these areas should not serve as significant population sinks). 5. Where possible, given other MPG viability requirements, some populations meeting viability standards should be contiguous AND some populations meeting viability standards should be disjunct from each other. 6. All major life history strategies (i.e. adult “races,” A-run/B-run, resident and anadromous) that were present historically within the MPG must be present and viable. . **ESU-level Viability Criteria:** 1. All extant MPGs and any extirpated MPGs critical for proper functioning of the ESU must be at low risk. 2. ESU’s that contained only one MPG historically must meet the following criteria: a. Two-thirds or more of the populations within the MPG historically must meet minimum viability standards; AND e. Have at least two populations categorized as meeting more than minimum viability requirements. *Note: These populations are not ESA-listed, and formal ICTRT VSP analyses have not been conducted as were done for the ESA-listed populations in the Interior Columbia Domain.	✓
Consequences of Decision Errors:	Incorrectly concluding that conservation criteria are being achieved: • Decisions to relax management restrictions increase risks to the ESU Incorrectly concluding that conservation criteria have not been achieved:	

DQO STEPS	INTERIOR COLUMBIA WILD UNLISTED SPRING CHINOOK SALMON IN OREGON	Policy Inputs[1] (✓)
	• Minimal biological impact given that decisions do not relax management restrictions • May over-invest in intensity of monitoring efforts • Unnecessary restrictive management measures • Loss of harvest opportunity	

[1]**Policy Inputs -** indicate with a check steps where group really needs policy feedback.