Research, Monitoring & Evaluation Plan for the NOAA-Fisheries 2000 Federal Columbia River Power System Biological Opinion

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1. Introduction

A. Background and Motivation

The National Ocean and Atmospheric Administration Fisheries (NOAA-Fisheries, formerly NMFS) and the Federal Columbia River Power System (FCRPS) Action Agencies (AA) (Bonneville Power Administration (BPA), Corps of Engineers (Corps), and Bureau of Reclamation (BOR)) are working together to design and implement a Research, Monitoring and Evaluation (RME) Plan that is called for under the NOAA-Fisheries 2000 FCRPS Biological Opinion (BiOp)[1] and the Federal Columbia River Salmon Recovery Strategy (All-H Strategy)[2]. The resulting RME program is intended to provide information needed for assessment of Endangered Species Act (ESA)-listed Columbia Basin salmon and steelhead populations at the 2005- and 2008-year NOAA-Fisheries BiOp check-in evaluations. In addition, this program will also result in the identification and prioritization of actions that are the most effective towards improved stock performance and will provide information for the 2010 NOAA-Fisheries Biological Opinion. Significant elements of the RME program are identified through a number of specific action items called for within the NOAA-Fisheries BiOp Reasonable and Prudent Alternative (RPA). Of the 199 RPA actions listed in the BiOp, RPA actions 158-162 and 179-199 are explicit to RME.

This document defines an RME program that is limited to the specific requirements of the NOAA-Fisheries FCRPS BiOp. Additional RME requirements of the U.S. Fish and Wildlife Service (USFWS) FCRPS BiOp for ESA-listed resident fish will be integrated with this RME program as they are developed in coordination with resident fish recovery planning. This RME program will also be integrated with the broader RME needs of the Federal All-H Strategy and the Northwest Power and Conservation Council's (NPCC) Fish and Wildlife (F&W) Program, in coordination with other regional Federal, state and tribal RME programs. The AAs and NOAA-Fisheries are working with these other regional entities to identify areas of program overlap, coordination efficiencies and funding responsibilities.

The NOAA-Fisheries FCRPS BiOp assessment and resulting RPA are based on the best available scientific information but recognize substantial uncertainty that must be addressed through (1) biological and physical performance standards, (2) a mid-point evaluation check-in process and (3) a research, monitoring and evaluation program. The BiOp identifies performance standards for population status (trends and growth rates), hydro-system survival improvements and offsite mitigation survival improvements. Additional biological and physical performance standards for hydro, hatchery, harvest, and habitat actions are being developed in 2003. These performance standards will be checked with periodic evaluations that rely on research and monitoring of performance. Figure 1.1 below showing Figure 9.5-2 in Section 9.5.1 of the BiOp depicts the linkage among the performance standards, evaluations and subsequent decisions. This RME Plan is designed to support the evaluation process and address the uncertainties in the RPA.

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1 http://www.nwr.noaa.gov/1hydrop/hydroweb/docs/Final/2000Biop.html

2 http://www.salmonrecovery.gov/strategy.shtml

2000 FCRPS BIOLOGICAL OPINION DECEMBER 21, 2000

Figure 9.5-2. Evaluation Flow Chart

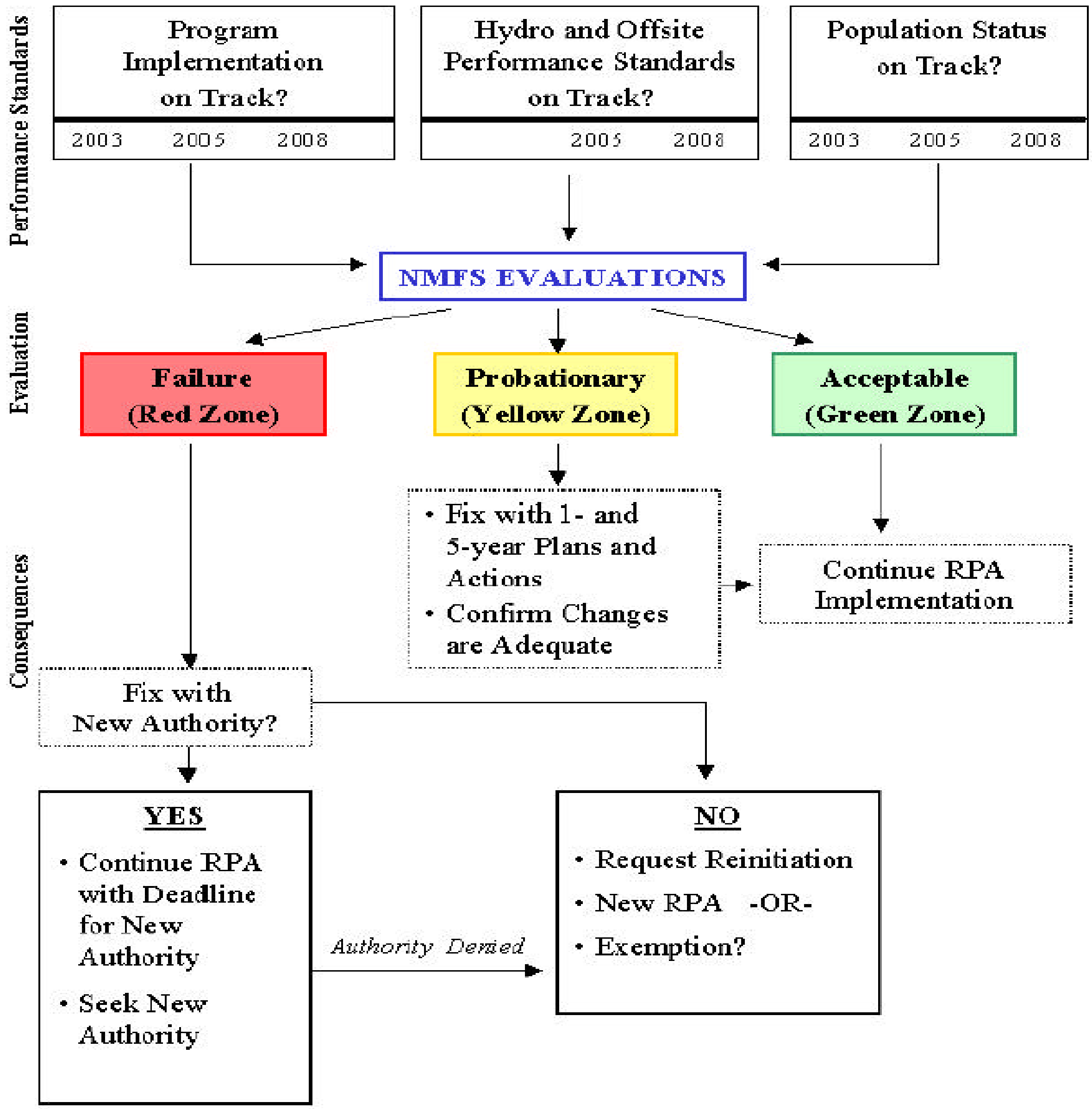

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Figure 1.1 - NOAA-Fisheries 2000 FCRPS BiOp Evaluation Flow Chart.

The RME program describes six principal components that must be addressed to meet the BiOp requirements: (1) Population and Environmental Status Monitoring, (2) Action Effectiveness Research, (3) Critical Uncertainty Research, (4) Project Implementation Monitoring, (5) Data Management and (6) Regional Coordination. The RME Plan addresses each of these six principal components within a common format by: (i) identifying the RME requirements of the BiOp specific to that component; (ii) identifying ongoing and planned research or monitoring projects that address these RME requirements within the Corps' Anadromous Fish Evaluation Program (AFEP) forum, BOR's priority subbasin program, and the BPA-funded NPCC's Fish and Wildlife Program; (iii) comparing the RME requirements of the BiOp with the existing and planned research projects to identify gaps in existing coverage; and (iv) recommending any necessary additional research or changes to planned research to meet these gaps.

The RME program requires the development of new efforts and the revision of some ongoing efforts, as well as the continuation of certain established monitoring activities. Where possible, some existing projects can alter scope and revise work statements to more closely address RME BiOp requirements. RME requirements are being implemented to the greatest extent possible through existing AA and NOAA-Fisheries funding processes.[3] If gaps in BiOp requirements cannot be met through the existing AA and NOAA-Fisheries funding processes (i.e., NPCC F&W Program Provincial Review Process or Congressional appropriations process), a special, targeted request for proposals (RFP) or qualifications (RFQ) may be developed as a means to fill these gaps. An independent scientific review process typically accompanies this implementation process.

B. RME Plan Core Scientific Principals

The RME Plan recognizes three critically important features of a regional RME program, features that are key to the success of the program. Firstly, that all RME data collection efforts be designed to generate data of known accuracy and precision. Secondly, to detect the biological impact of management actions, these actions must be implemented within a Columbia River basin-wide experimental framework. Finally, without proper, regional data management, the ability to evaluate monitoring data will be critically compromised.

Monitoring data that lacks an accompanying accuracy and precision assessments is of far less utility for resource management decision making than similar data with known confidence. While it is impossible to know with absolute certainty the accuracy and precision of any data, under established sampling and error measurement approaches confidence levels for monitoring data can be generated that make the information far more powerful in a management context. While not necessarily specifying required confidence levels, the RME Plan is built on the principal of generating data with measured accuracy and precision.

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[3] During the months of September, October, and November of 2003, this RME Plan is being reviewed by the Independent Scientific Advisory Board (ISAB), the Independent Scientific Review Panel (ISRP), the state and tribal fish agencies through the CBFWA Collaborative Monitoring Project, the lead staff of the state monitoring programs of Oregon, Washington, and Idaho, and other Federal Caucus agencies (USFWS, EPA, BLM, USFS, BIA). Upon completion of this review and any needed changes, there are plans for a series of workshops to be held through the Northwest Power and Conservation Council to work with ongoing RME projects under the Columbia Basin Fish and Wildlife Program. The objective of these meetings with project sponsors is to align these projects to the greatest extent practical with this RME plan and a more programmatic approach to regional RME that is being coordinated with other federal, state and tribal programs.

A primary responsibility of the RME program for the BiOp is an assessment of the biological impact of a wide suite of management actions (e.g., hydro-system modifications, off-site mitigation activities); however, the implementation of these actions is not undertaken within the large-scale experimental framework necessary to demonstrate their effect. The RME Plan addresses the effectiveness of management actions given the opportunistic approach to action implementation, but also identifies where a coordinated approach to action implementation would vastly improve the ability to assess their effectiveness.

The RME Plan describes numerous data collection efforts, all in response to the requirements of BiOp evaluation procedures. These myriad data types are directly linked to the analytical framework that supports the BiOp implementation performance evaluation. To be used in this manner the data must be compiled, spatially-referenced, cross-referenced, include QA/QC protocols, and made available in a distributable, searchable fashion – in other words, a formal data management process is required as part of the BiOp RME program.

C. RME Plan Framework

The RME Plan identifies six principal components and the associated sub-components that must be addressed to meet the BiOp requirements:

1. Populations and Environmental Status Monitoring – abundance, trend and condition of fish populations and key environmental attributes.

   - Ecosystem/Landscape – broad-scale, periodic monitoring (Tier 1 @ BiOp)
   - Geographic Zone – localized, frequent monitoring (Tier 2 @ BiOp)
     - Tributary Habitat
     - Hydro-corridor
     - Estuary/Ocean

2. Action Effectiveness Research (Tier 3@ BiOp) – effects of hydro and offsite mitigation actions on fish survival and habitat attributes.

   - Hydro
   - Habitat
   - Hatchery
   - Harvest

3. Critical Uncertainty Research – addresses key uncertainties in population survival assessments (e.g., "D," extra mortality, hatchery spawner reproductive success, etc.)

4. Implementation/Compliance Monitoring – tracking execution of management actions

5. Data Management – support system for data storage and access

6. Regional Coordination – across the various Federal, State and Tribal RME programs

Two of the components, Action Effectiveness Research (AER) and Critical Uncertainty Research (CUR), are distinguishable from status monitoring activities in that some evaluations may require formal experiments and rigorous statistical analyses. However, AER and CUR complement and sometimes depend on status monitoring for baseline conditions. In some cases, indicators tracked for status monitoring may also apply to action effectiveness and critical uncertainties research and vice versa. However, the objectives and scopes of those monitoring components differ from status monitoring in terms of spatial and temporal sampling and the required statistical framework.

Six workgroups were formed to draft the principle RME components and sub-components of the RME Program. These workgroups wrote the technical sections of the BiOp RME Plan and could form the core of technical teams to guide the further development and implementation of the BiOp RME program. The six workgroups were:

1. Population and Environmental Status Monitoring Workgroup
   - Status Monitoring Ecosystem/Landscape component
   - Tributary Habitat Geographic Zone subcomponent

2. Action Effectiveness Research (AER) Workgroup – tributary habitat actions
   - Action Effectiveness Research at the Tributary Habitat sub-component

3. Hydro Workgroup
   - Status Monitoring for the Hydro-corridor geographic zone
   - Action Effectiveness Research at the Hydro action sub-component
   - Critical Uncertainty Research for extra mortality (EM) and delayed transport effects "D"

4. Estuary/Ocean Workgroup
   - Status Monitoring for the Estuary/Ocean geographic zone
   - Action Effectiveness Research at the Estuary/Ocean Habitat subcomponent
   - Critical uncertainties that involve processes that may be manifested in the estuary/ocean because of effects that originate upstream

5. Hatchery-Harvest Workgroup
   - Action Effectiveness Research as it pertains to hatchery reforms and conservation hatcheries, and the effectiveness of harvest reforms in limiting impacts on listed fish while allowing harvest of abundant runs
   - Critical Uncertainty Research with respect to reproductive success of hatchery fish spawning in the wild

6. Data Management Workgroup
   - Data Management and Implementation Monitoring components

The structure of the BiOp RME Plan follows that of the workgroups with the following three variations:

- Of the six principal components of the BiOp RME Plan identified above, two were not addressed by the technical workgroups, Implementation/Compliance Monitoring and

Regional Coordination. These components represent areas of ongoing development by the BiOp Action Agencies. An overview of current and planned activities is presented in the Overview section below. The remaining four components were addressed by the technical workgroups. The Overview section introduces the technical sections that follow and highlights key recommendations from each workgroup's RME plan.

- Due to strongly overlapping programs, the RME plans from the Status Monitoring and tributary action AER workgroups were combined into a Tributary RME plan.

- The RME plan from the Estuary and Ocean workgroup is undergoing separate review by regional entities, and for the moment, has been decoupled from this draft of the BiOp RME Plan. [4] In the future, it will be reintegrated to ensure compliance with the recommendations from the Hydro-system RME plan and consistency with other status and AER components of the overall BiOp RME Plan.

[4] The Estuary and Ocean RME Workgroup Plan will be submitted separately to the ISAB and ISRP for review in October 2003.

2. Overview of BiOp RME Plan

A. Tributary RME

The goal of the tributary monitoring program, as proposed under the NOAA-Fisheries 2000 Federal Columbia River Power System Biological Opinion (FCRPS BiOp), is to provide the necessary data for resolving a wide range of uncertainties, determining population status, establishing the baseline for the causal relationships between habitat attributes and population response, and assessing the impact of management activities, in particular habitat restoration actions.

The FCRPS BiOp outlines a hierarchical comprehensive monitoring and evaluation program. The program consists of three levels of effort: (i) a broadscale assessment of ecosystem status, (ii) an annual sampling of the status of fish populations and their habitat, and (iii) the effectiveness of specific recovery actions. The first two components form the Population and Environmental Status Monitoring Program, while the third component is addressed in the Action Effectiveness Research program.

The Tributary RME plan outlines an approach for developing a Columbia Rive basin-wide status and trends monitoring program to address the following questions:

Ecosystem status questions:
What is the distribution of adult salmonids?
What is the ecosystem status for Columbia River Basin (CRB) fish populations?

Population and habitat status monitoring questions:
What is the size of CRB fish populations?
What is the annualized growth rate of CRB fish populations?
What is the freshwater productivity (e.g., smolt/female) of CRB fish populations?
What is the age structure of CRB fish populations?
What is the fraction of potential natural spawners that are of hatchery origin?
What is the biological condition of CRB fish spawning and rearing habitat?
What is the chemical water quality in CRB fish spawning and rearing habitat?
What is the physical habitat condition of CRB fish spawning and rearing habitat?

The Tributary RME plan also develops a strategy for assessing the effectiveness of tributary habitat restoration actions. Effectiveness, in this context, is defined as increasing life-stage survival rates or condition of listed anadromous species, increasing local abundance by attracting fish to improved habitat or improving environmental conditions. Because any or all of these indicators of effectiveness could change by chance or due to causes unrelated to habitat actions, effectiveness must be demonstrated via well-designed experiments—with treatment and control sites—using a statistically rigorous framework. The Action Effectiveness Research (AER) plan developed in the Tributary RME plan addresses the issue of effectiveness monitoring and evaluation at multiple scales such that it is designed to answer the following questions:

1. Did a given single habitat action work in the sense of increasing local fish abundance or improving local environmental conditions, compared to a similar, nearby control site?

2. Did all actions in aggregate for a given sub-population increase juvenile survival or adult abundance, compared to a similar sub-population with few or no actions?

3. Did some types of actions (e.g., riparian planting) perform better than other action types (e.g., irrigation screening) in improving localized conditions or sub-population juvenile survival rates?

4. What contribution did all habitat actions for an entire ESU make toward increasing the ESU-level population growth rate?

There are many parallels between the tributary research approaches recommended by the ISAB (ISAB 2003, *A review of strategies for recovering tributary habitat*) and the tributary RME outlined in the BiOp RME Plan. The ISAB Tier 2 monitoring uses statistical inference to extrapolate data from sample sites to larger areas. The BiOp RME Plan recommends the use of EMAP-style methods for monitoring status and trends of listed populations and their habitats. Tributary monitoring pilot studies will be used to test the implementation of the status and trend sampling regime, prior to extending it to larger areas.

The ISAB also recommends two types of Tier 3 (experimental research) monitoring. The first is a paired treatment/control, watershed scale monitoring/research, in which a single type of habitat action is applied to a large number of sites (reaches) and compared to nearby, untreated controls. The second ISAB research type is intensive watershed monitoring (IWM), where closely spaced measurements are directed at a few intensively monitored watershed pairs. These approaches are analogous to the two approaches recommended in the BiOp RME Plan. The paired treatment-control method (ISAB) is very similar to the project-based monitoring, in which a number of sites with the same type of treatment (e.g., riparian fencing, irrigation screening) will be systematically compared to similar control sites, across a number of watersheds. The IWM approach is nearly identical to the watershed-scale approach. In the BiOp RME Plan's watershed-scale approach, all treatment sites in a given subbasin will be monitored, along with similar control sites. As with status monitoring, this will also be implemented first with pilot studies. In both cases, statistical analysis of the results will be needed to provide estimates of the actions' effects on local environmental conditions, fish distribution and abundance, and life-stage survival rates. The Tributary Monitoring chapter of the BiOp RME Plan discusses the monitoring and analysis in more detail.

Tributary RME recommendations

The Tributary RME program for the FCRPS BiOp has a number of specific recommendations that concern the design and development of a tributary monitoring program as well as recommendations that address the efficient implementation of a consistent Columbia River basin-wide monitoring program.

Status and Trends Monitoring

-In order to track the status of a population, spawner escapement and removals *en route* to the spawning ground must be estimated. In addition, it is recommended that reproductive effort (e.g., redd counts) be monitored where ever possible to compliment abundance based population status assessments.

-The abundance of juvenile salmonids in tributary habitats is a critical indicator of population productivity.

-Quantifying and characterizing the biological and physical condition of habitat occupied by listed anadromous salmonids is critical. These data are required to describe the current environmental conditions that support native salmonids and to develop associations with population trends.

-To monitor and evaluate the status and trends of populations and habitat metrics in the most effective manner, data collection schemes must be capable of generating data of known spatial and temporal accuracy and precision. The recommended approach to achieve this goal is the application of spatially balanced random sampling schemes coupled with field protocols measurement error assessments.

Habitat Restoration Action Effectiveness Monitoring

-A two-pronged approach to habitat restoration action effectiveness research is recommended. The first approach is an extensive, watershed-scale top-down approach that monitors all treatment sites in a given geographic area. The second is an intensive, project-based bottom-up approach that monitors a large number of actions of the same class (e.g., riparian plantings or irrigation screening) across a broad, possibly discontinuous, region. The recommended analytical framework for both types of effectiveness monitoring will be a formal Observational Studies approach.

-Currently the region relies on an opportunistic approach to the implementation of project based monitoring – projects are not designed, implemented and monitored within the context of a population, sub-basin or ESU. To be truly effective, restoration action implementation must be modified such that subbasin scale restoration planning is tightly integrated with the monitoring program.

Programmatic and Implementation

-A critical first step in the FCRPS BiOp status monitoring program development is a more thorough assessment of the gaps that exist between the proposed status monitoring program and the myriad currently implemented status monitoring programs.

-In addition to the biological and environmental data, a critical part of the effort will be compiling a detailed inventory of past, current, and planned habitat projects.

-The tributary monitoring outlined in this plan supports the development of a status monitoring program that would address many of the Columbia River basin Technical Recovery Team's (TRT) requirements for FCRPS BiOp relevant ESUs except: Snake River sockeye, Snake River Fall Chinook, and Columbia River chum. These ESUs' monitoring needs may be met through other programs; however, a targeted assessment of these projects must be done in conjunction with the TRT's data requirements.

-Based on draft population delineations, factors for decline and viability criteria, the Columbia River basin TRTs point to several major short comings in the region's status monitoring data collection program. In particular, the Columbia River basin lacks any systematic tributary habitat survey work that is linked to assessments of aquatic habitat condition. Several other major data gaps have emerged from the TRTs' work to date: a comprehensive assessment of the fraction of naturally spawning fish of hatchery origin, a comprehensive assessment of the utilization of mainstem habitat by steelhead, more complete population assessments of steelhead in general, and better monitoring of natural juvenile fish production and movement at the tributary level. Therefore, the FCRPS BiOp tributary monitoring program should explicitly address these issues to better support regional scale recovery planning.

-A programmatic framework that integrates the monitoring of populations and habitat by all regional federal, state and tribal entities is required to cost-effectively achieve the monitoring objectives of this RME plan. Agreement among regional entities on compatible tributary monitoring sample designs and data collection protocols is an essential component of this regional, programmatic approach. This programmatic framework will be advanced through independent scientific review and confirmed through contract requirements for funding of monitoring projects and incorporation into Subbasin Plans under the NPPC Fish and Wildlife Program.

-Implementation of a regionally coordinated, programmatic approach to the Tributary RME is being tested through pilot projects in the Wenatchee and John Day subbasins, with an additional subbasin in the Salmon being planned. A Monitoring Strategy for the Wenatchee subbasin pilot project based on the BiOp RME Plan is currently in draft form and will be made available in October, 2003.

Data Management

-There is no formal database in place that houses all of the information necessary to generate annual production, productivity and recovery progress performance metrics for populations, ESUs and fish habitat. One must be established. Until then, data management options will be tested and further developed through the Tributary Monitoring pilot projects and the ongoing coordination with the Columbia Basin Coordinated Information System.

B. Hydro-system RME

The hydro-system RME plan addresses issues that are directly associated with the FCRPS hydro-system, particularly with respect to effects on life stages directly impacted by the dams and their operation. The objectives specified in this plan are as follows:

- Satisfy hydro-related RME actions presented in the FCRPS BiOp, and
- Develop an approach for evaluating progress toward and compliance with survival performance standards specified in the BiOp.

In the hydro-corridor, the focus of status monitoring is to document the survival of juveniles and adults within the FCRPS, and general environmental conditions. The BiOp specified target values or performance standards for survival that NOAA-Fisheries deemed necessary to avoid further jeopardy to the species. Part of status monitoring will include testing compliance with those survival standards.

Assessing the effectiveness of hydro-system actions, project reconfigurations and operations is called for under sub-strategy 2.3 of the 2003/2003-2007 FCRPS BiOp Implementation Plan (IP). These field studies focus on structural changes and operations occurring at individual projects. The vast majority of these are designed and conducted under the COE Anadromous Fish Passage Evaluation Program. This plan does not treat those specifically but relies on the established program to plan that collective research.

Within the hydro-corridor, critical uncertainty research focuses on two key uncertainties as described in FCRPS BiOp IP sub-strategies 3.3 and 3.4. The research called for under those sub-strategies is meant to resolve important issues related to delayed effects associated with transporting smolts (D), and Extra Mortality (EM) attributable to passage through the hydro-system or different routes in the system that may be expressed in-river or following seawater entry.

Hydro-system RME recommendations

The hydro-system RME program for the FCRPS BiOp has a number of specific recommendations that concern the design and development of a RME program as well as recommendations that address the efficient implementation of a consistent FCRPS monitoring and evaluation program.

Programmatic and Implementation

-A technical group is required to review all estimates of performance measures, critical parameters, and compliance tests as they are submitted, ensuring they are sound and consistent with those prescribed herein. It is recommended that this technical work group be established to address all of these aspects and other new or ongoing issues associated with the implementation of the Hydro RME Actions. It is recommended that the NOAA-Fisheries-AA work group that drafted this plan remain in place to perform these critical tasks.

-All monitoring necessary for generating performance standards and other critical parameters should continue through at least the decade following the publication of the 2000 BiOp.

-There is a critical need to continue wild fish PIT-tagging for use as a comparison to the current use of tagged hatchery fish for hydro-system performance assessments. Tracking the performance of each group through common reaches is the only method by which hatchery stocks can be assessed as a consistently acceptable surrogate for the wild component of the ESU.

Performance Standards and Critical Parameter Estimation

-There are no final recommendations for how representative annual estimates of D can be calculated and applied in a timely manner. However, the following actions are recommended:

- Acquire more reliable D-estimates for wild Snake stream-type populations by increasing the transported percent of PIT-tagged wild fish arriving at LGR and LGO dams.

- By the 2003 check-in, devise a strategy that clearly describes analytical procedures regarding the application of D at the 2005 and 2008 check-ins.

-Direct survival during transportation is presumed to be a constant 98 percent, but this value is based on anecdotal observations only. It is recommended that some effort should be expended to empirically establish the actual value. It is possible that some of the effect currently designated as D may be expressed during the collection and transport process.

Evaluation and Assessment

-Recent analytical efforts (Hydro RME plan Attachment 3) show that most conventional testing procedure will have limited power in testing key hypotheses pertaining to the BiOp hydrosystem performance standards. The alternative developed involves a suite of tests. Furthermore, the alternative approach suggests that even these tests may be inappropriate for the application and recommend that a multi-dimensional framework for testing be explored.

-Given the difficulties and considerable uncertainty associated with annual survival indexing, an alternative approach for determining if adult passage conditions are satisfactory and in accordance with BiOp standards is proposed. This alternative approach is more action oriented and focuses on determining if the recommended passage improvements prescribed in the BiOp have been adequately implemented. This approach shifts focus from annual survival indexing, focusing instead on confirming that the suite of adult passage management actions prescribed in the BiOp are satisfactorily implemented.

-A PIT-tag based survival indexing approach is recommended for use at the 2005 check-in, including an assessment of its merits and deficiencies at that time. The approach relies on adjustments (stray, fallback) derived from Radio tag data that are currently needed to adjust PIT tag data.

Data Management

-There is no formal database in place that houses all of the information necessary to generate annual survival estimates and hydro-system performance standards. One must be established.

C. Hatchery/Harvest RME

The hatchery- and harvest-related RME addresses actions 182 and 184, which focus on hatcheries or hatchery fish, and on action 167, which relates to harvest.

Artificial production of anadromous salmonids has occurred on a large scale for many years in the Columbia River Basin to mitigate for development and support fisheries. Recently, artificial production has been seen as a tool that might be useful to contribute to recovery of depressed populations, particularly those listed under the ESA. One result of artificial production, intentional in some cases and inadvertent in others, is that many populations in the basin are a mix of natural-origin and hatchery-origin spawners. This circumstance presents two kinds of problems, one biological and one data related, that combine to mask the true status of natural populations in the basin.

The biological aspect of the masking problem stems from peer-reviewed studies indicating that hatchery-origin spawners have lower reproductive success when they spawn in the wild than natural-origin spawners. The causes of the differences in reproductive success of wild-spawning hatchery fish are attributed largely to genetic effects. The data-related, or "counting," aspect of the masking problem stems from uncertainty about the numbers of hatchery fish spawning in the wild and their spatial and temporal distribution. The BiOp calls for studies designed to address the critical uncertainty regarding the relative reproductive success of hatchery fish spawning in the wild. The Hatchery/Harvest RME plan outlines the recommended approaches to address the critical uncertainties surrounding the reproductive effectiveness of wild spawning hatchery fish, and the potential population level impacts that may result.

While the reproductive efficacy of hatchery origin fish spawning in the wild is a major unknown impact of hatchery operations, artificial propagation activities can impart other deleterious genetic, ecological or management effects on natural populations. In recent years, many reforms have been enacted or proposed that are designed to reduce these deleterious effects and improve the performance of hatchery fish used in conservation programs, thereby contributing to the recovery effort. The hypothesis is that deleterious effects of artificial production on listed populations can be reduced, thereby contributing to a reduction in extinction risk for affected natural populations. For conservation activities, the hypothesis is that properly designed intervention with artificial production, under certain circumstances, can make a net positive contribution to recovery of listed populations.

As noted in the BiOp, the fundamental premise underlying hatchery reforms is that artificial production programs can be operated consistent with and complementary to the goals of the ESA while still achieving their fishery mitigation objectives. A list of artificial production reforms designed to reduce ecological, genetic and/or management risks to listed species, and/or to improve the performance of hatchery fish, is identified in Section 9.6.4.2 of the FCRPS BiOp. Many of the reforms on this list have been implemented in recent years for some hatchery programs. Unfortunately, many reforms flow from hypotheses that are difficult to test with limited empirical data. The Hatchery/Harvest RME plan develops a comprehensive RME approach for evaluating hatchery reforms, particularly in terms of their ultimate efficacy in reducing extinction risk of listed species and contributing to recovery.

A major, biological issue pertinent to managing fisheries is the extent of incidental mortality imparted on other species or runs. Incidental mortality estimation is particularly critical to the development and implementation of new types of selective fisheries necessitated by the presence of listed species throughout the year in the Columbia River Basin. For catch-and-release fisheries, accurate estimates of mortality rates of nontargeted fish are difficult to obtain yet are essential to determining whether a particular gear or method is suitable for its intended purpose, i.e., in catching the target species while limiting impacts on listed fish. Many variables impact these mortality rates, including encounter rates, gear type, handling techniques, temperature and recapture rates. Though gear development studies pertinent to the Columbia River Basin and elsewhere typically focus on immediate and short-term mortality, the critical question relates to effect on ultimate spawning (reproductive) success. The Hatchery/Harvest RME plan seeks to improve estimates of incidental mortality rates (in terms of impact on spawning success) for existing fisheries and to determine or verify rates in new or experimental fisheries utilizing new kinds of selective gear and/or methods.

Hatchery/Harvest RME recommendations

The recommendations concern the design and development of a RME program as well as address the efficient implementation of a consistent FCRPS monitoring and evaluation program.

Programmatic and Implementation

-Additional studies designed to produce quantitative results on the relative reproductive success of hatchery fish spawning in the wild are needed for the following ESUs or populations: Upper Columbia steelhead ESU, Mid-Columbia River steelhead ESU; an ocean-type Chinook ESU (either directly involving the Snake River fall Chinook ESU or a suitable representative population of ocean-type fall Chinook) and Columbia River Chum ESU, the latter primarily to better aid the development of recovery options.

-Based on an assessment of ongoing research relative to BiOp needs, it appears that sufficient studies directed at the effectiveness of conservation hatchery activities are underway. However, several issues were identified as gaps relating to the effectiveness of hatchery reforms in reducing extinction risk. They fall into two categories, the first being more urgent than the second:

Category 1 (most urgent, i.e., needed for 2003 check-in):

- Methodologies or analytical models (e.g., growth rate and extinction risk models) for synthesizing the results and detecting the effects at the population and ESU levels of a myriad of hatchery reforms and conservation hatchery activities in terms of their effects on extinction risk and/or recovery.

- Benefit/risk of steelhead kelt reconditioning, including evaluation of the relative reproductive success of steelhead kelts, as compared to standard broodstock collection and smolt supplementation techniques, with particular focus on effects on small, natural steelhead populations.

Category 2

- Predation by steelhead smolts on emerging steelhead, Chum, or Chinook fry

- Predation by spring Chinook smolts on emerging steelhead, Chum, or Chinook fry

- Short-term (but perhaps intensive) competition for food and space between hatchery releases of steelhead smolts and Chinook smolts and fingerlings and natural-origin fish in the tributary spawning and rearing habitat.

-Generally, studies of modified hatchery practices ("reform") should involve controlled scientific experiments designed and replicated sufficiently to provide statistically and biologically meaningful results pertinent to multiple programs. For studies of specific reforms, efficacy must be evaluated in terms of the specific fish affected by the study, and ultimately, in terms of their effects on extinction risk and/or recovery. In some cases, particular hatchery reforms or conservation hatchery activities already have been implemented, and the question is whether extinction risk was actually reduced or whether the action contributed to recovery. The potential may exist that useful information could be derived *post hoc* from actions taken in one area to inform reforms in other areas, assuming the reforms were accompanied by pertinent M&E. However, demonstrating the impact of reform-based hatchery operations will be most likely within studies designed as large-scale, controlled experiments. Since the overriding objectives are to determine the efficacy of reforms in reducing extinction risk for the affected populations and ESUs and the efficacy of conservation hatchery activities in contributing to recovery under a given set of circumstances, it will only be possible to do so when comparing hatchery operation strategies across multiple populations exposed to a gradient of hatchery practices. Given the myriad potential confounding factors in such a large scale experiment, the only practical manner to approach this issues is in situations of extreme contrast in hatchery practice. For example, natural production/productivity rates for wild populations in subbasins with and without any hatchery impacts, or natural production/productivity rates in subbasins with conservation vs. production hatchery practices. To implement this strategy will require significant regional coordination as existing hatchery operations may need to be modified to generate the proper setting for evaluation.

-In addition to the continuation of existing studies, additional incidental mortality studies should be undertaken coincident with the development of new selective fishery methods or gear prior to widespread deployment.

Data Management

-There is no formal database in place that houses all of the information necessary to assess the performance of hatchery reforms and conservation hatchery programs. The planned HGMP database may meet this need. If not, an adequate database will need to be established.

D. Data Management

The data management plan presented here specifically addresses the RME section of the BiOp; however, this description of data management needs is a subset of the overall information needs for the BiOp. Specifically, the data management plan directly addresses the data requirements for BiOp Actions 179-199 and complements regional fish and wildlife data-management requirements. In order to be complementary, other data and information management activities in the basin have been surveyed and approaches to integrate the proposed BiOp process with these basinwide activities are presented.

Data Management RME recommendations

The Data Management RME program for the FCRPS BiOp has a number of specific recommendations that concern the design and development of a regional RME program as well as recommendations that address the efficient implementation of a consistent FCRPS monitoring and evaluation program. Coordination with other Federal, State and Tribal programs is necessary to take advantage of current monitoring data and overlapping monitoring programs.

Programmatic and Implementation

-Since data management standards do not exist for the BiOp RME process, this plan presents draft standards as a first attempt to unify RME implementation planning efforts. The following general recommended actions reflect the needs assessment within the BiOp RME Plan, as well as across the region to support and facilitate implementing a BiOp RME data management system.

- A more comprehensive scoping of existing regional data-management projects/goals/needs.
- A formal comparison of regional data-management goals/needs compared to the FCRPS BiOp goals/needs.
- The development of an BiOp RME information system architecture or blueprint that is consistent with regional needs.
- The development/organization of information system capability in a modular fashion so the system(s) meets the practical needs of the local users while meeting the legal and administrative requirements of the region.

-Programmatic commitment to and funding for BiOp RME data management is a critical current gap in BiOp implementation planning.

E. Project Implementation/Compliance Monitoring

The objective of this category is to document that management actions have been executed as prescribed in the BiOp. It involves Contract Officers Technical Representatives (COTRs) tracking the execution and location of the management projects and determining if they are in compliance with the specifications in the directive or work statement. In some cases, such compliance monitoring may extend beyond the implementation phase. For example, it will be necessary to ensure that riparian fencing remains in place for some extended period beyond the construction phase. A project tracking system has been developed for programmatic BiOp reporting and continues to be developed further as part of the larger progress reporting requirements of the Federal Caucus Salmon Strategy. This information on project type and location is important for the design and evaluation of action effectiveness research.

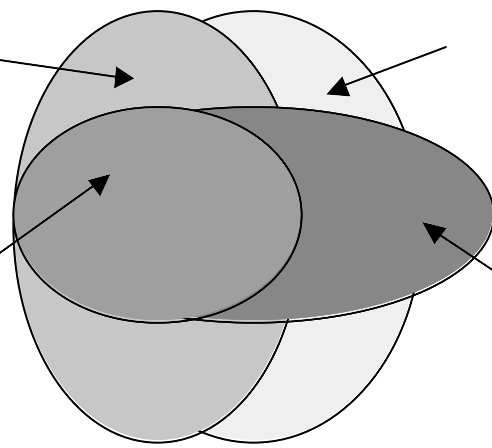
F. Regional Coordination

The preceding sections have described recommendations for further development and implementation of a comprehensive RME Plan. However, Federal agencies alone cannot implement such a plan because of limitations on authority and resources. Completion of a final plan and successful implementation of that plan will require the active participation and cooperation of state and tribal entities, as well as other federal agencies. While much work needs to be done in this area, significant progress towards achieving this coordination has been accomplished to date.

1. Programmatic Level Coordination

Currently there is a broad patchwork of regional RME efforts in different phases of planning, development and implementation that could benefit from increased coordination. The NOAA-Fisheries FCRPS BiOp, the Federal All-H Strategy, and the NPCC Fish and Wildlife Program all call for RME programs. In addition, there are existing Federal programs that focus on monitoring freshwater habitat and environmental conditions, such as the USFS and BLM's monitoring programs for the Northwest Forest Plan (Aquatic and Riparian Effectiveness Monitoring Program) and Pacfish/Infish Biological Opinions, the EPA's Environmental Monitoring and Assessment Program (EMAP) and the National Park Service Program. The USFWS is also developing a programmatic monitoring approach for ESA-listed bull trout and sturgeon. At the state level, Washington and Oregon have formulated their own strategies and plans for monitoring freshwater habitat conditions and fish populations. In addition, some tribes have developed their own monitoring programs or strategies. There also are collective efforts such as the Lower Columbia River Estuary Program (LCREP), a joint program involving agencies from Washington and Oregon, Federal agencies, and local jurisdictions. These monitoring programs overlap one another at various spatial and temporal scales (see Figure 2.1).

Figure 2.1. Regional RME needs - cross coverage.



The FCRPS BiOp RME Program overlaps with other regional programs having their own needs and geographic coverage. The NOAA-Fisheries and the AA intend to implement a RME program, for which major components must be in place by 2003, that addresses the NOAA-Fisheries BiOp requirements for ESA-listed salmon and steelhead stocks. This RME program will be coordinated with other Federal, state, and tribal programs and will take advantage of the current monitoring data and overlapping monitoring programs. NOAA-Fisheries and the AA are attempting to cooperatively develop the FCRPS RME Plan with the intent that it will also complement and be integrated within the other regional monitoring activities to the greatest extent practicable. This coordination will be essential to maximize the amount and quality of RME across the region within limited budgets. The AA and NOAA-Fisheries recognize that the various programs have different goals and objectives and that this will preclude region-wide reliance on any single monitoring program until much broader and comprehensive multi-agency agreements on RME are developed. As these multiple programs are coordinated, they are envisioned to form a comprehensive and integrated network.

The goal of regional coordination of Federal, state, and tribal RME requirements and associated programs includes the following more specific objectives:

- Coordinate research methods, data collection and reporting protocols. Recommend ways to standardize these elements.
- Identify opportunities and recommend collaboration or combination of studies to increase learning and statistical power of studies.
- Identify cost-sharing opportunities and agreements.
- Provide a point of contact for integrating TRT recovery planning monitoring requirements with regional monitoring programs.
- Assist with integrating F&W Program objectives, funding prioritization and subbasin planning efforts with other regional RME efforts.

The development of the AA and NOAA-Fisheries RME Plan is focused on meeting the requirements of the NOAA-Fisheries BiOp on the FCRPS and the parallel implementation of the Federal All-H Salmon Strategy. Key components of the RME requirements have been identified and shared with the region in these two documents and through the annual and 5-year AA BiOp Implementation Plans[5]. The framework and elements of this plan are built on similar work within other regional State, Tribal, and Federal monitoring programs, past experiences with other RME plans under the Fish and Wildlife Program, and interaction with the ISRP and recommendations of the ISAB. NOAA Fisheries participation has also provided ongoing coordination with TRT planning and connections to scientists within the NOAA-Fisheries Northwest Science Center. Additional regional coordination of programmatic level BiOp critical RME is planned at the local watershed levels through development of subbasin plans under the NPCC F&W Program.

2. Status and Tributary Habitat Action Effectiveness RME Coordination

Several multi-agency coordination groups are meeting to coordinate regional monitoring programs and strategies. The most prominent of these efforts is the State-Federal-Tribal Aquatic Monitoring Partnership. This partnership began over a year ago through coordination of the USFS and BLM Westside Forest Plan monitoring with the states of Oregon, Washington and California. This coordination effort has recently expanded to include the PacFish and InFish (Eastside Federal monitoring program), the AA and NMFS RME Program, the NPCC Fish and Wildlife Program, and participation by EPA, USGS, CRITFC, and CBFWA. This group is pursuing further expansion to other regional states and Tribes that would be interested in participation. The Federal executives for the Northwest Forest Plan, the Federal Caucus, the NPCC, and state agency executives have acknowledged that the Partnership is the appropriate group to undertake coordination of monitoring programs. The State-Federal-Tribal Aquatic Monitoring Partnership has recently agreed to work together to develop a Pacific Northwest Regional Monitoring Coordination Plan. Letters of invitation to regional Tribes have recently been sent to encourage their additional participation. A Regional RME Coordination White Paper that identifies a proposed coordination vision statement, objectives, operating principles and options for various levels of coordination has been drafted. This paper will be used in additional upcoming Federal, state, and Tribal executive level meetings to advance coordination of regional RME efforts.

Another parallel regional monitoring program coordination effort has begun as part of new Pacific Coast Salmon Recovery Fund (PCSRF) effectiveness reporting requirements that were recently legislated. This group (Effectiveness Monitoring Policy Group) has been coordinated through the Washington Governor's Salmon Recovery Board and includes participants from Oregon, Washington, California, NOAA-Fisheries, NPCC, BPA, and BOR. This group is developing common project implementation reporting metrics and project effectiveness monitoring indicators using existing work in this area coordinated at the Federal Caucus level to be used in reporting on project funding and results to Congress, Office of Management and Budget and the State governors.

In addition to these above efforts, BPA, NOAA-Fisheries, and NPCC staff are discussing with CBFWA their Mainstem/Systemwide proposal (#35033) for collaborative, systemwide

[5] see http://www.salmonrecovery.gov/implementation.shtml

monitoring and evaluation. This discussion includes how to connect the proposed work to the AA-NOAA-Fisheries RME Plan, Federal Caucus RME coordination, State-Federal Partnership coordination, and the PCSRF Reporting coordination. The primary focus of the CBWFA coordination funded under this proposal will be the development of technical products that will feed into and be informed by other regional policy and programmatic forums on RME coordination. We anticipate a major step forward in regional coordination as these coordination efforts and the CBFWA proposal are clarified and integrated over the next couple of months. As this effort expands, there will be additional efforts to include RME efforts associated with the USFWS bull trout recovery planning, NPCC Program, and Tribal RME programs in this coordination. Direct coordination is envisioned to occur over the next year through the implementation of the RME Plan status monitoring and action effectiveness research pilot studies in the John Day, Wenatchee and Upper Salmon (Mainstem/Systemwide proposal 35019). Key objectives of these pilot projects include working with regional entities at the implementation level to identify how best to integrate and coordinate with other RME programs and objectives.

3. Hydro RME Coordination

Hydro Workgroup activities and deliberations regarding RME have been coordinated with the COE AFEP and NOAA-Fisheries hydro branches. Coordination with AFEP is primarily accomplished by having representatives from the COE offices (Walla Walla and Portland) as official workgroup members. Research funded under AFEP is scrutinized in the context of priorities and needs of the BiOp RME Plan and includes project and program level reviews that include participation by state and Tribal fish agencies. Coordination with NOAA-Fisheries is accomplished through official membership on the Hydro workgroup from the NOAA-Fisheries management and research branches. Additional coordination with state and Tribal fish agencies is planned over the next few months through the expansion of the RME workgroup participation or through interaction of this group with a hydro subgroup of the CBFWA collaborative, systemwide monitoring and evaluation project.

4. Hatchery and Harvest RME Coordination

There are no over-arching forums engaged in coordinating RME efforts relating to hatcheries and harvest. Currently, hatchery and harvest RME activities are implemented by multiple parties, usually state, Tribal, and federal fish management agencies, acting either separately or through various multi-party organizations. With respect to hatchery RME efforts, a degree of coordination does occur through the NPCC's Fish and Wildlife Program, in the sense that all projects funded through the program are subjected to evaluation by the ISRP. Additionally, the NPCC's Artificial Production Review process, and NOAA-Fisheries' Hatchery Genetic Management Plan process (per RPA 169), are creating opportunities for greater interaction among the relevant parties and, potentially, improved coordination of RME efforts relating to artificial production. However, to implement the large-scale experiments that may be required to detect the impacts of various hatchery practices, significant regional coordination will be required.

Similarly, RME efforts relating to harvest occur in connection with various forums. For example, the Pacific States Marine Fisheries Commission coordinates tagging and some fishery monitoring programs, and acts as a collector and repository of coastal-wide catch data used for harvest management and stock status assessments. The Pacific Salmon Commission, acting through its various technical committees, solicits and selects among research projects proposed and implemented by the states and Tribes in furtherance of agreements relating to the Pacific Salmon Treaty, such as the Treaty's abundance-based Chinook management regime. And, the several states and Tribes each conduct RME programs relating to their respective fishery management needs. The potential exists for greater coordination and integration between these activities and the RME program prescribed by the BiOp.

5. Estuary/Ocean RME Coordination

Regional coordination of the Estuary/Ocean RME component has been initiated by the BPA and COE. Currently, the Estuary/Ocean Subgroup informs and receives comments and questions during monthly meetings of the Lower Columbia River Estuary Partnership's Science Work Group, a broad-based technical body. The Estuary/Ocean workgroup also intends to involve state and Tribal fisheries managers in workgroup sessions and review of workgroup products. Additional coordination on estuary/ocean RME occurs through the CBFWA and ISRP reviews of NPCC F&W project proposals and through the Corps' Anadromous Fish Enhancement Program review and planning of research projects. Coordination is essential in the estuary/ocean arena, as elsewhere, due to the myriad ongoing and proposed monitoring efforts by various entities for various purposes, such as trend analysis of habitat usage by juvenile salmon and effectiveness of salmon habitat restoration projects.

6. Data Management Coordination

At a regional level there is a specific objective for RME regional coordination of federal, state, and tribal data collection and reporting:

- Coordinate research methods, data collection and reporting protocols. Recommend ways to standardize these elements.

At the level of the individual RME work groups there is the need for considerable coordination of data management between work groups and within work groups, as detailed in the sections *2-5* immediately above. In addition, at the level of individual RPA's there are important data coordination needs: in particular RPA 198 calls for common data management system for fish populations, water quality, and habitat data. All of these are substantial requirements creating a need for extensive coordination that currently does not exist in the basin.

In an effort to understand the requirements of a regional information system, the NOAA-Fisheries and the NPCC agreed to work together to identify the steps necessary to develop a regional information system for the Columbia Basin. In April of 2002 NOAA-Fisheries and the NPCC agreed on a Memorandum of Understanding and a consultant company, Science Applications International Corporation (SAIC) was engaged to report on the steps necessary to develop a cooperative regional information system for the Columbia Basin. SAIC reported its findings to NOAA-Fisheries and the NPCC in May 2003, recommending steps for the establishment of a Columbia Basin Cooperative Information System (CBCIS). These steps are summarized below (Table 1.). It is important to understand that meeting even the most basic RME goals, there needs to be substantial need to achieve regional programmatic coordination, let alone the steps of achieving standardization of data collection protocols and the actual collection of data.

The RME Data Management Group, as a part of this RME effort, has recommended that the CBCIS effort be the basis for the development of the needed RPA 198 action item and as the foundation for the extensive regional RME coordination necessary to achieve standardization of data collection and reporting protocols. Achieving the needed level of coordination for RME will, as a first step, require agreement by the action agencies to support a level of regional information system development that is consistent with the CBCIS recommendations (Table 2.1), and the obligations of the Action Agencies under the Biop.

Table 2.1 Summary of CBCIS Recommendations

1. FOSTER INTEGRATION, COLLABORATION, AND COMMUNICATION
2. INTEGRATE INFORMATION MANAGEMENT WITH BASIN GOALS AND PERFORMANCE MEASURES
3. DEVELOP BASINWIDE INFORMATION MANAGEMENT PROTOCOLS
4. COLLABORATE WITH THE FULL SPECTRUM OF INFORMATION USERS
5. ENSURE LONG-TERM SUPPORT AND COMMITMENTS
6. MOVE TOWARD A DISTRIBUTED SYSTEM ARCHITECTURE, USING AN ENTERPRISE APPROACH
7. DESIGN AND DEVELOP INFORMATION SEARCHING (DATA INDEXING) TOOLS
8. DESIGN AND DEVELOP DECISION-SUPPORT TOOLS LINKED TO BASIN GOALS, OBJECTIVES AND MEASURES

In addition to the higher-level coordination efforts through the participation in the development of a CBCIS, the AA and NMFS are coordinating data management development through the Tributary Monitoring pilot projects.

7. Coordination Process Groups
Regional workgroups or committees that the AA and NMFS are participating in or interacting with to advance coordination of the different components of the RME Plan include:

- State-Federal-Tribal Aquatic Monitoring Partnership Group
  Primary focus is watershed-condition monitoring coordination but expanding to include fish and effectiveness monitoring and at a larger geographic area for coordination across regional RME programs.

- Pacific Coast Salmon Recovery Fund Coordination Group
  Focused on coordination of common project tracking metrics and action effectiveness monitoring protocols for the Pacific Coast Salmon Recovery Fund. Initiated by State of Washington Governor's Office and NMFS.

- CBFWA Collaborative Project Coordination Workgroups
  Two informal workgroups have been meeting. One to advance development of technical tasks under the project work statement and another to identify policy/programmatic oversight input that needs to be provided for guidance to the technical level work.

- Federal Caucus RME Group
  This is the current Federal Caucus RME workgroup that will continue to meet on Federal All-H policy and big picture issues for meeting Federal Caucus RME goals.

- Technical Oversight Group
  This is the current NMFS/AA RME Planning Group expanded to the Federal Caucus Level to provide oversight and direction to expanded RME Technical Workgroups.

- RME Technical Subgroup
  These are the existing NMFS/AA RME Workgroups (Status Monitoring, Tributary Action Effectiveness Research, Hydro, Hatchery/Harvest, Estuary/Ocean, Data Management).

- Tributary Habitat Status and Action Effectiveness Pilot Project Technical Workgroups
  Technical coordination groups within the pilot watersheds that are developing and implementing the watershed-level monitoring within a programmatic framework.

- LCREP Science Work Group

- AFEP workgroups

- Artificial Production Review Process workgroups

- Hatchery Genetic Management Plan workgroups

- Pacific States Marine Fisheries Commission

- Pacific Salmon Commission Technical Committee

- Columbia Basin Coordinated Information System workgroup

3. Tributary Population and Environmental Status and Restoration Action Effectiveness Monitoring

A. Introduction

The goal of the tributary monitoring program, as proposed under the NMFS 2000 Federal Columbia River Power System Biological Opinion (FCRPS BiOp), is to provide the necessary data for resolving a wide range of uncertainties, determining population status, establishing the baseline for the causal relationships between habitat attributes and population response, and assessing the impact of management activities, in particular habitat restoration actions.

The RME Plan for the population and environmental status and habitat restoration action effectiveness monitoring program of the FCRPS BiOp is organized along the following outline:

A. Introduction.

B. Define the Tributary Status and Habitat Action Effectiveness Monitoring component of the FCRPS RME program.

C. Identify performance standards for the Tributary Monitoring program.

D. Guidance for implementing the Tributary Monitoring program.

E. Identify the degree to which status monitoring is currently being successfully implemented, including identifying the gaps in current work in terms of occurance/non-occurance as well as quality. Incomplete or inadequate monitoring programs need to be identified as gaps so that they may be improved or replaced as necessary to achieve a consistently adequate monitoring program.

F. Develop Action plan to address gaps identified in (E).

G. Define the relationship of the Tributary Monitoring program to the other FCRPS RME components, as well as regional programs. Identify the structure of handling, storing, disseminating the data generated by the monitoring program so that appropriate evaluation can progress.

H. Identify strategies for design of evaluation or decision-making and planning tools.

I. References.

B. Tributary Status and Habitat Action Effectiveness Monitoring component of the FCRPS RME program

The FCRPS BiOp outlines a hierarchical comprehensive monitoring and evaluation program. The program consists of three levels of effort: (i) a broadscale assessment of ecosystem status, (ii) an annual sampling of the status of fish populations and their habitat, and (iii) the effectiveness of specific recovery actions. The first two components form the Population and

Environmental Status Monitoring Program, while the third component is addressed in the Action Effectiveness Research program.

Tributary Status Monitoring

There are several specific calls for the development of a status monitoring program in the FCRPS BiOp. In particular, Action Items 180 and 181 outline the scope and scale of a hierarchical monitoring program with two levels of status monitoring (Tier1 and Tier2). In addition, the status monitoring program is further developed in the FCRPS BiOp's Appendix G. However, the Actions 180 and 181, Appendix G, and the body of the FCRPS BiOp do not fully specify the details of a comprehensive status monitoring program such that an implementation plan can be readily developed. The purpose of this document is to specify many of the undefined aspects of the status monitoring program and outline an action plan for its further development. Aspects of the status monitoring program that are not fully specified in the BiOp include, but are not limited to: the form of the landscape scale monitoring, the statistical sampling framework of the habitat and population monitoring, the indicators to be measured in the habitat, population, and landscape scale monitoring programs, and the analytical framework for evaluating the data generated by the status monitoring program.

The status monitoring program for salmonid fishes and their tributary habitat in the Columbia River basin is designed to address the questions below. Each of these questions is framed in a general fashion to allow for geographic, logistical and biological constraints. For example, the spatial scale for many of the questions is either population, subbasin or ESU, depending on the most appropriate or convenient scale at which to collect the required response variable. Policy and technical representatives of the management entities must first work together to specify both the level of acceptable risk (uncertainty) for making management decisions and the costs that they are willing to bear for a monitoring program. Within these constraints, the accuracy and precision of all measurements must be specified in order to design the data collection scheme and to allow the development of confidence intervals for analyses based on these data.

Ecosystem status questions:

What is the distribution of adult salmonid fishes?

measured variate(s): presence/absence of adult salmonid fishes
spatial scale: Columbia River system, ESU
accuracy and precision: census
temporal scale: sampling on 3 – 5 year cycle

What is the ecosystem status for Columbia River Basin (CRB) fish populations?

measured variate(s): Geology/Soils, Land classification, Stream network, DEM, Road, Land ownership
spatial scale: Columbia River system, ESU
accuracy and precision: census
temporal scale: sampling on 5+ year cycle

Population and habitat status monitoring questions:

What is the size of CRB fish populations?

measured variate(s): numbers of adults, spawners or redds
spatial scale: population, sub basin, ESU
accuracy and precision: unbiased estimate with known sampling and measurement error
temporal scale: annual samples

What is the annualized growth rate of CRB fish populations?

measured variate(s): numbers of adults, spawners or redds
spatial scale: population, sub basin, ESU
accuracy and precision: unbiased estimate with known sampling and measurement error
temporal scale: trend in annual samples over at least 10 year period

What is the freshwater productivity (e.g., smolt/female) of CRB fish populations?
measured variate(s): index of juvenile population
spatial scale: population, subbasin, ESU
accuracy and precision: unbiased estimate with known sampling and measurement error
temporal scale: annual samples

What is the age-structure of CRB fish populations?
measured variate(s): age of returning adults
spatial scale: population, subbasin, ESU
accuracy and precision: unbiased estimate with known sampling and measurement error
temporal scale: annual samples

What is the fraction of potential natural spawners that are of hatchery origin?
measured variate(s): fraction of escapement that is of hatchery origin
spatial scale: population, subbasin, ESU
accuracy and precision: unbiased estimate with known sampling and measurement error
temporal scale: annual samples

What is the biological condition of CRB fish spawning and rearing habitat?
measured variate(s): macroinvertebrate, amphibian and fish assemblages
spatial scale: subbasin, watershed
accuracy and precision: unbiased estimate with known sampling and measurement error
temporal scale: annual samples

What is the chemical water quality in CRB fish spawning and rearing habitat?
measured variate(s): DO, pH, Conductivity, Nutrients, Solids, Pesticide and heavy metal conc., Temp.
spatial scale: subbasin, watershed
accuracy and precision: unbiased estimate with known sampling and measurement error
temporal scale: annual samples

What is the physical habitat condition of CRB fish spawning and rearing habitat?
measured variate(s): Channel Form, Valley Form, Valley Width Index, Geomorphic channel units, Channel Substrate, Canopy cover, Large woody debris, Riparian vegetation, Land use, Number of diversions or dams, Assessment of erosion processes, Channel modification, Instream flow
spatial scale: sub basin, watershed
accuracy and precision: unbiased estimate with known sampling and measurement error
temporal scale: annual samples

Tributary Effectiveness Monitoring (Action Effectiveness Research)

Managers often implement habitat actions (e.g., riparian enhancement) within tributary streams to improve habitat conditions for one or more fish species. While it is generally assumed that the improved habitat conditions will in turn improve the survival or production of the species, empirical studies that demonstrate this are exceedingly rare. In fact, Bayley (2002) reviewed almost 2,500 references and found only a handful that addressed the effectiveness of habitat work in tributaries. Because different habitat actions have unknown effects on fish populations, there is a need to demonstrate their effects on fish populations within tributary streams.

Effectiveness monitoring encompasses a suite of methods for evaluating whether some action achieved the desired effect or goal. The success or failure of an action is assessed by comparing treated sites with controls, baseline conditions, or desired future conditions. As such, effectiveness monitoring, as defined in this plan, encompasses the essence of experiment driven research. To capture this approach, effectiveness monitoring is referred to as "Action Effectiveness Research" (AER) – data will be collected within an experimental design, actions will be evaluated with respect to control sites, variability in the data will be described, and decision making will be based on established rules of scientific inference and statistical confidence.

The overall purpose of the research plan described here is straight-forward: to rigorously assess whether or not tributary habitat actions improve environmental conditions and increase life-stage survival rates, thereby reducing the likelihood of extinction for listed stocks. No previous research program has tried to estimate environmental or fish survival effects of habitat actions on the scale that is required by the 2000 NMFS Federal Columbia River Power System Biological Opinion (BiOp). This will present substantial managerial, logistical, and scientific challenges.

The establishment of a rigorous AER program is called for in Section 9.4.2.8 of the 2000 NMFS Biological Opinion:

> ***Action 9:*** *The Action Agencies, with assistance from NMFS and USFWS, shall annually develop 1- and 5 year plans for research, monitoring, and evaluation to further develop and to determine the effectiveness of the suite of actions in this RPA.*

The BiOp also sets a timetable for the development of a monitoring program, and defines the scope for effectiveness monitoring.

> *Research, monitoring, and evaluation will provide data for resolving a wide range of uncertainties, including…establishing causal relationships between habitat (or other) attributes and population response, and assessing the effectiveness of management actions. Progress on resolving these uncertainties will be a primary consideration in the 1- and 5-year planning process as well as in the 5- and 8-year check-ins.* (BiOp, page 9-31)

Research on tributary mitigation actions is specifically identified in Reasonable and Prudent Alternative (RPA) Action 183:

> ***Action 183:*** *Initiate at least three tier 3 studies* [6] *(each necessarily comprising several sites) within each ESU (a single action may affect more than one ESU). In addition, at least two studies focusing on each major management action must take place within the Columbia River basin. The Action Agencies shall work with NMFS and the Technical Recovery Teams*

[6] Note that "Tier 3" refers to action effectiveness. The research described here assumes that habitat actions are actually implemented as planned, or, alternatively, that researchers will be aware of actions that were planned, but, for whatever reason, were not actually carried out on schedule.

to identify key studies in the 1-year plan. Those studies will be implemented no later than 2003.

Categories of management actions discussed in Action 183 include:

1. Instream flow
2. Nutrient enhancement
3. Barrier removal
4. Diversion screen
5. Sediment reduction
6. Riparian buffer
7. Instream structure
8. Water quality improvement

In addition, Section 9.6.5.3.3 of the BiOp states that:

> *Each major habitat or hatchery management action should be assessed immediately to obtain enough information for a complete evaluation at the 5- and 8-year check-in points.* (BiOp, page 9-170)

For the purposes of establishing a valid AER program, Action 183 is distilled into two primary goals:

1. Evaluate the contribution of tributary actions toward meeting fish population targets for the 5-year and 8-year check-ins (e.g., answers the question, "are projects in aggregate improving fish populations?").

2. Develop information on the utility of categories of habitat actions to facilitate strategic planning for future habitat mitigation activities (e.g., answers the question, "do barrier removal projects generally work, and if so or if not, under what conditions?").

These two goals place different demands on the scope of the AER program and the design of monitoring plans for individual actions.

C. Tributary Status and Effectiveness Monitoring Performance Standards and Indicators

The FCRPS BiOp uses Performance Standards as the metric by which implementation of the RPA Actions will be assessed. Performance standards for the RPA Actions derive from the biological requirements of the listed populations for their entire life-cycle as well as at particular isolated life stages. FCRPS BiOp performance standards are defined in three tiers. The most general tier is the population level performance standards. These standards define the performance needed for the listed population to achieve adequate likelihoods of survival and recovery. Life-stage-specific performance standards at the intermediate tier allocate across the life cycle the performance expectations necessary to achieve the population–level standards. This tier guides the development of performance standards for categories of actions in habitat, harvest hatcheries, and hydropower. The third-tier standards are intended to achieve the life-stage standards. In addition, the FCRPS BiOp explicitly calls for particular biological indicators to be monitored in order to address specific tests that will be applied at the out-year biological check-ins. At this level there are four specific population level check-ins requiring population numbers and productivity assessments (FCRPS BiOp, 9.2.2.1). Satisfying these check-in assessments arises directly from the status monitoring program.

In order to accomplish the required data collection and evaluation implied by the FCRPS BiOp life-cycle and life-stage performance standards the tributary monitoring program itself requires standards of performance. These standards specify the design of the status and effectiveness monitoring programs, for example the spatial and temporal resolution, as well as the acceptable levels of measurement and sampling error for each indicator. Ideally these design performance standards would be established by working back from data needs specified by FCRPS BiOp check-in assessments and other management decision points. However, the analytical approaches underlying the evaluation phase of the monitoring program are not fully established. Therefore, some of the performance standards advanced in the FCRPS BiOp RME Plan are to be determined during pilot implementation of the tributary monitoring program, some are specified as commonly accepted values, while others are unknown prior to a complete assessment of the monitoring program.

Population Level Performance Standards

In accordance with 2000 FCRPS BiOp, the anadromous salmonid monitoring program under the Action Agencies Implementation Plan must collect data to answer the following four questions at the 2005 and 2008 check-in evaluations. These questions constitute quantitative tests, and they are specified as requirements for assessing the status of ESA listed salmonid species in the Columbia River Basin (FCRPS BiOp, 9.2.2.1).

1. Is the annual population growth rate greater in 2005 and 2008 than during the base period (1980 – 2000)?

2. Is the annual population growth rate in 2005 and 2008 greater than or equal to the projected growth rate based on improvements from actions taken in the 1995 biological opinion, reductions in harvest that occurred after 2000, and the survival standards in the Mid-Columbia Habitat Conservation Plan?

3. Is the projected annual population growth rate in 2005 and 2008 (based on best available information about the expected effects of hydro and off-sight mitigation actions and other regional actions under the All-H strategy) equal to or greater than the growth rates believed necessary to achieve the 48-year recovery criteria?

4. Is the annual adult return of wild fish as represented by the 5-year geometric mean for each ESU and population greater than the ESU and population size (5-year geometric mean) in 2000?

To address these standards, the Actions Agencies must measure and document the change in population status by monitoring adult abundance. This requires enumerating (census of all adults), or estimating via a statistically rigorous sampling program, adult abundance on an annual basis. What is unclear at present is the scale (population/subbasin/ESU) and precision (+/- 10%, 20%, 30%) of the monitoring for each ESU. Additionally, the BiOp specifies that the evaluation procedure will result from regional discussions. Therefore, the strict reliance on adult abundance measures could change, requiring the collection of additional population information as part of the status monitoring program. However, since initial ESU status determinations were based on existing data collection approaches it is sensible to continue collecting data in the same manner (e.g., index area redd counts), while pilot studies of more statistically-based methods get underway. One task for these pilot studies will be to systematically compare existing methods, with their long, relatively consist time series, to the newer methods proposed in this plan.

Environmental and Physical Performance Standards
Except for the Hydro-corridor, The BiOp only generally describes the types of performance standards that may be derived for Habitat and Hatchery areas. For the Hydro-corridor the standards take the form of flow targets and spill and transportation schedules, intended to maximize smolt survival. In terms of developing specific sets of habitat and environmental indicators for the three geographic zones, the BiOp offers only general guidance.

Population-Based Indicators
To determine changes in population growth rate and abundance, spawner escapement and removals must to be estimated. Removals may be caused by passage mortality or in-river harvest. Different species offer different opportunities for estimating spawner escapement. For example, redds counts have generally been adopted as acceptable for tributary spawning chinook. In contrast, steelhead redds can be difficult to observe during spawning periods when flows are high, thus other enumeration techniques may be required. For mainstem spawning species like fall chinook, deep water redds are difficult to identify, so dam counts must usually suffice.

Defining the goals of the proposed monitoring effort is a fundamental first step. To initially define performance measures, the data requirements of existing analytical processes have been used. For example, the life cycle analyses employed in the BiOp requires annual estimates of age composition and sex ratio for the returning adults. In compiling this list of candidate performance measures the data needs were not restricted to BiOp driven analyses, to allow for broader applications as well. Furthermore, future models for population viability and other BiOp applications may change, requiring additional data (e.g., spatial population structure, life history diversity).

Candidate fish population indicators/performance measures are:

Adult Life Stage-
1. Adult counts: weir or dam counts.
2. Spawners: carcass or redd counts.
3. Removals by fisheries or passage mortality
4. Hatchery fraction of natural spawning fish: hatchery marks.
5. Sex ratio of spawners or adults: carcass surveys or traps.
6. Age structure: scale or length analysis.

Juvenile Life Stage-
1. Abundance estimates at strategic locations by life stage

The enumeration or estimation of spawner abundance is required to conduct the BiOp-specified performance standard tests. Estimates of juvenile abundance are necessary to generate estimates of survival, SARs, and as population status indices. Opportunities to obtain useful juvenile indicators will vary by ESU. For example, Snake River fall chinook are particularly problematic. They migrate throughout the year in the mainstem, including periods when sampling devices are inactive. However, whenever possible, juvenile abundance should be estimated for populations/ESUs.

Landscape Classification Indicators

Both status monitoring and AER require landscape classification. The purpose of classification is to describe the "setting" in which habitat actions occur. Classification will also aid in identifying potential reference or control areas. Thus, the classification system needs to include both ultimate and proximate control factors (Naiman et al. 1992). Ultimate controls include factors such as climate, geology, and vegetation that operate over large areas, are stable over long time periods, and act to shape the overall character and attainable conditions within a watershed or basin. Proximate controls are a function of ultimate factors and refer to local conditions of geology, landform, and biotic processes that operate over smaller areas and over shorter time periods. These factors include processes such as discharge, temperature, sediment input, and channel migration. Ultimate and proximate control characteristics help define flow (water and sediment) characteristics, which in turn help shape channel characteristics within broadly predictable ranges (Rosgen 1996).

To meet these identified needs the tributary monitoring plan includes a classification system that incorporates the entire spectrum of processes influencing stream features and recognizes the tiered/nested nature of landscape and aquatic processes. This system captures physical/environmental differences spanning from the largest scale (regional setting) down to the channel segment (Table 3.1). By recording these descriptive characteristics, an assessment of differential responses of habitat and fish indicators to habitat actions within different classes of streams and watersheds is possible. Attachment 1 describes methods for measuring classification variables.

Table 3.1. List of classification variables that will be measured as part of status monitoring and effectiveness research. The variables are nested according to spatial scale and their general characteristics. Recommended sampling protocols are also included (Table is modified from Hillman and Giorgi 2002).

Spatial scale	General characteristics	Classification variable	Example protocols	Sampling frequency (years)
Regional setting	Ecoregion	Bailey classification	Bain and Stevenson (1999)	20
		Omernik classification	Bain and Stevenson (1999)	20
	Physiography	Province	Bain and Stevenson (1999)	20
	Geology	Geologic districts	Overton et al. (1997)	20
Drainage basin	Geomorphic features	Basin area	Bain and Stevenson (1999)	20
		Basin relief	Bain and Stevenson (1999)	20
		Drainage density	Bain and Stevenson (1999)	20
		Stream order	Gordon et al. (1992)	20
Valley segment	Valley characteristics	Valley bottom type	Cupp (1989); Naiman et al. (1992)	20
		Valley bottom width	Naiman et al. (1992)	20
		Valley bottom gradient	Naiman et al. (1992)	20
		Valley containment	Bisson and Montgomery (1996)	20
Channel segment	Channel characteristics	Elevation	Overton et al. (1997)	10
		Channel type (Rosgen)	Rosgen (1996)	10
		Bed-form type	Bisson and Montgomery (1996)	10
		Channel gradient	Overton et al. (1997)	10
	Riparian veg.	Primary vegetation type	Platts et al. (1983)	5

Spatial Scale of Environmental / Biological Indicators

Action effectiveness research can be conducted at different spatial scales, depending on the objectives of the study. For example, it is possible to assess the effect of a habitat action on a specific ESU (which may encompass several populations), a specific population (may include several sub-populations), at the sub-population level (may encompass a watershed within a basin), or at the reach scale. Clearly, the objectives and hence the indicators measured dictate the spatial scale at which action effectiveness research is conducted. For example, if the objective is to assess the effects of nutrient enhancement on egg-smolt survival of a specific sub-population of spring chinook, then the spatial scale covered by the study must include the entire area inhabited by the eggs, fry, parr, and smolts. If, on the other hand, the objective is to assess the effects of a sediment reduction project on egg-fry survival of a local group of spring chinook (i.e., chinook within a specific reach of stream), then the study area would only encompass the reach of stream used by spawners of that local group.

In theory there might be no limit to the scale at which effectiveness monitoring can be applied, but in practice there is a limit. This is because as the spatial scale increases, the tendency for multiple treatments (several habitat actions) affecting the same population increases (Table 3.2).

That is, at the spatial scale representing an ESU or population, there may be many habitat actions within that area. Multiple treatment effects make it very difficult to assess the effects of specific actions on an ESU (see Hillman and Giorgi 2002). Even though it may be impossible to assess specific treatment effects at larger spatial scales, it does not preclude the conduction of effectiveness research at this scale. Indeed, it is possible to assess the combined effects of the management actions on the ESU or population; however, additional effectiveness research is needed at finer scales to assess the effects of individual actions on the ESU or population.

Table 3.2. Relationship between biological indicators, spatial scales, and the ability to assess effects of specific management actions. Examples of each scale are shown in parentheses.

Biological Indicators	**Example of spatial scales**	**Ability to assess effects of specific management actions**
ESU (Snake Spring/summer chinook, Upper Col. Spring chinook) ? **Population** (Middle Fork Salmon spring chinook, Wenatchee spring chinook) ? **Sub-Population** (Marsh Ck. Spring chinook, Nason Ck. Spring chinook) ? **Local Group**	**Basins** (Snake, Upper Col.) ? **Basin** (Middle Fk. Salmon, Wenatchee) ? **Watershed** (Marsh Ck., Nason Ck.) ? **Reach** (100 m. of Marsh Ck., 1 km of Nason Ck.)	**Low** ? **High**

If the biological indicator of interest is some life-stage specific survival, as noted frequently in the BiOp, the spatial scale for most life-stage specific survivals (fry-parr, parr-smolt, egg-smolt, spawner-adult recruit) should be equal to the area occupied by a specific sub-population. Here, sub-population is defined as the smallest geographic unit where juvenile life-stage survival can plausibly be assumed to be independent of other sub-populations. It is not possible to measure independent fry-parr, parr-smolt, and recruit-per-spawner survival rates at smaller scales because of mixing and migration. For egg-fry survival, the spatial scale could be smaller because eggs and alevins are more confined in space than are fry and parr, which tend to move both upstream and downstream from spawning locations. Although the sub-populations are similar to distinct population segments (DPS), the DPS designation has other implications for management, analysis of extinction probabilities, etc.

Because of the conflict between spatial scale and multiple treatment effects, and thus the ability to assess specific management actions, there may be times when the effects of individual habitat actions on life-stage specific survival of specific sub-populations cannot be effectively analyzed. This can, for example, occur if multiple actions may increase parr-smolt survival rates for a particular sub-population. These might include riparian plantings, irrigation screening, and flow increases. In this case, it will be necessary to measure other indicator(s) to assess the effectiveness of specific habitat actions. Other biological indicators identified in the BiOp include distribution, abundance, growth, and condition. In addition, the BiOp calls for the monitoring of physical/environmental attributes. These too can be used to assess the effects of habitat actions. Therefore, to establish the linkages between habitat actions and biological indicators as called for in the BiOp, physical/environmental indicators must be measured. These studies often can be conducted at scales small enough to avoid treatment effects from multiple habitat actions. They can also help infer which action or actions had the greatest affect on life-stage specific survival at the sub-population scale.

D. Guidelines for the Implementation of a Tributary Monitoring Program

Status Monitoring

The following sections briefly outline the proposed guidelines for implementing a status monitoring program targeting salmonid ESUs listed under the ESA. They may also have broader application for resident fish populations and their habitats. The Action Agencies and NMFS suggest that if the guidelines are implemented the status monitoring program will likely meet the needs of the BiOp and may satisfy broader regional goals.

Ecosystem Level Status Monitoring

Much of the critical data for assessing ecosystem status should be collected at a watershed to sub-basin scale. There are two classes of landscape-level ecosystem attributes: salmonid species presence/absence and environmental/habitat conditions. Both fish and environmental data should be compiled and reported every 5-10 years, although sampling may occur in more frequent time-steps.

Tasks will include:

1. The acquisition and digitizing of aerial or satellite imagery of the entire Columbia River Basin, for key landscape attributes.
2. Survey the presence/absence of adult anadromous salmonids to document range expansion or contraction.

Landscape-level data collection will allow a more detailed assessment of land use and land cover variables than is currently available. This assessment, in turn, will allow the association of potentially important watershed-level characteristics with salmon population status. In addition, repeated collection and assessment of the variables through time will allow analysts to assess if changes in environmental characteristics are associated with changes in salmonid population status. These data will have value for resource and wildlife management well beyond listed salmon species.

Guidelines: Ecosystem status indicators:

1. Clearly identify the appropriate geographic scales (e.g. sub-basin, watershed) and resolution (e.g., 1:24k, 4m pixels) at which the status indicators are measured.
2. Identify the indicators that will be directly measured (e.g. fish presence/absence, DEM) to estimate ecosystem status.
3. Describe the method used for determining derived indicators (land classification, stream network).
4. Provide an assessment of the accuracy and precision associated with the proposed methods for estimating indicator values.

The Action Agencies and NMFS will rely heavily on federal land use agencies and state agencies to identify a set of key environmental/habitat indicators that should be monitored at the landscape scale, although this plan does offer some suggestions including geology/soils, land classification, stream network, DEM, roads, passage barriers, and land ownership. Other sources of input that will help refine this monitoring effort are ongoing programs such as The Pacific Northwest Ecosystem Research Consortium, which has described sampling methods and associated precision estimates for these indicators, as well as AA funded pilot scale research described in subsequent sections. If coordinated and evaluated in a regional forum, these programs, both ongoing and recently initiated, may provide the raw material for a broader regional program.

Population Status Monitoring-Adults:
In order to track the status of a population, spawner escapement and removals en route to the spawning ground must be estimated. In the Columbia River Basin, redd counts have generally been adopted as acceptable for tributary spawning chinook. However, for some ESUs, or in deeper water mainstem systems, redds are difficult to observe during spawning periods when flows are high, and are not particularly useful for estimating escapement using traditional peak count methods. In these cases alternative approaches/technologies should be explored. For example, approaches applied by the Oregon Department of Fish and Wildlife Corvallis Research Lab indicate that cumulative steelhead redd counts may be a reliable method for estimating adult steelhead abundance (Jacobs et al. 2001), while counts of spawners based on sonar or videography have been successfully applied to populations in the Snake River ESUs. Recent work by the USFS Rocky Mountain Research Lab has begun to address the measurement error associated with a variety of types of redd count methods (Dunham et al. 2001, Thurow 2000).

Guidelines: Population Status-Adult Life Stage:

1. Clearly identify the demographic scale (e.g. population, ESU, deme; wild/natural or hatchery origin) for which abundance estimates will be produced.

2. Demonstrate that the target unit is readily distinguishable from other sympatric population units (e.g. spawning location, timing, etc.).

3. Identify the performance measure or indicator that will be monitored/enumerated (e.g. redds, carcasses, weir counts, dam counts etc.) in order to estimate spawner escapement. If multiple methods (e.g., weir counts and redd counts) are used to enumerate the same population, specify. If multiple methods are used, systematic, statistically sound methods should be used to carefully compare the results.

4. Describe the method used to enumerate the indices, e.g., aerial or ground surveys, peak or cumulative (repeated) counts, and the error associated with the method.

5. Specify any expansion factors (e.g. spawners/redd, expansions beyond index areas) or other adjustments (e.g. harvest removals, passage mortality) that need to be applied to the raw counts. Provide the rationale supporting the use of those expansion factors, how the factors change over time, how they are estimated, and assess their reliability.

6. Provide estimates of the annual age structure of the sampled population, and how this is estimated.

7. Provide an assessment of the accuracy and precision associated with the proposed methods for estimating spawner escapement, or total numbers of returning adults.

Proposed precision targets (Coefficient of Variation: CV = 100 x standard deviation/mean for controllable variance components, e.g., within year, within population, across field crews, unless otherwise noted) associated with key indicators are to be CV < 15%, unless noted otherwise. All data needs to identify precision. It is assumed that estimates are unbiased, and monitoring groups can verify this empirically. Data will be collected on an annual basis at the sub-basin scale:

- Adults, Spawners, or Redds
- Age structure of spawning population
- Sex ratio of spawning population
- Fraction of naturally spawning fish that are of hatchery origin.

Recent work by ODFW (2002), IDFG (Kiefer et al. 2002) and Jacobs and Nickelson (1998) suggest protocols and sampling methods that may provide satisfactory precision for the above indicators.

Population Status Monitoring-Juveniles:
The abundance of juvenile salmonids in tributary habitats can be a useful indicator of population productivity. Some measure of juvenile production for each listed ESU would be advantageous, however information in selective sub-basins may have to suffice. The juvenile component of the status monitoring program seeks to generate at a minimum a trend in the juvenile production index at the sub-basin scale, but when possible should generate the status of the juvenile population by demographic unit. In most cases, population size estimates will be based on sampling by trap, snorkeling, or mark recapture. Often such estimates are so coarse they are characterized as general indices. Depending on the life stage of interest (fry, parr, smolt) sampling opportunities vary.

Guidelines: Population Status-Juvenile Life Stage:

1. Clearly identify the demographic unit (e.g., population, ESU, deme; wild/natural or hatchery origin) over which sampling will take place.

2. Clearly identify the spatial scale represented by each samples (e.g., reach, watershed, basin).

3. Identify the performance measure or indicator that will be monitored (e.g. summer/winter juveniles, outmigrating smolts). If different methods are used to enumerate the same population, specify. If multiple methods are used, systematic, statistically sound methods should be used to carefully compare the results.

4. Describe the method used for enumerating the indices, e.g., snorkel surveys, electro-fishing, smolt trap, and the error associated with the method.

5. Specify any expansion factors (e.g. expansions, trap efficiency) or other adjustments (e.g., daylight trapping only) that need to be applied to the raw counts. Provide the rationale supporting the use of those expansion factors, how the factors change over time, how they are estimated, and assess their reliability.

6. Provide an assessment of the accuracy and precision associated with the proposed methods for estimating juvenile abundance or an index of juvenile abundance.

Precision targets (CV < 15%) associated with key indicators are proposed. It is assumed that estimates are unbiased. Data will be collected on an annual basis at the sub-basin scale:

- Estimate abundance of instream juveniles
- Estimate out-migrating juveniles
- Age/size classes of sampled juveniles
- Condition of sampled juveniles

A recent work by Rodgers (2000) and previous papers by Hankin and Reeves (1984, 1988) suggest protocols for sampling methods that provide satisfactory precision for the above indicators.

Habitat Status Monitoring:
The goal of habitat or environmental status monitoring is to quantify and characterize the condition of habitat occupied by listed anadromous salmonids at the appropriate geographic scales. Information derived from these analyses may be useful to describe the current environmental conditions that support native salmonids and to develop associations with populations trends. The responsibility for monitoring environmental conditions in the hydro-corridor is clearly the responsibility of the Action Agencies. The responsibility for environmental/habitat monitoring in the tributary and estuarine zone will be jointly shared with established programs like EMAP, PACFISH/INFISH, the OR Plan, WA CMS, and the Lower Columbia River Estuary Plan. Guidelines proposed here are generic and may be appropriate for all applications.

Guidelines: Environmental/Habitat Status Monitoring:

1. Clearly identify the appropriate geographic scales (e.g. province, ecoregion, subbasin, etc.) for sampling.

2. Identify the indicators that will be monitored (e.g. land cover, habitat types, stream temperature, summer base flow, etc.).

3. Describe the protocol for measuring or estimating each indicator.

4. Provide an assessment of the accuracy and precision associated with the proposed methods for estimating indicator values.

5. Describe the known or probable relationships between environmental attributes and salmonid productivity.

6. What is the status of environmental attributes potentially affecting salmonid populations?

7. How do these attributes change through time?

8. Assess the associations between environmental attributes and salmonid population status.

Candidate indicators and suggested precision (CV) are proposed for habitat attributes at the sub-basin scale for annual estimates. All estimates must be unbiased. The following list may be changed (expanded/contracted) as the program is developed further.

Biological Condition (CV < 15%)

- Macroinvertebrate index or assemblage.
- Fish and amphibian assemblage.

Chemical Water Quality (CV < 15%)

- Dissolved oxygen.
- pH.
- Conductivity.
- Nutrients (N and P).
- Solids.
- Pesticide and heavy metal contamination.
- Stream temperature.

Physical Habitat (CV < 25%)

- Channel Form
- Valley Form
- Valley Width
- Geomorphic channel
- Channel Substrate
- Canopy cover
- Large woody debris
- Riparian vegetation
- Land use
- Number of diversions or dams
- Qualitative or quantitative assessment of erosion processes
- Channel modification
- Instream flow

References describing protocols for sampling methods that provide the desired precision include: Attachment 1, Hillman and Giorgi 2002.

Kaufmann P.R. et al. 1999, Thom, B.A. et al. 1999.
ODFW Habitat sampling protocol manuals: Jones & Moore 1999, Moore et al. 1997.
ODEQ Habitat sampling protocol manuals/reports: OPSW 1999, Hubler 2000, Drake 1999, Canale 1998.

Statistically based sampling design for status monitoring

For the system-wide status monitoring program to be both accurate and cost effective, data must be gathered using a rigorous, unbiased sampling design. Sampling designs for spatially explicit data such as habitat surveys are quite complex. The sampling scheme must provide information on the status and trends in abundance, geographic distribution, and productivity of listed anadromous salmonid populations and their habitat at the population to sub-basin scale. The sampling design must estimate these quantities with no bias and known precision. The primary concern is selecting sites across a large spatial area without inflating the variance or biasing the estimate. The traditional sampling approach, simple random samples, has the potential to inflate variance and bias the estimators because the samples can end up clumped in space. The next generation of sampling schemes, stratified random sampling, addresses the spatial distribution of sites if the strata are themselves evenly distributed, but has the potential to introduce hidden biases if the strata are not correctly chosen. In addition, stratification always requires more samples to maintain power across strata. For landscape-scale sampling the ideal system has built-in spatial distribution – sampling on a grid rather than randomly across space.

For grid-based sampling, the question becomes one of grid shape and site selection. Randomly selected points on the grid will generate the least biased estimators, but can suffer the same problem as simple random samples if the grid units are too small relative to the area of interest. There are many grid-based site selection techniques that provide probabilistic samples that generate unbiased estimates of status and trend. The US Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP) is an example of a spatially balanced environmental monitoring site selection process especially designed for aquatic systems. The state of Oregon has successfully implemented an EMAP based sampling program for coastal coho salmon (Moore 2002). The monitoring program as implemented in Oregon is spatially explicit, unbiased, and has reasonably high power for detecting trends. The sample design is sufficiently flexible to use on the scale of multiple large river basins and can be used to estimate the numbers of adult salmon returning each year, the distribution and rearing density of juvenile salmon, productivity and relative condition of stream biota, and freshwater habitat conditions. In addition, the EMAP site selection approach supports sampling at varying spatial extents. All grids are interpenetrating so that a lower density grid is a subset of all higher density grids.

Tributary Restoration Action Effectiveness Research

Although the BiOp does not specify how habitat actions would be monitored, it does identify some general guidelines. For example, it stipulates that the Plan must quantify the effects of habitat actions, must measure changes in life-stage survivals, and must be able to identify the mechanisms by which the actions affect survival. Based on these guidelines, there are three objectives to be considered in developing the AER Plan:

1. Design a monitoring plan to detect life-stage survival changes (e.g., egg-fry, fry-parr, parr-smolt, spawner-adult recruit), local changes in distribution, and changes in physical/environmental conditions.

2. Design a plan to detect cause-and-effect relationships between habitat actions and effects on tributary environment and fish survival rates.

3. Design a plan to assess the effects of habitat actions at different spatial scales (i.e., ESU, population, subpopulation, and reach scales).

In response to the above constraints, a two-pronged approach to habitat restoration action effectiveness research is recommended. The first approach is an extensive, top-down approach that monitors all treatment sites in a given geographic area (watershed to subbasin scale). The second is an intensive, bottom-up approach that monitors a large number of actions of the same class (e.g., riparian plantings or irrigation screening) across a broad, possibly discontinuous, region. Both will monitor a standard set of environmental and biological variables at treatment sites and control sites (chosen to be as similar as is practicable to treatment sites). The project based approach will also monitor variables specific to a given action class (e.g., entrainment on irrigation screens). Both approaches recognize that resource managers cannot control what, when, where, or how habitat actions are implemented and allow for the loss of control units, by having a large number of control sites. In addition, the watershed scale approach allows for multiple treatment effects.

As noted, the watershed scale approach is designed to monitor all habitat actions within a watershed or subbasin. Although this may seem like overkill, there is no existing information that allows an assessment of the minimum number of each type of habitat action that should be monitored to measure a statistically significant or biologically important change in habitat conditions and fish survival. If all habitat actions are monitored within a few pilot watersheds, those data can be used to estimate the minimum number (sample size) of each habitat type required to identify treatment effects reliably. Recommend sample sizes for the remaining watersheds within the basin can then be generated.

Although the watershed scale approach should be able to quantify the effects of habitat actions and will likely be sensitive enough to measure changes in life-stage survivals, there is no guarantee it will be able to identify clearly the mechanisms by which the actions affect changes in survival. This is potentially disturbing not only because it may not be possible to trace the effects of habitat actions through various components of the ecosystem, but under the influence of multiple treatment effects, it may not even be possible to link life-stage survival changes to specific habitat actions. Therefore, by itself, the watershed scale approach may not completely satisfy the requirements of the BiOp.

The NMFS BiOp requires the Action Agencies (AA) to assess the effects of tributary habitat actions on the survival of listed stocks. As described above, the tributary AER plan recommends two different but related programs to detect the effects of the habitat actions in tributary streams. The project based program is a bottom-up approach that addresses the effects of specific classes of habitat actions on fish and their environment. This approach seeks to identify mechanisms that explain cause-and-effect relationships within each class of habitat actions. As such, it will also monitor additional variables beyond those used in the watershed scale approach (e.g., entrainment in irrigation screens, or macro-invertebrates in riparian planning areas). An implicit assumption of this approach is that this program would be implemented by knitting together a substantial number of individual AER projects.

The watershed scale approach, on the other hand, focuses on how the suite of existing and future habitat actions can be used to address the requirements of the BiOp. This approach assumes that different classes of habitat actions will occur within a given stream or watershed. This approach is applicable where there is little to no control over how, when, or where habitat actions are implemented.

Watershed Scale Approach
The watershed scale approach is designed to address the effects of both existing (ongoing) activities and new or future activities on listed anadromous salmonids. Like the project based approach, this approach accepts the implementation of habitat actions at any time and does not assume that researchers can control where or how the actions are implemented.

The watershed scale approach has five parts:

1. Identify habitat actions that are or have been implemented;
2. Classify the landscape within the entire region of potential monitoring;
3. Present hypotheses for the effect of actions;
4. Collect data within a stratified scheme that includes:
   - Monitoring the same subset of indicators at all treatment (action) and control sites;
   - Monitoring a consistent set of sub-population and biological productivity indicators at a number of key informative locations;
5. Estimate the magnitude of effects on fish associated with habitat actions (pathways 1 and 2 in Figure 3.1).

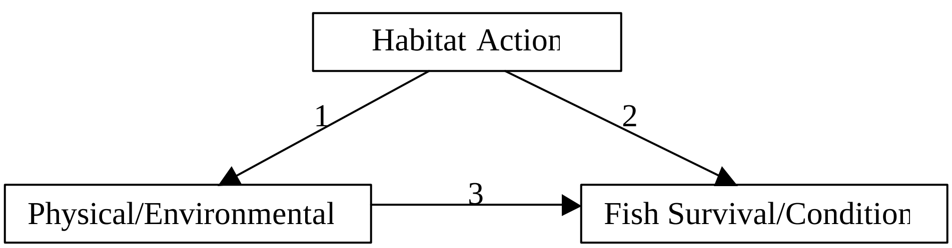


Figure 3.1. Direction of effects from habitat action to changes in the physical/environmental conditions and biological conditions.

Experimental Design

<u>Classification of watersheds</u>
Prior to conducting action effectiveness research, it will be necessary to classify the ecologic and geologic characteristics of the landscape supporting distinct sub-populations.[7] Investigators

[7] As noted earlier, "sub-population" denotes the smallest geographic or population unit where life-stage survival rates can be estimated independently. The Technical Recovery Team is charged with designating Distinct Population Segments.

should use the classification protocols identified in Table 3.1. Attachment 1 describes methods for measuring classification variables.

Detecting changes in survival due to habitat actions

The following guidelines for detecting survival changes are based on a couple of straight-forward considerations. First, the main driver for effectiveness monitoring is changes in survival rates. Second, as noted above, below the sub-population scale it makes little sense to try to measure survival rates. To make a difference in adult abundance over time (or ?, recruits-per-spawner, etc.), changes in life-stage survival rates must eventually translate into changes in survival or growth rates for adults. Any tributary action that only affects a portion of the sub-population will have a proportionately small effect on population growth rates. Although juveniles are generally thought to migrate downstream on net (e.g., Bjornn 1978), they are highly mobile. Therefore, almost any action, to be effective at increasing adult numbers, must affect most or all of the target sub-population.

As described earlier, there are a few exceptions to this general rule. One would be measurements of localized effects of actions on fish distribution and on the environment, which is covered in later sections. Another might be measuring the survival effects of actions that affect only a portion of the population's spawning area. Here, egg-fry survival can be monitored at the reach scale. Finally, multiple treatment effects at the sub-population scale may force us to conduct effectiveness research at smaller spatial scales using biological or environmental indicators other than survival rates.

To estimate life-stage specific survival rates, estimates of life-stage specific abundance (mark-recapture studies usually avoid this requirement) are needed. These biological variables are summarized in Table 3.4. Adult counts for most populations are conducted at weirs or by counting redds, and (at least for chinook) are believed to cover most of the spawning reaches for most stocks. In combination with annual, sub-population-specific age-at-return estimates, these can be used to estimate recruits-per-spawner. The spatial coverage could be expanded, if needed, to be regarded as a near-census; however, lacking quantitative assessments of detectability, miss-counts, etc, this approach is not recommended.

For juveniles, parr would be tagged in rearing areas each year, but probably not for the entire length of the area. Tagging more than 1,000-3,000 parr per population does little to increase the precision of parr-to-smolt survival estimates (at least for Snake populations; numbers will be larger for the Wenatchee and John Day). The results from this effort would be estimates of parr survival to the first dam they encounter with PIT tag detectors (LGR, MCN, or JDA). Details of survival rate estimates can be found in Paulsen and Fisher (2001) and references therein.

Table 3.4. Biological variables to be monitored for tributary habitat status and effectiveness research.

Biological data type & life stage	Geographic Scale	Temporal scale-frequency	Data collection methods	Spatial locations	Use in status monitoring	Use in effectiveness monitoring	Comments
Adults: **Redd counts**	Sub-population	Annual during spawning return season (once for single pass, multiple for multi-pass)	Single-pass or repeated ground counts (repeated preferred)	In known spawning areas (effectiveness), stratified-random (status)	Trends in spawner abundance over time	Differences in trends or R/S between sub-populations with lots of treatments vs. those with few or none	Precise location of redds may be useful for some actions (e.g., reduction of sediment in spawning gravel)
Weir counts	Sub-population	Annual during spawning return season	Counts at weirs	At bottom of sub-population watershed	Trends in spawner abundance over time	Ditto	Mark (tagging @ weir) and recapture (re-sight or carcass recovery) would be useful to estimate trap efficiency & efficiency of redd counts
Age-at-return	Sub-population	Annual during spawning return season	Scale samples, sex, and size at weirs or carcass recoveries	Spawning areas & bottom of watershed	Trends in R/S over time	Ditto	Age-at-return needed for "recruits" part of R/S.
Hatchery fraction	Sub-population	Annual during spawning return season	Adipose fin clipped or intact at weirs or in carcass recoveries	Ditto	Trends in hatchery fraction over time	Trends in hatchery fraction over time	Will need to get wild-origin returns, may be useful to assess effectiveness of hatchery fish spawning in wild.
Parr	Reach	Annual, during low flows	Snorkel surveys	Treatment (all project locations) and similar control reaches (effectiveness), stratified random (status)	trends in parr density or parr per spawner over time	Differences in trends or parr per spawner and/or parr density between sub-populations with lots of treatments vs. those with few or none	IDFG has abandoned parr density surveys for most ISS streams due to low precision. Back-checking against screw trap data will be essential.
	Sub-population	"Continuous" - see comment	Screw trap	At bottom of sub-population watershed	trends in parr emigrants or parr per spawner over time	Differences in trends or parr per spawner and/or parr emigrant abundance between sub-populations with lots of treatments vs. those with few or none	Trap efficiency estimates will be crucial, as will running traps as close to 24/7/365 as is practical.
Smolts:	Sub-population	"Continuous" - see comment	Screw trap	At bottom of sub-population watershed	trends in smolt emigrants or smolts per spawner over time	Differences in trends or smolts per spawner and/or smolts emigrant abundance between sub-populations with lots of treatments vs. those with few or none	Trap efficiency estimates will be crucial, as will running traps as close to 24/7 in springtime as is practical.

Table 3.4 also mentions two potential measures that are more problematic: parr density and parr abundance. While parr density surveys were conducted in Idaho Supplementation Study streams for 10 to 15 years, they have recently been discontinued by IDFG since the resulting estimates were imprecise, although they continue for some ISS organizations. The utility of these techniques depends on the research objectives and the questions the methods intend to answer. For example, looking for reliable estimates of juvenile abundance that can be compared across populations will at best require intensive, intrusive, sophisticated sampling efforts, and at worst may be impossible. If, on the other hand, the objective is to see if the spatial distributions of juveniles change over time in response to habitat actions – with fish moving upstream from former passage barriers or congregating in areas with improved in-stream habitat – this can probably be achieved with comparatively modest sampling effort. Careful, systematic testing of parr density estimates – including both precision, accuracy, and utility for status and effectiveness monitoring – should be an important component of the pilot studies.

Detecting changes in local fish distribution

Different action types probably will have differing effects on local fish distributions, as shown in Table 3.5. Monitoring activities are divided into two categories, since the intensity (and hence the costs) of the categories will be quite different, with changes in presence/absence due to actions being substantially less expensive than changes in juvenile densities. As noted above, the intensity of the effort depends on the objectives. In particular, monitoring to enable analysis of changes in parr density between sites over time will be very costly, and may be impossible as a practical matter.

Table 3.5. Action types and assessments as to effects on presence-absence and density.

Action Type	Change in presence-absence	Increase in current (non-zero) density
Instream flows	No, unless low flow is very low	Maybe
Nutrient additions	No	Maybe, if juveniles leave because of limited food supply
Barrier removal	Yes	No, unless current barriers are partially passable
Diversion screens	No	No
Sediment reduction	Maybe, if treated area is so heavily embedded that spawning is impossible	Maybe – removing sediment may increase spawning usage
Riparian buffers	No, unless area is currently uninhabitable due to lack of cover	Maybe – treatment may attract juveniles to improved habitat
Instream structures	No, unless area is currently uninhabitable due to lack of structures	Maybe – treatment may attract juveniles to improved habitat
Water quality improvements	No, unless temperature or chemicals render area uninhabitable	Maybe – treatment may attract juveniles to more hospitable habitat

Detecting changes in physical/environmental conditions

The watershed scale approach requires investigators to measure specific physical/environmental indicators in both treatment and control areas (Table3. 6). Flow and water temperature would be sampled continuously at fixed gaging stations located in the lower reaches of each population. In some cases, where actions are expected to have substantial effects on these variables, sampleing upstream and downstream from treatment and control reaches is needed as well. Similar spatial density would probably be needed for other water quality measures. The remaining variables, in Table 3.6, would be collected during treatment and control reach sampling similar to the juvenile sampling (previous section). The detailed habitat surveys would be conducted at the same times and locations as the surveys for juveniles. Methods for measuring physical/environmental indicators are described in Attachment 1.

Table 3.6. Physical/environmental indicator variables to be monitored for tributary habitat effectiveness research. Table is modified from Hillman and Giorgi (2002).

General characteristics	Specific indicators	Example protocols	Sampling frequency
Water Quality	MWMT/MDMT	Zaroban (2000)	Continuous (May -Sept)
	Turbidity	OPSW (1999)	Annual
	Depth fines	Schuett-Hames (1999)	Annual
	pH	OPSW (1999)	Annual
	DO	OPSW (1999)	Annual
	Nitrogen	OPSW (1999)	Annual
	Phosphorus	OPSW (1999)	Annual
Habitat Access	Road crossings	Parker (2000); WDFW (2000)	Annual
	Diversion dams	WDFW (2000)	Annual
	Fishways	WDFW (2000)	Annual
Habitat Quality	Dominant substrate	Peck et al. (2001)	Annual
	Embeddedness	Peck et al. (2001)	Annual
	LWD (pieces/km)	BURPTAC (1999)	Annual
	Pools per kilometer	Hawkins et al. (1993); Overton et al. (1997)	Annual
	Pool quality	Platts et al. (1983)	Annual
	Off-channels habitats	WFPB (1995)	Annual
Channel condition	Width/depth ratio	Peck et al. (2001)	Annual
	Wetted width	Peck et al. (2001)	Annual
	Bankfull width	Peck et al. (2001)	Annual
	Bank stability	Moore et al. (2002)	Annual
Riparian Condition	Structure	Peck et al. (2001)	Annual
	Disturbance	Peck et al. (2001)	Annual
	Canopy cover	Peck et al. (2001)	Annual
Flows and Hydrology	Streamflow	Peck et al. (2001)	Continuous
Watershed Condition	Watershed road density	WFC (1998); Reeves et al. (2001)	5 years
	Riparian-road index	WFC (1998)	5 years
	Land ownership	n/a	5 years
	Land use	n/a	5 years

Project Based Approach

The watershed scale approach is intended to assess the effects of *all* habitat actions that may affect a given sub-population or subbasin. These effects include both localized (reach scale) environmental and juvenile density changes, and sub-population scale effects on salmonid survival. However, Action 183 also calls for an assessment of the effects of classes of actions on listed salmonids (Table 3.5). While the watershed scale approach will provide useful data for this action-class assessment (since most action or treatment sites can be classified into one of the eight action categories), two problems may not be covered very well using watershed scale methods. First, there is no guarantee that all eight action types will have a sufficient number of treatment/control site pairs to have a reasonable likelihood of detecting their effects. Second, while the list of variables to be monitored in the watershed scale approach (Tables 1, 4, and 6) are those most likely to influence salmonid survival and local abundance, the lists are not exhaustive, and may exclude important local effects of some action types; additionally they may not uncover the mechanisms by which actions affect survival.

So, in parallel with the extensive, watershed scale approach, this plan calls for an intensive, project based approach, focused primarily on the local, reach-scale effects of actions. Under the project based approach, instead of monitoring all habitat actions and paired controls in a given subbasin, the program calls for monitoring large numbers of actions in a given category, across a broad geographic area. As with the watershed scale approach, to facilitate comparisons across projects, the project based approach uses the same classification variables and protocols (Table 3.1), reach-scale and sub-population scale biological variables (Table 3.4), and environmental variables (Table 3.6). Additional environmental and biological phenomena may be monitored to increase the probability of detecting the effects of each class of action, and help uncover the mechanisms by which actions affect changes in fish populations.

As with the watershed scale approach, it is important to note a number of potential problems at the outset. *First*, this is not an ideal experiment, in the sense that treatment sites will not be chosen at random. Instead, treatment locations will be chosen by regional managers, because they believe that the sites have problems that can be fixed via specific habitat actions (e.g., irrigation screening, riparian plantings, etc.). Indeed, in most cases the managers have already chosen these sites and are implementing restoration projects with no monitoring in place to detect their effects. This will limit the degree to which results generalize to locations treated in future, and will require attention to statistical details to be able to make useful inferences from the results. *Second*, both treatment and control sites may be "lost" over the course of the studies due to new habitat actions or other anthropogenic activity. *Third*, given the unprecedented scope of the research, it is very difficult to make useful predictions about the number of treatment/control pairs that will be needed to detect biologically meaningful effects. *Fourth*, attributing sub-population scale survival changes (as distinct from reach-scale environmental and local abundance changes) to any given class of actions will be very difficult, since most sub-populations will have more than one action type.

The first problem is that this cannot be an ideal experiment, in the sense that treatments (reaches or sites with habitat actions) are not chosen at random. In the present case, while the non-random assignment of treatments increases the difficulty in drawing rigorous conclusions about the effects of habitat actions on fish survival and environmental conditions, it is not necessarily an impossible task. Firstly, control sites with no ongoing habitat actions will be chosen to match, as closely as is practical, the treatment sites where actions are occurring or are planned. Since the classification variables have been chosen to cover many important influences on fish behavior and survival, this should allow matching treatment and control sites. Secondly, unlike efforts to assess the effects of disasters (e.g., major floods, chemical releases) a large number of treatment and control sites will be used, and in cases where actions are planned but not yet implemented the collection of "before" data for a subset of the treatment sites is possible. Thirdly, the treatment-control pairs will be distributed widely across the interior Columbia River basin. This should provide substantial contrast in classification variables, environmental conditions, and biological responses, increasing the likelihood of successfully assessing the effects of treatments on the response variables of interest.

The points above address localized, reach-scale environmental or population effects. A second objective for the project based approach is to assess the sub-population effects of classes of actions. Because many sub-populations will have more than one class of action ongoing in concert, the ability to measure effects – survival rates, recruits per spawner, etc. – at this scale will depend largely on the luck of the draw. If sub-populations with only a single class of action are chosen for monitoring, then the solution is straight-forward. If not, then the opportunistic approach to the implementation of a project based monitoring program will need to be modified so that subbasin scale restoration planning is tightly integrated with the monitoring program. While this last suggestion is only introduced as a remedy to the worst-case scenario, in fact this approach would remove most of the design difficulties identified above (i.e., random assignment of treatment and control).

If the constraints noted above were reduced, how might this program proceed in a way that would fit with subbasin planning and other regional processes? One product of subbasin planning will be, in effect, a list of tributary habitat sites thought to require treatment, and estimates of treatment costs. Suppose, instead of treating all sites on the list, the same total budget was used to do maximal treatment on half of the sites, randomly selected from the list, while leaving the rest alone. The treatments would, of course, be accompanied by the monitoring and evaluation activities described in previous sections. This would meet the requirements outlined above, while still resulting, it is hoped, in substantial improvements for affected species.

E. Current Tributary Monitoring Efforts, and Gaps Assessment to meet BiOp Needs.

General description of current projects and programs addressing these needs.

At the ecosystem scale, there have been several comprehensive one-time data collection efforts. For example, NWPPC Subbasin Assessments require the compilation of some, but not all, data layers recommended by the FCRPS BiOp status monitoring program. In addition, the Interior Columbia Ecosystem Management Project (USFS/BLM) has assembled a large collection of spatial data layers highly relevant to ecosystem scale status monitoring. However, both of these assessments are not meant to be ongoing and periodic, rather they are one-time data gathering efforts to support long-term land use and management planning. As such, they potentially can form the first round of ecosystem scale status monitoring data collection, but an ongoing program would need to be established. A plan for implementing status monitoring at this scale is presented in the following section.

At the subbasin scale, there are numerous state and tribal annual sampling programs targeting salmonid fishes, and to some extent their habitat, distributed across the Columbia River basin. For a summary of these programs see the following tables (Table 3.7 – 3.12) of the status of status monitoring programs. While there are a large number of status monitoring programs currently underway in the Columbia River basin, there is little coordination of these programs across administrative boundaries, and as such, the resulting status monitoring data may not be adequate to address regional, or basin-wide management needs. The subbasin scale status monitoring program outlined in this document was generated to meet the basin-wide management needs in that it attempts to unify the approaches to the monitoring of status and trends of salmonid populations and their tributary habitat environment. The plan to implement such a status monitoring program is presented in the following section; in particular, the staged implementation of pilot projects, and the mechanisms by which a large scale cooperative program could be developed by building on existing status monitoring programs.

Assessing the gaps between FCRPS BiOp status monitoring program guidelines and currently existing programs.

A critical first step in the FCRPS BiOp status monitoring program development is a more thorough assessment of the gaps that exist between the proposed status monitoring program and the myriad currently implemented status monitoring programs. To this end, a draft survey instrument has been developed that could inform the gaps assessment effort (Table 13). A gaps assessment would necessarily have three components: (i) a compilation of existing programs, (ii) an alignment stage whereby the list developed in (i) is compared to the FCRPS BiOp status monitoring guidelines, and (iii) an assessment of the actual and functional differences. A regional technical coordination group could undertake these tasks as a first step toward integrating and assessing existing status monitoring programs and mandates. Tasks (i) and (ii) are relatively straightforward data collection and organization efforts; however, task (iii) requires a complete working knowledge of the FCRPS BiOp status monitoring program's intention as well as that of each existing status monitoring program that appears to match the BiOp guidelines. That is to say, due to differing programmatic intents, existing status monitoring programs may appear to directly meet aspects of the FCRPS BiOp status monitoring program's needs, yet be functionally so different that almost no overlap actually exists. For example, if the spatial or temporal resolution of indicators and protocols differ substantially between two monitoring programs, the information, while similar in name, is not mutually useable. In general, sampling done at a coarser spatio-temporal scale than specified by the FCRPS BiOp status monitoring program will not be of direct utility. However, if on the scale of individual samples, the field protocols are similar, and the statistical basis for sampling in both cases allows for sampling schemes at multiple scales (e.g., the interpenetrating grids of EPA's EMAPdesigns), then coarse scale sampling can form part of a finer scale sampling program. While such a situation would be an ideal compromise between multiple programs with independent, seemingly mutually exclusive objectives, the coordination required for implementation and subsequent data analysis would be considerable.

Gaps Analysis

The first step in the development of a basin-wide status monitoring program is the comprehensive assessment of current programs, their ability to meet regional performance standards, and the resulting programmatic gaps. For the status monitoring program in general, and the subbasin scale pilot projects in particular, a targeted gaps assessment should be immediately undertaken. The ecosystem and subbasin scale status monitoring program performance standards and requirements are presented here as defined by the needs of the NMFS 2000 FCRPS BiOp. Therefore, the next step, a compilation of current status monitoring efforts, can be initiated. A regional technical coordination group could undertake these tasks as a first step toward integrating and assessing existing status monitoring programs and mandates. Ultimately, the gaps between needs and current programs can be modified as the regional needs for a status monitoring program are better defined, but these discussions will in no way interfere with the assessment of current efforts.

Table 3.7: Survey of Fall Chinook Monitoring

		Survey of Fall Chinook Monitoring								Habitat		
		adults	location	data source	comments	juv	location	data source	comments	biological condition	chemical water quality	physical habitat
ID	L Salmon R.	redd count								BPA 1991073. ShoBan, Nez Perce habitat monitoring associated with projects. USFS has main responsibility in anadromous zone. No systematic habitat sampling. PACFISH/INFISH watershed health assessment on some USFS/BLM lands.		
	SF Salmon R.											
	MF Salmon R.											
	U Salmon R.											
	Lemhi R.											
	Clearwater River					smolt counts	Clearwater River Trap	FPC's website	mortality, descaling, incidental catch, mark recapture			
	Salmon River					smolt counts	Salmon River Trap at Whitebird	FPC's website	mortality, descaling, incidental catch, mark recapture			

WA	Yakima R.	redd count		Streamnet(1983-1992)*, Streamnet(1959-1984)**	*data quality fair for 1982-1992, **sampling by fixed wing aerial					No systematic habitat sampling. SSHIAP and sub-basin assessements to be done once. WDE water sampling index project
		total live		Streamnet(1983-1991)*, Streamnet(1983-2000)**	*mixed production est. based on peak count or redd expansion, **dam counts for jack or subadult of mixed production	total live fish	Chandler Dam	Streamnet(1983-2000)*	*smolt est. based on dam counts	
	Wenatchee R.					RIS count				
	Entiat R.					RIS count				
	Methow R.					RIS count				
	Snake River					smolt counts	Snake River Trap at Lewiston	FPC's website	mortality, descaling, incidental catch, mark recapture	
	Snake River					smolt counts, passage index	Lower Monumental Dam	FPC's website	mortality, descaling, incidental catch, mark recapture	
	Snake River					smolt counts, passage index	Lower Granite Dam	FPC's website	mortality, descaling, incidental catch, mark recapture	
	Columbia River					smolt counts, passage index	Rock Island Dam	FPC's website	mortality, descaling, incidental catch, mark recapture	
	Columbia River					smolt counts, passage index	McNary Dam	FPC's website	mortality, descaling, incidental catch, mark recapture	

OR	Deschutes R.	redds/mile		Streamnet(1974-1999)*	*actual physical counts as observed by helicopter					
		total live fish		Streamnet(1957-1999)*, Streamnet(1977-	*actual physical counts, **est. based on peak count or redd expansion					
	John Day R.	redds								Scattered habitat surveys in upper basins
	Umatilla R.	redds/live count		Subbasin report*	*native pop. gone, stock reintroduced in 1982					
	Grande Ronde R.	redds	mainstem	Subbasin report (Bugert et al. 1989-1991; Mendel 1992; Seidel et al. 1987-1988) 1986-1991, (A.P. Garcia, USFWS, Ahsahka, Idaho; unpublished						
						smolt counts	Grande Ronde River Trap	FPC's website	mortality, descaling, incidental catch, mark recapture *undefined run type	
	Imnaha R.	redds	mainstem	Subbasin report (from Garcia 2000; Mundy and Witty 1998) 1964-1999.						
						smolt counts	Grande Ronde River Trap	FPC's website	mortality, descaling, incidental catch, mark recapture *undefined run type	
	Snake River					smolt counts, passage index	Little Goose Dam	FPC's website	mortality, descaling, incidental catch, mark recapture	
	Columbia River					smolt counts, passage index	John Day Dam	FPC's website	mortality, descaling, incidental catch, mark recapture	
	Columbia River					smolt counts, passage index	Bonneville Dam	FPC's website	mortality, descaling, incidental catch, mark recapture	

Table 3.8: Survey of Spring/Summer Chinook Monitoring

		Survey of Spring /Summer Chinook Monitoring								Habitat		
		adults	location	data source	comments	juv	location	data source	comments	biological condition	chemical water quality	physical habitat
ID	L Salmon R.	redds				LGD count				BPA 1991073. ShoBan, Nez Perce habitat monitoring associated with projects. USFS has main responsibility in anadromous zone. No systematic habitat sampling. PACFISH/INFISH watershed health assessment on some USFS/BLM lands.		
	SF Salmon R.	redds/ live count		NMFS abundance database		trap						
	MF Salmon R.	redds/ live count		NMFS abundance database		trap						
	U Salmon R.	redds/ live count	mainstem	NMFS abundance database, Steamnet- IDFG 1954-1997		trap		NMFS abundance database				
	Lemhi R.	spawner/ recruit	mainstem	Streamnet- Petrosky, C.E unpublished data. 1957-1995								
		redds	mainstem	NMFS abundance database, Steamnet- IDFG 1952-1997		trap		NMFS abundance database				
	Clearwater River					smolt counts	Clearwater River Trap	FPC's website	mortality, descaling, incidental catch, mark recapture			
	Salmon River					smolt counts	Salmon River Trap at Whitebird	FPC's website	mortality, descaling, incidental catch, mark recapture			

WA	Yakima R.	redds		Streamnet(1962-1970)*, NMFS Abundance database	*sampling by fixed wing aerial					No systematic habitat sampling. SSHIAP and sub-basin assessements to be done once. WDE water sampling index project
		redds/mile		Streamnet(1968-1992)*	*data quality good for 1968-1992, sampling method by ground					
		total live fish		Streamnet(1954-1982)*, Streamnet(1983-2000)**, Streamnet(1983-2000)***, NMFS Abundance Database	*Dam counts, **dam counts, ***dam sounts of jacks or subadults	total live fish	Chandler Dam	Streamnet(1959 2000)*, Streamnet(1986 1997)**	*smolt est. based on dam counts, **sub-yearling (age 0) est. based on dam counts	
	Wenatchee R.	redd counts		Streamnet(1956-1996)*, Streamnet (1959-1990)**, NMFS Abundance database***, WDFW****	*sampling by fixed wing aerial, **sampling method by ground, ***undefined run type, ****contact Tom Cooney NMFS					

	live counts	Rock Island Dam	Streamnet(1975-1995)*, Streamnet(1954-1995)**, NMFS Abundance database***	*adult est. based on dam counts, **jack est. based on dam counts, est. based on peak count or redd expnsion, includes hatchery fish in nat. spawn est., excludes harvest and dam counts 10% prespawn mort., ***undefined run type	RIS count			

Entiat R.	redd counts		Streamnet(1959-1994)*, NMFS Abundance database**, WDFW***	*sampling method by ground, **undefined run type, ***Contact Tom Cooney					
	live counts		Streamnet(1955-1995)*, NMFS Abundance database**	*est. based on peak count or redd expansion, includes hatchery fish in nat. spawn est., excludes harvest and 10% mort., **undefined run type	RIS count				
	fish/mile		Streamnet(1962-1991)*	*data quality poor for 1984-1991, sampling method by ground					

Methow R.	redd counts	Wells dam(a)	Subbasin report(1962-1999)a, Streamnet(1956-1996))*, Streamnet(1960-1993)**, NMFS Abundance database***, WDFW****	*sampling by fixed wing aerial, **sampling method on ground, ***undefined ryn type, ****contact Tom Cooney					
	live counts	Wells dam(a)	Subbasin report(1962-1999)a,Streamnet(1963-1996)*, Streamnet(1977-1991)**, Streamnet(1957-1991)***, NMFS Abundance database****	*mixed production, est. based on peak count or redd expansion, **adults and jacks sampled by fixed wing aerial, count is product of total number of reddsX3.1fish/redd, ***est. based on	RIS count				
	fish/mile		Streamnet(1960-1995)*,	*data quality is good for 1977-					
Snake River					smolt counts	Snake River Trap at Lewiston	FPC's website	mortality, descaling, incidental catch, mark recapture	

	Snake River					smolt counts, passage index	Lower Monumental Dam	FPC's website	mortality, descaling, incidental catch, mark recapture	
	Snake River					smolt counts, passage index	Lower Granite Dam	FPC's website	mortality, descaling, incidental catch, mark recapture	
	Columbia River					smolt counts, passage index	Rock Island Dam	FPC's website	mortality, descaling, incidental catch, mark recapture	
	Columbia River					smolt counts, passage index	McNary Dam	FPC's website	mortality, descaling, incidental catch, mark recapture	

OR	Deschutes R.	total live fish		Streamnet(1977-1999)*, Streamnet(1977-1999)**, Streamnet(1977-1999),	*Adult/jack determined by scale analysis/CWT returns, **Adult/jack					
	John Day R.	redds	mainstem(a), granite creek(b)	Subbasin report, 1959-2000a, 1962-1986 (Scribner et al. 1993)b, total 1987-1999 (Theiss, Yakama Indian Nation personal	*undefined run type					Scattered habitat surveys in upper basins
		total live fish		Streamnet(1970-1997)*, NMFS Abundance database**	est. derived from the number of redds observed X a 3 fish per redd					
		spawner/recruit est.		Streamnet(1959-1995)						
	Umatilla R.	live count/ redd		Subbasin report (Contor et al., 1997;1998; 2000	*native pop. gone, Spring Chinook reintroduced in					
		total live fish		NMFS Abundance database*	*undefined run type					

	Grande Ronde R.	redds	Mainstem, trib.	Subbasin report, (P. Kinery, ODFW, personal communication)1988-2000, (D. Bryson, NPT, personal communication,	*undefined run type					
		total live fish		Streamnet(1986-1993)*, Streamnet(1964-1990), NMFS Abundance database**	*total escapement est., **undefined run type	smolt counts	Grande Ronde River Trap	FPC's website	mortality, descaling, incidental catch, mark recapture *undefined run type	
		Spawners								

	Imnaha R.	spawner/ recruit	Mainstem, trib.(a)	Subbasin report, (Beamesderfer, 1997) 1939-1990a, Streamnet(1949-1995)						
		redds/dam count		Streamnet(1949-1999), NMFS Abundance database*	*undefined run type					
		total fish		NMFS Abundance database*	*undefined run type	smolt counts	Imnaha River Trap	FPC's website	mortality, descaling, incidental catch, mark recapture	
	Snake River					smolt counts, passage index	Little Goose Dam	FPC's website	mortality, descaling, incidental catch, mark recapture	
	Columbia River					smolt counts, passage index	John Day Dam	FPC's website	mortality, descaling, incidental catch, mark recapture	
	Columbia River					smolt counts, passage index	Bonneville Dam	FPC's website	mortality, descaling, incidental catch, mark recapture	

Table 3.9: Survey of Sockeye Monitoring

		Survey of Sockeye Monitoring								Habitat		
		adults	location	data source	comment	juv	location	data source	comments	biological condition	chemical water quality	physical habitat
ID	L Salmon R.	-				-				BPA 1991073. ShoBan, Nez Perce habitat monitoring associated with projects. USFS has main responsibility in anadromous zone. No systematic habitat sampling. PACFISH/INFISH watershed health assessment on some USFS/BLM lands.		
	SF Salmon R.	-				-						
	MF Salmon R.	-				-						
	U Salmon R.	LGD				LGD						
	Lemhi R.	-										
	Clearwater River					smolt counts	Clearwater River Trap	FPC's website	mortality, descaling, incidental catch, mark recapture			
	Salmon River					smolt counts	Salmon River Trap at Whitebird	FPC's website	mortality, descaling, incidental catch, mark recapture			
WA	Yakima R.	-								No systematic habitat sampling. SSHIAP and sub-basin assessements to be done once. WDE water sampling index project		
	Wenatchee R.	-										
		total live fish		Streamnet(1960-1996)*	adult and jack est. based on dam counts							
	Entiat R.	-										
	Methow R.	-				-						
	Snake River					smolt counts	Snake River Trap at Lewiston	FPC's website	mortality, descaling, incidental catch, mark recapture			
	Snake River					smolt counts, passage index	Lower Monumental Dam	FPC's website	mortality, descaling, incidental catch, mark recapture			
	Snake River					smolt counts, passage index	Lower Granite Dam	FPC's website	mortality, descaling, incidental catch, mark recapture			
	Columbia River					smolt counts, passage index	Rock Island Dam	FPC's website	mortality, descaling, incidental catch, mark recapture			
	Columbia River					smolt counts, passage index	McNary Dam	FPC's website	mortality, descaling, incidental catch, mark recapture			

OR	Deschutes R.	total live fish		Streamnet(1956-1998)*	dam counts					
	John Day R.	-				-				Scattered habitat surveys in upper basins
	Umatilla R.	-								
	Grande Ronde R.	-				smolt counts	Grande Ronde River Trap	FPC's website	mortality, descaling, incidental catch, mark recapture	
	Imnaha R.	-				smolt counts	Imnaha River Trap	FPC's website	mortality, descaling, incidental catch, mark recapture	
	Snake River					smolt counts, passage index	Little Goose Dam	FPC's website	mortality, descaling, incidental catch, mark recapture	
	Columbia River					smolt counts, passage index	John Day Dam	FPC's website	mortality, descaling, incidental catch, mark recapture	
	Columbia River					smolt counts, passage index	Bonneville Dam	FPC's website	mortality, descaling, incidental catch, mark recapture	

Table 3.10: Survey of Steelhead Monitoring

		Survey of Steelhead Monitoring								Habitat		
		adults	location	data source	comments	juv	location	data source	comments	biological condition	chemical water quality	physical habitat
ID	L Salmon R.	LGD count								BPA 1991073. ShoBan, Nez Perce habitat monitoring associated with projects. USFS has main responsibility in anadromous zone. No systematic habitat sampling. PACFISH/INFISH watershed health assessment on some USFS/BLM lands.		
	SF Salmon R.					trap						
	MF Salmon R.											
	U Salmon R.											
	Lemhi R.											
	Clearwater River					smolt sample counts	Clearwater River Trap	FPC's website	mortality, descaling, incidental catch, mark recapture			
	Salmon River					smolt sample counts	Salmon River Trap at Whitebird	FPC's website	mortality, descaling, incidental catch, mark recapture			

WA	Yakima R.	total live fish		Streamnet(1980-1994)*, NMFS Abundance database	*dam counts	total live fish	Chandler Dam	Streamnet(1960-2000)*, Streamnet(1986-1997)**	*smolt est. based on dam counts, **sub-yearling (age 0) est. based on dam counts	No systematic habitat sampling. SSHIAP and sub-basin assessements to be done once. WDE water sampling index project
	Wenatchee R.	dam				yes				
	Entiat R.	dam				yes				
	Methow R.	redd counts		Streamnet(1982-1991)*	*sampling method by air/ground combination					
		dam counts, total live fish	Wells dam(a)	Subbasin reporta, Streamnet(1991,1992)*	*adult est. based on dam counts	yes				
	Snake River					smolt counts	Snake River Trap at Lewiston	FPC's website	mortality, descaling, incidental catch, mark recapture	
	Snake River					smolt counts, passage index	Lower Monumental Dam	FPC's website	mortality, descaling, incidental catch, mark recapture	
	Snake River					smolt counts, passage index	Lower Granite Dam	FPC's website	mortality, descaling, incidental catch, mark recapture	
	Columbia River					smolt counts, passage index	Rock Island Dam	FPC's website	mortality, descaling, incidental catch, mark recapture	
	Columbia River					smolt counts, passage index	McNary Dam	FPC's website	mortality, descaling, incidental catch, mark recapture	

OR	Deschutes R.	redds/dam count								
		total live fish		Streamnet(1977-1998), NMFS Abundance database*	*undefined run type					
	John Day R.	redds		NMFS Abundance database*	*undefined run type					Scattered habitat surveys in upper basins
		total live		NMFS Abundance database*	*est. fish count, undefined run type,					
	Umatilla R.	trap/ redds	Birch creek, Trib.	Subbasin report (T. Bailey, ODFW , personal communication, January 2001), Contor et al, 1997.						
		dam count	three mile dam							
		total live fish		Streamnet(1966-2000)*, Streamnet(2000), NMFS Abundance database**	*counts done by actual trap count 1988+, **undefined run type					
	Grande Ronde R.	redds		NMFS Abundance database*	*undefined run type					
		total live fish		NMFS Abundance database*	*undefined run type	smolt counts	Grande Ronde River Trap	FPC's website	mortality, descaling, incidental catch, mark recapture	
		spawner	17 tribs.	Subbasin report (Data from Grande Ronde Watershed District Files) 1988-						

	Imnaha River	redds/weir counts	Camp creek	Subbasin report, Steamnet,ODFW 1965- 2000						
						density	Subbasin report, ODFW, 1992-2000			
						smolt counts	Imnaha River Trap	FPC's website	mortality, descaling, incidental catch, mark recapture	
	Snake River					smolt counts, passage index	Little Goose Dam	FPC's website	mortality, descaling, incidental catch, mark recapture	
	Columbia River					smolt counts, passage index	John Day Dam	FPC's website	mortality, descaling, incidental catch, mark recapture	
	Columbia River					smolt counts, passage index	Bonneville Dam	FPC's website	mortality, descaling, incidental catch, mark recapture	

Table 3.11: Survey of Trout Monitoring

		Survey Bull Trout Monitoring								Habitat		
		adults	location	data source	comments	juv	location	data source	comments	biological condition	chemical water quality	physical habitat
ID	L Salmon R.									BPA 1991073. ShoBan, Nez Perce habitat monitoring associated with projects. USFS has main responsibility in anadromous zone. No systematic habitat sampling. PACFISH/INFISH watershed health		
	SF Salmon R.											
	MF Salmon R.											
	U Salmon R.	live count	mainstem	Streamnet (IDFG) 1984								
	Lemhi R.											
	Clearwater River					smolt counts	Clearwater River Trap	FPC's website	mortality, descaling, incidental catch, mark recapture			
	Salmon River					smolt counts	Salmon River Trap at Whitebird	FPC's website	mortality, descaling, incidental catch, mark recapture			
WA	Yakima R.									No systematic habitat sampling. SSHIAP and sub-basin assessements to be done once. WDE water sampling index project		
	Wenatchee R.											
	Entiat R.											
	Methow R.	redds	trib.	Subbasin report, 1989-1999								
	Snake River					smolt counts	Snake River Trap at Lewiston	FPC's website	mortality, descaling, incidental catch, mark recapture			
	Snake River					smolt counts, passage index	Lower Monumental Dam	FPC's website	mortality, descaling, incidental catch, mark recapture			
	Snake River					smolt counts, passage index	Lower Granite Dam	FPC's website	mortality, descaling, incidental catch, mark recapture			
	Columbia River					smolt counts, passage index	Rock Island Dam	FPC's website	mortality, descaling, incidental catch, mark recapture			
	Columbia River					smolt counts, passage index	McNary Dam	FPC's website	mortality, descaling, incidental catch, mark recapture			

OR	Deschutes R.	redds								
	John Day R.	redds								Scattered habitat surveys in upper basins
	Umatilla R.	redds		Subbasin (ODFW data cited in Umatilla/ Walla Walla Bull Trout Working Group 1999, Northrup, 1997) 1994-2000						
	Grande Ronde R.	redds								
						smolt counts	Grande Ronde River Trap	FPC's website	mortality, descaling, incidental catch, mark recapture	
	Imnaha River	redds		Streamnet(1995)*	*production					
		fish density	Trib.	Subbasin report (ODFW data presented in Buchanan et al. 1997), 1992						
						smolt counts	Imnaha River Trap	FPC's website	mortality, descaling, incidental catch, mark recapture	
	Snake River					smolt counts, passage index	Little Goose Dam	FPC's website	mortality, descaling, incidental catch, mark recapture	
	Columbia River					smolt counts, passage index	John Day Dam	FPC's website	mortality, descaling, incidental catch, mark recapture	
	Columbia River					smolt counts, passage index	Bonneville Dam	FPC's website	mortality, descaling, incidental catch, mark recapture	

Table 3.12: Survey of Habitat Monitoring

	Survey of Habitat Monitoring						
		location	data source	project type	bio. Condition	chem. Condition	phys. Condition
	L.Salmon						
	SF Salmon R.	Johnson Cr	BP 13381-3 H43	barrier removal	yes		
		Johnson Cr	BP 13381-2 H35	barrier removal	yes		
		Johnson Cr	BP 13381-4 H50	barrier removal	yes		
		Dollar Cr	BP 21182-3 H88	barrier removal	yes		
		Johnson Cr	BP 13381-5 H54	barrier removal	yes		
		Dollar Cr	BP 13381-5 H54	barrier removal	yes		
	MF Salmon R	Bear Valley Cr	BP 13381-2 H 35	sed. Reduction	yes		
		Cache Cr	BP 13381-2 H 35	sed. Reduction	yes		
		Bear Valley Cr	BP 13381-5 H54	sed. Reduction	yes		
		Knapp Cr	BP 13381-6 H62	barrier removal	yes		
		Bear Valley Cr	BP 13381-5 H54	sed. Reduction	yes		
	U. Salmon R.	Big Springs Cr	BP 13381-2 H35	instream restoration	yes		
		Hayden Cr	BP 13381-2 H35	instream restoration	yes		
		Salmon R EFK	BP 13381-2 H35	instream restoration	yes		
		U. Salmon R	BP 13381-2 H35	instream restoration	yes		
		Valley Cr	BP 21182-3 H88	barrier removal	yes		
		Valley Cr	BP 21182-3 H88	sed. Reduction	yes		
		Redfish Lake	BP 22548-5 H129	fertilization	yes	yes	yes
		Altural Lake	BP 22548-5 H129	fertilization	yes	yes	yes
		Pettit Lake	BP 22548-5 H129	fertilization	yes	yes	yes
		Yankee Fork		off channel restoration	yes		yes
		Pole Cr	BP 13381-3 H43	barrier removal	yes		
		Salmon R EFK	BP 13381-4 H50		yes		
ID	Lemhi R.	Lemhi R.	BP 13381-2 H35	instream restoration	yes		

	Yakima R.						
	Wenatchee R.						
	Entiat R.						
WA	**Methow R.**						
OR	**Deschutes R.**	Jordan Cr	BP 868 H39	instream restoration	yes		yes
		Rock Cr	BP 868 H39	instream restoration	yes		yes
		Beaver Cr	BP 13047-1 H44	instream restoration	yes		yes
		Mill Cr	BP 13047-1 H44	instream restoration	yes		yes
		Shitike Cr	BP 13047-1 H44	instream restoration	yes		yes
		Warm Springs R.	BP 13047-1 H44	instream restoration	yes		yes
		Mill Cr	BP 32564-1 H111	barrier removal	yes	yes	yes
		Beaver Cr	BP 32564-1 H111	instream restoration	yes	yes	yes
		Low Beaver Cr	BP 32564-1 H111	riparian restoration	yes	yes	yes
		Lower Shitike Cr	BP 32564-1 H111	mult. Restoration	yes	yes	yes
		Lower Deschutes R.		instream restoration		yes	
		Upper Deschutes R.		instream restoration		yes	
	John Day R.	J.D. NFK	BP 39796-1 H27		yes		
		J.D. MFK	BP 39796-1 H27		yes		
		Granite Cr	BP 39796-1 H27		yes		
		Granite Cr	BP 66149-1 H145		yes		yes
		J.D. NFK	BP 66149-1 H145		yes		yes
		Deer Cr	BP 294 H9	mult. Restoration	yes	yes	yes
		Camp Cr	BP 294 H9	mult. Restoration	yes	yes	yes
		Clear Cr	BP 294 H9	instream restoration	yes	yes	yes

	Umatilla R.	Birch Cr	BP 35769-5 H 92	reveg.	yes		
		E. Birch Cr	BP 35769-5 H 92	reveg.	yes		
		Meacham Cr	BP 35769-5 H 92	reveg.	yes		
		Squaw Cr	BP 75349-1 H101		yes		
		Camp Cr	BP 75349-1 H101		yes		
		Meacham Cr	BP 75349-1 H101		yes		
		Moonshine Cr	BP 75349-2 H114		yes		
		Cottonwood Cr	BP 75349-2 H114		yes		
		Coonskin Cr	BP 75349-2 H114		yes		
		Umatilla R.	BP 98636-1 H 87	instream restoration	yes		yes
		Birch Cr	BP 35769-4 H79	barrier removal	yes		
		Twomile Cr	BP 35769-4 H79	riparian restoration	yes		
	Grande Ronde R.	Grand Ronde R.	BP 66149-1 H145		yes		yes
		Catherine Cr	BP 66149-1 H145		yes		yes
		Grande Ronde R.	BP 628-1 H188	instream restoration	yes		
		McCoy Cr	BP 628-2 H193	instream restoration	yes		yes
	Imnaha R.						

Table 3.13: Tributary Status Monitoring Current Activities Assessment
Survey Instrument (Do existing status monitoring programs capture these fish and habitat indicators?)

Ecosystem Scale (Tier 1)

For the anadromous portion of the Columbia River basin:
Adult fish presence/absence
    Species
    Spatial Resolution
    Temporal Resolution
Geology/soils
    Spatial Resolution
    Temporal Resolution
Land classification
    Spatial Resolution
    Temporal Resolution
Stream network
    Spatial Resolution
    Temporal Resolution
DEM
    Spatial Resolution
    Temporal Resolution
Roads
    Spatial Resolution
    Temporal Resolution
Passage barriers
    Spatial Resolution
    Temporal Resolution
Land ownership
    Spatial Resolution
    Temporal Resolution

Subbasin Scale (Tier 2)

For each major subbasin within the anadromous portion of the Columbia River basin:
Fish Indicators, by species
    Adult counts, as well as:
Age Structure
Sex Ratio
Hatchery Fraction
Marks/Tags
    Juvenile counts, as well as:
Age/Stage
Origin
Condition
Habitat indicators
    Valley Characteristics
Valley bottom type
Valley bottom width
Valley bottom gradient
Valley containment
    Channel Characteristics
Elevation
Channel type

Bed-form type
Channel gradient

Riparian Vegetation

Cover group
Community type

Water Temperature

MDMT
MWMT

Sediment/Turbidity

Turbidity
Depth fines

Contaminants/Nutrients

Metals/Pollutants
Conductivity
pH
DO
Nitrogen
Phosphorus

Substrate

Dominant Substrate
Embeddedness

LWD

Pieces per mile

Pools

Pools per mile
Pool quality

Off-Channel Habitat

Backwaters & side channels

Channel Condition

Width/depth ratio
Wetted width
Bank full width
Bank stability
Canopy cover
Channel modification

Streamflows

Change in peak Q
Change in base Q
Change in timing of Q

Watershed Condition

Watershed road density
Riparian-road index
Equivalent clearcut
Percent veg altered
Erosion processes
Land use

Metadata for all indicators above

Sample location (spatial reference)
Sample date
Protocol
- Reference
- Variations on reference

QA/QC process associated with protocol
Accuracy/precision metrics for protocol
Data are raw/expanded
- Expansion protocol

Data collection mechanism
- Auto-detect/logged
- Field notes transcribed/entered

Data base used
- Data entry QA/QC
- Data base available to regional/local co-managers now
- Data base available to regional/local co-managers if needed

Length of data collection
- Changes in protocols
- Changes in field crews

Reports/publications based on data
Current uses of data with respect to management decisions
Mandate for data collection
Funding source for data collection

F. Action Plans for meeting RME Needs

A well-designed monitoring and evaluation program is a critical component of any conservation or restoration activity. Monitoring is vital in determining whether specific management actions have been effective, and large-scale monitoring and evaluation is important in assessing the success of integrated actions having achieved desired population size, distribution and trends. Moreover, well-coordinated management actions, when coupled with relevant monitoring and evaluation programs, can reduce uncertainty about the effect of those actions on population productivity.

The primary goal of this monitoring and evaluation effort is to design and implement a system of statistically rigorous data collection schemes to answer questions fundamental to the management and recovery of anadromous salmonids. In spite of tremendous past efforts many of the most important questions remain unanswered due to basic uncertainties in these fishes' population processes, both with respect to trends in abundance as well as the factors that regulate salmonid population dynamics. At present there are a number of high-quality population and habitat monitoring and assessment programs within the Columbia River Basin (e.g. Oregon Plan 1997; Alverts et al. 1997, CBFWA 2001). However, none of these programs has both comprehensive geographic coverage and a sampling theoretic basis. In particular, there are no comprehensive guidelines to be drawn from these plans that can be used as a template for monitoring the status and recovery of impacted populations as well as their breeding, rearing and migratory corridor habitat in the entire Columbia River Basin. At issue is both the type of data traditionally collected to assess population and habitat status, as well as the manner by which the data collection scheme is implemented in time and space.

Thus the primary objective of this tributary monitoring action plan for the Columbia River basin is a statistically sound sampling design that when implemented will generate useful data with known analytical and predictive power. Several technical challenges are immediately apparent, and this work is distinct from previous efforts in how it will approach these challenges. The primary complication arises from the enormous spatial scale and resulting heterogeneity of the sampling areas and indicators. As such, the manner of population and habitat sampling, and the manner in which the samples are distributed in time and space, will strongly influence the assessment of status and effectiveness. To satisfy this constraint requires considerable knowledge of both the spatial extent of true demographic units and the mechanisms of population regulation, potentially more than is currently known. However, lacking these key pieces of information does not limit the ability to accurately assess population and habitat status, but it does constrain the need to do so under a modern and statistically rigorous sampling program informed by knowledge of demographic and habitat processes. The plan presented here is intended to develop and test status, trend, and effectiveness monitoring approaches capable of the statistical rigor specifically required by the region's natural resource management agencies and personnel.

Action Plan for Implementation of a Tributary Monitoring Program

A FCRPS BiOp motivated monitoring program for anadromous salmonid populations and their habitat at both the ecosystem and subbasin scale will be implemented in a step-wise fashion guided by the following components: a comprehensive gaps analysis of ecosystem and subbasin scale monitoring programs; subbasin scale pilot projects; coordination with federal, state and tribal monitoring programs; and coordination with the recovery planning efforts of the Lower Columbia/Willamette and Interior Columbia Technical Recovery Teams.

Pilot Studies

The initial phase of basin-wide implementation of a FCRPS BiOp motivated tributary monitoring program will be three subbasin scale pilot programs funded by the Action Agencies: (i) an assessment of ecosystem scale status monitoring approaches based on remote sensing data in the John Day and Salmon River basins; (ii) status and trend monitoring efforts for anadromous salmonids and their habitat in the Wenatchee, John Day and upper Salmon River basins; and (iii) watershed scale habitat restoration effectiveness monitoring pilot studies in the Wenatchee, John Day and Salmon River basins. The ecosystem scale status monitoring project is designed to directly assess the utility of large scale remote sensing data collection (i.e., as specified by RPA Action 181). The subbasin scale status monitoring pilot project builds on current status and trend monitoring programs being developed in the Oregon portion of the Columbia Plateau (e.g., BPA/CBFWA proposals 25088, 25010) by extending the pilot program development process to subbasins in Washington and Idaho. The watershed scale effectiveness monitoring is a completely new program, truly a pilot scale implementation of the watershed-scale effectiveness monitoring approaches described in this document. In all cases, the pilot studies differ from much of the ongoing ecosystem and subbasin scale status, trend, and effectiveness monitoring in the Columbia River basin as they focuses on the explicit development and testing of the protocols and methodologies required for generating ecosystem, habitat, population, and restoration monitoring data of known spatio-temporal resolution, accuracy and precision.

Ecosystem scale

Given the enormous area over which Pacific salmonids interact with their environs, the task of measuring habitat quality and quantity becomes problematic. Local scale habitat linkages are fairly well understood, however, broad scale, landscape habitat linkages are poorly understood. While there are clear patterns in the correlations between land use and land cover at a landscape scale and salmonid population trajectories, these correlations are often too general for extrapolating mechanistic connections between habitat type and condition, and salmon population status. This inability to make mechanistic connections is a result of two limitations. First, most studies that attempt to relate gross habitat attributes with population trends, use static geospatial data layers. Clearly, a time series of land use and land cover change is a better choice to correlate habitat conditions over time with salmon population trends. Second, to date, there has never been a classification of remote sensed imagery that was specific to Pacific salmonid habitat requirements. Therefore, pilot projects to explicitly address these two major limitations to the potential utility of ecosystem scale status monitoring programs need to be initiated.

Pilot projects will be supported by previously acquired satellite imagery, and will be most useful if coordinated with subbasin scale habitat and population monitoring pilots for data sharing and ground truthing. Specifically, the pilot projects must each address the following list of issues.

Change detection:

- Is it feasible to use change detection on LANDSAT TM remote sensed data, in particular for the following land use land cover classes: Agriculture, Urban, Logging, Riparian vegetation, Wetland vegetation, Roads?

- Does a time series of land use and land cover improve the fit of fish habitat models?

- Can riparian and wetland habitats be classified accurately using LADNSAT TM remote sensed data?

The project area is six subbasins within the Columbia River basin: Grande Ronde (OR); John Day (OR); Salmon (ID); Wenatchee (WA); Willamette (OR); and Yakima (WA). The project will be based on an existing time series (1984, 1988, 1992, 1996, and 2000) of raw LANDSAT TM imagery. It is recommended that this project build upon existing efforts to classify land use and land cover in the United States, such as U.S. Geological Survey (USGS) National Land Cover Database; USGS Land Use and Land Cover Program, National GAP Analysis Program; and the Northwest Habitat Institute Current and Historic Wildlife-Habitat Types Program.

Practicality of ecosystem monitoring via remote sense data:

- How much of field or ground surveyed information can be gathered using remote sensed data?

- What are the limitations of various remote sensed data layers with respect to habitat feature delineation?

- How much of he remote sensed imagery classification process can be automated?

- Can remote sensed data of different spatial and spectral resolutions be used in combination to generate high spatial resolution habitat classifications?

- Can pattern recognition or texture analysis be used to enhance classification of high spatial resolution/low spectral resolution remote sensed data?

The project area is the Upper Salmon River within the Salmon River basin, Idaho. The project will be based on existing raw LANDSAT TM images, as well as IKONOS 1 m panchromatic and 4 m multispectral images. The final product should be a geospatial data layer containing the various land use and land cover categories, with particular focus on the following habitat attributes or features:

- Logging extents
- Riparian vegetation
- Wetland vegetation
- Roads
- Push-up dams
- Salmon redds or nests
- In stream habitat variables
- Pools, riffles, glides, etc.
- Stream channel width
- Log jams and large woody debris
- Substrate type
- Channel incision (as a result of loss of beaver habitat, grazing [trampling, compaction, and devegetation], and climate change)

Subbasin scale pilot studies

The following outline describes the basic process by which a series of subbasin scale pilot monitoring projects seek to develop subbasin scale status, trend, and effectiveness monitoring programs for anadromous salmonids and their habitat. This monitoring program's implementation is meant to pilot the development of a comprehensive monitoring program for the entire Columbia River basin. As such, the primary focus of this work is on the development and testing of the approach. Therefore, during program assessment and evaluation, addressing questions of how the pilot programs will scale up to cover a larger spatial extent will be critical.

The monitoring program is to be piloted in the Wenatchee, John Day and Salmon River basins (generally in the tributary portions of the subbasins), targeting natural spawning and rearing of steelhead (*O. mykiss*) and spring chinook (*O. tshawytscha*). The spatial extent of the pilot monitoring program is limited by two major considerations, firstly the protocols and approaches being tested are specifically designed for wadeable streams, and secondly, as pilot programs the focus is on testing and development, rather than complete basin-wide coverage. In addition, by restricting the program's extent to portions of these three major each subbasin will be considered to consist of multiple major watersheds. The division of the subbasins into major watersheds is based roughly on population structure information being developed by the Interior Columbia River Technical Recovery Team, and will be used for organizational purposes, for post-hoc stratification of data to address issues of monitoring program scale, and effectiveness monitoring and evaluation of demographic units as a function of land management and restoration practices.

The Wenatchee, John Day, and Salmon River basins were chosen as potential monitoring pilot program locations for a variety of programmatic, logistical and biological reasons. The basins contain breeding and rearing listed and non-listed anadromous salmonid species. Listed species imply the attention and interest of resource management agencies while non-listed species might allow opportunities to develop approaches prior to implementation on listed species. Each river basin is of interest for monitoring program development by USFWS, NMFS, FCRPS Biological Opinion Action Agencies, multiple Tribal entities, States of Washington, Oregon, and Idaho, and others. Each river basin consists of multiple major watersheds of similar size covering a wide range of human impacts, uses and management levels including wilderness areas as reference points, all with reasonable access. In each basin there are high quality existing status monitoring efforts against which a sampling framework could be tested. For example, in the Wenatchee there is an annual census of adult chinook and steelhead spawning grounds, and the US Forest Service has conducted modified Hankin-Reeves survey of upper watersheds. While in the John Day ODFW and others have significant historical and on-going life-history and life-stage survival research on spring Chinook, and in the Salmon River basin, IDFG has a long-term redd survey program. Thus, in each basin there is the potential for expanding the ability to verify difficult sampling procedures, e.g., smolt traps on major watersheds to test snorkel-based sampling. And finally, each river basin has a range of hatchery impacts, with clearly identified areas that represent completely natural production watersheds.

While the genesis of this proposed work was initially strictly status and trend monitoring of populations and habitat condition a natural extension of these data collection programs is a watershed scale assessment of habitat action efficacy. Habitat restoration actions are generally implemented on a reach or habitat unit scale and can be assessed for effectiveness at that scale. However, when needing to determine the population level response to restoration actions, the actions' cumulative impact must be assessed on the scale of the demographic unit as a whole. At this scale, determining the effect of multiple simultaneous actions is more an issue of differences in population growth rates (alternatively stage specific survivals, or productivity expressed as juveniles per adult) than an elucidation of the mechanism by which a particular action or class of actions alters the population processes of these fishes. Therefore, assessments of watershed scale population trajectories so closely resembles status monitoring that their combination is a natural pairing.

Effectiveness monitoring of tributary habitat restoration actions is a multi-dimensional undertaking. The designers of such programs have struggled to best capture the range of spatial scales involved with understanding simultaneously the mechanisms by which a particular action alters physical environmental conditions that in turn impact local population processes that ultimately manifest themselves as altered population dynamics (MDT 2002). As a result, a multi-scale approach to effectiveness monitoring is often recommended, one that addresses the following three questions either within a single program, or as multiple coordinated programs.

- Q1 – Is this project effective?
- Q2 – Did projects within a subpopulation or subwatershed on aggregate effect the demographic unit?
- Q3 – Are classes of projects effective?

For these questions, “effective” refers to having the anticipated impact on the habitat and the correlated fish demographic response.

While all of these questions are raised in the BiOp in the context of Action Effectiveness Research, answering them places quite different expectations on the monitoring program. Among these, Q1 is largely of interest to individual project sponsors. Q2 operates on a spatial scale that is defined by the characteristics of the demographic unit of study – usually a larger scale than individual projects and within the framework established by status monitoring programs. Q3, on the other hand, is not defined by a single spatial scale; rather, it addresses characteristics of project categories – wherever they may be implemented. These pilot studies are explicitly designed to address Q2.

Even though the pilot studies will address habitat and population status monitoring and watershed scale effectiveness monitoring within the same program, the status and trend monitoring remains distinctly different from the watershed scale effectiveness monitoring. The distinction arises from the manner by which sampling locations are chosen in space. The proposed status monitoring program is based on a spatially balanced random sampling design (EPA’s EMAP) to capture unbiased representative samples of physical/environmental indicators across the landscape. The watershed scale effectiveness monitoring program will sample the same suite of reach scale physical / environmental indicators at each project location, but because the project locations are not randomly distributed in space these samples represent the population of projects, not the background habitat condition. However, the two programs do overlap in the evaluation phase – the habitat status samples can serve as within and between watershed control sites if the appropriate covariate matching is performed (Rosenbaum, 1995).

Subbasin Scale Status and Trend Monitoring

A comprehensive status monitoring program should address the three major attributes of fish populations and their habitats that together provide indicators of ecosystem productivity and resilience in the face of environmental uncertainty: (1) The absolute *abundance and survival* of fish populations and their trends through time (e.g., indicators of productivity); (2) The *geographic patterns* (e.g., spatio-temporal distribution, genetic, and life-history diversity) of populations relative to their habitats (e.g., indicators of biological adaptation in a heterogeneous environment); and (3) The *variance* of populations through time (e.g., an indicator of resilience). In addition to these population indicators, the program also requires an understanding of (4) *ecological processes* such as climatic, hydrologic, or biotic interactions that naturally cause changes in fish populations. Indicators of these processes are critical to determine whether population responses are due to restoration activities, unrelated fluctuations in the natural environment, or some interaction of these effects. Failure to account for the background processes of variation may lead to erroneous conclusions about the success or failure of recovery measures. The status monitoring program proposed for development will explicitly address these four critical attributes of salmonid populations and habitat. Generating data to assess these four attributes requires a monitoring program that is designed with the specifics of these fishes natural history in mind, as well as a detailed knowledge of their geographic distribution and its spatio-temporal dependence on landscape scale features and ecological processes. Lacking these critical components that underlie the design process requires and explicit design phase to elucidate these important determinants of the performance of the proposed monitoring program.

Developing this monitoring program will involve a 3-step process, the components of which are organizational, logistical, statistical and biological. The three primary steps are detailed below, expressed as *Objectives* with associated *Tasks* and *Methods*. The *Objectives* are sequentially arranged, but could be implemented in a somewhat parallel or phased manner.

Objective 1.

Define cooperative agreements under which the salmonid and habitat status and trend monitoring program design, development and implementation will occur. Detailed cooperative agreements to partition the implementation of particular tasks during monitoring program development are needed. The development of the cooperative agreement will occur in parallel to the initial phases of monitoring program development (*Tasks* associated with *Objective 2*), but must be finalized prior to initiating *Tasks* associated with *Objective 3*.

Task 1.

Currently individuals and Agency members of the Upper Columbia Regional Technical Team, Interior Columbia Technical Recovery Team, Washington Department of Fish and Wildlife, Washington Department of Ecology, Washington State Comprehensive Monitoring Strategy, Oregon Department of Fish and Wildlife, Oregon Department of Environmental Quality, Oregon Watershed Enhancement Board, Confederated Tribes of the Warm Springs Reservation, Idaho Department of Fish and Game, Nez Perce Tribe, US Forest Service, US Fish and Wildlife Service, US Environmental Protection Agency, and the NMFS-FCRPS-BiOp-Action-Agency RME Team are participating in the coordination of monitoring program development and implementation in the Wenatchee, John Day, and Salmon River basins. Refine cooperative agreement between these parties (identifying other participants if necessary) to implement *Tasks* associated with *Objectives 2-5*.

Objective 2.

Develop a salmonid population and habitat status and trend monitoring approach with known accuracy and precision through field-testing of protocols and sampling design.

Task 2. – Develop and test a status monitoring program specific to the Wenatchee, John Day, and Salmon River basin ecosystems.

The testing and development of habitat assessment methods involves three components: assessing the measurement error associated with the recommended protocols, quantifying the spatio-temporal variance components for each indicator based on recommended sampling program coverage, and assessing the information content of the indicators given uncertainty in indicator value due to sampling/measurement/process error and correlation of indicator to salmonid population abundance/productivity metrics. The three components of this task are accomplished within a single field-testing framework by implementing a suite of habitat indicator protocols under a variety of sampling regimens.

A key feature of the testing framework is the use of census or validation reaches. These are locations where the indicator in question is known with high accuracy and precision through extensive sampling or a census independent of the protocol testing process. For example, for habitat survey method testing in the absence of any background information or other monitoring programs, a reach is chosen that represents the diversity of natural conditions to be encountered in a random sampling of the watershed. The validation reach is then extensively mapped by expert personnel other than those on project field crews. This reach can then be used as a test case, since the 'true' value of its habitat indicators are known. Alternatively, in locations with smolt traps, or exhaustive adult spawning surveys, these areas will represent 'true' values against which indicator and sampling protocols can be assessed.

With validation reaches it is reasonably straightforward to design test for protocols, crews and sampling schemes. Measurement error is assessed absolutely for a crew or protocol by sampling within the area of known habitat indicator values. For relative measurement error between crews or protocols, resampling of randomly chosen reaches will be used, provided the resampling is done within 7 days of the initial pass. Important components of the variance structure of indicators can be determined by resampling on a variety of spatio-temporal scales (Larsen et al. 2001). On some spatio-temporal scales all habitat and population indicators will be highly autocorrelated (e.g., two points in a watershed separated by several meters are more likely to be similar than two point separated by 100s of meters). However, while such spatio-temporal similarities should generally decay with increasing time/distance, there are numerous situations where this is not the general case (e.g., periodic patterns due to ocean/climate cycles or strong brood year cycles). Therefore, to properly assess the spatio-temporal component of habitat and population indicator variance, a component of the sampling program should always be within and between years and watersheds. Finally, to determine the natural resource management value, or information content, of each monitoring variable or indicator, habitat and population indicator sampling will be conducted within an analytical evaluation framework. Simultaneously constructing and testing hierarchical correlative models of habitat indicators and population processes will support the development of both the data collection process and the evaluation of monitoring data in a management context. Validation or census reaches will be particularly valuable in this context as the predictive power of random variables is strongly determined by their error term (Holmes 2001, Holmes and Fagan 2002)– data collection associated with validation/census areas allows for the further partitioning of the variance terms discussed above into their process and non-process components.

Subtask 2.1. – Test habitat assessment methods.

Methods 2.1. – Habitat and Riparian Survey

Ideally, channel habitat and riparian surveys will be conducted as described by in the attached environmental indicators protocol document and references therein. However, modification will be required to adapt these methods to the pilot study river basins. Some known modifications will include: survey lengths of 500-1000m and measurement of all habitat unit lengths and widths (as opposed to estimation; based on experience with these methods, Thom et al. 1999, 2000, 2001). Additional modifications will arise due to field-testing of methods and measurement error estimation approach described below.

All habitat survey locations will be determined using a spatially balanced random sampling site selection process with the sampling universe determined by the spatial extent of the fish species of interest. The project proponents propose to use the USEPA's EMAP site selection algorithms. The advantage to using these well developed site selection algorithms is the additional supporting work that has been done on refining the estimators of the sample data (most importantly, the variance terms). Alternative sampling schemes would be possible, but the long history of development, refinement and implementation of, and statistical support (provided by the USEPA's western research lab, Corvallis, OR) for, EMAP makes this approach the most sensible.

To quantify within-season habitat variation and differences in estimates between survey crews, sites will be resampled with a separate two-person crew. Repeat surveys will be a randomly selected sub-sample from each survey crew. Variation in survey location was assumed minimal because survey starting and ending points were marked in the field. The precision of individual metrics will be calculated using the mean variance of the resurveyed streams "Noise" and the overall variance encountered in the habitat surveys "Signal". Three measures of precision are calculated, the standard deviation of the repeat surveys SDrep, the coefficient of variation of the repeat surveys (CVrep), and the signal to noise ratio (S:N). S:N ratios of < 2 can lead to distorted estimates of distributions and limit regression and correlation analysis. S:N ratios > 10 have insignificant error caused by field measurements and short term habitat fluctuations (Kauffman et al. 1999).

Habitat conditions will be described using a series of cumulative distributions of frequency (CDF). The variables described are indicators of habitat structure, sediment supply and quality, riparian forest connectivity and health, and in-stream habitat complexity. The specific attributes are:

Density of woody debris pieces (> 3 m length, >0.15 m diameter)
Density of woody debris volume (> 3 m length, >0.15 m diameter)
Density of key woody debris pieces (>10 m length, >0.6 m diameter)
Density of wood jams (groupings of more than 4 wood pieces)
Density of deep pools (pools >1 m in depth)
Percent pool area
Density of riparian conifers (>0.5 m DBH) within 30 m of the stream channel
Riparian and Bank disturbance
Percent of channel shading (percent of 180 degrees)
Percent of substrate area with fine sediments (<2 mm) in riffle units
Depth of fine sediments in riffle units
Percent of substrate area with gravel (2-64 mm) in riffle units
Embeddedness (percent)
Channel condition (Width/Depth, wetted width, bankfull width)
Water Temperature (MDMT, MWMT)
pH
Dissolved Oxygen
Nitrogen/Phosphorus (Nitrate, nitrite, Ammonium, Phosphate, Total N&P)
Macroinvertebrate (Transport of drift and composition of benthic)

While these attributes do not describe all of the conditions necessary for high quality salmonid habitat, they do describe important attributes of habitat structure within and adjacent to the stream channel. The attributes are also indicative of streamside and upland processes. The median and first and third quartiles will be used to describe the range and central tendencies of the frequency distributions of the key habitat attributes used in the analysis of current habitat conditions (Zar 1998). Frequency distributions will be tested to determine if significant differences ($p<0.05$) exist between subbasins for each habitat attribute (Thom et al. 2000). The information content, or predictive power of the habitat indicators will be assessed within a hierarchical modeling framework to test the extent of correlation between habitat indicators and fish indicators within and between baseline reaches and sampling reaches.

Subtask 2.2. – Test adult population assessment methods.

Methods 2.2. – Adult Steelhead and Spring Chinook Redd Surveys

Each pilot study river basin has considerable adult survey work currently underway to exhaustively enumerate adult spring Chinook. The development of a probabilistic sampling scheme for redd counts is meant to complement this work, if the methods prove sufficiently accurate and precise for regional needs. The key to testing the following sampling based approaches will be the ongoing census based surveys that will act as the 'truth' against with the sampling data can be compared. For steelhead surveys, the testing will focus on the protocol/method development due to the logistical difficulty of surveying these fishes during the spring. In this case, assessments of population status could be strongly influence by uncontrolled measurement error. Methods for assessing the accuracy and precision of steelhead redd surveys will be developed in conjunction with adult counting facilities (e.g. explore potential for instrumenting Tumwater Dam on the Wenatchee River).

Certainly there is sampling and measurement error associated with ongoing "census" work for adult population assessments. However, due to the extensive nature of the spawning ground surveys (weekly counts with all redds identified and flagged) and the potential for total adult counts in a number of watersheds (dam counts and hatchery weirs), good estimates of accuracy and precision of these counts can be developed. The idea being to have a population estimate of known characteristic against which to test sampling methods. Ideally, the sampling methods could return data of known accuracy and precision that is sufficient for management decisions, but is less labor intensive (i.e., costly) to generate. In particular, if range expansion is anticipated to accompany extensive habitat restoration, then an alternative status monitoring program that can capture an increasing scale of interest without the concomitant increase in cost would be a very valuable and attractive tool for resource managers.

Where the subbasins have on-going index surveys, assess the cost/information gained relationship for index surveys, census methods and probabilistic sampling. To fully explore this issue, develop a dataset that covers the range of abundance seen under the historic index surveys to examine the relationship between the three methods. From this analysis a strong relationship can be developed that will allow the indexing of the historic surveys to the probabilistic surveys, and assess the best monitoring program for the future. This will take an unknown length of time but will probably be on the order of 5-10 years.

Subtask 2.3 – Test juvenile population/productivity assessment methods.

Methods 2.3. – Juvenile Salmonid Survey

Ideally, juvenile salmonid monitoring will be accomplished by snorkel surveys involving a single upstream pass through each pool during daylight along a 1-km survey reach. This approach will be assessed and modified as needed in the pilot study river basins.

To quantify the measurement error in the snorkel data, and to provide information on temporal changes in abundance during the course of the sampling season, supervisory staff will resurvey a random sample of 10 to 20 percent of the sites surveyed in each subbasin. The goal is to limit between diver error to ± 20% or less with intensive presurvey training of field crews and regular random resurveys.

Data analysis will involve calculating the percentage of survey sites that contain at least one juvenile fish for *O. mykiss* and spring chinook and the percentage of pools per site that contain juvenile *O. mykiss* and spring chinook to quantify changes in the relative distribution interannually. Confidence limits for summary estimates will be developed based on quantifying the measurement error in the snorkel data and site-to-site variability based on a variance estimator developed by the EPA EMAP Program for this application (Pers. Comm. Don Stevens, EPA Research Lab, Corvallis).

In the current application of these methods to coho salmon juveniles, the small pools and non-pool habitat are not sampled. If the habitat use characteristics of over-summering juveniles is known (as it is in this case for coho salmon), then the validity of counting in pools only can be assessed. Part of the process will be to assess this approach for other salmonid species at summer low flows. Alternative sampling approaches are used for other species and life history variants, and as such, can be assessed, tested and if appropriate, incorporated. The primary goal of juvenile sampling will be to develop an index of juvenile population size and productivity. The “pool-only” approach only works when this habitat type contains the majority of the summer low-flow juveniles. In the worst case sampling scenarios (e.g., poor visibility), presence/absence data only will be developed to assess the cumulative distribution of pool use by juveniles. Nonetheless, the CDF of pool use has been shown to index the productivity of coho salmon juveniles when it is not possible to develop sufficiently precise counts. The intent of this program development is not to impose a suite of protocols on a sampling scheme, but rather to assess their ability to generate data of known accuracy and precision that meets the resource management needs of the local and regional co-managers.

Subtask 2.4 – Test probabilistic sampling based approaches.

Methods 2.4. – Sampling methods, domains and site selection

Based on current environmental monitoring programs (U.S. EPA 1998, 2000, Oregon Plan 1997, WA CMS 2001), and scientific review of proposed salmonid and habitat monitoring programs (ISRP reviews of numerous proposals across several provinces) the sampling framework adopted for testing in this project is the US Environmental Protection Agency's EMAP. While the program has been implemented regionally for water quality monitoring (U.S. EPA 2000) and salmonid population and habitat monitoring (Oregon Plan, WA CMS), there are a number of aspects of the sampling frame that should be tested prior to program implementation in each new ecoregion. Therefore, while an EMAP sampling framework will underlie the development of this monitoring program, concomitant testing of the sampling program design will occur.

To balance the needs of status (more random sites) and trend (more repeated sites) monitoring, EMAP based sampling programs generally implement a rotating panel design (general recommendations from the EPA EMAP Design Group; Pers. Comm. P. Larsen, EPA, Corvallis). Thus, for a subbasin scale program 50 sites drawn on an annual basis for each would be assigned to the rotating panel design as follows:

- 3 panels with different repeat intervals
- 17 of the sites will be sampled every year
- 16 sites will be allocated to a 4 year rotating panel (sites visited once every 4 years on a staggered basis)
- 17 sites will be new sites each year

With this sampling strategy, 50 sites will be drawn the first year and 33 new sites will be drawn in subsequent years because 17 of the originally drawn sites will be repeated each year. The rotating panel strategy is essentially a bet-hedge against the distribution of indicator variance over space and time. The best estimator of trend is thought to be from random sites fixed through time (drawn once, resampled annually), while the best estimator of status captures both the spatial and temporal variance components and their interactions (drawn randomly each year). Since the spatio-temporal variance structure (first and higher order terms) for these data is poorly understood, a rotating panel approach is a good compromise. One goal of this project will be to explicitly sample for the spatial, temporal and interaction variance components (as recently outlined by Larsen et al. 2001). Armed with a more complete picture of indicator variance the most efficient implementation scheme for site selection over space and time can be developed. Again, the motivation is to increase the information content of the monitoring data collected for the effort expended.

Objective 3.

Implement the salmonid and habitat status and trend monitoring program developed in *Objective 2* through the cooperative agreement developed in *Objective 1.*

Task 3.

Implement a pilot status and trend monitoring program for salmonids and their habitat in the Wenatchee, John Day, and upper Salmon River basins.

Methods 3.1. – Habitat and Juvenile Salmonid Monitoring

Sample 50 randomly selected 1-km reaches across the four major watersheds of the pilot study river basin. The sampling universe will be 5^{th} order and smaller stream from the 1:100k EPA River Reach file. Sample size was determined based on the minimum number of sites necessary to quantify current conditions (status) and detect trends in conditions over time.

Methods 3.2. – Steelhead and Spring Chinook Adult Monitoring
Sample 50 randomly drawn 1-km reaches across the four major watersheds within each of the pilot study river basins. The sampling universe will be the range of steelhead and Chinook spawning in each of the four watersheds. Sample size is based on the minimum number of sites necessary to quantify current conditions (status) and detect trends in conditions over time.

Objective 4.
Implement a watershed scale habitat restoration action effectiveness monitoring approach with known accuracy and precision through field-testing of protocols and sampling design.

Task 4.1.
Implement a watershed scale habitat restoration action effectiveness monitoring program for salmonids and their habitat in each pilot subbasin.

Task 4.1.1. – Develop GIS data layers for land use including the locations of the status monitoring sites, the major human uses of the environment, the location of monitored projects, and the changes in the key landscape-scale status variables through time. Many necessary data layers already exist, but are not coordinated as a single data set; the primary task will be to compile exiting layers and assess quality and gaps.

Task 4.1.2. – Monitor physical/environmental/biological indicators at each project location within target watershed, and control locations within and outside of watershed. All unmonitored projects need to be covered and approaches coordinated with existing monitoring.

Task 4.1.3. – Monitoring integration response variables at base of each target watershed in the form of juvenile emigration rate and water quality metrics.

Task 4.1.4. – Coordinate implementation of status, trend and effectiveness monitoring program.

Objective 5.
Implement a project based habitat restoration action effectiveness monitoring approach with known accuracy and precision through field-testing of protocols and sampling design. This is a hypothetical component of the Action Plan and Tributary Monitoring Pilot Program since no funding has been identified, nor has a schedule been established to implement this component of the AER strategy.

G. Strategies for Developing Evaluation, Assessment and Decision-Making Tools.

Evaluation and Long-term Program Design

Objectives, *Tasks*, and *Methods 1 – 4* of the above tributary monitoring pilot program represent the effort required to implement subbasin-scale pilot status and effectiveness monitoring projects. However, the program must also contain an evaluative component capable of assessing the quality and utility of the data gathered by the pilot projects, as well as the mechanism by which the program is scaled up to meet full implementation requirements of a Columbia River basinwide monitoring project. Unfortunately no such evaluation framework currently exists. Therefore, as an extension of the pilot project's activities, additional components are described below to outline the development of an assessment and evaluation framework for the status, trends, and watershed scale effectiveness monitoring pilot projects.

Objective 6.

Develop an evaluation framework for the status, trend and watershed scale effectiveness monitoring program.

Task 6.1.

Compile and evaluate the annual assessments of population and habitat status.

Methods 6.1.1. – Compile status and trend monitoring data.

This project does not explicitly contain a data management element, but is linked to the proposed data management development guidelines in Appendix F targeting spatially explicit status and trend data for salmonid populations and habitat condition indicators. Data compilation, quality checking, and metadata development must occur in parallel to the data collection efforts undertaken in these pilot studies. It is unwise for the data collection and management efforts to become unsynchronized.

Methods 6.1.2. – Evaluate status and trend monitoring data.

The intent of the project is to implement a quantitative monitoring and evaluation plan. The sampling protocols are to be implemented and tested to assess their ability to capture status and trend aspects of anadromous salmonid habitat and populations with known measurement error. The individual protocols are implemented within a statistically rigorous sampling scheme such that the data generated is of known spatial representation, with known accuracy and precision. The status and trend evaluations arise directly from the sampling scheme, as the estimators of the first and second moments of the data are given by the sample weights and distributions in time and space. Nonetheless, while the reduction of the monitoring data may be reasonably straightforward, the evaluation of the program itself, *i.e.,* its ability to generate data that meets regional decision-making performance standards, will be more complex. In fact, such an assessment will be impossible in many cases, as no regionally agreed upon standards for performance of status monitoring programs exist. However, the status and trend data from this proposed monitoring program will be used to suggest design and performance criteria for population and habitat monitoring programs.

Task 6.2.

Compile and evaluate the annual assessments of watershed scale habitat action effectiveness.

Methods 6.2.1. – Compile project effectiveness monitoring data.
This project does not explicitly contain a data management element, but is linked to the proposed data management development guidelines in Appendix F targeting spatially explicit status and trend data for salmonid populations and habitat condition indicators. Data compilation, quality checking, and metadata development must occur in parallel to the data collection efforts undertaken in these pilot studies. It is unwise for the data collection and management efforts to become unsynchronized.

Methods 6.1.2. – Evaluate watershed-scale habitat action effectiveness monitoring data.
The quantitative framework for watershed-scale habitat action effectiveness evaluations was described in *Objective 4*. What should be apparent from the description of the analytical approaches described above is that large matrices of response variables and descriptive covariates must be compiled, linked and manipulated in a spatially explicit fashion. As such, the evaluation framework will depend heavily on the parallel development of a GIS based database system to support the statistical analysis of large complex data structures. For example, the requirements of observational studies statistics for optimizing multidimensional pair-wise matching of “treatment” and “control” sites based on continuously varying independent variables will require a flexible, dynamically searchable database of all Tier 1 and Tier 2 physical and environmental habitat indicators. Annual assessments of the watershed-scale effectiveness monitoring program and its data will be performed by updating and verifying the statistical models for detecting biological responses within and between watersheds, as well as the stratification process by which site are grouped.

Evaluation Framework
If the tributary monitoring pilot project is implemented as described here, at the end of 2007 the project data set will consist of the following:

One-Time:
1. Census of classification variables (Table 2), probably updated no more than once at the start of the program;

Subbasin scale status and trends monitoring:
1. Annual counts of spawners/redds;
2. Annual counts of juveniles;
3. Annual assessment of physical and biological habitat quality.

Watershed scale/integrating indicator monitoring:
1. Water quantity and quality measured in lower reaches of each population and perhaps upstream and downstream from some project sites;
2. Annual redd or weir counts for spawning adults (multiple counts of entire spawning reach where feasible, peak index counts otherwise), with age-at-return information for by year;
3. Annual estimates of parr and smolt emigration.

4. Parr PIT tagging of 1,000-3,000 parr tagged each year.

Reach-scale indicator monitoring:(note - no current implementation plans)

1. Annual parr density surveys for treatment and control reaches;
2. Annual physical/environmental indicators from Table 3.5 for treatment and control reaches;
3. Annual estimates of hatchery origin fish on spawning grounds, and outplants of hatchery juveniles;

In addition to the biological and environmental data, a critical part of the effort will be compiling a detailed inventory of past, current, and planned habitat projects. The inventory is required to select treatment and control monitoring sites, to assess how extensive the required juvenile distribution and detailed habitat monitoring effort will be, and will also be useful for other programs (e.g., subbasin planning). The inventory will be a substantial effort in its own right.

Ultimately, the AER program must be able to answer a variety of questions at different spatial and temporal scales:

1. Do subbasins or sub-populations in aggregate help move an entire ESU toward recovery goals?

2. Did habitat projects in aggregate within a watershed increase recruits per spawner, life-stage survival rates, etc.?

3. Is an individual habitat project in a given reach effective in changing fish distributions or improving environmental conditions?

4. Are classes of projects effective, and why or why not?

The recommended analytical framework adopts an "Observational Studies" approach to project effectiveness. Techniques for observational studies are commonly applied to tests of drug effectiveness or tests of environmental toxicology and correlated human response. As such, there already are tools for the design and analysis of experiments of this type (see Rosenbaum, 2002).

Unfortunately, it is uncommon for the details and limitation of observational studies to be incorporated explicitly into work plans for field studies of the type described in this plan. For example, researchers commonly monitor a couple of indicators in populations of treatments and controls and simply perform a t-test or ANOVA to identify differences between those populations. This is inadequate for BiOp purposes. The ISRP said as much in its recent review of the Clearwater Subbasin Plan (ISRP, 2003) when they distinguished randomized treatments and controls from the non-random selection in observational studies:

> *Large scale observational studies that involve "treatment-control", "before-after" or "before-after-control-impact (BACI)" designs fall under Tier 1 or 2 trend monitoring and do not establish cause and effect relationships as in Tier 3 research monitoring*. (ISRP, 2003)

This clearly points to the statistical challenges presented by non-randomization of treatments. It may be too conservative to treat observational studies as inadequate for these purposes. In fact, Cochran defines observational studies as empirical studies where:

> *"…the objective is to elucidate cause-and-effect relationships…(where)…it is not feasible to use controlled experimentation, in the sense of being able to impose the procedures or treatments … or to assign subjects at random to different procedures."* (Cochran, 1965)

So the potential to infer cause and effect from properly designed and analyzed observational studies exists. Having said that, however, the word "properly" places a heavy responsibility squarely on the design of these studies to incorporate the analytical features adequate to generate the required cause-and-effect inferences.

Luckily, there are strategies for dealing with these design issues. In particular, the non-random assignment of treatments can result in some feature of the treated area being responsible for differences from the control areas that have nothing to do with the treatment itself – the problem of hidden bias. A familiar example is the correlation of smoking and heart attacks. Looking at the number of heart attacks among 500 smokers and 500 non-smokers might reveal a significant correlation between smoking and heart disease. However, on that data alone other correlated hypotheses cannot be excluded. For example, it is possible that the smokers were on average more obese, in which case heart disease may be correlated strongly with obesity, but poorly with smoking, independent of body condition – obesity is biasing the correlation.

The formal process of initiating an observational study involves an extensive pre-treatment or pre-analysis assessment of the "treatment" and "control" data. Until proper hypothesis generation, matching and hidden bias assessment are done, all of the problems with non-randomly distributed samples are present, and the results of any analysis highly suspect. Observational studies statistical approaches differ markedly from standard inferential statistics at this point: it is essential to generate as many alternative hypotheses as possible and to collect all of the classification variables that might be correlated with each hypothesis; since there is no randomization of treatment and control application across a single population, proper contrast due to treatment can only be established by proper matching of treatment and control samples (pre- or post-hoc); and finally, as a result of the non-random nature of the samples, bias (hidden) may be present in the data and must be assessed. However, it is a relatively straightforward process of correlation analysis to establish that treatments in these studies are free from hidden bias. If bias is present in a proposed matching scheme for "treatment" and "control" samples it can be dealt with in several manners, the most effective being re-matching to minimize the bias. Once hidden bias is removed, standard statistical approaches that are familiar to randomized experiments can be applied to draw similar quality inferences (Rosenbaum, 2002).

Since hidden bias reduction is critical to the successful analysis of an observational study, the process merits further discussion. One of the strategies for eliminating hidden bias is to stratify treatment and control comparisons with a long vector of correlated variables ($\mathbf{x}_{[j]}$). If $\mathbf{x}_{[j]}$ is the same in treatment and control groups, or that the likelihood of elements in $\mathbf{x}_{[j]}$ being the same ($\lambda(\mathbf{x}_{[j]})$) is itself the same in treatments and controls, then standard statistical approaches to evaluating the consequences of treatments can be employed (Rosenbaum, 2002). If $\mathbf{x}_{[j]}$ is of high dimension with continuous variables, and so is unlikely to be exactly equivalent in treatments and controls, there are approaches to determine confidence intervals on $\mathbf{x}_{[j]}$ and rules for when standard analytical approaches for randomized treatments to observational studies can be applied (Rosenbaum, 2002).

These features of observational studies will be incorporated into the study designs for effectiveness research. The utility of $\mathbf{x}_{[j]}$ in validating inferences has, in part, motivated the long list of classification variables that is a required components of this program. In the study design, common values of $\mathbf{x}_{[j]}$ will be used to identify suitable controls for treatment sites. In the response design changes in other indicators to will discriminate the differences between treatments and controls.

To summarize, the watershed scale habitat project effectiveness monitoring program will assess the aggregate impact of all habitat restoration projects (ongoing or recently completed) within target watersheds that lie within the subbasin scale status and trends monitoring program. To assess the impact of actions over which this monitoring project exerts little or no siting or implementation control will be a challenge; however, the program is specifically designed to capture the observational studies nature of the resulting program. The fundamental design concept common to all watersheds included in the project is as follows: (i) within target watersheds, monitor at a reach scale physical / environmental indicators at each habitat action, (ii) monitor juvenile salmonids for density and distributional associations with projects, (iii) monitor control locations for habitat and population indicators within and outside of target watersheds, (iv) monitor integrator population and water quality indicators at base of target watershed. Items (i) and (iv) are specific to the watershed-scale effectiveness monitoring, though the trapping specified in (iv) could be part of the status monitoring program. Items (ii) and (iii) are central to the status monitoring program, though tagging for survival estimates in (ii) could be specific to the effectiveness monitoring program. Thus, the status monitoring program will overlap significantly with the effectiveness monitoring program, and as such, both programs must be developed cooperatively by the same entities.

Figure 3.2 shows an example watershed. It has three actions: riparian planting in a juvenile rearing reach, sediment reduction in a spawning reach, and a barrier removal on a small tributary. The entire length accessible to spring chinook (including small tributaries not shown on the diagram) will be surveyed for the eight variables listed under question (1), above, in 2003. A gaging station for measuring flow, water temperature, and water chemistry is located at the bottom of the system.

Counts of adults are conducted in summer/fall at a weir at the bottom (lower right) of the system. Red counts and carcass surveys (for age, sex, and hatchery origin) are also done in the spawning reach near the top (upper left) each year. Juvenile emigrants (parr in summer, smolts in spring) are caught at a screw trap above the weir, and, in conjunction with PIT tagging of all captured fish and re-release of some fish above the trap, estimates of trap efficiency and hence emigrant abundance can be made each year.

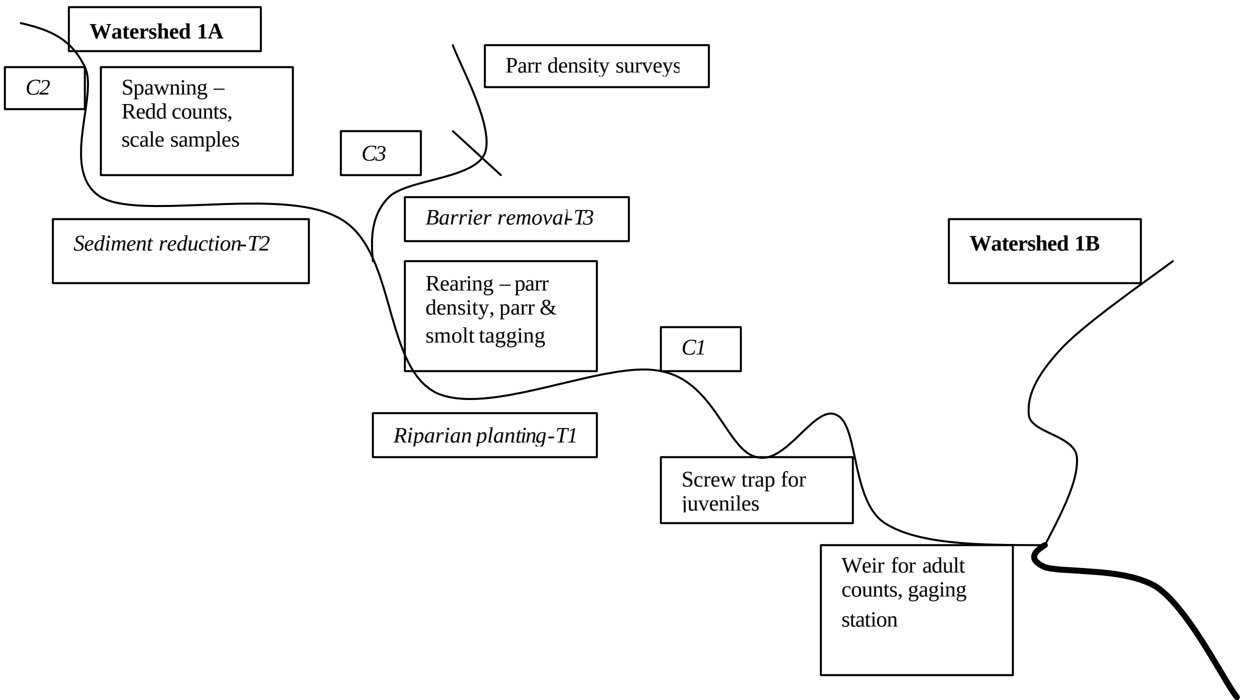


Figure 3.2. Example watershed showing layout of habitat actions and sampling sites. Biological monitoring locations are in regular type; action and control locations are italicized. "T(n)" denotes sites for intensive monitoring at treatment sites; "C(n)" similar monitoring for control sites.

The treatment and control reaches (three of each) will be intensively monitored each year for the environmental variables described above, and for juvenile (parr) density. Similar monitoring is also occurring for watershed 1B (right-hand side of diagram), and assumed for convenience that watershed 1B has no habitat actions occurring, with 6 sites (reaches) intensively monitored. It is assumed that all monitoring occurred for both sub-populations for five years before any actions were taken for 1A. It is also assumed that tagged juveniles are detected at mainstem dams.

So, for this example, the program would generate 5 years of pre-treatment and 5 years of post-treatment data for 1A, and 10 years of "control" data for the same time period for 1B. As previously described a long list of data types will be collected, but for this example focus on a couple of reach-scale variables – sediment and parr density – and on two watershed scale variables – parr-to-smolt survival and smolts per spawner.

With two watersheds and three habitat actions, it will be possible to test a number of hypotheses, going from smaller (reach) scales to larger (watershed) scales. These might include:

1. Sediment in spawning gravels has decreased at the (single) treatment site compared to both pre-treatment conditions, the control site for watershed 1A, and control sites for watershed 1B.
2. Parr density has increased at the riparian treatment site compared to both pre-treatment conditions, the control site for watershed 1A, and control sites for watershed 1B.

3. Parr-to-smolt survival has increased for watershed 1A compared to pre-treatment conditions and compared to watershed 1B.

4. Smolts-per-spawner has increased for watershed 1A compared to pre-treatment conditions and compared to watershed 1B.

Statistical methods would be a basic Before-After-Control-Impact (BACI) design for testing all four hypotheses, since by assumption there would be 5 years of pre-treatment data for both watersheds and the 12 reaches (six per watershed). If no pre-treatment data had been collected (which implies a different experimental design), analyses would rely on simpler but less powerful paired treatment-control designs. The latter approach, of course, runs a risk: attribution survival improvements to the habitat actions could be confounded if watershed 1A *always* had lower sediment levels, higher parr density, etc. than 1B.

Other potential problems at this scale are amenable to reasonably well-established solutions. For example, there will be a plethora of potential independent variables that could be used in regression or ANOVA models. All of the variables noted above (e.g., flow, temperature, stream characteristics, etc.) might be important in explaining differences between treatment and control sites. One approach, assuming the use of models with maximum likelihood solutions, is to use Akaike Information Criterion (AICc) weights, corrected for degrees of freedom, to select the most plausible model(s). In addition, it will be necessary to systematically ascertain that the treatment sites are indeed similar to their paired control sites.

Solutions to some statistical problems are less clear-cut, of course. For example, if an action increases egg-fry survival rates, then, absent density dependent effects, there is an expectation that abundance would increase at all subsequent life stages (i.e., parr, smolt, and adult). Since the monitoring effort may well generate abundance estimates at each life stage, there will likely be a temptation to try to estimate separate models for effects of habitat actions on, for example, parr-per-spawner, smolts-per-spawner, and adult recruits-per-spawner, and use the "best" model to evaluate the results. At some level, however, this is clearly incorrect, since the three models would not be truly independent of one another. Hierarchical Bayesian or multi-variate methods may be useful here to account for the interdependence among models and dependent variables.

In any event, the preceding sort of analysis has been done before (e.g., Solazzi et al. 2000) on the scale of a watershed or subbasin with a few actions and a few affected sub-populations of juveniles. So what happens when scaling up the analysis from 1 or 2 sub-populations and a few actions to 5-10 sub-populations and many actions? The basic statistical methods (BACI, etc.) do not change. What does change is that the categorical or classification variables (ecoregion, channel characteristics, etc.) may come into play to help explain differences among survival rates for sub-populations or reach-level effects for actions. For example, it may well be the case that the effectiveness of riparian planting varies with both the pre-treatment conditions and the quality of surrounding habitat. That is, if prior to treatment riparian habitat quality is very poor, treatment may be more effective than if existing habitat is in fair condition. Similarly, if surrounding habitat is in poor condition, treatment may be more effective at attracting juveniles than if surrounding habitat is already in good condition. An analysis at this scale is unprecedented, and surprises are to be expected. In addition, as the number of actions and action types increases with the number of sub-populations analyzed, it should be possible to draw inferences about the local effects of different action types.

Finally, how will it be possible to conduct an analysis that examines the effects of actions on the ESU scale, with 50+ sub-populations (this requires extending the effort beyond the pilot subbasins, as will occur in 2004 and later)? There are two broad possibilities. First, depending on the luck-of-the-draw for how actions and action types are distributed across sub-populations, it may be possible to determine how effective different action types are at increasing survival rates. If, on the one hand, all sub-populations have roughly the same mix of action types, then it will be very difficult to determine which actions are contributing the most to changes in survival rates. On the other hand, if action types are concentrated in particular sub-populations – with some having mostly irrigation screening, others mostly flow augmentation, etc. – then it should be possible to tease out the effects of each class, since there will be many observations on life-stage survival in hand by 2008.

The second possibility is to track the effects of habitat actions on the ESUs as a whole. Again, this will depend on the luck-of-the-draw, since in this case some sub-populations would need to be "intensively" treated, with many habitat actions, while others are subject to few or none. If that is indeed the case, then there should be substantial contrast in the changes in life-stage survival rates, recruits-per-spawner, and trends in adult abundance among the stocks. These differences, in turn, should be detectable using BACI designs or related statistical models.

As noted earlier, no fish habitat effectiveness research, monitoring, and analysis has ever been attempted on this scale. Surprises – pleasant and otherwise – are therefore to be expected. There are few, if any, well-established estimates of effect size. In many cases experienced habitat analysts believe that effect sizes are likely to be small, and therefore difficult to detect. Doing true controlled experiments on this scale is impossible, due to uncontrollable natural, anthropomorphic disturbances, and non-random assignment of treatment sites. Finally, standardized monitoring on the scale proposed, with attendant quality assurance/quality control, data management and access, etc. will be a substantial management challenge in its own right. While all of these are reasons to be cautious about predicting the ultimate outcome of the experiment, none appears at this point to be an insurmountable obstacle.

H. Relationship of Tributary Monitoring Program to other BiOp and Regional Programs.

Coordination with natural resource co-managers

The tributary monitoring program development as proposed herein will require extensive collaborative work with ongoing research and monitoring programs. The ecosystem scale pilot projects will require extensive collaboration with regional data management entities, as well as a wide range of resource management agencies currently doing landscape assessments (*e.g.*, States, USGS, USFS/BLM) and research units developing novel approaches and techniques (*e.g.*, OSU, PNWERC, CLAMS). For the subbasin scale status and trend monitoring pilot projects, the design and testing phase for this project will require collaboration with US Environmental Protection Agency research staff for statistical components of the design, and subbasin planning entities for programmatic components of the design. Implementation of the status and trend monitoring program will require extensive coordination with local co-manager groups in each subbasin. For example, in the Wenatchee River basin the pilot project will interface directly with the following ongoing efforts: US Forest Service's Aquatic Habitat survey program, Chelan County PUD's juvenile salmonid sampling program, Washington Department of F&W's juvenile and adult salmonid sampling program, Washington Department of Ecology's Regional Environmental Monitoring and Assessment Program. Similarly in the other subbasins, local coordination is key to the design, testing and implementation of this program. At the regional scale, the pilot projects must be coordinated with basin-wide recovery planning, regional development of monitoring strategies, and the implementation of a basin-wide data management system. Overarching coordination groups such as CBFWA, Federal Caucus, and the ISRP and ISAB should play a major role in establishing and maintaining the regional context for the status monitoring pilot projects.

Coordination with Technical Recovery Teams

The Technical Recovery Teams (TRT) are charged with establishing demographic unit delineations, identifying factors for decline, and viability criteria for all populations of listed anadromous salmonids within their recovery domains. Two recovery domains overlap with the ESUs covered by the NMFS FCRPS BiOp. Therefore, the tributary monitoring program generated by the FCRPS BiOp must support the efforts of the Interior Columbia and Lower Columbia/Willamette TRTs with respect to the following ESUs: Snake River steelhead, Snake River Fall chinook, Snake River Spring/Summer Chinook, Snake River sockeye, Mid-Columbia River steelhead, Upper Columbia River steelhead, Upper Columbia River Spring chinook, and Columbia River chum. The pilot monitoring projects outlined above support the development of a status monitoring program that would address many of the TRT's requirements for all ESUs above except: Snake River sockeye, Snake River Fall Chinook, and Columbia River chum. These ESUs' monitoring needs may be met through other programs (SR sockeye are primarily a captive breeding population, CR chum are currently monitored by USFWS and WDFW, and SR Fall chinook are monitored by IDFG and FPC); however a targeted assessment of these projects must be done in conjunction with the TRT's data requirements.

Based on draft population delineations, factors for decline and viability criteria, the Columbia River basin TRTs point to several major short comings in the region's status monitoring data collection program. In particular, the Columbia River basin lacks any systematic tributary habitat survey work that is linked to assessments of aquatic habitat condition. Several other major data gaps have emerged from the TRTs' work to date: a comprehensive assessment of the fraction of naturally spawning fish of hatchery origin, a comprehensive assessment of the utilization of mainstem habitat by steelhead, more complete population assessments of steelhead in general, and better monitoring of natural juvenile fish production and movement at the tributary level. Therefore, the FCRPS BiOp tributary monitoring program should explicitly address these issues to better support regional scale recovery planning.

Estimated Costs of full implementation of Tributary Monitoring Program

The estimated cost of these programs represents a significant coordination issue, one that could ultimately be the primary stumbling block for implementation of a basin-wide rigorous monitoring program. As such, it is important to outline the potential financial cost of this program to motivate the regional discussions around the costs borne by the resource if the region does not choose to engage fully in implementing a rigorous tributary status, trends and effectiveness monitoring program.

Status and Trends Monitoring
Based on the cost estimates for the pilot subbasin scale status and trend monitoring program, full implementation of the status monitoring program for the anadromous portion of the Columbia River basin could cost at most $7M/yr. This estimate is based on a per subbasin cost of $350,000/yr and 20 "subbasins" in the anadromous portion of the Columbia River basin. The above costs are maximum estimates since they represent complete population and habitat monitoring programs independent of the extensive current ongoing monitoring work. However, lacking effective regional coordination and planning, regional technical and policy advisory forums, and a single basin-wide fish and wildlife management initiative that implements a consistent restoration, recovery, monitoring and evaluation program, the likelihood that significant duplication of monitoring and evaluation can be identified and avoided across the entire Columbia River basin is low. However, the potential for extensive cost-savings, not to mention the readily apparent utility of a uniform monitoring and evaluation program for the Columbia River basin aquatic ecosystem, especially when integral to a fish and wildlife management program, are strong motivating factors.

AER
Arriving at costs for annual sampling of treatment and control reaches, requires estimates of both per-site or per-mile costs and estimates of the number of sites that need to be sampled. Very rough costs per mile appear to be about $2K - $5K, including costs for measuring the habitat variables in Table 3.6 and snorkel surveys to estimate changes in parr density and distribution. At least in the Snake, some juvenile tagging and density surveys are already ongoing. In Idaho, for example, about 10 percent of the habitat suitable for parr has been snorkeled each year. As noted, however, many of these surveys have been discontinued.

Lengths of survey sites (treatment and control) will range from a minimum of 150 m to a maximum of 20 times the mean bankfull width. Monitoring a total of 1000[8] sites, with an average length of 500M (approx. 1/3 mile), the resulting annual cost would be about:

1000 sites * 1/3 mile per site * $5K per mile ˜ $1.7M per year.

A guess at additional biological sampling not included in the above would be $500K-$1M per year, roughly $30K-$50K for each of the 15 sub-populations, with many needing little new effort. This would cover PIT tagging efforts, juvenile (parr and smolt traps), and increased redd or weir counting efforts, as needed.

Other costs would include additional stream gaging, data management, and data analysis. Data management, including QA/QC, data access via the Web, etc. might add $50K to $100K. This number is based on a rough-and-ready extrapolation from the annual data management costs for PTAGIS (199008000 , $795K for their Task 1), and an assumption that the volume of data to be managed will be far lower than 1 million or so PIT tags PTAGIS tracks each year. Data analysis costs are difficult to estimate, but seem unlikely to run more than $300K to $600K per year.

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[8] Based on very rough estimates of 150 sites in the John Day, 100 in the Wenatchee, and 300 in the upper salmon, with a roughly equal number of control sites. The 1/3 mile estimate will be high in many cases, where stream width may be 10 m or less.

So, the total for the three pilot basins might be annual costs of about $2.5M to $3M in round numbers. This does not include the cost of the habitat inventories, which might run an additional $100K. Whoever conducts the inventories should probably be charged with collection and compilation of existing biological data and metadata as well. While the cost estimates will surely change better information on per-mile survey costs are acquired, additional tagging that may be needed is conducted, etc., these estimates appear to be realistic.

Additional programmatic needs arising from non-status monitoring aspects of the NMFS FCRPS BiOp RME program

These additional programmatic requirements of the tributary monitoring program arise directly from status and effectiveness monitoring like components of the action plan for implementation of RME Actions other than 180 and 181, as well as from the indirect needs of the tributary monitoring program itself.

Coordination between implementation of Actions 180, 181, and 183

The subbasin scale status monitoring pilot projects will be directly coordinated with the AER projects in at least 4 ways. The AER and status monitoring programs have many biological and physical indicators in common. Therefore, the particular form of indicators, and in particular, specific protocol requirements, will be developed cooperatively between the status monitoring and AER programs. Since the status and trend components of the subbasin scale status monitoring program are relevant to the AER projects, status samples are similar to AER treatment samples, and trend samples are similar to AER control samples; therefore, the structure of rotating panel like sampling designs for the status monitoring program should be developed with the intent to be as directly applicable to the AER program as possible. Finally, direct interaction between the AER program and the status monitoring pilot projects will occur in the 3 pilot project subbasins. In these 3 locations, pilot scale implementation of both status monitoring and watershed scale effectiveness monitoring programs will be implemented.

Because AER will occur at a range of spatial scales, there may be some confusion between the roles of status monitoring and effectiveness research. Researchers often think of status monitoring as monitoring that occurs at coarser spatial scales and effectiveness research at finer scales. In reality, both will occur across different spatial scales, and the integration of both is needed to develop a valid monitoring program (ISAB 2003).

Status monitoring is used to characterize existing (baseline) conditions. The intent is to capture temporal trends and variability in the parameters of interest. Action effectiveness research, on the other hand, evaluates whether the management actions achieved the desired effect or goal. Success or failure is assessed by statistical comparisons with controls, baseline conditions, or desired future conditions. Although there is an important distinction between the two types of analysis, they often rely on the same monitoring data. What makes effectiveness research different from status monitoring/analysis is that effectiveness research compares an indicator in treatment and control areas and makes inferences regarding cause-and-effect based on those comparisons. Status monitoring does not use controls and therefore is not designed to identify cause-and-effect relationships. In short, both types often measure the same thing, but they use the data very differently, since they have different objectives and purposes.

It then follows that the data collected for action effectiveness research can be used for status monitoring,[9] but the reverse may not be true. Only under specific circumstances can status monitoring data be used in effectiveness research. For example, an existing status monitoring program may have measured egg-smolt survival within a watershed for the last five years. After the fifth year, the watershed is treated with some management action. Monitoring continues to measure survival following the treatment event. In this case, status monitoring becomes action effectiveness research when the survival data before treatment (temporal control) are compared to survival data after treatment.

Because the BiOp calls for both types of monitoring, and because both types often measure the same variables, the following Plan has a mix of both status monitoring and effectiveness research. This integrated approach avoids unnecessary, repeated sampling of the same parameters and thus reduces total monitoring effort and cost.

Coordination with the Hatchery/Harvest RME efforts (RPA Action 182)
The implementation plan for RPA Action 182 identifies two major components of required work: an assessment of the breeding efficacy of individual hatchery origin fish spawning in the wild; and the spatial and numerical extent to which this occurs. The Hatchery/Harvest RPA Action Plan addresses the first component of the implementation of RPA Action 182, leaving the issue of the assessment of the extent of naturally spawning hatchery fish to the status monitoring program. Therefore, to meet the needs of RPA Action 182, the status monitoring program must include as population scale indicators, the relative number of hatchery fish spawning in the wild. Specific performance standards for this assessment were presented above (Fraction of naturally spawning fish that are of hatchery origin, CV < 10%).

Coordination with the Data Management effort (RPA Action 198)
The implementation of pilot monitoring projects will necessitate the parallel implementation of a data management system capable of handling the projects' diverse data types. However, the data management system's function is much more than just data storage. The status monitoring program will be implemented by numerous agencies, each contributing a portion of the comprehensive status monitoring program. Thus, data management is key for coordinated implementation of the multiple sub-projects, since many of these sub-projects will be inter-related. For example, habitat surveys may be broken into riparian assessment and water quality assessment components due to the specializations of participating co-manager agencies. Further sub-division of biological sampling is expected, as adult and juvenile fish monitoring will occur via a variety of techniques distributed throughout the year. Thus, a complete picture of habitat and population status is only possible by coordinated data management with common standards for measuring and reporting and strict data quality control enforced to ensure proper alignment of multiple data sets. A data management system will also identify possible efficiencies in program implementation by illustrating duplication of effort and parallel sampling opportunities, especially if a common data management system is applied broadly across multiple RPA Action Item implementation projects (*e.g.*, RPA Actions 180, 181, 182 and 183). However, the most important role a common data management system will play in FCRPS BiOp RME program

[9] Exceptions are possible depending on the specific objectives of status monitoring. For example, the spatial extent of effectiveness research may not be sufficient for a given status monitoring program. This does not mean that the data collected for effectiveness research cannot be used. Rather, additional data may be needed to satisfy the objectives of status monitoring.

implementation is to support evaluation of monitoring data. The overall BiOp performance standards require the synthesis of data from multiple RPA Action Item implementation projects. As such, the organizing component of the entire BiOp evaluation process should be a data management effort common to all RPA Actions, in particular, the Actions specified in the FCRPS BiOp RME program.

Data collected, following quality assurance/quality control (QA/QC) by field crews and their managers, would go to repositories that, in turn, would make it available to anyone interested in doing summaries and analyses. This needs much additional thought and discussion, since this sort of ready access to detailed, current monitoring data has few regional precedents, PTAGIS (for PIT tag detections) being a notable exception. Close adherence to common data collection, QA/QC, and reporting protocols will be essential for comparisons across sites and sub-populations. While the previous tables and discussion, and Attachment 1, give considerable detail of what is to be monitored and how the variables should be measured, many details must still be worked out. These include:

1. Procedures for QA/QC of electronically recorded data;

2. Mechanisms to transfer data from field workers to a central location;

3. Methods and rules for taking data from spreadsheets, etc. to a more formal database structure, including variables' formats, metadata, etc.;

4. Rules for data access (who can change the content), and methods to make the data widely available for analysts and other interested parties (Web site, ftp sites, etc.);

5. Detailed rules for units (e.g., location in UTM or some other system), precision (e.g., temperature in degrees C rounded to the nearest integer), etc.;

6. Standards for metadata – how much detail is needed, etc.;

7. Methods to link or group observations for queries – temporally, spatially, by species affected or project type.

In addition, while the overall objective is timely access to accurate data, many details must still be worked out. For example, will everyone want access to all the raw data, or will summaries of some type suffice? Again, using PTAGIS as an example, a user can obtain highly summarized information on an adult detected at Bonneville (tag # N was last seen on 04/21/03) or very detailed data on each detection of tag N at each coil in each ladder. As with the data collection and experimental designs, a pilot and field trials will be required to get this working properly. BiOp and regional data management groups will be required for assistance and review.

Other Status Monitoring Needs And Programs

Collectively the indicators identified herein are the key elements comprising the Tributary Status and Effectiveness Monitoring component of Action Agencies FCRPS BiOp RME Program. However, there are other regional monitoring programs that need the same data, and additional information beyond the scope of the Action Agencies Plan.

The need for, and benefits of, a systematic, integrated, regional status and effectiveness monitoring program is recognized by a broad spectrum of federal, state, and tribal fish and wildlife recovery and restoration plans (ISAB 2003, NMFS 2000a, NMFS 2000b, CRITFC 1995, Roger et al. 2000). Despite this common goal, actual implementation of a cohesive status monitoring program has proven to be elusive. Obstacles are evident in the form of policy, technical, and on-the-ground challenges including:

1. Policy Challenges
   - Unspecified level of uncertainty that is acceptable for decision making
   - Cooperation of necessary private, local, state, tribal, and federal jurisdictions is difficult to achieve
   - Agencies have different scopes of responsibility and authority
   - Agencies often have no mandate for supporting regional programs
   - Different entities and programs operate at different spatial and temporal scales
   - Perceived high cost
   - Insufficient technical feedback to policy makers

2. Technical Challenges
   - No comprehensive catalog of existing monitoring efforts
   - No concise, clearly described basin-wide monitoring program presently exists
   - Specific monitoring responsibilities need to be assigned to, and accepted by a complex of agencies
   - Data management technology is evolving rapidly and the various entities are at different stages of ability and have different levels of available resources.

3. On-the-Ground Challenges
   - Coordinating field crews from multiple agencies is operationally difficult
   - Field crews often do not have time for data entry and QA/QC activities
   - A agreed upon manual describing field data collection methods is needed to guide diverse field crews

There is much work to be done in this regard, which will involve the participation of many agencies besides the Action Agencies and NMFS. A common vision and full participation by all affected agencies is required. NMFS and the Action Agencies cannot develop a regional plan on their own, nor would it be appropriate. But they can focus on particular issues in the context of the FCRPS BiOp. Of primary concern is the lack of regionally representative technical and policy groups through which large scale RME plan development and implementation could be affected. An additional, but equally important concern is that a standard set of guidelines or procedures for collecting monitoring information has not yet been established. This is necessary to ensure that compatible data are collected by different agencies, and the quality of that data is sufficient to satisfy the check-in tests envisioned by NMFS.

Herein NMFS and the Action Agencies propose preliminary guidelines for establishing sound protocols for collecting tributary status and action effectiveness monitoring data. The focus here is on biological indicators linked directly to listed salmonid ESUs. With respect to environmental indicators, NMFS and the Action Agencies rely on established environmental monitoring programs to develop appropriate methods for application in the tributary and estuary zones, as well as at the ecosystem/landscape level.

I. References

APHA, AWWA, and WEF (American Public Health Association, American Water Works Association, and Water Environment Federation). 1999. Standard methods for the examination of water and wastewater. 20th Edition. American Public Health Association, Washington, D.C.

Alverts, B., Horton, A. and Stone, B. 1997. Results of FY 1996: Implementation Monitoring Program for Management of Habitat for Late-Succession and Old-Growth Forest Related Species within the Range of the Northern Spotted Owl. United States Forrest Service.

Bain, M. B. and N. J. Stevenson, editors. 1999. Aquatic habitat assessment: common methods. American Fisheries Society, Bethesda, MD.

Bayley, P.B. 2002. A review of studies on responses of salmon and trout to habitat change, with potential for application in the Pacific Northwest. Department of Fisheries and Wildlife. OSU.

Bevenger, G. S. and R. M. King. 1995. A pebble count procedure for assessing watershed cumulative effects. Research Paper RM-RP-319, USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO.

Bisson, P. A. and D. R. Montgomery. 1996. Valley segments, stream reaches, and channel units. Pages 23-52 *in*: R. R. Hauer and G. A. Lamberti, editors. Methods in stream ecology. Academic Press, New York, NY.

Bjornn, T.C. 1978. Survival, production, and yield of trout and chinook salmon in the Lemhi River, Idaho. College of Forestry and Range sciences, University of Idaho, Boise, Idaho. Bulletin No. 27.

Botkin, D. B., Peterson, D. L. and Calhoun, J. M., Ed's, (2000). The scientific basis for validation monitoring of salmon for conservation and restoration plans. Olympic Natural Resources Center Technical Report. University of Washington, Olympic Natural Resources Center, Forks, Washington, USA.

Bunte, K. and S. R. Abt. 2001. Sampling frame for improved pebble count accuracy in coarse gravel-bed streams. Journal of the American Water Resources Association 37:1001-1014.

BURPTAC (Beneficial Use Reconnaissance Project Technical Advisory Committee). 1999. 1999 beneficial use reconnaissance project workplan for wadable streams. Idaho Division of Environmental Quality, Boise, ID.

Canale, G. 1998. Analysis of Macroinvertebrate Data from theGrande Ronde Long Term 319 NPS Project 1993 – 1996. Oregon Department of Environmental Quality. Laboratory Division, Biomonitoring Section, Report: BIO98-003. Portland, OR.

Cochran, W. G. 1965. The planning of observational studies of human populations. J. Royal Statistical Soc., Series A, 128:134-155.

Columbia Basin Fish and Wildlife Authority (CBFWA) (2001). Provincial ReviewProcess and Sub basin Planning: Sub basin summaries and Workplan. http://www.cbfwa.org/files/province/gorge/subsum.htm

CRITFC. 1995. Wy-Kan-Ush-Mi Wa-Kish-Wit: Spirit of the salmon - the Columbia River anadromous fish restoration plan of the Nez Perce, Umatilla, Warm Springs and Yakama Tribes. Columbia River Inter-Tribal Fish Commission, Portland, Oregon. 2 vols.

Cupp, C. E. 1989. Identifying spatial variability of stream characteristics through classification. Master's thesis. University of Washington, Seattle, WA.

Drake, D. 1999. Oregon Coast Range REMAP Study: Stream habitat index development and site results 1994 – 1996. Oregon Department of Environmental Quality. Laboratory Division, Biomonitoring Section, Report: BIO98-006. Portland, OR.

Dunham, J., B. Rieman, and K. Davis. 2001. Source and magnitude of sampling error in redd counts for bull trout *Salvelinus confluetus*. North American Journal of Fisheries Management 21(2): 343-352.

Gordon, N. D., T. A. McMahon, and B. L. Finlayson. 1992. Stream hydrology an introduction for ecologists. John Wiley and Sons, New York, NY.

Hankin, D.G. 1984. Multistage sampling designs in fisheries research: applications in small streams. Can. J. Fish. Aqu. Sci. 41:1575-1591.

Hankin, D.G., and G. H. Reeves. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Can. J. Fish. Aqu. Sci. 45:834-844.

Hillman, T. and A. Giorgi. 2002. Monitoring protocols: effectiveness monitoring of physical/environmental indicators in tributary habitats. BioAnalysts, Inc. Report to Bonneville Power Administration, Portland, OR. http://www.efw.bpa.gov/cgi-bin/FW/welcome.cgi?ViewMode=External

Holmes, E. E. 2001. Estimating risks in declining populations with poor data. Proceedings of the National Academy of Science USA 98:5072-77.

Holmes, E. E. and W. F. Fagan. 2002. Validating population viability analysis for corrupted data sets. Ecology, in press.

Hubler, S. 2000. Upper Deschutes River Basin REMAP: 1997-1998 Habitat summary. Oregon Department of Environmental Quality. Laboratory Division, Biomonitoring Section, Report: BIO00-xxx. Portland, OR.

Hughes, R. M., P. R. Kauffmann, A. T. Herlihy, S. S. Intelmann, S. C. Corbett, M. C. Arbogast and R. C. Hjort. 2002. Electrofishing distance needed to estimate fish species richness in raftable Oregon rivers. North American Journal of Fisheries Management 22:1229-1240.

Independent Scientific Advisory Board (ISAB) 2003. A review of strategies for recovering tributary habitat. Northwest Power Planning Council, Portland, OR.

Independent Scientific Advisory Board (ISAB), (2001). Model Synthesis Report: An analysis of decision support tools used in Columbia River Basin salmon management. March 2, 2001. ISAB 2001-1a. For the Northwest Power Planning Council and the National Marine Fisheries Service.

Independent Science Review Panel (ISRP). 2003. Review of Draft Clearwater Subbasin Plan. Available at: http://www.nwcouncil.org/library/isrp/isrp2003-3.pdf

Jacobs S., J. Firman, and G. Susac 2001. Status of Oregon coastal stocks of anadromous salmonids, 1999-2000; Monitoring Program Report Number OPSW-ODFW-2001-3, Oregon Department of Fish and Wildlife, Portland, Oregon.

Jacobs, S.E., and T.E. Nickelson. 1998. Use of stratified random sampling to estimate the abundance of Oregon coastal coho salmon. ODFW Fish Research Project Final Report: F-145-R-09. ODFW Portland, OR.

Jones, K. K. and K. M. S. Moore. 1999. Habitat assessment in coastal basins in Oregon: implications for coho salmon production and habitat restoration. Pages 329-340 In Sustainable Fisheries Management. E. E. Knudsen, C. R. Steward, D. D. McDonald, J. E. Williams, and D. W. Riser Eds. CRC Press New York 724 p.

Jones, K.K., R.L. Flitcroft, and B.A. Thom. 2001. Spatial patterns of aquatic habitat in Oregon. Pages 266–280 In First International Symposium on GIS in Fisheries Science. T. Nishida, Editor.

Kaufmann P.R., P. Levine, E.G. Robinson, C. Seeliger, and D.V. Peck. 1999. Quantifying Physical Habitat in Wadeable Streams. EPA/620/R-99/003. U.S. Environmental Protection Agency, Washington, D.C.

Keifer, R.B, P.R. Bunn, and J. Johnson. 2002. Natural Production Monitoring and Evaluation. IDFG Report 02-24.

King, J. G. 1989. Streamflow responses to road building and harvesting: a comparison with the equivalent clearcut area procedure. USDA Forest Service, Research Paper INT-401, Ogden, UT.

Larsen, D.P., T.M. Kincaid, S.E. Jacobs, and N.S. Urquhart. 2001. Designs for evaluating local and regional scale trends. BioScience 51(12):1069-1078.

MacDonald, L. H., A. W. Smart, and R. C. Wissmar. 1991. Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific Northwest and Alaska. U.S. Environmental Protection Agency, EPA/910/9-91-001, Seattle, WA.

MDT, 2002. Monitoring Design for the Forestry Module of the Governor's Salmon Recovery Plan. Monitoring Design Team. Draft July 18, 2002

Moore, K., K. Jones, and J. Dambacher. 2002. Methods for stream habitat surveys; aquatic inventory project. Oregon Department of Fish and Wildlife, Aquatic Inventories Project, Natural Production Program, Corvallis, OR.

Moore, K. 2002 DRAFT: Oregon Plan for Salmon and Watersheds Monitoring Strategy. Oregon Plan, Salem, OR

Moore, K.M.S., K.K. Jones, and J.M. Dambacher. 1997. Methods for stream habitat surveys. Oregon Department of Fish and Wildlife, Information Report 97-4, Portland, Oregon.

Naiman, R. J., D. G. Lonzarich, T. J. Beechie, and S. C. Ralph. 1992. General principles of classification and the assessment of conservation potential in rivers. Pages 93-123 *in*: P. J. Boon, P. Calow, and G. E. Petts, editors. River conservation and management. John Wiley and Sons, New York, NY.

National Marine Fisheries Service (NMFS). 2000a. Federal Columbia River Power System Biological Opinion: Reinitiation of Consultation on Operation of the Federal Columbia River Power System, Including the Juvenile Fish Transportation Program, and 19 Bureau of Reclamation Projects in the Columbia Basin. NMFS-NWR, Seattle, WA.

National Marine Fisheries Service (NMFS). 2000b. Recovery Planning Guidance for Technical Recovery Teams. 1 September, 2000 DRAFT. NMFS-NWR, Seattle, WA.

ODFW. 2002. Coastal Salmon Spawning Survey Procedures Manual.

Oregon Plan. 1997. Coastal Salmon Restoration Initiative. Salem, OR. http://www.oregon-plan.org/Final.html

OPSW (Oregon Plan for Salmon and Watersheds). 1999. Water quality monitoring, technical guide book. Version 2.0. Corvallis, OR.

Overton, C. K., S. P. Wollrab, B. C. Roberts, and M. A. Radko. 1997. R1/R4 (Northern/Intermountain Regions) fish and fish habitat standard inventory procedures handbook. USDA Forest Service General Technical Report INT-GTR-346, Ogden, UT.

Parker, M. A. 2000. Fish passage – culvert inspection procedures. Watershed Restoration Technical Circular No. 11. Ministry of Environment, Lands and Parks and Ministry of Forest, British Columbia.

Paulsen, C., S. Katz , T. Hillman, A. Giorgi, C. Jordan, M. Newsom, and J. Geiselman, 2002 "Guidelines for Action Effectiveness Research Proposals for FCRPS Offsite Mitigation Habitat Measures," http://www.efw.bpa.gov/cgiin/FW/welcome.cgi?ViewMode=ExternalView.

Paulsen, C.M. and T.R. Fisher. 2001. Statistical relationship between parr-to-smolt survival of Snake River spring-summer chinook salmon and indices of land use. Transactions of the American Fisheries Society 130: 347-358.

Paulsen, C. M. and R. A. Hinrichsen. 2002. Experimental management for Snake River spring/summer chinook (*Oncorhynchus tshawytscha*): trade-offs between conservation and learning for a threatened species. Canadian Journal of Fisheries and Aquatic Sciences 59:717-725

Paulsen, C.M. and T.R. Fisher. In review. Detecting juvenile survival effects of habitat actions: power analysis applied to endangered Snake River spring/summer chinook. Submitted to the Canadian Journal of Fisheries and Aquatic Sciences.

Peck, D. V., J. M. Lazorchak, and D. J. Klemm. 2001. Environmental monitoring and assessment program—surface waters: western pilot study field operations manual for wadeable streams. Draft Report. EPA/XXX/X-XX/XXX, U.S. Environmental Protection Agency, Washington, D.C.

Peterson, J., J. Dunham, P. Howell, R. Thurow, and S. Bonar. 2001. Protocol for determining bull trout presence. Draft report to the Western Division of the American Fisheries Society.

Platts, W. S., W. F. Megahan, and G. W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. USDA Forest Service General Technical Report INT-138, Ogden, UT.

Platts, W. S. and twelve others. 1987. Methods for evaluating riparian habitats with applications to management. USDA Forest Service General Technical Report INT-221, Ogden, UT.

Recovery Science Review Panel (RSRP) (2001). Report for the meeting held December 4-6, 2000. http://www.nwfsc.noaa.gov/cbd/trt.htm.

Reeves, G. H., and nine others. 2001. Aquatic and riparian effectiveness monitoring plan for the Northwest Forest Plan. USDA Forest Service, Pacific Northwest Research Station, Corvallis, OR.

Rodgers, J.D. 2000. Abundance of Juvenile Coho Salmon in Oregon Coastal Streams, 1998 and 1999. Monitoring Program Report Number OPSW-ODFW-2000-1, Oregon Department of Fish and Wildlife, Portland, Oregon. (http://osu.orst.edu/dept/pacrim/pdf's/snkrep99.pdf)

Roger, P., W. Bradley, R. Entz, T. Giese,V. Pero. 2000. DRAFT: Research, Monitoring and Evaluation Guidelines for Restoring Fish and Wildlife Resources in the Columbia River Basin. Columbia Basin Fish and Wildlife Authority Inter-Caucus Work Group

Roni, F., Beechi, T.J., Bilby, R.E., Leonetti, F.E., Pollock, M.M., and G.R. Pess. 2002. A review of stream restoration techniques and a hierarchical strategy for prioritizing restoration in Pacific northwest watersheds. North American Journal of Fisheries Management 22: 1-20.

Rosenbaum, P.R. 2002. Observational Studies. Second Ed. Springer-Verlag, New York. 230pp.

Rosgen, D. 1996. Applied river morphology. Wildland Hydrology, Pagosa Springs, CO.

Schuett-Hames, D., A. E. Pleus, E. Rashin, and J. Matthews. 1999a. Method manual for the stream temperature survey. Timber-Fish-Wildlife TFW-AM9-99-005, Northwest Indian Fisheries Commission, Olympia, WA.

Schuett-Hames, D., R. Conrad, A. Pleus, and M. McHenry. 1999b. Method manual for the salmonid spawning gravel composition survey. Timber-Fish-Wildlife TFW-AM9-99-006, Northwest Indian Fisheries Commission, Olympia, WA.

Streamnet, 2002. http://www.streamnet.org/online-data/GISData.html

Solazzi, M.F., T.E. Nickelson, S.L. Johnson, and J.D. Rogers. 2000. Effects of increasing winter rearing habitat on abundance of salmonids in two coastal Oregon streams. Canadian Journal of Fisheries and Aquatic Sciences 57:906-914.

Thurow, R.F. 2000. Dynamics of Chinook Salmon Populations Within Idaho's Frank Church Wilderness: Implications for Persistence. USDA Forest Service Proceedings. RMRS-P-15. Vol. 3.

Thom, B.A., K.K. Jones and R.L. Flitcroft. 1999. Stream Habitat Conditions in Western Oregon, 1998. Monitoring Program Report 1999-1 to the Oregon Plan for Salmon and Watersheds, Governor's Natural Resources Office, Salem, Oregon.

Thom B., K. Jones, P. Kavanagh and K. Reis. 2000. Stream Habitat Conditions in Western Oregon, 1999. Monitoring Program Report Number OPSW-ODFW-2000-5, Oregon Department of Fish and Wildlife, Portland, Oregon.

Thom, B. A., P. S. Kavanagh, and K. K. Jones. 2001. Reference Site Selection and Survey Results, 2000. Monitoring Program Report Number OPSW-ODFW-2001-6, Oregon Department of Fish and Wildlife, Portland, Oregon.

U.S. EPA. 1998. Environmental Monitoring and Assessment Program (EMAP): Research Plan 1997. EPA/620/R-98/002. U.S. Environmental Protection Agency, Washington, D.C.

U.S. EPA. 2000. Ecological Assessment of Streams and Rivers in the Western United States: A Cooperative Effort Between the U.S. EPA and Western States and Tribal Nations. U.S. Environmental Protection Agency, Corvallis, Oregon

USFS (U.S. Forest Service). 1974. Forest hydrology part II—hydrologic effects of vegetation manipulation. USDA Forest Service, Missoula, MT.

WA CMS. 2001. Washington State Comprehensive Monitoring Strategy. http://www.wa.gov/iac/SalmonMonitoring.html

WDFW (Washington Department of Fish and Wildlife). 2000. Fish passage barrier and surface water diversion screening assessment and prioritization manual. Washington Department of Fish and Wildlife Habitat Program, Environmental Restoration Division, Olympia, WA.

WFC (World Forestry Center). 1998. Pilot study report, Umpqua land exchange project. World Forestry Center, Portland, OR.

WFPB (Washington Forest Practices Board). 1995. Washington forest practices board manual: standard methodology for conducting watershed analysis under Chapter 222-22 WAC. Version 3.0. Washington Forest Practices Board, Olympia, WA.

Zar, J.H. 1998. Biostatistical Analysis. 4^{th} ed.. Prentice Hall, New York.

Zaroban, D. W. 2000. Protocol for placement and retrieval of temperature data loggers in Idaho streams. Idaho Division of Environmental Quality, Boise, ID.

ATTACHMENT 1 – Tributary Monitoring Methods

Methods for Measuring

The Tributary Population and Environmental Status and Restoration Action Effectiveness Monitoring Plan outlines an ambitious monitoring program for tributaries in the Columbia Basin. A central issue in that program is that the same indicators will be measured with the same methods in all watersheds. This will allow comparisons of physical/environmental conditions within and among watersheds and basins. In this appendix we identify methods to be used to measure each physical/environmental indicator.

There are several publications that describe methods for measuring physical/environmental indicators (see reviews by Johnson et al. 2001). Not surprisingly, there can be several different methods for measuring the same variable. For example, channel substrate can be described using surface visual analysis, pebble counts, or substrate core samples (either McNeil core samples or freeze-core samples). These techniques range from the easiest and fastest to the most involved and informative. As a result, one can define two levels of sampling methods. Level 1 (extensive methods) involves fast and easy methods that can be completed at multiple sites, while Level 2 (intensive methods) includes methods that increase accuracy and precision but require more sampling time. This appendix focuses primarily on Level 2 methods, which minimize sampling error.

Before we identify measuring protocols, it is important to define a few terms.

Sampling **–** sampling is the process of selecting a number of units in such a way that the units represent the larger group from which they were selected. Sampling should have some element of randomization.

Population **–** the population (or universe) is the total set of elements or units that are the target of our curiosity.

Sample **–** a sample is a subset of the population from which conclusions can be drawn about the characteristics of the population. If possible, samples should be selected with some element of randomization. This is not a concern with treatment sites, because in this program the entire population of treatments will be sampled. However, matching control sites should be selected randomly.

Sampling Frame **–** the sampling frame is a "list" of all the available units or elements from which the sample can be selected. The sampling frame should have the property that every unit or element in the list has some chance of being selected in the sample. A sampling frame does not have to list all units or elements in the population.

Reach (effectiveness monitoring) **–** for effectiveness monitoring, a stream reach is defined as a relatively homogeneous stretch of a stream having similar regional, drainage basin, valley segment, and channel segment characteristics and a repetitious sequence of habitat types. Reaches are identified by using a list of classification (stratification) variables. Reaches may contain one or more sites. The starting point and ending point of reaches will be measured with Global Positioning System (GPS) and recorded as Universal Transverse Mercator (UTM).

Reach (status/trend monitoring) – for status/trend monitoring, a reach is a length of stream (40 times the mean wetted width, but not less than 150-m long or longer than 500 m)[10] selected with a systematic randomized process (GRTS design). GRTS selects a point on the "blue-line" stream network represented on a 1:100,000 scale USGS map. This point is referred to as the "X-site." The X-site identifies the midpoint of the reach. That is, the sampling reach extends a distance of 20 times the average wetted width upstream and downstream from the X-site. Biological and physical/environmental indicators are measured within the reach. The X-site and the upstream and downstream ends of the reach will be measured with GPS and recorded as UTM.

Site (effectiveness monitoring) – a site is an area of the effectiveness monitoring stream reach that forms the smallest sampling unit with a defined boundary. Site length depends on the width of the stream channel. Sites will be 40 times the average wetted width with a minimum length of 150 m and a maximum length of 500 m. The upstream and downstream boundaries of the site will be measured with GPS and recorded as UTM.

Transect – a transect is a straight line across a stream channel, perpendicular to the flow, along which habitat features such as width, depth, or substrate are measured at pre-determined intervals. Effectiveness monitoring sites and status/trend monitoring reaches will be divided into 11 evenly-spaced transects by dividing the site into 10 equidistant intervals with "transect 1" at the downstream end of the site or reach and "transect 11" at the upstream end of the site or reach.

Classification Variables

Both status/trend and effectiveness monitoring require landscape classification. The purpose of classification is to describe the "setting" in which monitoring occurs. This is necessary because biological and physical/environmental indicators may respond differently to tributary actions depending on landscape characteristics. A hierarchical classification system that captures a range of landscape characteristics should adequately describe the setting in which monitoring occurs. The idea advanced by hierarchical theory is that ecosystem processes and functions operating at different scales form a nested, interdependent system where one level influences other levels. Thus, an understanding of one level in a system is greatly informed by those levels above and below it.

A defensible classification system should include both ultimate and proximate control factors (Naiman et al. 1992). Ultimate controls include factors such as climate, geology, and vegetation that operate over large areas, are stable over long time periods, and act to shape the overall character and attainable conditions within a watershed or basin. Proximate controls are a function of ultimate factors and refer to local conditions of geology, landform, and biotic processes that operate over smaller areas and over shorter time periods. These factors include processes such as discharge, temperature, sediment input, and channel migration. Ultimate and

[10] This reach length differs from the AREMP and PIBO protocols, which use 20x the bankfull width. The use of 40x the wetted width is consistent with the work of Simonson et al. (1994) and Reynolds et al. (2003).

proximate control characteristics help define flow (water and sediment) characteristics, which in turn help shape channel characteristics within broadly predictable ranges (Rosgen 1996).

This plan proposes a classification system that incorporates the entire spectrum of processes influencing stream features and recognizes the tiered/nested nature of landscape and aquatic features. This system captures physical/environmental differences spanning from the largest scale (regional setting) down to the channel segment (Table A1). By recording these descriptive characteristics, the investigator will be able to assess differential responses of indicator variables to proposed actions within different classes of streams and watersheds. Importantly, the classification work described here fits well with Level 1 monitoring under the ISAB (2003) monitoring and evaluation plan. Below we define each classification variable and recommend methods for measuring each variable.

Investigators may elect to describe additional classification variables depending on the objectives of the study. Here we provide only a general description of each classification variable. Because time and space do not allow us to describe methods in detail, we only identify recommended methods and instruments. We refer the reader to the cited documents for detailed descriptions of methods and measuring instruments.

The classification work described here is an exercise in GIS. That is, this work can be conducted in an office with GIS. It is important, however, to spend some time in the field verifying spatial data. We recommend that at least 10% of the channel segments identified in a subbasin be verified in the field. These segments can be selected randomly. Additional verification may be needed for those segments that cannot be accurately delineated from the remote sensed data.

Regional Setting

<u>*Ecoregions:*</u>
Ecoregions are relatively uniform areas defined by generally coinciding boundaries of several key geographic variables. Ecoregions have been defined holistically using a set of physical and biotic factors (e.g., geology, climate, landform, soil, vegetation, and water). Of the systems available, this plan includes the two most commonly used ecoregion systems, Bailey (1978) and Omernik (1987). Bailey's approach uses macroclimate and prevailing plant formations to classify the continent into various levels of detail. Bailey's coarsest hierarchical classifications include domains, divisions, provinces, and sections. These regional classes are based on broad ecological climate zones and thermal and moisture limits for plant growth (Bailey 1998). Specifically, domains are groups of related climates, divisions are types of climate based on seasonality of precipitation or degree of dryness or cold, and provinces are based on macro features of vegetation. Provinces include characterizations of land-surface form, climate, vegetation, soils, and fauna. Sections are based on geomorphology, stratigraphy and lithology, soil taxa, potential natural vegetation, elevation, precipitation, temperature, growing season, surface water characteristics, and disturbance. Information from domains, divisions, and provinces can be used for modeling, sampling, strategic planning, and assessment. Information from sections can be used for strategic, multi-forest, statewide, and multi-agency analysis and assessment.

The system developed by Omernik (1987) is used to distinguish regional patterns of water quality in ecosystems as a result of land use. Omernik's system is suited for classifying aquatic ecoregions and monitoring water quality because of its ecological foundation, its level of resolution, and its use of physical, chemical, and biological information. Like Bailey's system, this system is hierarchical, dividing an area into finer regions in a series of levels. These levels are based on characterizations of land-surface form, potential natural vegetation, land use, and soils. Omernik's system has been extensively tested and found to correspond well to spatial patterns of water chemistry and fish distribution (Whittier et al. 1988).

Until there is a better understanding of the relationships between fish abundance/distribution and the two classes of ecoregions, investigators should use both classifications. Chapter 3 in Bain and Stevenson (1999) outlines protocols for describing ecoregions. Published maps of ecoregions are available to assist with classification work.[11] This work will be updated once every 20 years.

Physiographic Province:

Physiographic province is the simplest division of a land area into hierarchical natural regions. In general, delineation of physiographic provinces is based on topography (mountains, plains, plateaus, and uplands) and, to a lesser extent, climate, which governs the processes that shape the landscape (weathering, erosion, and sedimentation). Specifically, provinces include descriptions of climate, vegetation, surficial deposits and soils, water supply or resources, mineral resources, and additional information on features particular to a given area (Hunt 1967). Physiographic provinces and drainage basins have traditionally been used in aquatic research to identify fish distributions (Hughes et al. 1987; Whittier et al. 1988).

Chapter 3 in Bain and Stevenson (1999) outlines methods for describing physiographic provinces. Physiographic maps are available to aid classification work.[12] Investigators will update physiographic provinces once every 20 years.

Geology:

Geologic districts are areas of similar rock types or parent materials that are associated with distinctive structural features, plant assemblages, and similar hydrographic character. Geologic districts serve as ultimate controls that shape the overall character and attainable conditions within a watershed or basin. They are corollary to subsections identified in the U.S. Forest Service Land Systems Inventory (Wertz and Arnold 1972). Watershed and stream morphology are strongly influenced by geologic structure and composition (Frissell et al. 1986; Nawa et al. 1988). Structural features are the templates on which streams etch drainage patterns. The hydrologic character of landscapes is also influenced by the degree to which parent material has been weathered, the water-handling characteristics of the parent rock, and its weathering

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[11] Bailey's digital-compressed ARC/INFO ecoregion maps are available at http://www.fs.fed.us/institute/ecolink.html. Omernik's digital level III ecoregion maps of the conterminous U.S. are available at http://www.epa.gov/OST/BASINS/gisdata.html (download BASINS core data) with documentation at http://www.epa.gov/envirofw/html/nsdi/nsditxt/useco.txt.

[12] Detailed information about physiographic provinces of the U.S. can be found at http://www.salem.mass.edu/~lhanson/. Digital maps can be found at http://water.usgs.gov/GIS/.

products. Like ecoregions, geologic districts do not change to other types in response to land uses.

Geologic districts can be identified following the methods described in Overton et al. (1997). Published geology maps aid in the classification of rock types. This work will be updated once every 20 years.

Drainage Basin

<u>*Geomorphic Features:*</u>
This plan includes four important geomorphic features of drainage basins: basin area, basin relief, drainage density, and stream order. Basin area (a.k.a. drainage area or catchment area) is the total land area (km^2), measured in a horizontal plane, enclosed by a drainage divide, from which direct surface runoff from precipitation normally drains by gravity into a wetland, lake, or river. Basin relief (m) is the difference in elevation between the highest and lowest points in the basin. It controls the stream gradient and therefore affects flood patterns and the amount of sediment that can be transported. Hadley and Schumm (1961) demonstrated that sediment load increases exponentially with basin relief. Drainage density (km) is an index of the length of stream per unit area of basin and is calculated as the drainage area (km^2) divided by the total stream length (km). This ratio represents the amount of stream necessary to drain the basin. High drainage density may indicate high water yield and sediment transport, high flood peaks, steep hills, and low suitability for certain land uses (e.g., agriculture). The last geomorphic feature, stream order, is based on the premise that the order number is related to the size of the contributing area, to channel dimensions, and to stream discharge. Stream ordering follows the Strahler ordering system. In that system, all small, exterior streams are designated as first order. A second-order stream is formed by the junction of any two first-order streams; third-order by the junction of any two second-order streams. In this system only one stream segment has the highest order number.

Chapter 4 in Bain and Stevenson (1999) outlines standard methods for estimating basin area, basin relief, and drainage density. Gordon et al. (1992) describes the Strahler stream-ordering method. Investigators will use USGS topographic maps (1:100,000 scale) and GIS to estimate these parameters. This work will be updated once every 20 years.

Valley Segment

<u>*Valley Characteristics:*</u>
The plan incorporates four important features of the valley segment: valley bottom type, valley bottom width, valley bottom gradient, and valley confinement. Valley bottom types are distinguished by average channel gradient, valley form, and the geomorphic processes that shaped the valley (Cupp 1989a,b; Naiman et al. 1992). They correspond with distinctive hydrologic characteristics, especially the relationship between stream and alluvial ground water (Table A2). Valley bottom width is the ratio of the valley bottom[13] width (m) to active channel width (m). Valley gradient is the slope or the change in vertical elevation (m) per unit of

[13] Valley bottom is defined as the essentially flat area adjacent to the stream channel.

horizontal valley distance (m). Valley gradient is typically measured in lengths of about 300 m (1,000 ft) or more. Valley confinement refers to the degree that the valley walls confine the lateral migration of the stream channel. The degree of confinement can be classified as strongly confined (valley floor width < 2 channel widths), moderately confined (valley floor width = 2-4 channel widths), or unconfined (valley floor width > 4 channel widths).

The latter three variables, valley bottom width, valley gradient, and confinement, are nested within valley bottom types. Therefore, these three variables will be described for each valley bottom type identified within the drainage basin (i.e., the valley bottom type defines the scale at which these variables are described).

Investigators should follow the methods of Cupp (1989a,b) and Naiman et al. (1992) to describe valley bottom types. Naiman et al. (1992) also describe methods for measuring valley bottom width and valley bottom gradient. Bisson and Montgomery (1996) outline methods for measuring valley confinement. GIS will aid in estimating these parameters. These variables will be updated once every 20 years.

Channel Segment

<u>*Channel Characteristics:*</u>
The plan includes four important characteristics of the channel segment: elevation, channel gradient, channel type, and bed-form type. These characteristics are nested within valley bottom types and therefore should be described for each valley bottom type identified within the drainage basin. Elevation (m) is the height of the stream channel above or below sea level. Channel gradient is the slope or the change in the vertical elevation of the channel per unit of horizontal distance. Channel gradient can be presented graphically as a stream profile.

Channel type follows the classification technique of Rosgen (1996) and is based on quantitative channel morphology indices.[14] These indices result in objective and consistent identification of stream types. The Rosgen technique consists of four different levels of classification. Level I describes the geomorphic characteristics that result from the integration of basin relief, landform, and valley morphology. Level II provides a more detailed morphological description of stream types. Level III describes the existing condition or "state" of the stream as it relates to its stability, response potential, and function. Level IV is the level at which measurements are taken to verify process relationships inferred from preceding analyses. All monitoring in subbasins in the Upper Columbia Basin will include at least Level I (geomorphic characterization) classification (Table A3).

Bed-form type follows the classification proposed by Montgomery and Buffington (1993). This technique is comprehensive and is based on hierarchies of topographic and fluvial characteristics. This system provides a geomorphic, process-oriented method of identifying valley segments and stream reaches. It employs descriptors that are measurable and ecologically relevant. Montgomery and Buffington (1993) identified three valley segment types: colluvial, alluvial, and bedrock. They subdivided the valley types into one or more stream-reach types

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[14] Indices include entrenchment, gradient, width/depth ratio, sinuosity, and dominant channel material.

(bed-form types) depending on whether substrates are limited by the supply of sediment or by the fluvial transport of sediment (Table A4). For example, depending on sediment supply and transport, Montgomery and Buffington (1993) recognized six alluvial bed-form types: braided, regime, pool/riffle, plane-bed, step-pool or cascade. Both colluvial and bedrock valley types consist of only one bed-form type. Only colluvial bed-forms occur in colluvial valleys and only bedrock bed-forms occur in bedrock valleys.

Methods for measuring elevation and channel gradient can be found in Overton et al. (1997). Bisson and Montgomery (1996) describe in detail the method for identifying channel bed-form types, while Rosgen (1996) describes methods for classifying channel types. All classification work will include at least Level I (geomorphic characterization) channel type classification. Depending on the objectives of the monitoring program, additional levels of classification may be necessary. These variables will be updated once every 10 years.

Riparian Vegetation:
Because riparian vegetation has an important influence on stream morphology and aquatic biota, the plan incorporates primary vegetation type as a characteristic of riparian vegetation. Primary vegetation type refers to the dominant vegetative cover along the stream. At a minimum, vegetation should be described as barren, grasses or forbs, shrubs, and trees. If remote sensing allows, it would be better to further classify the types of shrubs and trees. For example, trees could be described as cottonwoods, fir, cedar, hemlock, pine, etc. Primary vegetation type should be described for a riparian width of at least 30 m along both sides of the stream. More desirably, primary vegetation type should be described for the entire floodplain.

Remote sensing will be used to describe the primary vegetation type along streams within valley bottom types. Remote sensing may include aerial photos, LANDSAT ETM+, or both.

Physical/Environmental Indicator Variables
In this section we identify the "core" set of biological and physical/environmental indicator variables that will be measured within all watersheds and streams that receive status/trend and effectiveness monitoring. The "core" list of variables represents the minimum, required variables that will be measured. Investigators may elect to measure additional variables depending on their objectives and past activities. For example, reclamation of mining-impact areas may require the monitoring of pollutants, toxicants, or metals. Some management activities may require the investigator to monitor thalweg profile, placement of artificial instream structures, or livestock presence. Adding these indicators will supplement the core list.

The physical/environmental variables can be grouped into seven general categories: water quality, habitat access, habitat quality, channel condition, riparian condition, flow/hydrology, and watershed condition. Each of these categories consists of one or more indicator variables. In sum, these categories and their associated indicators address watershed process and "input" variables (e.g., artificial physical barriers, road density, and disturbance) as well as "outcome" variables (e.g., temperature, sediment, woody debris, pools, riparian habitat, etc.), as outlined in Hillman and Giorgi (2002).

Table A5 identifies indicator variables, example protocols for measuring indicators, and sampling frequency. There is no space here to describe each method in detail; therefore, we refer the reader to the cited documents for detailed descriptions of methods and measuring instruments. To a large extent, the methods identified in this plan tend to follow EMAP protocols (Peck et al. 2001). Importantly, all habitat sampling would follow fish sampling (snorkeling and electrofishing) within status/trend monitoring reaches and effectiveness monitoring sites.

Water Quality

<u>*Water Temperature:*</u>
The plan includes two temperature metrics that will serve as specific indicators of water temperature: maximum daily maximum temperature (MDMT) and maximum weekly maximum temperature (MWMT). MDMT is the single warmest daily maximum water temperature recorded during a given year or survey period. MWMT is the mean of daily maximum water temperatures measured over the warmest consecutive seven-day period. MDMT is measured to establish compliance with the short-term exposure to extreme temperature criteria, while MWMT is measured to establish compliance with mean temperature criteria.

Data loggers will be used to measure MWMT and MDMT. Zaroban (2000) describes pre-placement procedures (e.g., selecting loggers and calibration of loggers), placement procedures (e.g., launching loggers, site selection, logger placement, and locality documentation), and retrieval procedures. This manual also provides standard methods for conducting temperature-monitoring studies associated with land-management activities and for characterizing temperature regimes throughout a watershed.

The number of loggers used will depend on the number of reaches and treatment and control sites. For effectiveness monitoring, at a minimum, at least one logger will measure water temperatures at the downstream end and one at the upstream end of each reach that contains treatment or control sites. Additional measurements may be needed within reaches (at treatment sites) if management actions directly affect water temperature (e.g., restore riparian function). For status/trend monitoring, one logger will be placed at or near the X-site within the monitoring reach. Temperatures will be monitored continuously throughout the period May through September of each year.

<u>*Sediment and Turbidity:*</u>
The plan includes two sediment-related specific indicators: turbidity and depth fines. Turbidity refers to the amount of light that is scattered or absorbed by a fluid. Suspended particles of fine sediments often increase turbidity of streams. However, other materials such as finely divided organic matter, colored organic compounds, plankton, and microorganisms can also increase turbidity of streams. Depth fines refer to the amount of fine sediment (<0.85 mm) within the streambed. Depth fines will be estimated at a depth between 15-30 cm (6-12 inches) within spawning gravels.

Chapter 11 in OPSW (1999) provides a standardized method for measuring turbidity, data quality guidelines, equipment, field measurement procedures, and methods to store and analyze turbidity data. For effectiveness monitoring, at a minimum, turbidity will be measured at the downstream end and at the upstream end of each reach that contains treatment or control sites. Additional measurements may be needed at treatment sites within reaches if management actions directly affect turbidity (e.g., sediment reduction actions). For status/trend monitoring, turbidity should be measured at or near the X-site within the monitoring reach. Turbidity will be measured during base-flow (summer) conditions.

Investigators will measure depth fines with McNeil core samplers.[15] Methods for conducting core sampling can be found in Schuett-Hames et al. (1999). For effectiveness monitoring, four randomly-selected samples (subsamples) will be taken from each spawning area (pool tailout or riffle) within each site (samples will not be taken from sites that lack spawning areas). For status/trend monitoring, four subsamples from one randomly-selected spawning area within a reach will be collected. The volumetric method will be used for processing samples sorted via a standard set of sieves. The volumetric method measures the millimeters of water displaced by particles of different size classes. At a minimum, the following sieves will be used to sort particles: 64.0 mm, 16.0 mm, 6.4 mm, 4.0 mm, 1.0 mm, 0.85 mm, 0.50 mm, 0.25 mm, and 0.125 mm. Fines will be measured once annually during base-flow conditions.

Contaminants and Nutrients:
The plan includes four specific indicators associated with contaminants and nutrients: pH, dissolved oxygen (DO), nitrogen, and phosphorus. Most of these indicators are commonly measured because of their sensitivity to land-use activities, municipal and industrial pollution, and their importance in aquatic ecosystems.

The plan included pH and DO because these parameters are often incorporated into water quality monitoring programs (e.g., OPSW 1999; Bilhimer et al. 2003). pH is defined as the concentration of hydrogen ions in water (moles per liter). It is a measure of how acidic or basic water is—it is not a measure of acidity or alkalinity (acidity and alkalinity are measures of the capacity of water to neutralize added base or acid, respectively). The logarithmic pH scale ranges from 0 to 14. Pure water has a pH of 7, which is the neutral point. Water is acidic if the pH value is less than 7 and basic if the value is greater than 7.

DO concentration refers to the amount of oxygen dissolved in water. Its concentration is usually measured in mg per liter (mg/L). The capacity of water to hold oxygen in solution is inversely proportional to the water temperature. Increased water temperature lowers the concentration of DO at saturation. Respiration (both plants and animals) and biochemical oxygen demand (BOD) are the primary factors that reduce DO in water. Photosynthesis and dissolution of atmospheric oxygen in water are the major oxygen sources.

The plan includes nitrogen and phosphorus as indicators of nutrient loading in streams. Nitrogen in aquatic ecosystems can be partitioned into dissolved and particulate nitrogen. Most water quality monitoring programs focus on dissolved nitrogen, because it is more readily available for both biological uptake and chemical transformations. Both dissolved and particulate nitrogen

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[15] Because of the extensive equipment needed to conduct substrate core sampling, core sampling within sites located long distances from access points (> 1 km) may be skipped. Every effort, however, should be made to collect the data.

can be separated into inorganic and organic components. The primary inorganic forms are ammonia (NH_4^+), nitrate (NO_3^-), and nitrite (NO_2^-). Nitrate is the predominant form in unpolluted waters.

Phosphorus can also be separated into two fractions, dissolved and particulate. Dissolved phosphorus is found almost exclusively in the form of phosphate ions (PO_4^{-3}), which bind readily with other chemicals. There are three main classes of phosphate compounds: orthophosphates, condensed phosphates, and organically-bound phosphates. Each can occur as dissolved phosphorus or can be bound to particulate matter. In general, biota use only orthophosphates.

OPSW (1999) identifies standard methods for measuring pH (pH meter—Chapter 8), DO (Winkler Titration Method—Chapter 7)[16], and nitrate/nitrites, ammonium, total nitrogen, total phosphorous, and orthophosphates (Chapter 10). OPSW (1999) also includes criteria for data quality guidelines, equipment, field measurement procedures, and methods to store and analyze water quality data. For effectiveness monitoring, at a minimum, these indicators will be measured at the downstream end and upstream end of each reach that contains treatment or controls sites. Additional measurements may be needed at treatment sites within reaches if management actions directly affect these water-quality parameters (e.g., nutrient enhancement). For status/trend monitoring, samples should be collected at or near the X-site within the monitoring reach. These indicators will be measured once during base flow (summer).

Habitat Access

Artificial Physical Barriers:
The plan includes three specific indicators associated with artificial physical barriers: road crossings (culverts), dams, and fishways. Roads and highways are common in the Upper Columbia River Basin and where they intersect streams they may block fish passage. Culverts can block passage of fish particularly in an upstream direction (WDFW 2000). In several cases, surveys have shown a difference in fish populations upstream and downstream from existing culverts, leading to the conclusion that free passage is not possible (Clay 1995). Dams and diversions that lack fish passage facilities can also block fish passage. Unscreened diversions may divert migrating fish into ditches and canals. Entrained fish can end in irrigated fields and orchards. Fishways are man-made structures that facilitate passage of fish through or over a barrier. Although these structures are intended to facilitate passage, they may actually impede fish passage (Clay 1995; WDFW 2000).

The WDFW (2000) manual provides guidance and methods on how to identify, inventory, and evaluate culverts, dams, and fishways that impede fish passage. WDFW (2000) also provides methods for estimating the potential habitat gained upstream from barriers, allowing prioritization of restoration projects. The manual by Parker (2000) focuses on culverts. The methods outlined in this manual assess connectivity of fish habitats on a watershed scale. These manuals can be used to identify all fish passage barriers within monitoring reaches. Assessment of fish passage barriers will occur once annually during base-flow conditions.

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[16] According to OPSW (1999), the Winkler Titration Method is the most accurate method for measuring DO concentration. Although this plan recommends the Winkler Titration Method, calibrated DO meters with an accuracy of ±0.2 mg/L can be used in place of the chemical method.

Habitat Quality

Substrate:

The Plan includes two specific indicators of substrate: dominant substrate and embeddedness. Dominant substrate refers to the most common particle size that makes up the composition of material along the streambed. This indicator describes the dominant material in spawning and rearing areas. Embeddedness is a measure of the degree to which fine sediments surround or bury larger particles. This measure is an indicator of the quality of over-wintering habitat for juvenile salmonids.

Peck et al. (2001) provides a method for describing substrate composition within each site or reach. Investigators will measure substrate at five equidistant points along each of the 11 "regular" transects, plus along an additional 10 transects placed mid-way between each of the 11 transects. The investigator will visually estimate the size of a particle at each of the five points along the 21 transects (total sample size of 105 particles). Classification of bed material by particle size will follow Table A6.

Peck et al. (2001) also provides methods for measuring embeddedness. Embeddedness will be estimated at the five equidistant points along the 11 "regular" transects (total sample size of 55). At each sampling point along a transect, all particles larger than sand within a 10-cm diameter circle will be examined for embeddedness. Embeddedness is the fraction of particle surface that is surrounded by sand or finer sediments. By definition, sand and fines are embedded 100%, while bedrock is embedded 0%. Both substrate composition and embeddedness will be measured once annually during base-flow stream conditions.

Large Woody Debris:

The plan includes the number of pieces of large woody debris (LWD) per stream kilometer as the one specific indicator of LWD in streams. LWD consists of large pieces of relatively stable woody material located within the bankfull channel and appearing to influence bankfull flows. LWD is also referred to as large organic debris (LOD) and coarse woody debris (CWD). LWD can occur as a single piece (log), an aggregate (two or more clumped pieces, each of which qualifies as a single piece), or as a rootwad.

The definition of LWD differs greatly among institutions. For example, NMFS (1996) defined LWD east of the Cascade Mountains as any log with a diameter greater than 30 cm (1 ft) and a length greater than 10.6 m (35 ft). Armantrout (1998) and BURPTAC (1999) defined LWD as any piece with a diameter >10 cm and a length > 1 m. Schuett-Hames et al. (1994) defined it as any piece with a diameter >10 cm and a length >2 m, while Overton et al. (1997) defined LWD as any piece with a diameter >10 cm and a length >3 m or two-thirds of the wetted stream width. Some Forest Service crews currently define LWD as any piece with a diameter >15 cm and a length >6 m. Because of the wide range of definitions, this plan recommends that LWD be placed within three size categories: >10-cm diameter x >1 m long; >15-cm diameter x >6 m long; and >30-cm diameter x >3 m long. By counting the number of pieces of LWD within each category, the plan will satisfy the requirements of the Forest Service, PIBO, and other institutional needs. This will also allow one to assess the association between different size categories of wood and fish production.

Investigators will simply count the number of LWD pieces within sites or reaches in forested streams (e.g., see BURPTAC 1999). LWD will be divided into the three size categories: >10 cm x >1 m; >15 cm x >6 m; and >30 cm x >3 m (diameter x length, respectively). This indicator will be measured once annually during base-flow conditions.

Pool Habitat:
The plan includes two specific indicators associated with pool habitat: pool frequency (number of pools per kilometer) and pool quality. A pool is slow-water habitat with a gradient less than 1% that is normally deeper and wider than aquatic habitats upstream and downstream from it (Armantrout 1998). To be counted, a pool must span more than half the wetted width, be longer than it is wide, include the thalweg, and the maximum depth must be at least 1.5 times the crest depth. Pool quality refers to the ability of a pool to support the growth and survival of fish (Platts et al. 1983). Pool size (diameter and depth) and the amount and quality of cover determine overall pool quality. Pool cover is any material or condition that conceals or protects fish from predators or competitors and may consist of logs, organic debris, overhanging vegetation, cobble, boulders, undercut banks, or water depth.

Investigators will count the number of pools throughout a monitoring reach. Hawkins et al. (1993) and Overton et al. (1997) provide good descriptions of the various types of pools and how to identify them. Pool frequency will be measured in all monitoring sites and reaches.

Platts et al. (1983) describe methods for estimating pool quality. This plan includes a slight modification to the Platts protocol by adding residual pool depth to the criteria (Table A7). Residual pool depth is the difference between the maximum pool depth and the pool crest outlet depth (Overton et al. (1997) describe methods for measuring these two depths). Residual pool depth is independent of streamflow at time of measurement and is sensitive to land-management actions. For effectiveness monitoring, pool quality will be assessed for all pools within treatment and control sites. For status/trend monitoring, pool quality will be measured for all pools within a reach. Both pool frequency and pool quality will be measured once annually during base-flow conditions.

Off-Channel Habitat:
Off-channel habitat consists of side-channels, backwater areas, alcoves or sidepools, off-channel pools, off-channel ponds, and oxbows. A side channel is a secondary channel that contains a portion of the streamflow from the main or primary channel. Backwater areas are secondary channels in which the inlet becomes blocked but the outlet remains connected to the main channel. Alcoves are deep areas along the shoreline of wide and shallow stream segments. Off-channel pools occur in riparian areas adjacent to the stream channels and remain connected to the channel. Off-channel ponds are not part of the active channel but are supplied with water from over bank flooding or through a connection with the main channel. These ponds are usually located on flood terraces and are called wall-based channel ponds when they occur near the base of valley walls. Finally, oxbows are bends or meanders in a stream that become detached from the stream channel either from natural fluvial processes or anthropogenic disturbances.

Following the definitions for each off-channel habitat type, the investigator will count the number of each type of off-channel habitat within a monitoring reach. Sampling will occur once annually during base-flow conditions.

Channel Condition

Width/Depth Ratio:

The width/depth ratio is an index of the cross-section shape of a stream channel at bankfull level. The ratio is a sensitive measure of the response of a channel to changes in bank conditions. Increases in width/depth ratios, for example, indicate increased bank erosion, channel widening, and infilling of pools. Because streams almost always are several times wider than they are deep, a small change in depth can greatly affect the width/depth ratio.

The width/depth ratio is expressed as bankfull width (geomorphic term) divided by the mean cross-section bankfull depth. Peck et al. (2001) offer the recommended protocol for measuring bankfull widths and depths. This indicator will be measured at the 21 transects (includes the 11 "regular" and 10 "additional" transects) within each reach (for status/trend monitoring) or treatment and control sites (for effectiveness monitoring). Sampling will occur once annually during base-flow conditions.

Wetted Width:

Wetted width is the width of the water surface measured perpendicular to the direction of flow. Wetted width is used to estimate water surface area, which is then used to calculate the density (i.e., number of fish divided by the water surface area sampled)[17] of fish within the site or reach.

Peck et al. (2001) describes the recommend method for measuring this indicator. Wetted width will be measured at the 21 transects (11 "regular" and 10 "additional" transects) within each reach or treatment and control sites. Widths of multiple channels are summed to represent the total wetted width. Sampling will occur once annually during base-flow conditions.

Bankfull Width:

Bankfull width is the width of the channel (water surface) at the bankfull stage, where bankfull stage corresponds to the channel forming discharge that generally occurs within a return interval from 1.4 to 1.6 years and may be observed as the incipient elevation on the bank where flooding begins. There are several indicators that one can use to identify bankfull stage. The active floodplain is the best indicator of bankfull stage. It is the flat, depositional surface adjacent to many stream channels. These are most prominent along low-gradient, meandering reaches, but are often absent along steeper mountain stream. Where floodplains are absent or poorly defined, other useful indicators may serve as surrogates to identify bankfull stage (Harrelson et al. 1994). Those include:

[17] By definition, the measure of the number of fish per unit area is called "crude density" (Smith and Smith 2001). However, not all of the water surface area provides suitable habitat for fish. Density measured in terms of the amount of area suitable as living space is "ecological density."

- The height of depositional features (especially the top of the pointbar, which defines the lowest possible level for bankfull stage;
- A change in vegetation (especially the lower limit of perennial species);
- Slope or topographic breaks along the bank;
- A change in the particle size of bank material, such as the boundary between coarse cobble or gravel with fine-grained sand or silt;
- Undercuts in the bank, which usually reach an interior elevation slightly below bankfull stage; and
- Stain lines or the lower extent of lichens on boulders.

Peck et al. (2001) describe methods for measuring bankfull width. Bankfull width will be measured at the 21 transects within each reach (for status/trend monitoring) or treatment and control sites (for effectiveness monitoring). Widths of multiple channels are summed to represent the total bankfull width. Sampling will occur once annually during base-flow conditions.

Streambank Condition:

The plan includes streambank stability as the one specific indicator of streambank condition. Streambank stability is an index of firmness or resistance to disintegration of a bank based on the percentage of the bank showing active erosion (alteration) and the presence of protective vegetation, woody material, or rock. A stable bank shows no evidence of breakdown, slumping, tension cracking or fracture, or erosion (Overton et al. 1997). Undercut banks are considered stable unless tension fractures show on the ground surface at the bank of the undercut.

Moore et al. (2002) describe the recommended method for assessing stream bank stability. The method estimates the percent of the lineal distance that is actively eroding at the active channel height on both sides of the transect. Active erosion is defined as recently eroding or collapsing banks and may have the following characteristics: exposed soils and inorganic material, evidence of tension cracks, active sloughing, or superficial vegetation that does not contribute to bank stability. Bank stability will be measured once annually during base-flow conditions at the 11 evenly-spaced transects within each reach (for status/trend monitoring) or treatment and control site (for effectiveness monitoring).

Riparian Condition

Riparian structure:

Riparian structure describes the type and amount of various types of vegetation within the riparian zone. Information on riparian structure can be used to evaluate the health and level of disturbance of the stream corridor. In addition, it provides an indication of the present and future potential for various types of organic inputs and shading.

Peck et al. (2001) offer methods for describing riparian structure. Riparian structure will be assessed within a 10 m x 10 m plot on both ends of each of the 11 transects. Within each riparian plot, the investigator will divide the vegetation into three layers: canopy layer (>5-m high), understory layer (0.5-5-m high), and the ground-cover layer (<0.5-m high). Areal cover will be estimated within each of the three vegetation layers. The type of vegetation will be described in both the canopy and understory layers. Vegetation types include deciduous, coniferous, broadleaf evergreen, mixed, and none. Riparian structure will be measured once annually during base-flow conditions.

Riparian disturbance:

Riparian disturbance refers to the presence and proximity of various types of human land-use activities within the riparian area. Influences associated with agriculture, roads, urbanization, channelization, logging, and mining are included in the assessment. All these activities have an effect on the riparian vegetation, which in turn affects the quantity and quality of aquatic habitat for listed fish species.

Peck et al. (2001) provide the recommended method for assessing this indicator. The presence/absence and proximity of 11 categories of human influences will be described within 5 m upstream and 5 m downstream from each of the 11 transects. Human influences include: (1) walls, dikes, revetments, riprap, and dams; (2) buildings; (3) pavement/cleared lot; (4) roads or railroads; (5) inlet or outlet pipes; (6) landfills or trash; (7) parks or maintained lawns; (8) row crops; (9) pastures, rangeland, hay fields, or evidence of livestock, (10) logging; and (11) mining. Proximity classes include: (1) present within the defined 10 m stream segment and located in the stream or on the stream bank; (2) present within the 10 x 10 m riparian plot but away from the bank; (3) present but outside the riparian plot; and (4) not present within or adjacent to the 10 m stream segment or the riparian plot area at the transect. Riparian disturbance will be measured once annually during base-flow conditions.

Canopy cover:

Riparian canopy cover over a stream is important not only in its role in moderating stream temperatures through shading, but it also serves to control bank stability and provides inputs of coarse and fine particulate organic materials. Organics from riparian vegetation become food for stream organisms and structure to create and maintain complex channel habitat.

Peck et al. (2001) describe the recommended method for measuring canopy cover. Canopy cover will be determined at each of the 11 equally-spaced transects using a Convex Spherical Densiometer (model B). Six measurements are collected at each transect (four measurements in four directions at mid-channel and one at each bank). The mid-channel measurements estimate canopy cover over the channel, while the two bank measurements estimate cover within the riparian zone. The two bank measurements are particularly important in wide streams, where riparian canopy may not be detected at mid-channel. Canopy cover will be measured once annually during base-flow conditions.

Flows and Hydrology

Streamflows:

The plan includes three specific indicators of streamflows: change in peak flow, change in base flow, and change in timing of flow. Peak flow is the highest or maximum streamflow recorded within a specified period of time. Base flow is the streamflow sustained in a stream channel and is not a result of direct runoff. Base flow is derived from natural storage (i.e., outflow from groundwater, large lakes, or swamps), or sources other than rainfall. Timing of flow refers to the time when peak and base flows occur and the rate of rises and falls in the hydrograph. These indicators are based on "annual" flow patterns.

Changes in streamflows will be assessed by collecting flow data at the downstream end of monitoring reaches and/or at the downstream end of the distribution of each population or subpopulation. Investigators will use USGS or State flow data where available to assess changes in peak, base, and timing of flows. For those streams with no USGS or State stream-gauge data, investigators will use the velocity-area method described in Peck et al. (2001) to estimate stream flows. Water velocities will be measured with a calibrated water-velocity meter rather than the float method.

Watershed Conditions

Road Density:
A road is any open way for the passage of vehicles or trains. The plan includes both road density and the riparian-road index (RRI) as indicators of roads within watersheds. Road density is an index of the total miles of roads within a watershed. It is calculated as the total length of all roads (km) within a watershed divided by the area of the watershed (km^2). The RRI is expressed as the total mileage of roads (km) within riparian areas divided by the total number of stream kilometers within the watershed (WFC 1998). For this index, riparian areas are defined as those falling within the federal buffers zones; that is, all areas within 300 ft of either side of a fish-bearing stream, within 150 ft of a permanent nonfish-bearing stream, or within the 100-year floodplain.

Investigators will measure the road density and riparian-road index within each watershed in which monitoring activities occur. Road density will be calculated with GIS as the total length (km) of roads within a watershed divided by the area (km^2) of the watershed. The riparian-road index will be calculated with GIS as the total kilometers of roads within riparian areas divided by the total number of stream kilometers within the watershed. WFC (1998) provides an example of calculating the riparian-road index in the Umpqua Basin. Both road density and the riparian-road index will be updated once every five years.

Watershed Disturbance:
The plan includes land ownership and land use as the two indicators of watershed disturbance. Land ownership describes the surface status of the basin. That is, it delineates the portions of the basin owned by federal, state, county, tribal, and private entities. Land use, on the other hand, delineates the portions of the basin that are subject to specific land uses, such as urban, agriculture, range, forest, wetlands, etc.

Using available GIS layers, the investigator will map the spatial extent of land ownership and land uses within each watershed that includes monitoring reaches or sites. These indicators will be updated once every five years.

Table A1. List of classification (stratification) variables, their corresponding measurement protocols, and temporal sampling frequency. The variables are nested according to spatial scale and their general characteristics.

Spatial scale	General characteristics	Classification variable	Example protocols	Sampling frequency (years)
Regional setting	Ecoregion	Bailey classification	Bain and Stevenson (1999)	20
		Omernik classification	Bain and Stevenson (1999)	20
	Physiography	Province	Bain and Stevenson (1999)	20
	Geology	Geologic districts	Overton et al. (1997)	20
Drainage basin	Geomorphic features	Basin area	Bain and Stevenson (1999)	20
		Basin relief	Bain and Stevenson (1999)	20
		Drainage density	Bain and Stevenson (1999)	20
		Stream order	Gordon et al. (1992)	20
Valley segment	Valley characteristics	Valley bottom type	Cupp (1989); Naiman et al. (1992)	20
		Valley bottom width	Naiman et al. (1992)	20
		Valley bottom gradient	Naiman et al. (1992)	20
		Valley containment	Bisson and Montgomery (1996)	20
Channel segment	Channel characteristics	Elevation	Overton et al. (1997)	10
		Channel type (Rosgen)	Rosgen (1996)	10
		Bed-form type	Bisson and Montgomery (1996)	10
		Channel gradient	Overton et al. (1997)	10
	Riparian veg.	Primary vegetation type	Platts et al. (1983)	5

Table A2. Examples of valley bottom types and valley geomorphic characteristics in forested lands of Washington. Table is from Naiman et al. (1992).

Valley bottom type[a]	**Valley bottom gradient**[b]	**Sideslope gradient**[c]	**Valley bottom width**[d]	**Channel patterns**	**Strahler stream order**	**Landform and geomorphic features**
F1 Estuarine delta	=0.5%	<5%	>5X	Unconstrained; highly sinuous; often braided	Any	Occur at mouth of streams on estuarine flats in and just above zone of tidal influence
F2 Alluviated lowlands	=1%	>5%	>5X	Unconstrained; highly sinuous	Any	Wide floodplains typically formed by present or historic large rivers within flat to gently rolling lowland landforms; sloughs, oxbows, and abandoned channels commonly associated with mainstream rivers
F3 Wide mainstream valley	=2%	<5%	>5X	Unconstrained; moderate to high sinuosity; braids common	Any	Wide valley floors bounded by mountain slopes; generally associated with mainstream rivers and the tributary streams flowing through the valley floor; sloughs and abandoned channels common.
F4 Wide mainstream valley	=1-3%	=10%	>3X	Variable; generally unconstrained	1-4	Generally occur where tributary streams enter low-gradient valley floors; ancient or active alluvial/colluvial fan deposition overlying floodplains of larger, low-gradient stream segments; stream may actively downcut through deep alluvial fan deposition.
F5 Gently sloping plateaux and terraces	=2%	<10%	1-2X	Moderately constrained; low to moderate sinuosity	1-3	Drainage ways shallowly incised into flat to gently sloping landscape; narrow active floodplains; typically associated with small streams in lowlands, cryic uplands or volcanic flanks.
M1 Moderate sloping plateaux and terraces	2-5%	<10-30%	<2X	Constrained; infrequent meanders	1-4	Constrained, narrow floodplains bounded by moderate gradient sideslopes; typically found in lowlands and foothills, but may occur on broken mountain slopes and volcano flanks.
M2 Alluviated, moderate slope bound	=2%	<5%, gradually increase to 30%	2-4X	Unconstrained; moderate to high sinuosity	1-4	Active floodplains and alluvial terraces bounded by moderate gradient hillslopes; typically found in lowlands and foothills, but may occur on broken mountain slopes and volcano flanks.
V1 V-shaped moderate-gradient bottom	2-6%	30-70%	<2X	Constrained	=2	Deeply incised drainage ways with steep competent sideslopes; very common in uplifted mountainous topography; less commonly associated with marine or glacial outwash terraces in lowlands and foothills.
V2 V-shaped high-gradient bottom	6-11%	30-70%	<2X	Constrained	=2	Same as above, but valley bottom longitudinal profile steep with pronounced stair-step characteristics.

Table A2. (continued)

Valley bottom type[a]	Valley bottom gradient[b]	Sideslope gradient[c]	Valley bottom width[d]	Channel patterns	Strahler stream order	Landform and geomorphic features
V3 V-shaped, bedrock canyon	3-11%	70%+	<2X	Highly constrained	=2	Canyon-like stream corridors with frequent bedrock outcrops; frequently stair-stepped profile; generally associated with folded, faulted or volcanic landforms.
V4 Alluviated mountain valley	1-4%	Channel adjacent slopes <10%; increase to 30%+	2-4X	Unconstrained; high sinuosity with braids and side-channels common	2-5	Deeply incised drainage ways with relatively wide floodplains; distinguished as "alluvial flats" in otherwise steeply dissected mountainous terrain.
U1 U-shaped trough	<3%	<5%; gradually increases to 30%+	>4X	Unconstrained; moderate to high sinuosity; side channels and braids common	1-4	Drainage ways in mid to upper watersheds with history of glaciation, resulting in U-shaped profile; valley bottom typically composed of glacial drift deposits overlain with more recent alluvial material adjacent to channel.
U2 Incised U-shaped valley, moderate-gradient bottom	2-5%	Steep channel adjacent slopes, decreases to <30%, then increases to >30%	<2X	Moderately contrained by unconsolidated material; infrequent short flats with braids and meanders	2-5	Channel downcuts through deep valley bottom glacial till, colluvium, or coarse glacio-fluvial deposits; cross-sectional profile variable, but generally weakly U-shaped with active channel vertically incised into valley fill deposits; immediate side-slopes composed of unconsolidated and often unsorted coarse-grained deposits.
U3 Incised U-shaped valley, high-gradient bottom	6-11%	Steep channel adjacent slopes, decreases to <30%, then increases to >30%	<2X	Moderately constrained by unconsolidated material; infrequent short flats with braids and meanders	2-5	Channel downcuts through deep valley bottom glacial till, colluvium, or coarse glacio-fluvial deposits; cross-sectional profile variable, but generally weakly U-shaped with active channel vertically incised into valley fill deposits; immediate side-slopes composed of unconsolidated and often unsorted coarse-grained deposits.
U4 Active glacial out-wash valley	1-7%	Initially <5%, increasing to >60%	<4X	Unconstrained; highly sinuous and braided	1-3	Stream corridors directly below active alpine glaciers; channel braiding and shifting common; active channel nearly as wide as valley bottom.
H1 Moderate-gradient valley wall/head-water	3-6%	>30%	<2X	Constrained	1-2	Small drainage ways with channels slightly to moderately entrenched into mountain toe-slopes or head-water basins.
H2 High-gradient valley wall/head-water	6-11%	>30%	<2X	Constrained; stair-stepped	1-2	Small drainage ways with channels moderately entrenched into high gradient mountain slopes or headwater basins; bedrock exposures and outcrops common; localized alluvial/colluvial terrace deposition.

Table A2. (concluded)

Valley bottom type[a]	**Valley bottom gradient**[b]	**Sideslope gradient**[c]	**Valley bottom width**[d]	**Channel patterns**	**Strahler stream order**	**Landform and geomorphic features**
H3 Very high-gradient valley wall/head-water	11%+	>60%	<2X	Constrained; stair-stepped	1-2	Small drainage ways with channels moderately entrenched into high gradient mountain slopes or headwater basins; bedrock exposures and out-crops common; localized alluvial/colluvial terrace deposition.

[a]Valley bottom type names include alphanumeric mapping codes in italic (from Cupp 1989a, b).
[b]Valley bottom gradient is measured in length of about 300 m (1,000 ft).
[c]Sideslope gradient characterizes the hillslopes within 1,000 horizontal and about 100 m (300 ft) vertical distance from the active channel.
[d]Valley bottom width is a ratio of the valley bottom width to active channel width.

Table A3. General stream type descriptions and delineative criteria for Level I channel classification. Table is from Rosgen (1996).

Stream type	General description	Entrenchment ratio	W/D ratio	Sinuosity	Slope %	Landform/ soils/features
Aa+	Very steep, deeply entrenched, debris transport, torrent streams.	<1.4	<12	1.0-1.1	>10	Very high relief. Erosional, bedrock or depositional features; debris flow potential. Deeply entrenched streams. Vertical steps with deep scour pools; waterfalls.
A	Steep, entrenched, cascading, step/pool streams. High energy/debris transport associated with depositional soils. Very stable if bedrock or boulder dominated channel.	<1.4	<12	1.0-1.2	4-10	High relief. Erosional or depositional and bedrock forms. Entrenched and confined streams with cascading reaches. Frequently spaced, deep pools in associated step/pool bed morphology.
B	Moderately entrenched, moderate gradient, riffle-dominated channel, with infrequently spaced pools. Very stable plan and profile. Stable banks.	1.4-2.2	>12	>1.2	2-4	Moderate relief, colluvial deposition, and/or structural. Moderate entrenchment and W/D ratio. Narrow, gently sloping valleys. Rapids predominate with scour pools.
C	Low gradient, meandering, point-bar, riffle/pool, alluvial channels with broad, well defined floodplains.	>2.2	>12	>1.4	<2	Broad valleys with terraces, in association with floodplains, alluvial soils. Slightly entrenched with well-defined meandering channels. Riffle/pool bed morphology.
D	Braided channel with longitudinal and transverse bars. Very wide channel with eroding banks.	n/a	>40	n/a	<4	Broad valleys with alluvium, steeper fans. Glacial debris and depositional features. Active lateral adjustment, with abundance of sediment supply. Covergence/divergence bed features, aggradational processes, high bedload and bank erosion.

Table A3. (concluded)

Stream type	General description	Entrenchment ratio	W/D ratio	Sinuosity	Slope %	Landform/ soils/features
DA	Anastomosing (multiple channels) narrow and deep with extensive, well-vegetated floodplains and associated wetlands. Very gentle relief with highly variable sinuosities and width/depth rations. Very stable streambanks.	>2.2	Highly variable	Highly variable	<0.5	Broad, low-gradient valleys with fine alluvium and/or lacustrine soils. Anastomosed (multiple channel) geologic control creating fine deposition with well-vegetated bars that are laterally stable with broad wetland floodplains. Very low bedload, high wash load sediment.
E	Low gradient, meandering riffle/pool stream with low sidth/depth ratio and little deposition. Very efficient and stable. High meander width ratio.	>2.2	<12	>1.5	<2	Broad valley/meadows. Alluvial materials with floodplains. Highly sinuous with stable, well-vegetated banks. Riffle/pool morphology with very low width/depth ratios.
F	Entrenched meandering riffle/pool channel on low gradients with high width/depth ratio.	<1.4	>12	>1.4	<2	Entrenched in highly weathered material. Gentle gradients, with a high width/depth ratio. Meandering, laterally unstable with high bank erosion rates. Riffle/pool morphology.
G	Entrenched "gully" step/pool and low width/depth ratio on moderate gradients.	<1.4	<12	>1.2	2-4	Gullies, step/pool morphology with moderate slopes and low width/depth ratio. Narrow valleys, or deeply incised in alluvial or colluvial materials, i.e., fans or deltas. Unstable, with grade control problems and high bank erosion rates.

Table A4. Characteristics of different bed-form types. Table is modified from Montgomery and Buffington (1993).

Valley types	**Bed-form types**	**Predominant bed material**	**Dominant roughness elements**	**Typical slope (%)**	**Typical confinement**	**Pool spacing (channel widths)**
Colluvial	Colluvial	Variable	Boulders, large woody debris	>20	Strongly confined	Variable
Bedrock	Bedrock	Bedrock	Streambed, banks	Variable	Strongly confined	Variable
Alluvial	Cascade	Boulder	Boulders, banks	8-30	Strongly confined	<1
	Step-pool	Cobble/boulder	Bedforms (steps, pools) boulders, large woody debris, banks	4-8	Moderately confined	1-4
	Plane-bed	Gravel/cobble	Boulders and cobbles, banks	1-4	Variable	None
	Pool-riffle	Gravel	Bedforms (bars, pools) boulders and cobbles, large woody debris, sinuosity, banks	0.1-2	Unconfined	5-7
	Regime	Sand	Sinuosity, bed-forms (dunes, ripples, bars), banks	<0.1	Unconfined	5-7
	Braided	Variable	Bedforms (bars, pools)	<3	Unconfined	Variable

Table A5. Example protocols and sampling frequency of physical/environmental indicator variables. Table is modified from Hillman and Giorgi (2002).

General characteristics	Specific indicators	Example protocols	Sampling frequency
Water Quality	MWMT/MDMT	Zaroban (2000)	Continuous (May -Sept)
	Turbidity	OPSW (1999)	Annual
	Depth fines	Schuett-Hames (1999)	Annual
	pH	OPSW (1999)	Annual
	DO	OPSW (1999)	Annual
	Nitrogen	OPSW (1999)	Annual
	Phosphorus	OPSW (1999)	Annual
Habitat Access	Road crossings	Parker (2000); WDFW (2000)	Annual
	Diversion dams	WDFW (2000)	Annual
	Fishways	WDFW (2000)	Annual
Habitat Quality	Dominant substrate	Peck et al. (2001)	Annual
	Embeddedness	Peck et al. (2001)	Annual
	LWD (pieces/km)	BURPTAC (1999)	Annual
	Pools per kilometer	Hawkins et al. (1993); Overton et al. (1997)	Annual
	Pool quality	Platts et al. (1983)	Annual
	Off-channels habitats	WFPB (1995)	Annual
Channel condition	Width/depth ratio	Peck et al. (2001)	Annual
	Wetted width	Peck et al. (2001)	Annual
	Bankfull width	Peck et al. (2001)	Annual
	Bank stability	Moore et al. (2002)	Annual
Riparian Condition	Structure	Peck et al. (2001)	Annual
	Disturbance	Peck et al. (2001)	Annual
	Canopy cover	Peck et al. (2001)	Annual
Flows and Hydrology	Streamflow	Peck et al. (2001)	Continuous
Watershed Condition	Watershed road density	WFC (1998); Reeves et al. (2001)	5 years
	Riparian-road index	WFC (1998)	5 years
	Land ownership	n/a	5 years
	Land use	n/a	5 years

Table A6. Classification of stream substrate channel materials by particle size. Table from Peck et al. (2001).

Class name	Size range (mm)	Description
Bedrock (smooth)	>4,000	Smooth surface rock larger than a car
Bedrock (rough)	>4,000	Rough surface rock larger than a car
Hardpan		Firm, consolidated fine substrate
Boulders	>250-4,000	Basketball to car size
Cobbles	>64-250	Tennis ball to basketball size
Gravel (coarse)	>16-64	Marble to tennis ball size
Gravel (fine)	>2-16	Ladybug to marble size
Sand	>0.06-2	Smaller than ladybug size, but visible as particles
Fines	<0.06	Silt, clay, muck (not gritty between fingers)

Table A7. Rating of pool quality (Table is modified from Platts et al. 1983).

	Description	Pool rating
1A	If the pool maximum diameter is within 10% of the mean stream width of the study sites ……………………………… Go to 2A	
1B	If the maximum pool diameter exceeds the mean stream width of the study site by 10% or more…………………… Go to 3A	
1C	If the maximum pool diameter is less than the mean stream width of the study site by 10% or more…………………… Go to 4A	
2A	If the residual pool depth is <0.6 m ……………………… Go to 5A	
2B	If the residual pool depth is >0.6 m ……………………… Go to 3A	
3A	If the residual pool depth is >1 m, or it is >0.6 m and has abundant cover[1]	Rate 5
3B	If the residual pool depth is <0.6 m, or if it is between 0.6 and 1 m and lacks cover	Rate 4
4A	If the residual pool depth is >0.6 m with intermediate cover	Rate 3
4B	If the residual pool depth is <0.6 m but cover is intermediate or better	Rate 2
4C	If the residual pool depth is <0.6 m and has poor cover	Rate 1
5A	If the pool has intermediate to abundant cover	Rate 3
5B	If the pool has poor cover	Rate 2

[1]If cover is abundant, the pool has excellent instream cover and most of the perimeter of the pool has fish cover. If cover is intermediate, the pool has moderate instream cover and 50% of the pool perimeter has fish cover. If cover is poor, the pool has poor instream cover and less than 25% of the pool perimeter has cover.

References

Armantrout, N. B., compiler. 1998. Glossary of aquatic habitat inventory terminology. American Fisheries Society, Bethesda, MD.

Bain, M. B. and N. J. Stevenson, editors. 1999. Aquatic habitat assessment: common methods. American Fisheries Society, Bethesda, MD.

BAILEY, R. G. 1978. DESCRIPTION OF ECOREGIONS OF THE UNITED STATES. U.S. FOREST SERVICE, INTERMOUNTAIN REGION, OGDEN, UT.

Bilhimer, D., J. Carroll, S. O'Neal, and G. Pelletier. 2003. Draft quality assurance project plan: Wenatchee River temperature, dissolved oxygen, pH, and fecal coliform total maximum daily load year 2 technical study. Washington State Department of Ecology, Olympia, WA.

Bisson, P. A. and D. R. Montgomery. 1996. Valley segments, stream reaches, and channel units. Pages 23-52 *in*: R. R. Hauer and G. A. Lamberti, editors. Methods in stream ecology. Academic Press, New York, NY.

BURPTAC (Beneficial Use Reconnaissance Project Technical Advisory Committee). 1999. 1999 beneficial use reconnaissance project workplan for wadable streams. Idaho Division of Environmental Quality, Boise, ID.

Clay, C. H. 1995. Design of fishways and other fish facilities. Second edition. Lewis Publishers, Boca Raton, Florida.

Cupp, C. E. 1989a. Identifying spatial variability of stream characteristics through classification. Master's thesis. University of Washington, Seattle, WA.

Cupp, C. E. 1989b. Valley segment type classification for forested lands of Washington. Washington State Timber/Fish/Wildlife Agreement, TFW-AM-89-001, Department of Natural Resources, Olympia, WA.

Frissell, C. A., W. J. Liss, C. E. Warren, and M. D. Hurley. 1986. A hierarchical framework for stream habitat classification; viewing streams in a watershed context. Environmental Management 10:199-214.

Gordon, N. D., T. A. McMahon, and B. L. Finlayson. 1992. Stream hydrology an introduction for ecologists. John Wiley and Sons, New York, NY.

Hadley, R. F. and S. A. Schumm. 1961. Sediment sources and drainage basin characteristics in upper Cheyenne River basin. U.S. Geological Survey, Water-Supply Paper 1531-B, Reston, Virginia.

Harrelson, C. C., C. L. Rawlins, and J. P. Potyondy. 1994. Stream channel reference sites: an illustrated guide to field technique. USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, General Technical Report RM-245, Fort Collins, CO.

Hawkins, C. P., and ten others. 1993. Hierarchical approach to classifying stream habitat features. Fisheries 18:3-12.

Hillman, T. W. and A. E. Giorgi. 2002. Monitoring protocols: effectiveness monitoring of physical/environmental indicators in tributary habitats. BioAnalysts, Inc. Report to Bonneville Power Administration, Portland, Or. http://www.efw.bpa.gov/cgi-bin/FW/welcome.cgi?ViewMode=External

Hughes, R. M., E. Rexstad, and C. E. Bond. 1987. The relationship of aquatic ecoregions, river basins and physiographic provinces to the ichthyogeographic regions of Oregon. Copeia 2:423-432.

Hunt, C. B. 1967. Physiography of the United States. W. H. Freeman, San Francisco, CA.

ISAB (Independent Scientific Advisory Board). 2003. A review of strategies for recovering tributary habitat. Independent Scientific Advisory Board for the Northwest Power Planning Council, ISAB 2003-2, Portland, OR.

Johnson, D. H., and nine others. 2001. Inventory and monitoring of salmon habitat in the Pacific Northwest—directory and synthesis of protocols for management/research and volunteers in Washington, Oregon, Montana, Idaho, and British Columbia. Review draft. Washington Department of Fish and Wildlife, Olympia, WA.

Lazorchak, J. M., D. J. Klemm, and D. V. Peck (editors). 1998. Environmental monitoring and assessment program—surface waters: field operations and methods for measuring the ecological condition of wadeable streams. EPA/620/R-94/004F, U.S. Environmental Protection Agency, Washington, D.C.

Montgomery, D. R. and J. M. Buffington. 1993. Channel classification, prediction of channel response, and assessment of channel condition. Washington State Timber/Fish/Wildlife Agreement, TFW-SH10-93-002, Department of Natural Resources, Olympia, WA.

Moore, K., K. Jones, and J. Dambacher. 2002. Methods for stream habitat surveys; aquatic inventory project. Oregon Department of Fish and Wildlife, Aquatic Inventories Project, Natural Production Program, Corvallis, OR.

Naiman, R. J., D. G. Lonzarich, T. J. Beechie, and S. C. Ralph. 1992. General principles of classification and the assessment of conservation potential in rivers. Pages 93-123 *in*: P. J. Boon, P. Calow, and G. E. Petts, editors. River conservation and management. John Wiley and Sons, New York, NY.

Nawa, R. K., C. A. Frissell, and W. J. Liss. 1988. Life history and persistence of anadromous fish stocks in relation to stream habitats and watershed classification. Annual progress report to Oregon Department of Fish and Wildlife, Portland, OR.

NMFS (National Marine Fisheries Service). 1996. Making Endangered Species Act determinations of effect for individual or grouped actions at the watershed scale. The National Marine Fisheries Service Environmental and Technical Services Division, Habitat Conservation Branch, Seattle, WA.

Omernik, J. M. 1987. Aquatic ecoregions of the conterminous United States. Annals of the Association of American Geographers 77:118-125.

OPSW (Oregon Plan for Salmon and Watersheds). 1999. Water quality monitoring, technical guide book. Version 2.0. Corvallis, OR.

Overton, C. K., S. P. Wollrab, B. C. Roberts, and M. A. Radko. 1997. R1/R4 (Northern/Intermountain Regions) fish and fish habitat standard inventory procedures handbook. USDA Forest Service General Technical Report INT-GTR-346, Ogden, UT.

Parker, M. A. 2000. Fish passage – culvert inspection procedures. Watershed Restoration Technical Circular No. 11. Ministry of Environment, Lands and Parks and Ministry of Forest, British Columbia.

Peck, D. V., J. M. Lazorchak, and D. J. Klemm. 2001. Environmental monitoring and assessment program—surface waters: western pilot study field operations manual for wadeable streams. Draft Report. EPA/XXX/X-XX/XXX, U.S. Environmental Protection Agency, Washington, D.C. *[Although this draft document states that it should not be cited or quoted, some of the material in the report is an important improvement to Lazorchak et al. (1998). By not citing the document, it may give the appearance that we improved some of the methods outlined in the Lazorchak et al. report. To avoid this, we feel it necessary to offer credit where credit is due.]*

Platts, W. S., W. F. Megahan, and G. W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. USDA Forest Service General Technical Report INT-138, Ogden, UT.

Reeves, G. H., and nine others. 2001. Aquatic and riparian effectiveness monitoring plan for the Northwest Forest Plan. USDA Forest Service, Pacific Northwest Research Station, Corvallis, OR.

REYNOLDS, L., A. T. HERLIHY, P. R. KAUFMANN, S. V. GREGORY, AND R. M. HUGHES. 2003. ELECTROFISHING EFFORT REQUIREMENTS FOR ASSESSING SPECIES RICHNESS AND BIOTIC INTEGRITY IN WESTERN OREGON STREAMS. NORTH AMERICAN JOURNAL OF FISHERIES MANAGEMENT 23:450-461.

ROSGEN, D. 1996. APPLIED RIVER MORPHOLOGY. WILDLAND HYDROLOGY, PAGOSA SPRINGS, CO.

Schuett-Hames, D., J. Ward, M. Fox, A. Pleus, and J. Light. 1994. Large woody debris survey module. Section 5 *in*: D. Schuett-Hames, A. Pleus, L. Bullchild, and S. Hall, editors. Ambient monitoring program manual. Timber-Fish-Wildlife TFW-AM9-94-001, Northwest Indian Fisheries Commission, Olympia, WA.

Schuett-Hames, D., R. Conrad, A. Pleus, and M. McHenry. 1999. Method manual for the salmonid spawning gravel composition survey. Timber-Fish-Wildlife TFW-AM9-99-006, Northwest Indian Fisheries Commission, Olympia, WA.

Simonson, T., J. Lyons, and P. Kanehl. 1994. Quantifying fish habitat in streams: transect spacing, sample size, and a proposed framework. North American Journal of Fisheries Management 14:607-615.

Smith, R. L. and T. M. Smith. 2001. Ecology and field biology. Sixth edition. Benjamin Cummings, New York, NY.

WDFW (Washington Department of Fish and Wildlife). 2000. Fish passage barrier and surface water diversion screening assessment and prioritization manual. Washington Department of Fish and Wildlife Habitat Program, Environmental Restoration Division, Olympia, WA.

Wertz, W. A. and J. F. Arnold. 1972. Land systems inventory. U.S. Forest Service, Intermountain Region, Ogden, UT.

WFC (World Forestry Center). 1998. Pilot study report, Umpqua land exchange project. World Forestry Center, Portland, OR.

WFPB (Washington Forest Practices Board). 1995. Washington forest practices board manual: standard methodology for conducting watershed analysis under Chapter 222-22 WAC. Version 3.0. Washington Forest Practices Board, Olympia, WA.

Whittier, T. R., R. M. Hughes, and D. P. Larsen. 1988. Correspondence between ecoregions and spatial patterns in stream ecosystems in Oregon. Canadian Journal of Fisheries and Aquatic Sciences 45:1264-1278.

Zaroban, D. W. 2000. Protocol for placement and retrieval of temperature data loggers in Idaho streams. Idaho Division of Environmental Quality, Boise, ID.

4. Hydro-System RME Plan

Introduction
This plan addresses RME issues that are directly associated with the FCRPS hydro-system, particularly with respect to effects on life stages directly impacted by the dams and their operation. The objectives specified in this plan are as follows:

- Satisfy hydro-related RME actions presented in the FCRPS BiOp, and
- Develop an approach for evaluating progress toward and compliance with survival performance standards specified in the BiOp.

In the hydro-corridor, the focus of status monitoring is to document the survival of juveniles and adults within the FCRPS, and general environmental conditions. The BiOp specified target values or performance standards for survival that NMFS deemed necessary to achieve recovery. Part of status monitoring will include testing compliance with those survival standards.

Assessing the effectiveness of hydro-system actions, project reconfigurations and operations is called for under FCRPS BiOp 2003/2003-2007 Implementation Plan (IP) sub-strategy 2.3. These field studies focus on structural changes and operations occurring at individual projects. The vast majority of these are designed and conducted under the COE Anadromous Fish Passage Evaluation Program. This plan does not treat those specifically but relies on the established program to plan that collective research.

Within the hydro-corridor, critical uncertainty research focuses on two key uncertainties as described in FCRPS BiOp IP sub-strategies 3.3 and 3.4. The research called for under those sub-strategies is meant to resolve important issues related to delayed effects associated with transporting smolts (D), and EM attributable to passage through the hydro-system or different routes in the system that may be expressed in-river or following seawater entry.

The RME actions from the FCRPS BiOp that are addressed in this plan are summarized in Table 4.1.

Table 4.1. RME actions identified as Hydro-related in the FCRPS BiOp. A brief descriptor accompanies each one.

RPA	Description
185	Calculate D
186	Determine where D-mortality is expressed
187	Examine the relation of D to timing of seawater (estuary) entry
188	Investigate hydro-system delayed effects on stock productivity
189	Study effects of passage history on SAR
190	Snake R. fall Chinook- early life history
191	Improve year-round adult counts
192	Install adequate # of adult PIT tag detectors
193	Investigate new tagging systems
195	Estimate and geographically partition post-Bonneville smolt mortality

199	Hydro Research Actions (RA) – Appendix H of 2000 BiOp

Plan Elements

The Hydro-System RME Plan has the following elements:

A. Identification of key performance indicators (measures) and standards. Performance indicators are responses or conditions that are monitored. They can be either biological or environmental.

B. Assessment of research and monitoring needs – gap analysis. This involves a description of RPA requirements, RME projects satisfying each action, the identification of deficiencies and recommended remedies.

C. Presentation of guidelines for conducting RME, if applicable.

   1. Status Monitoring
      a. Recommend approaches for conducting the required RME.
      b. Identify options for testing progress towards and compliance with numerical standards presented in the BiOp.

   2. Critical Uncertainty Research (CUR)
      a. Describe project coverage of CUR actions.
      b. Assess the connection between RPA expectations and true research capabilities.
      c. Offer recommendations if disconnects are apparent.

   3. AER- The class of management actions is only briefly discussed in this plan. Because most of these projects fall under the auspices of the COE AFEP process, we defer to that planning process.

A. Performance Standards and Indicators

***FCRPS performance standards (PS*)** for the hydro-system are prescribed in Section 9.2.2 and 9.2.3 of the 2000 FCRPS BiOp. There are two general categories of PS: survival rates and physical/environmental conditions. The monitoring of life stage survival and environmental conditions through the FCRPS constitute status monitoring as prescribed in the BiOp.

Physical performance standards (BiOp Section 9.2.3) are further described in BiOp Section 9.6.1. These standards are guidelines for operating the system. They include flow targets and spill schedules. The BiOp does not call for specific tests to determine compliance with the guidelines, nor does it call for additional mechanisms to monitor these beyond procedures in place. So, this plan does not treat this further.

Life stage survival standards – The most specific performance standards are those expressed in the form of life stage survival estimates for juvenile and adult life stages (Section 9.2.2.2.1). Table 9.2-3 of the BiOp lists those PS. Survival rates are specified by ESU over the geographic expanse of the FCRPS that each ESU encounters. Several types of survival standards are identified for adult and juvenile salmonids (Table 4.2). These include 1) a combined survival that includes transport, in-river and delayed effects incurred by transported ESUs, 2) survival experienced in-river while passing the complex of dams and 3) survival past individual projects (dam and pool).

Table 4.2. Performance standards that apply to either juvenile or adult salmonids migrating through the FCRPS. The asterisk indicates that these stocks are not currently transported, however strategies may change in the future at which time combined survival would be the preferred performance standard.

	Performance Standard		
Life Stage	**Combined survival w/ D**	**System Survival (in-river)**	**Per Project Survival**
Adult	NA	All ESUs	All ESUs
Juvenile	Snake and *Upper Columbia	All ESUs	All ESUs

The BiOp did not formally specify which type of PS is preferred for application to a particular ESU. However, a footnote in that BiOp table implies that the per-project standard may have limited applicability, and the other two carry more weight.

The survival performance standards represent the best passage survivals that could be realized if the hydro actions were successfully implemented. Juvenile standards were derived using SIMPAS. Reach survival estimates used in the exercise were a combination of empirical and extrapolated values. Also, the analysis used some empirical and assumed default values for passage route survivals and efficiencies.

Adult survival standards were based on the assumption that base-case system survival for Snake River salmonid stocks could be increased by three percentage points. This equated to approximately 0.5 percent per project, a value applied to other ESUs.

With respect to the juvenile standards, the HWG has been deliberating whether it would be advisable to update standards originally reported in the BiOp. NMFS representatives are discussing the situation with their managers to determine how to resolve this matter.

Indicators **-** The indicators (performance measures) for survival monitoring are directly reflected in the standards; estimates of smolt and adult survival are required. However, the type of survival standard can vary by ESU. Thus, the action plan recommends the most appropriate and preferred type of estimate for each ESU. Preference is dictated by the management needs as well as the practicality of generating a representative survival estimate for the ESU of interest. These issues are discussed in detail later in this plan. Additionally, performance measures associated with certain CUR projects can include in-river survival estimates, as well as estimates such as SAR, TIR and D.

B. RME needs

General RPA requirements **–** In the 2000 FCRPS BiOp, Research monitoring and evaluation efforts are identified in the actions. Some of those deal specifically with hydro-related RME matters. That subset appears in Table 4.1.

Research Actions **–** One action (#199) details a number of specific RAs; these are described in Appendix H of the BiOp. Some are redundant with other actions but provide more detail on some points. Most refer to specific types of estimates (FPE, survival etc.) that need to be obtained at different dams. Others focus on migratory behavior, and general smolt monitoring. Many of the RAs are funded under the COE AFEP program and undergo formal review in that forum.

There are numerous additional RPA actions that involve hydro-related issues, but that lie outside the bounds of the RME-specific set (actions 179-199). Most of those are in the form of directives to fix or change some operation or structure at dams. These fall under the category of AER. They are treated under the AFEP and the interagency System Configuration Team and are not treated here.

RME projects, Overview **–** A key part of the RME assessment involves a gap analysis that identifies omissions or deficiencies in planned or ongoing research and monitoring. The work group has conducted an assessment for the hydro-related projects. The overview here only indicates whether RME is being conducted and is generally related to the RPA goals. A more detailed evaluation of gaps by the RPA immediately follows this overview.

Table 4.3. Funding agencies assessment of RME actions in the form of projects or proposals that cover RPA topics.

Action	**Description**	**Funding Agency**	**RME Category**	**RME Actions**
185	estimate D	COE	CUR	Ongoing
186	Determine where D-mortality is expressed	COE	CUR	Ongoing
187	D - timing of seawater entry	COE BPA	CUR	Ongoing
188	EM Hydro-related	COE BPA	CUR	Planned & ongoing
189	passage history - SAR	COE	CUR	Ongoing
190	SRFC - early life history	BPA	SM	Ongoing
191	Improve adult counts	COE	SM	no specific project, but part of established COE adult counting program
192	Install adult detectors	COE BPA	SM	Ongoing
193	new tagging systems	COE BPA	SM	Ongoing
195	Partition Post-Bonneville mortality	COE	CUR	Ongoing and additional projects planned

Action	Description	Funding Agency	RME Category	RME Actions
199	Hydro RME-related RAs – Appendix H in the BiOp	COE BPA USBR	AER, SM	Ongoing or Planned for most if not all RME-related RAs

Tables 4.3 & 4.4 display project coverage across the hydro-related actions. This overview indicates what research is being done on the individual actions, and does not necessarily imply that the research is entirely satisfying the intent of the RPA. It would be inappropriate to expect that any single research project could completely resolve the issues stated in any particular RME action. Thus, in the gap-assessment section of this plan, we synthesize the effective coverage of the collective research projects.

Table 4.4. Hydro-related RME action coverage by project, as indicated by the project sponsors, or as recognized by the RME workgroup. The list includes ongoing projects as well as proposals submitted for 2003 research, which were likely to be funded. Highlighting indicates projects that have hydro aspects but were more fully addressed by other work groups, particularly by the estuary and population status monitoring workgroups.

	RME actions - Hydro										
Project	**185**	**186**	**187**	**188**	**189**	**190**	**191**	**192**	**193**	**195**	**199**
					NPPC F&W Program						
199302900 -NMFS PIT survival	x		x		x	x			x		x
199602000- CSS	x		x	x	x						x
35047- EM experiment				x						x	x
198331900- new tag methods					x			x			x
199900301- fall/chum spawning monitoring below BON											x
199102900-USFWS – SR falls-Flow Aug						x					x
35025- FCRPS-plume			x								x
35031- tag coordination committee											x
35046- plume use – micro acoustic tag		X							x	x	x
1997-024-000 – avian predation		X								x	x
2001-003-00 – adult PIT detectors								x			
199008000 – PTAGIS	x		x		x	x			x		x
199102800 – wild tagging NMFS	x		x	x							
199403300 – FPC	x				x	x					x
198712700 – smolt	x				x	x					x

	RME actions - Hydro										
Project	**185**	**186**	**187**	**188**	**189**	**190**	**191**	**192**	**193**	**195**	**199**
monitoring											
1989107001 – Statistical support UW	x				x	x					x
19105100 – Statistical support UW	x				x	x					x
COE-Funded											
Tpe-w-00-1- NMFS transport Snake and McN	x	X	x					x			x
BPS-00-11 -Bird PIT		X	x							x	x
Est-02-3 timing est.			x								x
Tpe-w-00-2 -barge post release survival		X									x
EST-P-01-NMFS acoustic tag				X					x	x	x
BPS-W-00-10a, -D in estuary and plume		X									x
BPS-W-00-9b migration histories		X			x						x
BPS-W-00-9a -physiology and bypass history					x						x
TPE-W-00-1c -physiology and transport		X			x						x

This general survey indicates that all hydro RME-actions are being actively pursued at some level and that every action except one (191) is being addressed by more than one research effort.

Status Monitoring - Survival through the FCRPS

RME Needs – RPA Directives: The BiOp presents specific survival standards that smolts and adults should ultimately achieve once the FCRPS is entirely upgraded with respect to fish passage (Section 9.2.2.2.1 of the BiOp; table 9.2-3). However, none of the BiOp RPA actions specifically refer to the need for acquiring the estimates necessary to test compliance with those standards. To assess whether survival standards (juvenile and adult) are being achieved requires annual estimates of survival. A number of actions and associated RAs request that certain survival estimates be obtained. Thus certain research projects offer the potential of being useful in producing survival estimates for use at the check-ins. The BiOp survival standards for inriver migrants extend from the uppermost dam encountered by each ESU to the tailrace of Bonneville Dam. Estimates of D are also required for ESUs that incur some level of transportation. Action 185 directly requests that estimates of D be provided for ESUs that are transported. To satisfy that request also requires that estimates of in-river survival are available.

Current projects/proposals: Smolt survival – At least four projects are either underway or planned that will generate in-river survival estimates for smolts over long river segments, (199302900, 199602000, 35047 and TPE-W-00-1). All of these utilize PIT-tag methods.

Adult survival – The COE funds a broad-based adult passage study at the University of Idaho and NMFS. That study has the capacity to generate estimates of minimum survival for species radio-tagged in any given year. However, the COE has suggested that such estimates may not be available every year. Alternatively PIT-tag based survival estimates offer new opportunities that may be realized with the installation of adult detectors at strategic sites by 2003. Also, stock-specific estimates may soon be available by combining radio and PIT technologies. The action plan section of this document proposes an approach for annually monitoring adult passage survival using ongoing and planned research efforts.

Gap and adequacy assessment: Clearly there are a variety of projects that are producing survival estimates in the mainstem. All of these studies employ state-of-the-art technology and survival estimation protocols. However, it is not possible to determine whether these projects will generate a suite of empirical survival estimates for each ESU that will adequately satisfy BiOp requirements.

Closing the Gaps: The challenge is to determine how progress and compliance with PS will be assessed, given the type of estimates that are practical to obtain. The solution involves an analytical exercise. The initial phase of that exercise has been completed and reported herein as part of the action plan. The exercise relies on the use of empirical rather than model-based estimates whenever possible.

Other Monitoring Needs and Programs - FCRPS

RME Needs-RPA Directives: Some actions (190, 191, 192 and 193) call for information and actions that either support or can contribute to improving survival estimates necessary for hydro status monitoring, or other related estimates. For example, action 192 calls for increasing the number of adult PIT-tag detectors at mainstem dams. The expansion of the detection system affords new and improved opportunities for estimating passage survival of adults. Similarly action 191 calls for improving adult counts at dams. Satisfying this action may contribute to improving population status monitoring for some stocks. Action 193 requests that research be directed at improving and developing new tagging and detection systems to enhance monitoring and evaluation capabilities related to survival estimation. Action 190 is more general than others in this category. It directs the AA to provide better information describing early life history and requirements of Snake River fall Chinook.

Snake River fall Chinook early life history (Action 190)

Current projects and proposals: Two projects are collecting information and generating estimates that pertain to action 190 (SR fall Chinook); 199302900 (NMFS) and 199102900 (USFWS). The NMFS study generates survival estimates for hatchery fall Chinook above Lower Granite Dam and through part of the FCRPS. The USFWS project is also an ongoing research effort that describes a variety of early life history characteristics of fall Chinook in the Snake and Clearwater drainage. In addition to these studies, a Snake River fall Chinook transportation study was initiated in 2001 and will continue for some years. Although primarily a passage strategy study, insights regarding early life history will no doubt accrue.

Gap Assessment: Collectively, the two research projects focusing on fall Chinook appear adequate in terms of scope and intensity to satisfy the intent of action 190. Research reports dating back nearly a decade are providing quality information describing rearing and migratory characteristics of this stock. The survival estimates rely heavily on the use of hatchery stock from Lyons Ferry. Opportunities to generate robust estimates using wild fish are very limited but do occur periodically.

Recommendations for Filling Gaps: The early life history research is adequate to satisfy the intent of the action.

Improving year-round counts for adult salmonids at dams (Action 191)
Current projects and proposals: Action 191 involves expanding an existing COE adult counting program and does not require a specific project. These activities fall under the auspices of the established COE Fish Passage Program.

Gap Assessment: According to the action, the need is to expand the coverage period for enumerating adult passage at dams. Extending the adult ladder counting period into the winter is requested as is documenting fall back through the juvenile facilities, particularly at McNary.

Recommendations for Filling Gaps: The expansion of the program is underway and appears satisfactory to meet the needs of the action.

Increase Adult PIT tag detection capabilities (Action 192)
Action 192 calls for increasing the number of adult PIT detectors. The expansion of the detection system affords new and improved opportunities for estimating passage survival of adults. Project 2001-003-00 addresses needs expressed in the action.

Gap Assessment: The project scope as submitted to the NPCC appears to adequately satisfy the needs expressed in the action. The project plans on expanding of current PIT-tag interrogation technologies for adult PIT detection in fish ladders (RPA actions 50 and 192). Soon PIT coverage will be in place at five dams, including BON, MCN, IH, PR and LGR. Additional installations are being considered for other sites. This detection network forms the infrastructure necessary to monitor adult passage survival (see Action Plan section).

Recommendations for Filling Gaps: No gap is apparent.

Investigate feasibility of novel tagging/detection systems (Action 193)
Current projects and proposals: Action 193 requests that research be directed at developing and applying new tagging and detection systems to enhance monitoring and evaluation capabilities related to survival estimation. Two projects address this action. One project (198331900), is now funded by the NPCC F&W Program, and includes the development of a high-Q detection system. The other is a proposal submitted by NMFS to the COE (EST-P-01-nmfs), which is investigating the feasibility of designing and producing a miniaturized acoustic tag with specific capabilities.

Gap Assessment: Both projects address the action satisfactorily. However, there is no way to predict whether these design/development projects will be successful in producing a tag or detection system that adequately meets the specifications presented in the action. Those specifications are general, but demanding. They include the capability to discriminate between hatchery and wild fish, differentiate populations and describe their use of different geographic estuary/marine areas. It is unclear whetherany single tool can satisfy all these requirements. The two NMFS projects are certainly responsive to RPA requests. There is no gap in research effort.

However, if the capabilities of the acoustic system are inadequately realized, survival investigations in the estuary/marine waters will likely be hampered.

Recommendations for Filling Gaps: No gap in research effort is apparent.

Hydro-System - Action Effectiveness Research

Action 199 directs the AA to fund a variety of RAs that are largely action effectiveness research projects. The gap analysis conducted by Fisher (2002) lists these RAs in his appendix Table A8. Each of these RAs has at least one research or evaluation project associated with it. Coverage is complete. Because the COE funds these projects, the adequacy of the research is assessed through the AFEP forum.

Critical Uncertainty Research

There were two critical uncertainties that emerged in the BiOp analysis that are linked to FCRPS effects on listed stocks: the extent of delayed effects associated with D and the existence and extent of EM associated with smolt passage in river.

D (Actions 185, 186, 187)

RME Need-RPA Directives: Delayed mortality associated with transporting smolts is a critical uncertainty explicitly identified in the BiOp. The BiOp includes three actions (185, 186 and 187) directed at resolving key issues associated with D. Action 185 requests expanding marking efforts with the intent of improving and refining estimates of D. Current estimates have several deficiencies most notably including poor precision and limited stock coverage. Research needs to improve on these points. Action 186 requests that research also focus on identifying the causes of D as well as the geographic zones where delayed effects are expressed. Action 187 is even more focused, by requesting research to assess the effects of ocean entry timing on the magnitude of delayed effects. This complex of information will prove challenging to acquire. Obtaining reliable estimates of D is critical to resolving key assumptions inherent in population modeling and extinction risk assessments.

Current projects and proposals: Three projects address key aspects related to D; Tpe-w-00-1 (NMFS transport Snake and McN), 199302000 (CBFWA - Comparative Survival Study), 199302900 (NMFS in-river survival).

Gap and adequacy assessment: Survival estimates for transported and in-river groups are necessary to calculate D. All of these projects generate such estimates using a variety of hatchery and wild, and run of river stocks through different river segments. A review of the NPCC proposals raised the issue as to whether the precision and stock coverage proposed by the investigators would ultimately be satisfactory to conduct performance tests at the check-ins for hydro-survival and population growth rate standards. The same concerns may exist for the COE transport study (tpe-w-00-1), although that proposal has not been reviewed with respect to the statistical properties of projected estimates of D.

Recommendations for Filling Gaps: An assessment regarding the adequacy of D estimates emanating from these studies with respect to ESU coverage, statistical properties of the estimates and reliance on estimates derived from hatchery fish is required. The latter is critical because hatchery stocks are likely the only groups that can be tagged in sufficient numbers to provide D estimates with suitable precision.

EM (Actions 188, 189, and 195)

RME Need-RPA Directives: The BiOp clearly identifies EM as a critical uncertainty requiring resolution. This is necessary to improve population-modeling analyses used in extinction risk assessments. Concerns regarding the existence and magnitude of delayed effects associated with exposure to the hydro-system are of particular interest. The existence of this effect was first hypothesized through the Plan for Analyzing and Testing Hypotheses (PATH) modeling and later applied in analyses conducted in the BiOp. Within the context of the NPCC F&W Program and COE AFEP forum, a complex of studies and proposals have been developed to resolve important aspects of EM. These research efforts are focused on the hydro and estuary/near-shore zones and are linked to actions 188, 189 and 195, all of which may be EM related. This need is generally expressed in action 188, which calls for PIT tagging of lower river stocks to use in comparisons with upper river stocks being PIT tagged. Related actions include 189 and 195 where objectives are more specific. Action 189 focuses on establishing the cause and effect of particular passage routes on existence and magnitude of EM. Action 195 directs investigators to determine the geographic zones where post-Bonneville mortality is expressed and the magnitude in each zone. Furthermore, the research should be designed to distinguish between natural and anthropogenic-based mortality as associated with such factors as hydro-passage experience or general fitness of the stock monitored. Also, expression of any perceived EM could extend well into the marine environment.

Current projects/proposals: At least 16 projects are identified in Table 4 that can be construed as EM related. The projects span a wide range of topics, including the physiological effects of passage on survival, estimates of in-river survival required to estimate the magnitude of EM and developing systems to estimate survival in the estuary. Projects directed at estimating or identifying causes of EM include 35047 (NFMS-Extra Mortality), 199302000 (CBFWA - Comparative Survival Study) and 199302900 (NMFS- In-river Survival). Other projects that are obviously related to EM issues include 35046 (Plume Use by Salmonids), 1997-024-000 (Avian predation), BPS-00-11 (PIT tags in birds), TPE-W-00-1c (physiology during passage), BPS-W-00-9a (migration history) and EST-P-01 (Acoustic Tag System Development). Other projects may contribute in some manner but are not particularly focused on EM issues.

Gap Assessment: This complex of RME activities will be useful to help clarify the existence, magnitude and causes of EM, and will help define future research needs in this area. However, it is unclear whether they individually, or collectively, fully satisfy the primary intent of actions 188, 189 and 195. The proposal that focuses most clearly on hydro-related EM is 35047. The objective of that project is to quantify delayed effects associated with passage through the hydro-system. It is unclear, however, if the project could consistently obtain satisfactory numbers of fish to tag as required in the experimental design. The ISRP expressed more substantive concerns regarding the design suitability for resolving the project's central hypothesis. Project 199302900 is limited in scope relative to assessing delayed effects associated with different passage routes (action 189). The proposed research will contribute estimates of survival associated with screen-bypassed fish but not other routes separately. The review of 199602000 suggested power analyses were warranted, before the value of resulting inferences regarding EM could be assessed.

Recommendations for Filling Gaps: It is difficult to ascertain whether the collective research will adequately satisfy the full intent of the action. Even so, the collective research will expand the understanding of delayed effects associated with dam passage, but not necessarily resolve all outstanding EM issues identified in the BiOp. For example, the approach proposed in project 35047 is probably the only practical way to attempt to detect any delayed mortality associated with dam passage. However, because only a few dams were included in the assessment, inferences to passage through the entire FCRPS will be limited.

Synthesizing this information and determining progress on these points will be a critical assessment to be performed in 2005. Toward that end, a workshop will be convened in 2005 that assembles all researchers conducting RME explicitly or implicitly treating aspects of EM. The workshop will determine if additional research effort is required and how to appropriately solicit it. Ideally, this effort would be jointly sponsored and endorsed by the ISRP, NMFS and others.

C. Action Plan

1. Monitoring Smolt Survival (Status Monitoring)

The objective of monitoring activities in the hydro-corridor is to assess progress toward and ultimately achieving the life stage–specific survival performance standards prescribed in the BiOp.

ESU-specific monitoring: To accomplish this for each ESUthe work plan identifies appropriate

- Performance standards,
- Experimental protocols (including tools) and analytical models and
- Populations to be used as experimental or index groups.

Performance Tests: Additionally, the plan specifies analytical/statistical performance tests that can be used to assess progress towards and compliance with survival standards.

Survival Standards: The BiOp identified two classes of smolt survival as candidate performance standards to judge the status of migrant smolt life stage:

- System (in-river through the FCRPS) and
- Combined, which includes survival of smolts migrating in-river as well as those transported, and includes an estimate of any delayed transport effects (D)?

A third type of standard (project survival) was presented in the BiOp, but has little utility in assessing the general performance of the hydro-system.

This plan identifies the most appropriate standard for each ESU, based largely on whether or not it is transported.

a. Blueprint for Smolt Survival Monitoring

Annual measures of performance for smolt survival should have the following global properties:

- PIT tag-based estimates,
- Using fish tagged prior to encountering FCRPS,
- Single release, mark-recapture model for empirical estimates and

- Where possible, statistically based progress and compliance tests should be conducted.

The following is a general overview prior to addressing each ESU in detail. Table 5 summarizes the recommendations regarding the preferred index stocks to use in monitoring smolt survival for each ESU. Also indicated is the preferred (#1) and secondary (#2) performance standard and the corresponding values from the BiOp. These values are the reference points against which progress and compliance are assessed. The distinction between primary and secondary designations for index stocks is dictated by several considerations, including the expected persistence of tagging efforts for each index stock and the likelihood of acquiring suitable numbers of tagged fish each year. With regard to type of performance standard, combined survival was preferred for any stock regularly subjected to transportation.

Table 4.5. Index stocks, response zone over which survival is estimated, nature of the estimate (empirical or model-derived), and primary (#1) and secondary PS.

ESU	Index stocks	Nature of estimate and Response zone	BiOp PS	
			Type	Survival %
Snake				
Spr/sum Chin	H & W originating above LGR	Empirical$_{(LGR-BON)}$	1. combined 2. system (inriver)	57.6 49.6
Fall Chin	Lyons Ferry Hatchery & Periodic validation with wild fish	Empirical $_{(LGR-LMO)}$ & Model$_{(LMO-BON)}$	1. combined 2. system (inriver)	12.7 14.3
Steelhead	H & W originating above LGR	Empirical$_{(LGR-BON)}$	1. combined 2. system (inriver)	50.8 51.6
Sockeye	-	-	-	NA
Upper Columbia				
Spring Chin	1. H & W originating above LGR 2. UC hatcheries-potential	Empirical$_{(MCN-BON)}$	1. system (inriver) 2. combined (if transported)	66.4 66.4
Steelhead	1. H & W originating above LGR 2. UC hatcheries-potential	Empirical$_{(MCN-BON)}$	1. system (inriver) 2. combined (if transported)	67.7 67.7
Middle Columbia				
Steelhead	1. H & W originating above LGR 2. MC hatcheries-potential	Empirical$_{(ENTRY-BON)}$	1. system (inriver)	67.7
Lower Columbia				
Chinook	-	-	-	-
Steelhead	-	-	-	-

Snake River ESUs

Spring/summer Chinook and steelhead

Performance Standard

Because these two ESUs are subjected to transport at Snake River dams, the primary PS is the combined survival for in-river and transported fish. To calculate this value on an annual basis requires that performance measures be acquired each year. These include estimates of the following:

- In-river survival from the head of LGR pool (ideally) to the tailrace of Bonneville Dam,
- Direct transport survival from collection through liberation,
- D-delayed effects associated with the transportation process and
- The proportion of the population arriving at LGR that are transported from all collector dams.

Experimental protocols and models

In-river survival estimates should remain consistent with those calculated and reported by NMFS since 1994 (See Attachment 1). Those estimates are based on a single-release model and PIT tag data obtained through the FCRPS. Some of the existing historical survival estimates from LGRpool-BONtailrace are solely based on empirical estimates. Others are a combination of empirical and extrapolated estimates.

However, there are concerns about extrapolating, or applying, empirical estimates derived in the Snake River to the lower Columbia River. Zabel et al. (2002) compared empirical estimates obtained through both reaches in 2001. They reported that per mile survival of both Snake River stocks through the lower Columbia projects was lower than that estimated through the Snake River. This has important implications to the BiOp performance standards because the extrapolation approach was used to establish survival standards cited in the BiOp.

Since 1997, it has been possible to empirically estimate survival over increasingly longer reaches of the FCRPS, particularly through the McNary to Bonneville Dam reach (Williams et al. 2001). This has been a consequence of increased sampling capability in the lower river, especially at Bonneville Dam and using PIT trawls in the lower river. There has been concern expressed that the activation of the corner collector at Bonneville Second Powerhouse could appreciably decrease PIT-tag detections at the dam, potentially compromising survival monitoring. However, this does not appear likely because provisions are in place to equip the corner collector with a PIT detector of suitable detection efficiency.

Weighted estimates: In recent years, the general approach has been to calculate and report weighted annual estimates of in-river survival. This plan calls for weighted estimates be reported annually in the future, in situations where they can be calculated.

Direct survival during transportation is presumed to be a constant 98 percent, but this value is based on anecdotal observations only. It is recommended that some effort should be expended to empirically establish the actual value. It is possible that some of the effect currently designated as D may be expressed during the collection and transport process. This estimate can reasonably be considered an information gap requiring resolution, albeit, of minor concern.

D estimates (representative, accurate and precise) on an annual basis are the most problematic estimates to obtain empirically because there are several complicating factors. NMFS analysts reported that wild and hatchery fish appear to respond differently to transport in terms of delayed effects (Williams personal communication and recent presentation to TMT). However, small sample sizes associated with wild estimates may reduce confidence in those estimates. To obtain suitable sample sizes, existing and future estimates of D may need to be based on a pooled estimate derived from hatchery and wild fish. Also, D estimates lag in-river survival estimates by 2 to 4 years. This limits usefulness for timely application at the check-ins. UW investigators have developed a model that predicts annual estimates of D based on prevailing water temperature during the migration. This model can potentially predict estimates of D in a timely manner. However, this hypothesis may not be a reliable means to confidently predict D for any migration year. Even so, as this approach is refined it may prove useful in the future.

There are no final recommendations for how representative annual estimates of D can be calculated and applied in a timely manner. However, the following actions are recommended:

- Acquire more reliable D-estimates for wild Snake stream-type populations by increasing the transported percent of PIT-tagged wild fish arriving at LGR and LGO dams.

- By the 2003 check-in, devise a strategy that clearly describes analytical procedures regarding the application of D at the 2005 and 2008 check-ins.

Because it is unclear what values for D will be deemed representative and can be confidently applied at the check-ins, the HWG supports continuing the planned research regarding this critical uncertainty, as described later in this plan.

Estimating the proportion of a population transported within the FCRPS is a necessary step. Two approaches were considered: one involves using SIMPAS with updated passage parameters; the other is a simpler process, dubbed SimplePass, that NMFS analysts are exploring.

Populations Monitored

Existing system-survival estimates (Attachment 1) are based on a composite population of hatchery and wild fish, the proportions of which can vary annually. To maintain consistency with baseline estimates, the same composite index group will be used in future assessments. In order to achieve this, NMFS must document the stock composition (proportions) of the index population as accurately as possible and report that annually. This is necessary because the SR model reflects not only hydro related but all of the effects influencing survival that are expressed while migrating through the FCRPS. If, for example, a particular hatchery dominates the migration in a given year and exhibits extremely good or bad survival in-river because of rearing conditions, then the annual estimate could be skewed. Knowing hatchery and wild proportions could prove useful when interpreting retrospective analyses conducted at the check-ins.

Monitoring and Generating Necessary Estimates

All monitoring should continue through at least the decade following the publication of the 2000 BiOp. NMFS investigators will continue to conduct research activities necessary to produce the estimates identified in this plan. These include annual estimates of in-river survival and appropriate estimates of D, ideally on an annual basis. A technical group is required to review those estimates as they are submitted, ensuring they are sound and consistent with those prescribed herein. It is recommended that a technical work group be established, potentially an extension of the NMFS-AA work group that drafted this plan, to address ongoing issues associated with the implementation of the Hydro RMA Actions. It is not clear which agency has responsibility for estimating direct transport survival only that this need exists. If additional work is required in this area, the AFEP process should solicit proposals on this topic for 2004.

Fall Chinook

Performance Standard

Because this ESU is subjected to transport at Snake River dams, the most informative PS would be the combined survival for in-river and transported fish. Calculating this value annually requires the same suite of performance measures cited previously for spring migrants in the Snake River. Unfortunately, no estimates of combined survival have ever been calculated or reported for Snake River fall Chinook. Thus, no baseline estimates exist. Furthermore, there are no obvious opportunities to empirically generate such estimates. To date, it has not been possible to estimate in-river survival through the entire FCRPS. This limitation is not expected to change in the foreseeable future.

Experimental protocols and models

In-river survival: A major constraint to generating representative estimates of system survival through long expanses of the FCRPS lies with the inability to empirically estimate survival past Lower Monumental Dam. All estimates published thus far only extend from upstream release sites to LOMO tailrace (Smith et al. 2002). Including survival through LGR pool may not be appropriate because fish are still displaying rearing tendencies and quasi-resident behavior while in that river segment. Whereas, by the time fish have passed LGR, they are demonstrating a clear tendency to initiate downstream passage.

Because this reach is considerably shorter than the required target reach (LGR to BON tailrace), it will be necessary to either extrapolate or model survival through the lower section. The resultant system survival estimate will then be a composite of annual empirical and model-based estimates. However, analysts at NMFS are reluctant to extrapolate survival over such a long, unmonitored reach. Rather they propose to model survival through the lower river using the method described by Zabel in Attachment 2. This approach is supported at this time, but alternatives should be considered depending on how the fall Chinook estimates and analyses develop.

Even though using in-river survival estimates based on the single release model as described by Smith et al. 2002 is recommended, there are remaining difficulties with these survival estimates. They may not accurately reflect the survival dynamics of the entire fall Chinook population because

- Some fraction of the population holds over and migrates the following spring, after incurring some unknown amount of over-winter mortality.

- Even within a year, late migrating fish are excluded from the estimate because they do not all move through the system prior to the termination of sampling at dams.

- Survival estimates are based on hatchery stock from Lyons Ferry, which have been observed to display survival very different from wild counterparts in some years. The differential survival appears to be associated with the fact that they often vary in size, disease-related mortality and migration timing from their wild counterparts.

Collectively, these observations and the reliance on empirical/model-based estimates indicate that it will be difficult to accurately represent passage mortality incurred by the wild Snake River ESU through the entire FCRPS. Moreover, the estimate is better depicted as a survival index. Thus it is recommended that two procedures be considered as candidates for quantitatively monitoring passage survival:

1. Construct survival estimates that span the FCRPS, but are compiled from empirical and model-based estimates (Attachment 2)

2. Construct survival estimates that span a segment of the FCRPS, but are composed only of empirical estimates.

Adopting the first approach would enable the selection of combined survival as a performance standard if reliable D-estimates are acquired in the future. Using the second approach would require that a new PS reflecting survival through the monitored portion of the FCRPS be developed and adopted by NMFS.

Direct survival during transport: As noted for other Snake River stocks, no empirical estimates of direct transport survival are available, only anecdotal observations. The presumed 98 percent survival estimate needs to be verified experimentally, as an element of critical uncertainty research treated later in this plan.

D estimates: Reliable and representative estimates of D do not exist for this ESU. This is yet another constraint that negates the utility of using combined survival as a performance standard for fall Chinook. The D value of 0.24 adopted in the PATH forum was a compromise value unsupported by any statistically sound empirical estimates. Obtaining representative annual estimates of D will require a concerted experimental effort. NMFS investigators have embarked on that line of study. It is too early to ascertain whether the estimates will be robust enough to satisfy BiOp needs, even if sound estimates emerge the same limitations expressed for spring migrants apply to this ESU. This body of transportation research was identified as a critical need in the preceding gap assessment.

Populations Monitored
Lyons Ferry hatchery fish will be used to generate in-river survival and D estimates. However, there is the need to continue wild fish PIT-tagging for use as a comparison. Tracking the performance of each group through common reaches will allow an assessment of the hatchery stock as a consistently acceptable surrogate for the wild component of the ESU.

Monitoring and Generating Necessary Estimates
It is recommended that the Snake River fall Chinook transportation studies continue from 2003 to 2008. This effort would also supply the in-river migrants for use in monitoring and estimating in-river survival.

Upper Columbia ESUs (Spring Chinook, Steelhead)

Performance Standard
The primary performance standard for Upper Columbia spring Chinook and steelhead is in-river system survival from McNary Dam to Bonneville Dam tailrace. Because these stocks are rarely transported from McNary Dam, in-river survival estimates through the FCRPS (system survival at BiOp) are the most instructive performance measures. The system survival goal according to Table 9.2-3 in the BiOp is to achieve 66.4 percent and 67.7 percent survival, respectively, through the FCRPS.

An important issue raised previously for Snake River stocks applies here as well. Because potentially outdated SIMPAS model-based estimates were used to set the PS values, the standards for Upper Columbia stocks will likely need revision, as this plan indicated for Snake River PS.

Experimental protocols and models
In-river survival: Empirical estimates of in-river survival from McNary Dam to BON tailrace are required. Future PIT-tag sampling capabilities at BON will in part determine the usefulness of any resulting estimates; however, the detector planned for the corner collector should yield estimates equivalent to recent estimates obtained through that reach. Unfortunately, no pre-2000 estimates have been compiled or even calculated for this reach of the FCRPS, so any progress and testing protocols would necessarily differ from those adopted for Snake spring migrants.

Populations Monitored
Two classes of index stocks have been identified. The primary stock is the composite hatchery and wild Snake River population migrating through the lower FCRPS. A secondary group consists of any Upper Columbia stock that is PIT tagged in sufficient numbers to yield reliable survival estimates. There is no wild fish PIT-tagging program in place in the Upper Columbia, tghus, estimates for wild fish would not be available for these ESUs.

Monitoring and Generating Necessary Estimates
All monitoring should continue through at least the decade following the publication of the 2000 BiOp. One reason the HWG selected Snake River stocks as the primary monitored population is because we expect NMFS will continue to conduct research activities necessary to produce the estimates identified in this plan. However, we have no assurance that adequate PIT tagging could be implemented throughout the Upper Columbia. Thus stocks from that drainage were assigned a secondary position governed by opportunity in using fish dedicated for other purposes.

Middle Columbia ESUs (Chinook and Steelhead)
Performance Standard
The performance standard for Middle Columbia spring Chinook and steelhead is in-river system survival from point of entry in the FCRPS to Bonneville Dam tailrace. The point of entry is designated as the first dam encountered.

Experimental protocols and models
In-river survival: Empirical estimates of inriver survival from the first FCRPS dam encountered to BON tailrace are required. Again, future PIT-tag sampling capabilities at BON corner

collector will in part determine the usefulness of any resulting estimates. Also, no pre-2000 estimates have been compiled or even calculated for this reach of the FCRPS, so any progress and testing protocols would necessarily differ from those adopted for Snake spring migrants.

Populations Monitored
Two classes of index stocks have been identified. The primary stock is the composite hatchery and wild Snake River population migrating through the lower FCRPS. A secondary group consists of any Middle Columbia stock that is PIT tagged in sufficient numbers to yield reliable survival estimates. There is no wild fish PIT-tagging program in place in the Upper Columbia, thus, estimates for wild fish would be unavailable for these ESUs.

Monitoring and Generating Necessary Estimates
All monitoring should continue through at least the decade following the publication of the 2000 BiOp. The rationale for designating primary and secondary index groups is the same as expressed for Upper Columbia ESUs.

Lower Columbia ESUs
Although the BiOp specified survival standards for the lower Columbia ESUs, there is no practical means to monitor survival below Bonneville Dam at this time.

b. Progress and Compliance Tests

Progress: The BiOp only provides general guidance as to what might constitute a progress test for *juvenile* survival in 2005 and 2008. Furthermore, approaches for testing adult performance were not quantified. The purpose of testing juvenile survival is to determine whether or not management actions in the hydro-system are improving survival and advancing toward recovery standards. The BiOp proposed that two-sample tests on one-sided hypotheses be conducted. A base period was specified as 1994 to 1999 (BiOp table 9.7-1). The BiOp describes the envisioned tests for juveniles, but details regarding data needs and the actual test protocols were not provided. Skalski and Ngouenet (2001) conducted a power analysis involving the two hypothesis tests proposed in the BiOp. They concluded that the proposed tests had a poor probability of correctly identifying the true state of progress or compliance. They suggest alternative decision rules be explored and considered.

Compliance: The timeline for attaining the specified PS is 10 years. However, the BiOp offers no guidance with respect to how attainment will be tested quantitatively. Also, there are no guidelines dictating the use of empirical data or models in monitoring.

Recently, Skalski, Lady and Smith (Attachment 3) offered an approach for evaluating progress and compliance with smolt survival standards. These recent analytical efforts show that most conventional testing procedure will have limited power in testing key hypotheses pertaining to the PS. The alternative they developed involves a suite of tests. Furthermore, they suggest that even these may be inappropriate for the application and recommend that a multi-dimensional framework for testing be explored.

The challenge in finding a statistical method to determine whether a system is in compliance is that there are many ways to ultimately reach compliance by year 2010. Compliance could occur relatively soon (i.e., 2002, 2003) or arrive at the very last possible moment (i.e., 2010). Furthermore, improvements in in-river survival are not anticipated to readily exceed target performance levels but simply meet expectations. As such, standard statistical methods that are neither flexible in their definitions of compliance nor designed to assess boundary conditions are ill suited to compliance testing.

Computer simulation studies found no simple statistical test was readily able to identify compliance under varied recovery scenarios. Some testing procedures were better able to discern compliance when it happened immediately; other tests were better able to discern compliance when it happened gradually. But no single decision rule worked well in all circumstances.

The mixed behavior of the various simple statistical tests suggested combining the best of their features into a composite rule. We found a set of three simple and familiar statistical tests that, when performed in unison, provided greater statistical power to identify compliance when it indeed occurred. One test looks for a trend of higher in-river survivals over time; another test looks for improvement in average survival pre- and post-2000; and the third test looks for a long-term projection of improved survival over time. None of these individual tests must be significant at traditional significance levels, but instead, all three tests must show positive evidence of compliance at a joint significance level.

The benefits of the multidimensional decision rule include:

- Better statistical power to detect compliance if it occurs.
- The error rate for falsely claiming compliance when it has not occurred is known and set in advance.
- The individual tests are simple to calculate using familiar statistical methods.
- Critical values for concluding compliance are well defined and objective. Statistical tests are easily calculated and compared to known critical values to immediately discern whether compliance has been attained.
- The decision rule is objective and criteria for compliance specified in advance for all parties to monitor.

ESU Coverage

These quantitative tests can only be effectively applied to Snake River steelhead and spring/summer Chinook. The tests are not sensitive enough to detect expected changes in survival envisioned for other ESUs. To date, it has not been possible to devise any testing procedure that would be applicable to other ESUs. This means that only qualitative evaluations may be possible at the check-ins for most ESUs.

c. Adult Salmonid Passage Monitoring and Performance Standards

Adult Passage Survival Monitoring
The NMFS BiOp prescribes performance standards for adult survival while migrating through the FCRPS. Those standards were developed using empirical survival estimates obtained during radio telemetry studies conducted by NMFS and the University of Idaho.
That approach produced survival estimates that reflect adjustments for the following:

- Fallback at BON & terminal dam
- Harvest removals in zone 6 and upstream to terminal dam
- Straying into tributaries
- Passage through navigation locks

Thus, the survival standard estimates reported in the BiOp appear to represent a minimum because they do not reflect either electronic tag failure or regurgitation that may have occurred during migration. Furthermore, those estimates do not reflect any live fish with active tags that may have eluded detected at the uppermost dam or tributary monitoring sites.

The purpose of annually monitoring survival is to produce a measure of performance that is equivalent to the standard presented in the BiOp. This provides a direct means to assess progress towards or compliance with those standards. To produce this "apples to apples" comparison, it is necessary to incorporate the same adjustments in the annual performance measure that were used in the derivation of the original BiOp standard. However, using PIT-tag data rather than conduct radio-telemetry studies on an annual basis should be considered for the following reasons:

- It is possible to passively monitor the migration of adults of known origin.

- The data collection and management system is well established, and it is efficient and timely in its ability to generate estimates of interest.

- The data collection, database and estimation procedures are transparent and readily accessible to a broad complex of analysts.

- ESU-specific sample sizes may increase as more juvenile investigations adopt PIT tags. As a consequence the scope of juvenile tag coverage in terms of stocks and geographic range will likely expand.

- Annual PIT monitoring appears to be inexpensive relative to telemetry studies because it takes advantage of fish tagged as juveniles for a variety of purposes.

- No special adult tagging or interrogation effort is required.

- Handling and tagging effects and tag regurgitation associated with telemetry studies are avoided.

However, there are some deficiencies in relying solely on PIT data as discussed herein.

Documenting Adequate Performance: Two Approaches
This plan describes two approaches for determining if adult passage conditions are satisfactory according to BiOp standards. One involves attempting to quantitatively estimate passage survival annually. The alternative approach is more action oriented and focuses on determining if the recommended passage improvements (specific actions related to adult passage) have been adequately implemented. Descriptions of these approaches follow.

Annual Monitoring of Adult Survival:
To process PIT data so that it yields survival estimates equivalent to the standard, a set of independent estimates will be needed to make the appropriate adjustments. Some of the accounting adjustments are the same as those used in the telemetry approach used in the BiOp. However, additional adjustments are required because the PIT interrogation system does not afford the same coverage as the radio-telemetry systems. This type of estimate entails accounting of fish fates, in contrast to estimates that are generated using mark-recapture statistical models.

- Using PTAGIS, select the subset of PIT-tagged adults detected at BON that represent the ESU of interest.

- Of those, determine the number detected in the fishway at the key terminal detection site upstream, e.g., LGR or MCN Dam.

- Account for any documented interdam loss, apart from mortality associated directly with migration. Documenting that "loss" may require independent estimates of

    - Harvest removals in-river. Use TAC-reported harvest rates and correct for Bonneville counting error using the following factor.

    - Bonneville count correction factor that is based on fallback (non-reascent) rates at BON. This is necessary to increase the accuracy of the TAC harvest rate. Estimated fallback rates at BON are based on existing radiotelemetry data. To obtain annual estimates absent telemetry investigations, NMFS and UI staff are determining if it is feasible to model fallback as a function of river flow or other variables.

    - PIT tag detection rate within the fishway at the upstream dam.

    - Estimate navigation lock passage rate at the upstream detection site using radio-telemetry data. Current estimates at LGR are inferred and based on upstream detection of fish not detected passing dams. At MCN, direct estimates of navigation lock passage have been obtained in some years.

    - Straying rate, as defined as observed turn-off into a tributary downstream from the expected destination. Use a general model or estimate based on existing radio telemetry, or use estimates acquired in any given year when telemetry evaluations are being conducted. Alternatively, it would be advantageous to design and deploy detection systems that can monitor adults returning to major index streams. But as yet, there is no practical design available.

- Fallback rate at the terminal dam. This value represents net fallback, which does not reflect re-ascending fish, or fish that fell back but were observed entering spawning tributaries.

- Using these estimates, calculate a survival rate (index) through the FCRPS reach each ESU traverses.

Following is an example (Table 6) of how the different adjustment factors are applied in the survival index accounting process.

Table 4.6. Adult passage survival indexing–2001 Snake River Steelhead (combined wild and hatchery).

# detected at BON adult PIT system	325
# of those detected at LGR	229
Unadjusted survival rate(coarse conversion)	70.5% (229/325) (summer steelhead)
Adult PIT Detection rate of LGR	100% (assumed)
straying rate @ telemetry estimates	6.8% (Snake R. UI estimate)
TAC Harvest Rate	11.6%
BON count correction factor =	0.957 (all steelhead)
Corrected harvest (TAC / BON correction)	12.1%
nav. lock passage rate	0.7%
LGR fallback rate (non-stray, non re-ascend)	0.4%

Survival index (adjusted survival rate) = 90.5%
Un-adjusted survival rate (70.5%)
+ straying rate (6.8%)
+ corrected harvest rate (12.1%)
+ Nav. lock passage rate (0.7%)
- Fallback adjustment at LGR (0.4%)

Targeted survival rate (BiOp performance standard) to LGR for steelhead = 80.3%

There are certain conditions or assumptions that are critical for generating sound, annual survival indices. Adult PIT detectors need to consistently yield high PIT-tag detection rates. If 100% detection cannot be demonstrated, then it will be necessary to estimate the actual detection rates in the ladders at each key terminal, upstream monitoring dam. Rates of straying, harvest and navigation lock passage can be adequately modeled or estimated yearly to adequately correct the survival index for each ESU. Furthermore, it is assumed that the harvest rates as reported by TAC adequately represent the harvest mortality incurred by each ESU.

It will be difficult to satisfy these assumptions. There will be gaps in many years because only direct telemetry observations for each species on an annual basis will yield reasonably accurate estimates of passage fates en route to the terminal dam.

Also, the accuracy of the harvest removal estimates has been questioned – there are a number of uncertainties regarding TAC harvest estimates:

- The TAC's estimates of harvest rates in Zone 6 may include considerable uncertainty and variability, particularly as the percentage of over-the-bank sales increases. Although these catches are estimated by TAC and included in their computed harvest rates, they are difficult to verify.

- Estimates of gillnet dropout rates are not readily available for Columbia fisheries. This is the case everywhere with gillnet fisheries. However, unlike other regions that employ at least a crude estimate of this mortality (e.g., Puget Sound uses 2% of the reported catch), the assumed value in Columbia River gillnet fisheries is zero.

- Effects of cumulative gear encounters are unknown, which could be a significant problem especially in the context of a gauntlet of mark-selective fisheries (both sport and commercial gear). For this reason, it is one of the particular issues highlighted in action 167.

- Estimated values of incidental mortalities associated with catch and release fisheries, including mark-selective fisheries, are quite uncertain and may vary across fisheries more than is currently assumed, e.g., they may vary as a function of water temperature. Also see action 167.

Concerns About Generating Survival Estimates Annually

There are a number of concerns about how useful annual estimates of survival would be through 2010, if based on PIT observations. Key issues include the following:

- If the required adjustments cannot be reliably estimated each year for each species, then how useful are the survival estimates?

- Many of the required adjustments require telemetry investigations. Estimates obtained to date indicate inter-annual variation is high, precluding the use of some constant value that can be applied universally. Stray rates and fallback rates are expected to exhibit such high variability. However, the region is reluctant to fund expensive radio-telemetry studies every year ($2M+), given other regional fishery needs.

- PIT tag data can probably yield a useful index of minimum survival each year, even if some adjustment factors are unknown. However, this may be an apples to oranges comparison to the BiOp standards if the full suite of adjustments is unavailable annually. Managers will need to decide if such performance measures are useful in the decision-making process, particularly at the check-ins. Even so, in cases where the annual minimum survival exceeds the standard this would indicate that goals are being achieved.

- Statistical demonstration of progress and compliance is not tractable. Because the BiOp expects only a three percent improvement in adult survival with all adult passage actions implemented, detecting such a small change with even the best direct survival estimates is not practical.

- Using the PIT tag approach it will be necessary to rely on Snake and Upper Columbia index stock monitoring as indicators for Mid- and Lower-Columbia ESUs (except to use Yakima stock when available). This is because there are no adult PIT tag detectors between BON & MCN or are any planned.

- Because PIT-tagged Snake Sockeye are so few in most years, it will not be practical to index survival of that stock to LGR. It will be necessary to rely on other species as indicators of overall passage conditions.

Blueprint
In planning how to conduct annual monitoring it is necessary to identify which stocks will be tracked and which river reaches are the appropriate response zones. The following table is a blueprint for indexing adult survival each year, if the PIT tag approach is adopted in some form.

Table 4.7. Proposed index populations that would be used to characterize passage survival for each ESU. Hatchery (H) and wild (W) fish would be combined to form one annual estimate. If adequate numbers of PIT-tagged wild fish were detected, a separate estimate could be calculated fro the wild component. The response zone is that portion of the FCRPS through which the estimate is obtained. It corresponds to that portion of the FCRPS each ESU encounters. The survival performance standard is taken from Table 9.2-3 in the BiOp.

ESU	**Index stocks**	**Response zone**	**BiOp PS (system or reach survival %)**
Snake River:			
Spr/sum Chin	H & W originating above LGR	BON – LGR	85.5
Fall Chin	H & W originating above LGR	BON – LGR	74.0
Steelhead	H & W originating above LGR	BON – LGR	80.3
Sockeye	NA	NA	88.7
Upper Columbia			
Spring Chin	1. H & W originating above PR. 2. all H&W originating above MCN	BON – MCN	92.2
Steelhead	1. H & W originating above PR. 2. all H&W originating above MCN	BON – MCN	89.3
Middle Columbia			
Steelhead	all H&W originating above MCN	BON – MCN	89.3
Lower Columbia			
Chinook	NA	NA	98.1

Steelhead	NA	NA	97.3

Once the PIT-tag data for those stocks are compiled, the next step is to compile the correction factors needed to derive the passage survival index each year. A template is presented to organize that information.

Table 4.8. Templates – Estimates of adjustment factors needed to calculate minimum passage survival for PIT-tagged populations each year (generate table for each species/population).

Adjustment factor spr/su Chinook	Year			
	2000	2001	2002	………
Harvest rate- TAC	6.3%	13.1%	11.2%	
Fallback				
BON	13%	4%	6%	
MCN	5%	2%		
LGR	3%	0.1%	1.5%	
BON count correction factor)	0.809	0.933		
PIT-detection rate (in ladder)				
MCN				
LGR				
Nav. Lock passage rate BON	1.68%	1.03%		
MCN	0.95%	0.32%		
LGR	0%	0.3%		
Stray rate	-NA-	1.3%		

Adjustment factor Steelhead	Year			
	2000	2001	2002	………
Harvest rate- TAC		11.7%		
Fallback				
	7%	4%		
MCN				
LGR	2.3%	2.0%		
BON count correction factor	0.965	0.957		
PIT detection rate (in ladder)				
MCN				

Adjustment factor Steelhead	Year			
	2000	2001	2002	………
LGR				
Nav. Lock passage rate BON				
MCN				
LGR	0.23%	0.67%		
Stray rate	NA	6.8%		
Adjustment factor Fall Chinook	**Year**			
	2000	**2001**	**2002**	**………**
Harvest rate				
Fallback				
BON				
MCN				
LGR				
PIT detection rate (in ladder)				
MCN				
LGR				
BON count correction factor				
Nav. Lock passage rate BON				
MCN				
LGR				
Stray rate				

Table 4.9. Annual estimates of passage survival (performance measures) for each ESU.

ESU	Year			
	2000	2001	2002	…………..
Snake River:				
Spr/sum Chin		92.8%		
Fall Chin				
Steelhead	85.1% + stray rate (unknown)	90.5%		
Upper Columbia				
Spring Chin				
Steelhead				

Table 4.10. Coarse conversion, or un-adjusted adult survival estimates, based on PIT-tag data starting population is that set of tags detected as passing BON Dam. All data are not yet compiled.

ESU	Year			
	2000	**2001**	**2002**	**…………..**
Snake River:				
Spr/sum Chin	79%	78%	73%	
Fall Chin	73%	78%	65%	
Steelhead	67%	71%	74%	
Upper Columbia (To MCN)				
Spring Chin			89%	
Steelhead				

d. Assessing Progress and Compliance – Adults

There may be no means to quantitatively test compliance with survival standards presented in the BiOp. Because the BiOp expects only a three percent improvement in adult survival with all adult passage actions implemented, it is not practical to detect such a small change. This is evidenced by the limited ability to detect survival improvement for juveniles, with as expected 9 to 10 percent improvement. Furthermore, the quality of adult survival indices may vary yearly, depending on the availability and reliability of the suite of correction factors acquired each year. Therefore, the evaluation at the check-ins may need to be more qualitative, rather than quantitatively rigorous.

Check-in Evaluations:

The PIT-tag based survival indexing approach previously described is recommended for use at the 2005 check-in, including an assessment of its merits and deficiencies at that time. The approach relies on adjustments (stray, fallback) derived from R-tag data that are currently needed to adjust PIT tag data. Furthermore, 2003 is the last planned year for R-tag studies. It is unclear how correction factors can be estimated for application in future years. This may depend on the variability in fallback and stray estimates as documented in 2001-2003 with telemetry data. It is unclear how 2004 PIT tag only data will be adjusted at the 2005 check-in. However, if the coarse survival estimates exceed the survival standard then the need to document adjustments becomes moot, unadjusted PIT observations alone will suffice. Results from the 2005 evaluation will be used to determine whether the approach should be a component of future check-ins.

Action-Oriented Monitoring Approach: An Alternative

Given the difficulties and considerable uncertainty associated with annual survival indexing, an alternative approach for determining if adult passage conditions are satisfactory and in accordance with BiOp standards is proposed. This alternative approach is more actionoriented and focuses on determining if the recommended passage improvements prescribed in the BiOp have been adequately implemented.

This approach shifts focus from annual survival indexing, focusing instead on confirming that the suite of adult passage management actions prescribed in the BiOp are satisfactorily implemented. When those actions are demonstrated to have been properly implemented, the overall generic standard of optimizing adult passage survival will have been met. In some cases, there may be opportunities to conduct dam-specific research/evaluations to confirm the magnitude of the change in the fish response at a particular site. In the context of the RME plan, those research evaluations fall in the category of action effectiveness research. Such studies are formulated within the AFEP process. Depending on how many adult passage studies emerge from the needs and priorities phase of AFEP it may be possible to show the that collective actions have improved adult passage survival by three percent, as expected in the BiOp.

Summary – Adult Survival
At the 2005 check-in evaluate the efficacy of the PIT tag–based survival index monitoring approach. Based on that assessment, determine if it practical to implement that approach through 2010. Also, at 2005 and 2008 check-ins, document the completion and performance of individual adult passage improvements specified in actions.

2. Critical Uncertainty Research

1. *Estimating D for transported stocks. (Include direct survival during transport.)*

Estimates of D are required to calculate combined survival for every transported stock. Acquiring these estimates is critical for all species transported from Snake River Dams, especially Snake River fall Chinook for which there is a paucity of data. Acquiring these estimates for listed stocks transported from McNary will also be important, depending on the passage strategies adopted for that site. If transport is ever used for spring migrating steelhead and spring Chinook, then estimates of "D" become critical and are required to calculate combined survival. The transport projects listed in Table 4.4 should be executed through 2010 where possible. Estimates for Snake fall Chinook are critically important, given the current absence of any reliable estimates.

A major limitation of producing annual estimates of "D" is the extensive time-lag required to make the estimate. Because the estimate is based on a full complement of returning adults, it takes 2- 4 years beyond the smolt migration year to make the estimate. As a consequence the check-in evaluations will be incomplete where combined survival is the preferred indicator. Alternatively, for years when annual estimates are not yet available, a mean or range of values for D could be applied. It is unclear which would be the most appropriate to select at this time. However, at the 2005 checking a detailed evaluation of these alternatives is recommended. By that time the suite of annual D-estimates should be large enough to make an informed decision. This analysis will be a key task in 2005.

2. *Investigating EM attributable to passage history or timing of seawater entry.*

The concept of EM first arose during the PATH modeling process. During life-cycle model analyses mortality exceeded that estimated, modeled or assumed for the various individual life stages. The theory emerged that some extra or delayed effect associated with certain life stage experiences resulted in the unexplainably poor survival from gravel to gravel. Hypotheses were offered to explain the culprit mechanisms. For example, mechanisms associated with hatchery fish, dam passage or climatic shifts were suggested as causative agents. Extinction risk analyses conducted in the BiOp were particularly sensitive to the existence, magnitude and persistence of this hypothetical effect. Resolving the nature, magnitude and agents responsible for EM was a critical directive in the RME portion of the BiOp.

These are thorny issues to resolve through research. A gap exists between what the population modelers would like to know and how practical it is to conduct investigations that will resolve this matter. It appears that the ISRP shares our view. Their recent review of an AA/NMFS RFP for EM studies was fraught with concern. At this juncture, it is unclear that the perceived EM still exists. Some populations are showing surges in recent years. Updated, life-cycle model analyses may be required to even identify the existence of the effect.

In the gap assessment a workshop is recommended for 2005 to synthesize the broad array of EM-related research being funded by the COE and BPA. Those projects appear in Table 4.4 as linked to actions 188, 189 or 195. Based on findings during the workshop, evaluate the need for or practicality of further research on this topic.

Recommended targeted research
Some focused research may be instructive to address additional key uncertainties, specifically:

- Estimate the straying effect associated with transport (this may be tractable with the complement of new adult PIT systems).
- Determine the cause and remedy for head burns.
- Estimate pre-spawning mortality.
- Estimate kelt passage survival.

A kelt passage study is in place that will provide insight regarding survival through the FCRPS. Also, the planned transport studies offer the ability to document cross-basin straying once the IH and PR PIT tag detectors are functional.

3. Action Effectiveness Research
These collective studies are designed, reviewed and funded under the auspices of AFEP. They are not treated separately in this plan.

4. Data Management Issues
Data types: PIT-tag mark-recapture data form the basic information that is required to calculate survival estimates for smolts and adults (as proposed). PTAGIS is the formal infrastructure for collecting and archiving that information. No further compilation of these data is necessary. However, the estimates of interest for monitoring purposes are the annual survival estimates identified herein. There is no formal database in place that houses this information. One will need to be established. Some of the annual estimates for smolts appear in Attachment 1 of this plan and in Table 4.8 for adult survival. Other estimates required for archiving include estimates of the proportion of each ESU transported each year from each dam, and estimates of "D," including clear documentation of what groups of tagged fish were used to generate the estimates.

In summary, survival and related estimates that require archiving annually include

- Inriver smolt survival
- Percent of ESU transported at each dam
- "D" – including identification of tagged groups used in estimates
- Adult survival estimates and any required adjustments indicated in Table 4.8

In addition to the survival data, there will be a need for background information, particularly regarding environmental conditions and dam operations. These data are generally available for FCRPS projects, storage reservoirs and dams owned and operated by public utilities in the upper Columbia River. These data are regularly reported by the FPC and housed at the FPC, Corps and Columbia River Dart system. No expansion of the set of attributes contained collectively therein is required.

Data generators – Survival and supporting estimates identified herein will be collected, calculated and archived by investigators at the NMFS Science Center in Seattle, Washington.

References

Bouwes, N. et al. 2001. Comparative survival study of PIT tagged spring/summer chinook. Status report for years 1997-2000 mark/recapture activities. BPA contract #8712702.

Giorgi, A., M. Miller, and J. Stevenson. 2002. Mainstem passage strategies in the Columbia River System: transportation, spill, and flow augmentation. Report to NPCC.

Sandford, B. and S. Smith. 2002. Estimation of smolt-to-adult return percentages for Snake River Basin anadromous salmonids, 1990-1997. Journal of Agriculture, biological and environmental Statistics, 7(1): 79-100.

Skalski, J., and R. Ngouenet. 2001. Evaluation of the compliance testing framework for RPA improvements as stated in the 2000 FCRPS BO. Prepared for BPA.

Smith et al. 2002. fall chinook…….

Williams, J., S. Smith, and W. Muir. 2001. Survival of downstream migrant yearling juvenile salmonids through the Snake and Columbia rivers hydropower system, 1966-1980 and 1993-1999. NAJFM 21:310-317.

Zabel, R., S. Smith, W. Muir, D. Marsh, and J. Williams. Survival estimates for the passage of spring-migrating juvenile salmonids through Snake and Columbia River dams and reservoirs, 2001. Research report to BPA, 80 pages, plus appendices.

Attachment 1 – Smith

Another look at in-river survival estimates for juvenile salmonids leading to performance standards in the BiOp

Summary

The purpose of this exercise was to compare empirical data and SIMPAS-based estimates for recent years and to determine whether these comparisons gave information regarding the accuracy of SIMPAS-based estimates for the "pre-BiOp" period (1994-1999). For some years in the pre-BiOp period no empirical data were available downstream from McNary Dam, so SIMPAS was used to estimate survival. These model-based estimates were then the basis for the baseline survival from which performance standards were developed, and against which post-BiOp survival estimates are to be compared to determine whether anticipated improvements are realized.

In recent years, in which empirical data and SIMPAS estimates are available, SIMPAS estimates were, on average, 6.9 percent greater than empirical estimates for Snake River yearling Chinook salmon, and 3.8 percent less than empirical estimates for Snake River steelhead. We assumed that the average relationship between SIMPAS estimates for the pre-BiOp period and what would have been obtained empirically was the same as in recent years. We adjusted the estimates in BiOp Table 6.2.-7 accordingly, and arrived at the following conclusions:

The current best estimate of the average 1994-1999 spring/summer yearling Chinook salmon survival from LGR to BON is **38.7** percent, rather than the 40.8 percent in Table 6.2-7 in the 2000 BiOp.

For steelhead the 1994-1999 mean survival from LGR to BON in the BiOp was 41.5 percent, but our best current estimate is **43.7** percent.

Introduction

Table 6.2-7 of the BiOp included project, total in-river, and system survival estimates for Snake River salmonids out-migrants from 1994 through 1999. One purpose of the table was to support performance standards regarding juvenile in-river survival. Survival in the years 1994 through 1999 was used to establish a baseline ("pre-BiOp") condition, i.e., a base from which the actions called for in the BiOp were envisioned to improve juvenile survival in the hydro-system. It is generally agreed that empirical data should provide the basis for estimates and standards, rather than "pure" model output. However, the BiOp table necessarily included some estimates that were modeled (using SIMPAS) because empirical data were unavailable for some river reaches. In light of recent empirical information obtained in the years since the BiOp was finalized in 2000, we took a fresh look at the historical estimates that were used to establish baseline survival, and hence the hydro performance standards, in the BiOp.

Empirical data were unavailable for some reaches in some of the early years, so the BiOp relied on SIMPAS output, i.e., for survival below McNary Dam for spring/summer (sp/su) Chinook salmon in 1994 through 1998 and in the same stretch for steelhead in 1994 through 1996. A direct comparison of SIMPAS output with empirical data for those years is not possible. However, empirical data for survival through the FCRPS are available since 1999 for sp/su

Chinook salmon and since 1997 for steelhead. If we apply the SIMPAS model to recent years' data, and we assume that the relationship between SIMPAS output and empirical data is the same in recent years as it was in earlier years, then we have an indirect method to assess the accuracy of the SIMPAS output in years with no empirical data. For example, if we find that between 1999 and 2002 SIMPAS output exceeded empirical estimates for sp/su Chinook salmon by certain amount, on average, then we might assume that the same average overestimate occurred between 1994 and 1998. By adjusting the estimates derived from SIMPAS in those years accordingly, we would presumably obtain a more accurate baseline survival from which to assess progress toward and compliance with performance standards (the standards themselves would likely need revision because they were calculated as improvements from the baseline).

Snake River Spring/Summer Chinook Salmon

1994-1999 in-river survival estimates from BiOp

Portions of BiOp Table 6.2-7. dealing strictly with in-river survival of Snake River spring/ summer Chinook salmon (i.e., omitting information on transportation and delayed mortality) are reproduced in Table 1, with annotations added. The table gives estimated survival probabilities (percent survival) for passage through the eight hydroelectric projects encountered by juvenile salmonids migrating seaward from the Snake River basin. Each survival probability is identified by a three-letter abbreviation for the dam, and the quantity itself represents the combined survival probability for passage through the dam and the pool behind it. Estimates based on empirical data are unshaded; shaded cells represent SIMPAS output.

For most years (1994 is the exception, as noted below), survival estimates are calculated in three components: 1) LGR alone; 2) LGS, LMN, IHR and MCN; and 3) JDA, TDA and BON.

The empirical estimates for "LGR" in 1994, 1995, 1996 and 1998 are derived from survival estimates of PIT-tagged fish released from the Snake River smolt trap, which is located near the head of LGR pool. In each of those years, survival was estimated separately for hatchery and wild sp/su Chinook salmon from the trap to the tailrace of LGR dam. The survival estimate in Table 1 is the average of the two survival estimates, weighted by the number of fish used to estimate survival for each group. For 1999, hatchery and wild fish PIT tagged at the trap were pooled, and a single, survival estimate was calculated for the combined group. In 1997, river flow was too high to operate the trap during the bulk of the sp/su Chinook salmon migration, so no PIT-tagged fish were released that year. SIMPAS was used to estimate LGR survival in that year (see below).

Empirical estimates for LGS and LMN in all years and for IHR and MCN in all years, except 1994, were estimated from PIT-tagged fish grouped daily at LGR according to their date of passage or tagging at LGR. Each daily group comprised all sp/su Chinook salmon of hatchery or wild origin that were either 1) PIT tagged above LGR and were detected and returned to the tailrace at LGR, or 2) collected and tagged at the dam and released into the tailrace on the same day. Survival was estimated for each daily group (groups were sometimes pooled over two or more days to obtain sufficient sample sizes for estimation). The survival estimates in the table for LGS and LMN are the annual averages of the corresponding reach estimates for daily groups. The averages are weighted by the respective estimated relative variances of the daily survival estimates. Because PIT tags are undetected at IHR, it is not possible to estimate IHR and MCN survival separately. Instead, the weighted average was calculated for the combined survival for the two projects, and the square root of the average was entered as the empirical estimate in the table for both projects because these reservoirs are approximately the same length.

The empirical estimates in 1999 for the JDA, TDA and BON reaches were calculated in a similar way: hatchery and wild fish detected and returned to the river at MCN were combined in weekly groups according to passage date and survival was estimated for each group. The survival estimates in the table for JDA are the annual weighted averages of the corresponding reach estimates for weekly groups. Because PIT tags are undetected at TDA, it is not possible to estimate TDA and BON survival separately. Instead, the weighted average was calculated for the combined survival for the two projects, the SIMPAS-modeled dam survival was accounted for, and the remaining combined pool survival was apportioned to the two pools according to their respective lengths.

All other estimates for individual reaches in Table 1 were obtained from SIMPAS. The Pool+Dam estimates were obtained by first modeling dam survival for all eight dams, based on the particular flow and spill conditions, operations at each dam and using best available passage parameters. Empirical estimates from PIT-tagged fish are by nature estimates for pool+dam combined. Pool survival estimates for these reaches were obtained by dividing the PIT-tag estimate by the SIMPAS-modeled dam survival. An empirical estimate of per-pool-mile survival was then calculated from these pool survival estimates. Pool-survival estimates for JDA, TDA and BON (and LGR in 1997 and IHR and MCN in 1994) were calculated by applying the per-mile survival rate in the "empirical reaches" to their respective pool lengths.[18] Finally, the modeled dam survival and the pool estimates from per-mile extrapolation were combined to give the project (combined pool+dam) survival.

Table 1 includes columns to summarize the estimates for each of the three "components" (series of project survival estimates) and for all eight projects, which estimates the complete in-river hydro-system survival from the head of Lower Granite reservoir to the tailrace of Bonneville Dam. The six-year mean survival from LGR to BON was estimated as 40.8 percent.

1999-2002 empirical estimates vs. SIMPAS output

Table 2 repeats the line for 1999 from Table 1, and extends that table with empirical survival estimates for 2000 through 2002. Empirical estimates for the combined reaches IHR+MCN and TDA+BON were partitioned to the individual reaches as described above.

Table 3 repeats the columns from Table 2 for JDA, TDA and BON, and adds a column for the empirical estimate for the combined JDA-BON reach. The next four columns are the estimates from SIMPAS methods described above, applied to 1999 through 2002 conditions. The SIMPAS survival estimates for JDA-BON exceeded the empirical estimates for 1999 (SIMPAS was five percent greater), 2000 (15 percent), and 2001 (19 percent). The SIMPAS estimate was only 91 percent of the empirical estimate in 2002 (preliminary, but "pretty close," estimate and

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[18] In all that follows, when the phrases, "SIMPAS estimate" or "SIMPAS survival," are used, the estimate is based on this per-mile extrapolation of pool survival.

SIMPAS run). For the four years, the geometric mean of the SIMPAS/empirical ratio was 1.0691. That is, on average, SIMPAS overestimated the empirical estimate by 6.9 percent from 1999 through 2002. Reach-by-reach, SIMPAS exceeded the empirical survival estimate by 1.7 percent for JDA, by 1.8 percent for TDA, and by 3.4 percent for BON.

Adjustments to original BiOp estimates

Table 4 repeats the estimates in Table 1, but the SIMPAS output for 1994-1998 has been adjusted according to the 1999-2002 SIMPAS vs. empirical analysis above. For example, it was assumed that the 1998 SIMPAS survival estimate of 63.4 percent for JDA-BON exceeded what would have been derived empirically by 6.91 percent. Thus, the 1998-estimated survival of 63.4 percent is adjusted downward to 59.3 percent, and the corresponding LGR-BON survival estimate is adjusted from 45.1 percent to 42.3 percent.

Overall, the six-year mean survival from LGR to BON is adjusted from 40.8 percent to 38.7 percent.

(Table 4 incorporates one other, minor adjustment from the original BiOp estimates from Table 1. Namely, all the empirical estimates for LGR in Table 4 are for pooled hatchery and wild fish from the Snake River smolt trap, rather than weighted averages of separate estimates for hatchery and wild fish. This adjustment causes very small changes in the estimated survival. We have included this adjustment so that the estimates are consistent with our preferred approach of estimating survival after pooling groups if the separate estimates for the groups are not significantly different).

Snake River Steelhead

1994-1999 in-river survival estimates from BiOp

Portions of BiOp Table 6.2-7 dealing strictly with in-river survival of Snake River steelhead are reproduced as Table 5 here, with annotations added. See the Chinook salmon section for details regarding table structure and general methods. Where methods for steelhead differed from those for Chinook salmon, it is noted in Table 5 and discussed below. As with Chinook salmon, for steelhead in all years, except 1994 survival estimates were calculated in three components: 1) LGR alone; 2) LGS, LMN, IHR and MCN; and 3) JDA, TDA and BON.

In 1994, estimates for wild and hatchery steelhead from the Snake River smolt trap to LGR tailrace were unreliable. SIMPAS estimates were used for that reach in 1994. Unlike Chinook salmon, sufficient steelhead were tagged at the trap in 1997 to obtain an empirical estimate.

With one exception, noted below, methods that led to the table values of steelhead survival for LGS, LMN, IHR and MCN were identical to those for Chinook salmon.

Steelhead detection at dams downstream from MCN was sufficient to estimate survival to BON tailrace in 1997, 1998 and 1999. In 1997, detections at JDA were insufficient to estimate survival for specific reaches, but survival was estimated between MCN tailrace and BON tailrace. SIMPAS was used to estimate dam survival at JDA, TDA and BON, and to apportion estimated total pool mortality to the three pools. Accordingly, the combined SIMPAS estimates for JDA, TDA and BON match the empirical PIT-tag estimate between MCN tailrace and BON tailrace. In 1998 and 1999, separate empirical estimates were available for JDA and for the TDA and BON projects combined (i.e., JDA tailrace to BON tailrace). In 1999, SIMPAS was used to model dam survival at TDA and BON and to apportion estimated total pool mortality to the two pools. In 1998, a different method was used, as explained in the next paragraph.

There were three instances where empirical (PIT-tag) reach-specific survival estimates were available, but were not used directly in the BiOp analysis. In all three cases, empirical estimates were "overruled" because, along with the SIMPAS-modeled dam survival, they implied pool survival in excess of 100 percent. (PIT-tag estimates apply to one pool and one dam. Using SIMPAS, pool survival is estimated by dividing the PIT-tag reach survival estimate by a modeled value of survival for the dam alone. If the PIT-tag estimate exceeds the modeled dam passage survival, then the pool estimate exceeds 100 percent). Two of these instances occurred for LMN: the empirical estimates of 96.2 percent and 95.1 percent for 1995 and 1996, respectively, were reduced to 95.0 percent and 93.7 percent (the reduction represents one standard error), so the pool estimate was below 100 percent.

The third instance was for TDA and BON in 1998. The empirical estimate for the combined two pools and dams was 93.5 percent, while the SIMPAS model of TDA and BON dam survival alone was only 85.3 percent. In this case, the survival number in Table 5 represents the SIMPAS-modeled dam survival and pool survival for TDA and BON calculated from estimated per-mile survival based on the empirical estimate of survival between MCN tailrace and BON tailrace. The resulting estimates were 89.7 percent for TDA and 91.8 percent for BON; the product of the two is 82.3 percent, considerably lower than the empirical estimate of 93.5 percent.

The consequence of "overruling" empirical data in cases where implied pool survival was greater than 100 percent is that the numbers entered into Table 6.2-7 (Table 5 here) are less than the estimates from empirical data. The effect is particularly great in 1998, where the BiOp analysis gave LGR-BON survival of 41.8 percent (Table 5) and the empirical estimate is 47.4 percent (Table 6, and see below).

The six-year mean survival from LGR to BON was estimated in the BiOp as 41.5 percent.

1999-2002 empirical estimates vs. SIMPAS output

Table 6 repeats the lines for 1997 through 1999 from Table 5 (reinstating the empirical estimates for TDA and BON for 1998), and extends that table with empirical estimates for 2000 through 2002.

Table 7 repeats the columns from Table 2 for JDA, TDA and BON, and adds a column for the empirical estimate for the combined JDA-BON reach. The next four columns are the output from SIMPAS methods described above applied to 1997 through 2002 conditions. The SIMPAS survival for JDA-BON exceeded the empirical estimate in 3 years and was less than the empirical estimate in three years. The geometric mean of the SIMPAS/empirical ratios for the six years was 0.962 (i.e., SIMPAS underestimated empirical survival for steelhead). Reach-by-reach, SIMPAS overestimated the empirical by 3.0 percent for JDA, underestimated by 2.4 percent for TDA, and underestimated by 4.4 percent for BON.

(1) Adjustments to original BiOp estimates

Table 8 repeats the estimates in Table 5 (restoring empirical estimates for LMN in 1995 and 1996 and TDA+BON in 1998), but the SIMPAS output for 1995 through 1997 has been adjusted according to the 1997-2002 SIMPAS vs. empirical analysis above. For example, it was assumed that the 1994 SIMPAS survival of 47.5 percent for JDA-BON was 96.2 percent of what would have been derived empirically. Thus, 47.5 percent was adjusted upward to 49.4 percent. The corresponding LGR-BON survival estimate is adjusted from 32.2 percent to 33.5 percent.

Overall, the six-year mean survival from LGR to BON is adjusted upward from 41.5 percent to 43.7 percent.

(Note the other difference between Tables 5 and 8: all empirical estimates for LGR in Table 8 are for pooled hatchery and wild fish from the Snake River smolt trap rather than weighted averages of separate estimates for hatchery and wild fish. See sp/su Chinook salmon section for discussion.)

Discussion

The adjusted survival estimates in this document are based on a set of adjustment factors estimated from comparisons of recent empirical and SIMPAS estimates. The adjustment factors are estimates, calculated from four years of data for sp/su Chinook salmon and from six years of data for steelhead. In each future year in which it is possible to derive empirical estimates from the head of LGR pool to BON tailrace, it will be possible to apply these methods to gain one more "data point" for estimation of adjustment factors, and we presume that the estimated adjustment factor will become more accurate and precise as more data are added. We recommend that the estimated average pre-BiOp survival, and the hydro-system survival performance standards based on the estimated pre-BiOp average should be updated at each of the 3-, 5-, 8-year check-ins, and before conducting the final 10-year compliance test (estimated adjustment factors will not change appreciably between 8- and 10-year tests).

Table 1. Project and system survival for Snake River spring/summer Chinook salmon 1994-1999, excerpted from Table 6.2-7 of the BiOp, December 21, 2000. Unshaded cells represent empirical estimates from PIT-tag data. Shaded cells were calculated using SIMPAS: modeled dam survival and reservoir survival extrapolated from estimated per-mile reservoir survival extrapolated from reaches with empirical estimates.

	Project survival (% Pool + Dam Survival)								Components of Complete In-river Survival			Percent In-river Survival (LGR to BON)
Year	LGR	LGS[a]	LMN[a]	IHR[ab]	MCN[ab]	JDA	TDA	BON	LGR	LGS-MCN	JDA-BON	
1994	93.6[c]	83.0	84.7	89.0	85.8	77.3	84.5	82.9	93.6	70.3[d]	41.3[e]	27.2
1995	90.6[c]	88.2	92.5	93.6	93.6	85.2	87.2	86.9	90.6	71.5	64.6	41.8
1996	97.9[c]	92.6	92.9	87.0	87.0	84.4	86.9	87.0	97.9	65.1	63.8	40.6
1997	91.3	94.2	89.4	89.3	89.3	83.3	86.5	86.9	91.3	67.2	62.6	38.4
1998	92.4[c]	98.5	85.3	95.7	95.7	82.2	87.7	88.0	92.4	77.0	63.4	45.1
1999	94.1[f]	95.0	92.5	95.1	95.1	85.3[g]	89.3[gh]	91.1[gh]	94.1	79.5	69.4	51.9
6-yr avg	93.3	91.9	89.5	91.6	91.1	82.9	87.0	87.2	93.3	71.7	63.0	40.8

a. Empirical estimates based on pooled hatchery and wild fish grouped at LGR: average of estimates for daily groups weighted by relative variance.

b. When empirical (unshaded): square root of empirical estimate between LMN tailrace and MCN tailrace.

c. Average of hatchery and wild fish tagged at and released from Snake River smolt trap, weighted by respective number tagged.

d. LGS-LMN for 1994.

e. IHR-BON for 1994.

f. Pooled hatchery and wild fish tagged at and released from Snake River smolt trap.

g. Empirical estimates based on pooled hatchery and wild fish grouped at MCN: average of estimates for weekly groups weighted by relative variance.

h. Calculated from empirical estimate between JDA tailrace and BON tailrace, based on per-mile reservoir survival and SIMPAS-modeled dam survival.

Table 2. Empirical estimates of project and system survival for Snake River spring/summer Chinook salmon, 1999-2002, based on PIT-tag data.

	Project survival (% Pool + Dam Survival)								% In-river Survival (LGR to BON)
YEAR	**LGR[a]**	**LGS[b]**	**LMN[b]**	**IHR[bc]**	**MCN[bc]**	**JDA[d]**	**TDA[de]**	**BON[de]**	
1999	94.1	94.9	92.5	95.1	95.1	85.3	89.3	91.1	51.8
2000	92.2	93.8	88.7	96.3	96.3	89.8	83.9	81.5	43.7
2001	95.6	93.9	82.0	84.9	84.9	75.8	81.4	79.3	25.9
2002	95.3	90.1	97.4	90.9	90.9	90.7	90.1	93.2	52.6

a. Pooled hatchery and wild fish tagged at and released fromSnake River smolt trap.

b. Empirical estimates based on pooled hatchery and wild fish grouped at LGR: average of estimates for daily groups weighted by relative variance.

c. Square root of empirical estimate between LMN tailrace and MCN tailrace.

d. Emp irical estimates based on pooled hatchery and wild fish grouped at MCN: average of estimates for weekly groups weighted by relative variance.

e. Calculated from empirical estimate between JDA tailrace and BON tailrace, based on per-mile reservoir survival and SIMPAS-modeled dam survival.

Table 3. Empirical estimates of survival for Snake River spring/summer Chinook salmon in lower river compared to results of SIMPAS model based on survival to McNary Dam (method used in 1995-1998).

YEAR	Empirical estimates				SIMPAS Method				Ratio SIMPAS/Empirical			
	JDA	**TDA**	**BON**	**JDA-BON**	**JDA**	**TDA**	**BON**	**JDA-BON**	**JDA**	**TDA**	**BON**	**JDA-BON**
1999	85.3	89.3	91.1	69.4	90.8	88.9	90.4	73.0	1.0645	0.9955	0.9923	1.0512
2000	89.8	83.9	81.5	61.4	88.5	88.6	90.3	70.8	0.9855	1.0560	1.1080	1.1533
2001	75.8	81.4	79.3	48.9	80.1	84.8	85.6	58.1	1.0567	1.0418	1.0794	1.1887
2002	90.7	90.1	93.2	76.2	87.4	88.2	89.6	69.1	0.9636	0.9789	0.9614	0.9065
Geometric Mean									**1.0166**	**1.0176**	**1.0335**	**1.0691**

Table 4. Project and system survival for Snake River spring/summer Chinook salmon 1994-1999, derived from Table 6.2-7 of the BiOp, December 21, 2000 (see Table 1), and adjustments based on comparison of recent empirical estimates and SIMPAS model results (see Table 3). Unshaded cells represent empirical estimates from PIT-tag data. Shaded cells are based on adjusted SIMPAS results.

Year	Project survival (% Pool + Dam Survival)								Components of Complete In-river Survival			% In-river Survival (LGR to BON)
	LGR	LGS[a]	LMN[a]	IHR[ab]	MCN[ab]	JDA	TDA	BON	LGR	LGS-MCN	JDA-BON	
1994	93.0[c]	83.0	84.7	89.0	85.8	76.0	83.0	80.2	93.0	70.3[d]	38.7[e]	25.3
1995	90.5[c]	88.2	92.5	93.6	93.6	83.8	85.7	84.1	90.5	71.5	60.4	39.1
1996	97.8[c]	92.6	92.9	87.0	87.0	83.0	85.4	84.2	97.8	65.1	59.7	38.0
1997	91.3	94.2	89.4	89.3	89.3	81.9	85.0	84.1	91.3	67.2	58.6	35.9
1998	92.6[c]	98.5	85.3	95.7	95.7	80.9	86.2	85.1	92.6	77.0	59.3	42.3
1999	94.2[c]	95.0	92.5	95.1	95.1	85.3[f]	89.3[fg]	91.1[fg]	94.2	79.5	69.4	51.9
6-yr avg	93.2	91.9	89.5	91.6	91.1	81.8	85.8	84.8	93.2	71.7	59.7	38.7

a. Empirical estimates based on pooled hatchery and wild fish grouped at LGR: average of estimates for daily groups weighted by relative variance.

b. When empirical (unshaded): square root of empirical estimate between LMN tailrace and MCN tailrace.

c. Pooled hatchery and wild fish tagged at and released from Snake River smolt trap.

d. LGS-LMN for 1994.

e. IHR-BON for 1994.

f. Empirical estimates based on pooled hatchery and wild fish grouped at MCN: average of estimates for weekly groups weighted by relative variance.

g. Calculated from empirical estimate between JDA tailrace and BON tailrace, based on per-mile reservoir survival and SIMPAS-modeled dam survival.

Table 5. Project and system survival for Snake River steelhead 1994-1999, excerpted from Table 6.2-7 of the BiOp, December 21, 2000. Unshaded cells represent empirical estimates from PIT-tag data. Shaded cells were calculated using SIMPAS: modeled dam survival and reservoir survival extrapolated from estimated per-mile reservoir survival extrapolated from reaches with empirical estimates.

Year	Project survival (% Pool + Dam Survival)								Components of Complete In-river Survival			% In-river Survival (LGR to BON)
	LGR	LGS[a]	LMN[a]	IHR[ab]	MCN[ab]	JDA[c]	TDA[c]	BON[c]	LGR	LGS-MCN	JDA-BON	
1994	90.0	84.4	89.2	90.8	88.2	81.3	85.8	85.0	90.0	75.3[d]	47.5[e]	32.2
1995	94.4[f]	89.9	95.0[g]	92.7	92.6	88.4	88.1	88.7	94.4	73.3	69.1	47.8
1996	93.4[f]	93.8	93.7[g]	88.9	88.9	86.0	87.3	87.8	93.4	69.5	65.9	42.8
1997	96.3[f]	96.6	90.2	91.3	91.4	85.1[h]	87.0[h]	88.0[h]	96.3	72.7	65.2	45.5
1998	92.5[f]	93.0	88.9	89.3	89.3	83.1	89.7[hi]	91.8[hi]	92.5	65.9	68.4[j]	41.8
1999	90.8[k]	92.6	91.5	91.3	91.3	92.0	84.0[l]	81.2[l]	90.8	70.6	62.8	40.2
6-yr avg	92.9	91.7	91.4	90.7	90.3	85.8	87.0	86.9	92.9	71.2	65.1	41.5

a. Empirical estimates based on pooled hatchery and wild fish grouped at LGR: average of estimates for daily groups weighted by relative variance.

b. When empirical (unshaded): square root of empirical estimate between LMN tailrace and MCN tailrace.

c. When empirical (unshaded): based on pooled hatchery and wild fish grouped at MCN: average of estimates for weekly groups weighted by relative variance.

d. LGS-LMN for 1994.

e. IHR-BON for 1994.

f. Average of hatchery and wild fish tagged at and released from Snake River smolt trap, weighted by respective number tagged.

g. For BiOp, empirical estimates were decreased by one standard error to avoid estimates of pool survival in excess of 100 percent.

h. Calculated from empirical estimate between MCN tailrace and BON tailrace, based on per-mile reservoir survival and SIMPAS-modeled dam survival.

i. Empirical estimate between JDA tailrace and BON tailrace not used to avoid pool survival estimates in excess of 100 percent.

j. Product of JDA, TDA, and BON numbers. While the JDA number is the PIT-tag estimate between MCN tailrace and JDA tailrace, the others are calculated

from estimate between MCN tailrace and BON tailrace. The consequence is that the overall JDA-BON empirical estimate was underestimated.

k. Pooled hatchery and wild fish tagged at and released from Snake River smolt trap.

l. Calculated from empirical estimate between JDA tailrace and BON tailrace, based on per-mile reservoir survival and SIMPAS-modeled dam survival.

Table 6. Empirical estimates of project and system survival for Snake River steelhead, 1997-2002, based on PIT-tag data.

YEAR	Project survival (% Pool + Dam Survival)								% In-river Survival (LGR to BON)
	LGR[a]	LGS[b]	LMN[b]	IHR[bc]	MCN[bc]	JDA[d]	TDA[de]	BON[de]	
1997	96.4	96.6	90.2	91.3	91.4	85.1	87.0	88.0	45.6
1998	92.4	93.0	88.9	89.3	89.3	83.1	93.7	99.8	47.4
1999	90.8	92.6	91.5	91.3	91.3	92.0	84.0	81.2	40.2
2000	95.4	90.1	90.4	91.8	91.8	85.1	88.1	85.6	42.0
2001	91.3	80.1	70.9	54.4	54.4	33.7	87.6	86.0	3.9
2002	89.8	90.3	91.2	80.6	80.6	84.4	80.7	75.8	24.8

a. Pooled hatchery and wild fish tagged at and released from Snake River smolt trap.

b. Empirical estimates based on pooled hatchery and wild fish grouped at LGR: average of estimates for daily groups weighted by relative variance.

c. Square root of empirical estimate between LMN tailrace and MCN tailrace.

d. Empirical estimates based on pooled hatchery and wild fish grouped at MCN: average of estimates for weekly groups weighted by relative variance.

e. Calculated from empirical estimate between JDA tailrace and BON tailrace, based on per-mile reservoir survival and SIMPAS-modeled dam survival.

Table 7. Empirical estimates of survival for Snake River steelhead in lower river compared to results of SIMPAS model based on survival to McNary Dam (method used in 1995-1996).

YEAR	Empirical estimates				SIMPAS Method				Ratio SIMPAS/Empirical			
	JDA	TDA	BON	JDA-BON	JDA	TDA	BON	JDA-BON	JDA	TDA	BON	JDA-BON
1997	85.1	87.0	88.0	65.1	89.0	88.2	90.3	70.9	1.0456	1.0142	1.0267	1.0887
1998	83.1	93.7	99.8	77.7	83.7	86.5	85.9	62.2	1.0071	0.9234	0.8614	0.8010
1999	92.0	84.0	81.2	62.7	85.6	87.2	87.0	64.9	0.9300	1.0376	1.0715	1.0340
2000	85.1	88.1	85.6	64.2	85.9	89.7	88.5	68.2	1.0097	1.0180	1.0339	1.0627
2001	33.7	87.6	86.0	25.4	46.3	73.8	62.4	21.3	1.3729	0.8428	0.7262	0.8403
2002	84.4	80.7	75.8	51.7	74.4	83.9	81.4	50.8	0.8811	1.0390	1.0742	0.9835
Geometric Mean									**1.0303**	**0.9763**	**0.9562**	**0.9619**

Table 8. Project and system survival for Snake River steelhead 1994-1999, derived from Table 6.2-7 of the BiOp, December 21, 2000 (see Table 1), and adjustments based on comparison of recent empirical estimates and SIMPAS model results (see Table 3). Unshaded cells represent empirical estimates from PIT-tag data. Shaded cells are based on adjusted SIMPAS results.

Year	Project survival (% Pool + Dam Survival)								Components of Complete In-river Survival			% In-river Survival (LGR to BON)
	LGR	LGS [a]	LMN [a]	IHR [ab]	MCN [ab]	JDA [c]	TDA [c]	BON [c]	LGR	LGS-MCN	JDA-BON	
1994	90.0	84.4	89.2	90.8	88.2	78.9	87.9	88.9	90.0	75.3 [d]	49.4 [e]	33.5
1995	94.4 [f]	89.9	96.2	92.7	92.6	85.8	90.2	92.8	94.4	74.2	71.8	50.3
1996	93.4 [f]	93.8	95.1	88.9	88.9	83.5	89.4	91.8	93.4	70.5	68.5	45.1
1997	96.3 [f]	96.6	90.2	91.3	91.4	85.1 [g]	87.0 [g]	88.0 [g]	96.3	72.7	65.2	45.6
1998	92.5 [f]	93.0	88.9	89.3	89.3	83.1	93.7 [h]	99.8 [h]	92.5	65.9	77.7	47.4
1999	90.8 [f]	92.6	91.5	91.3	91.3	92.0	84.0 [h]	81.2 [h]	90.8	70.6	62.8	40.2
6-yr avg	92.9	91.7	91.4	90.7	90.3	84.7	88.7	90.4	92.9	71.2	65.1	43.7

a. Empirical estimates based on pooled hatchery and wild fish grouped at LGR: average of estimates for daily groups weighted by relative variance.

b. When empirical (unshaded): square root of empirical estimate between LMN tailrace and MCN tailrace.

c. When empirical (unshaded): based on pooled hatchery and wild fish grouped at MCN: average of estimates for weekly groups weighted by relative variance.

d. LGS-LMN for 1994.

e. IHR-BON for 1994.

f. Pooled hatchery and wild fish tagged at and released from Snake River smolt trap.

g. Calculated from empirical estimate between MCN tailrace and BON tailrace, based on per-mile reservoir survival and SIMPAS-modeled dam survival.

h. Calculated from empirical estimate between MCN tailrace and BON tailrace, based on per-mile reservoir survival and SIMPAS-modeled dam survival.

Attachment 2 – Smith & Zabel, NOAA

Steve Smith and Rich Zabel December 17, 2002

Estimating survival of Snake River fall Chinook salmon through the hydro-system

Overview

Estimating survival of Snake River fall Chinook salmon through the hydro-system has been problematic. Because survival of these fish is relatively poor, we are only able to reliably estimate survival to Lower Monumental Dam. With proposed increased sample sizes in 2003, though, we will have the potential to extend the range of our estimates. Below, we discuss the details of these increased sample sizes and the precision in survival estimates we expect to observe in migration year 2003 and beyond.

Extrapolating survival through the entire hydro-system also presents problems. It is clear that the behavior of Snake River fall Chinook changes substantially as the fish progress downstream. Here we propose a method that incorporates the change in behavior to extrapolate survival to downstream reaches.

Finally, survival estimates for fall Chinook are based primarily on hatchery fish. We briefly discuss protocols for comparing hatchery to wild fish to justify using fish as surrogates for wild fish.

Survival estimates for Snake River subyearling fall Chinook salmon downstream from Lower Granite Dam

Valid survival estimates for subyearling fall Chinook salmon cannot be obtained by taking PIT-tagged fish directly from Lyons Ferry Hatchery and releasing them in the tailrace of LGR. Such fish would not have the necessary period of rearing in the river before initiating migration and arriving at LGR. Thus, survival estimation downstream from LGR must rely on PIT-tagged fish released upstream from the dam. The approach is to track detections at LGR of subyearlings from all upstream release sites, to group them according to detection date, and to treat weekly groupings as separate "release groups" (fish returned to the tailrace rather than transported from LGR) for estimation of subsequent survival using the Cormack-Jolly-Seber (CJS) model.

Lyons Ferry fish have been PIT-tagged and trucked to release sites upstream from LGR every year since 1995. Sample sizes have been set primarily for estimation of survival to LGR, and the studies have provided considerable amounts of useful information. However, the numbers of fish detected at LGR and returned have been relatively small, and we have been able to obtain precise annual survival estimates only to Lower Monumental Dam (LMO). For only a few weekly groups over the eight years have there been sufficient detections at McNary Dam (MCN) and downstream (John Day Dam [JDA], Bonneville Dam [BON], estuary PIT-trawl) to estimate survival to MCN. Reliable estimates below McNary have not been obtained for any weekly group.

Most of the reliable estimates from LGR to MCN were for weekly groups in 1998. In that year a total of 20,330 PIT-tagged subyearling Chinook salmon were detected and returned to the river at LGR. Reasonably precise estimates were obtained for the following weekly groups from LGR:

Dates	Number	LGR-LMO Survival (std. err.)
Jun 22-29	355	0.512 (0.094)
Jun 30 – Jul 6	510	0.579 (0.104)
Jul 7-13	5,292	0.580 (0.032)
Jul 14-20	6,073	0.550 (0.024)
Jul 21-27	2,334	0.439 (0.028)
Jul 28-Aug 4	1,422	0.506 (0.034)
Aug 5-11	1,304	0.529 (0.041)
Aug 12-18	1,166	0.418 (0.045)
Aug 19-25	370	0.182 (0.033)
Aug 26-Sep 1	213	0.028 (0.015)

The number of PIT-tagged fish detected and returned to the river at LGR has been much lower in most other years: 2,680 in 1995; 4,397 in 1996; 15,891 in 1997; 6,123 in 1999; 3,397 in 2000; 11,449 in 2001.

In 2002, NMFS began a multi-year study of transportation of subyearling fall Chinook salmon from LGR. In the first year of the study almost 100,000 PIT-tagged Lyons Ferry fish were released about 40 km from the confluence of the Snake and Clearwater rivers. These fish were released in late May and early June, roughly corresponding in time to the earliest releases at Pittsburg Landing and Billy Creek for the NMFS subyearling survival study. Survival estimation using these fish was not successful, however. Fish condition was poor, leading to high mortality upstream from LGR, and 80 percent of all detected fish at LGR, LGO and LMO were transported. Only about 3,000 of these fish were detected and returned to the river at LGR; fewer than 300 were detected downstream from MCN.

The transportation study will continue in 2003 and beyond, for a minimum of three more years, and as many as six or more additional years. Prospects for survival estimation downstream from LGR are quite good in these years because 1) hatchery conditions that led to poor fish health in 2002 have been addressed, 2) release numbers have been increased to 150,000 and 3) a total of 20,000 detected fish will be returned to the river at LGR.

To determine the expected precision of survival estimates resulting from these 20,000 fish, we assumed that per-project survival probability was 0.8; detection probabilities were 0.45 at LGR, LGO, LMO, and MCN. Detection probability of 0.15 was assumed at JDA, and the probability that a PIT-tagged fish alive below JDA would survive to and be detected at some downstream site was assumed 0.10. Unintentional transportation of detected fish was set at 10 percent at all transport dams. A distribution through time of the 20,000 fish leaving LGR was assumed, based on annual passage distributions of fish from early release groups from the survival study. (All of these assumed numbers were derived from results of the survival study.)

The expected precision (half-width of 95 percent confidence interval) of the mean survival estimate through each reach is indicated in the following table:

Reach	Expected precision of mean estimate
LGR-LGO	0.030
LGO-LMO	0.036
LMO-MCN	0.057
MCN-JDA	0.148
LGR-JDA	0.048

Extrapolating survival estimates

The two commonly employed methods for extrapolating survival estimates from upstream reaches to downstream reaches are per-project or per-km extrapolations. Both of these methods assume that behavior among reaches is fairly uniform, but this is not the case for Snake River fall Chinook. A pattern that is consistent from year-to-year is that migration rate increases significantly as fish progress downstream (Figure 6). This is probably because fish undergo less rearing as they move downstream.

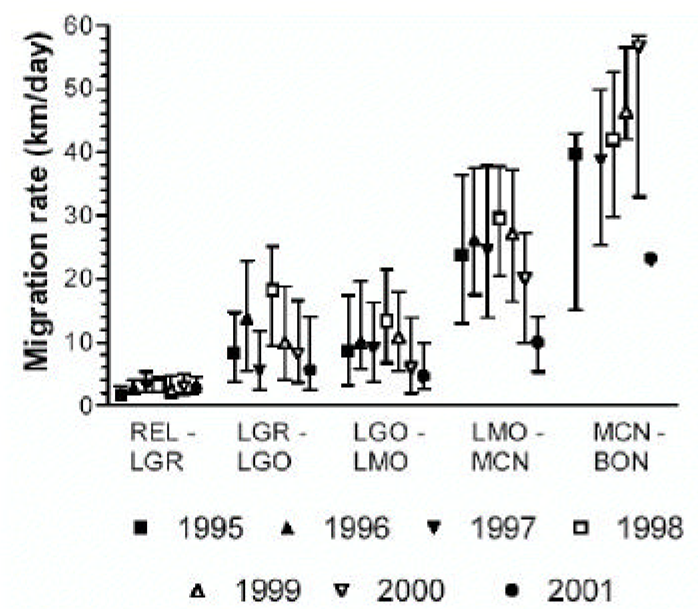

Figure 6. Median migration rates (with 20th and 80th percentiles) of Snake River fall Chinook salmon by reach and year. From Smith et al. (2002).

Snake River fall Chinook suffer considerable reservoir mortality (likely due to predation), and we expect that the level of mortality is related to exposure time. Because fish spend less time in lower reservoirs than in upper ones, we would expect lower mortality in lower reservoirs. A method that incorporates these expectations is to extrapolate reservoir mortality based on residence time after accounting for dam mortality. Although sample sizes in lower reaches are not large enough to estimate survival, they do provide information on residence times.

Methods

First, partition project survival *(Sp)* into dam survival *(Sd)* and reservoir survival *(Sr)*:

$$Sp = Sd \cdot Sr .$$

Next we assume that reservoir survival is related to residence time, T:

$$Sr = (S\ daily)\ T \sim exp\ (-r \cdot T) .$$

Sdaily is the daily survival rate, and raising this to the T^{th} power yields estimated survival through *T* days. The continuous-time analog to this is an exponential function with survival rate r. Because our residence time data are continuous, we used the exponential form.

To fit this equation to survival and residence time data, first take logs:

$$Log(Sp) = log(Sd) - r \cdot T .$$

This equation can be fit using standard linear regression. We can either specify dam survival (using SIMPASS, for example), or we can fit it as the intercept of the regression. The equation can be elaborated by incorporating year, site or temperature effects, if we desire.

Results and Discussion

As a demonstration, we applied the above equation to weekly survival estimates and median residence times through the Lower Granite to Little Goose and Little Goose to Lower Monumental reaches for 1995 to 2001 (Figure 7). We assumed a dam survival of 0.93. While the fit was highly significant ($P = 0.009$), the predictive power was relatively poor ($R^2 = 0.05$). However, because the survival estimates are highly variable, any predictive model will perform relatively poorly. We do believe, though, that the model captures the general trend in the data and will provide more realistic extrapolations of survival through the lower reaches. Also, including the factors mentioned above might improve model fit. To extrapolate to lower reaches, we simply apply the fitted relationship to observed residence times.

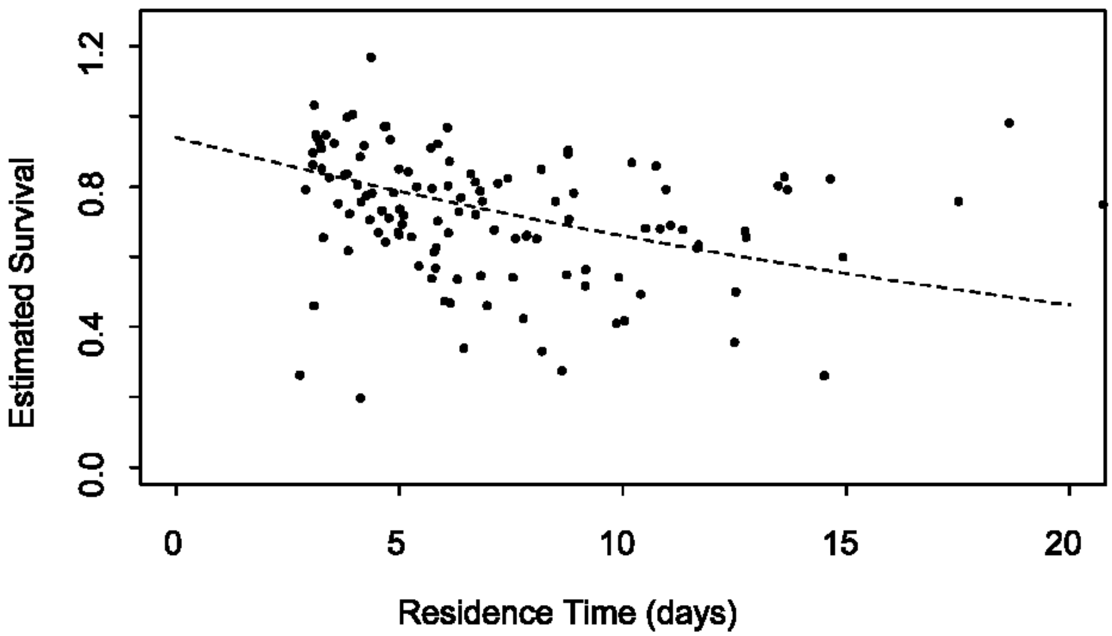

Figure 7. Regression of project survival versus residence time through the Lower Granite to Little Goose and Little Goose to Lower Monumental reaches for 1995-2001. Dam survival was set 0.93.

Comparing hatchery fish to wild fish

As mentioned above, estimating survival of Snake River fall Chinook salmon through the hydro-system relies on using hatchery fish as surrogates for wild fish. Capturing and tagging enough wild fish to generate reliable survival estimates through the hydro-system is impractical. However, enough fish are tagged to estimate survival through some reaches and travel times through more. Thus we suggest, as part of the RME process, that the group undertakes a comparison of survival and travel time for comparable release groups of wild and hatchery fish through as many reaches as possible. This would be essentially an extension of the analysis conducted by Smith et al. (2002). As part of this effort, we should assess the feasibility of estimating survival of wild fish through the Lower Granite to Little Goose reach. An important consideration is that size may play an important role in survival and travel time. Thus we may need to ensure that release groups of hatchery fish selected have a size distribution equivalent to wild fish.

Reference

Smith et al. 2002. Fall chinook survival report. Available at www.bpa.gov.

Attachment 3 – Skalski, Lady & Smith

Draft

Decision Rules for Progress and Compliance Testing

For Smolt Passage Survival

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Table of Contents

Introduction

The BiOp has established performance standards for in-river survival of out-migrating salmonid smolts. The stated goals for increases in the in-river survival are to achieve on or before the year 2010. In assessing the success of mitigation actions aimed at improving in-river smolt survival, comparisons of pre-2000 and post-2000 survival estimates will be performed. Comparisons performed in 2005 and 2006 will be used to assess interim progress in achieving recovery goals. The comparisons performed in 2010 will be used to assess compliance with the BiOp performance standards.

Greater statistical certainty will need to be ascribed to the discussions concerning compliance versus the less-formal statutory requirements needed for asserting progress. There will also be more information available at the time of the 2010 review than will be available in either 2005 or 2008. For these reasons, separate decision rules will be needed in assessing progress versus compliance.

In the following sections, the rationale and choice of decision rules proposed for progress and compliance testing will be presented. The anticipated performance of these decision rules will also be presented under non-recovery and recovery scenarios.

Compliance Rules

Initial Approach Using Standard Statistical Methods

Decision Rules

Statistical compliance testing in the year 2010 was initially conceptualized as applying standard statistical tests to one or more null hypotheses. Statistical tests performed at some a -level would be used to draw conclusions concerning possible compliance with stated performance standards. However, there is no unique set of hypotheses that adequately identifies the state of compliance or recovery. Instead, alternative testing procedures were evaluated. Ideally, a good test of compliance would have a low probability of concluding compliance if it had not occurred and a high probability of concluding compliance if it needed occurs. Therefore, the statistical performance of tests was evaluated by how close the statistical tests were to a nominal a -level when no recovery occurred and their power to conclude compliance when compliance was indeed true (i.e., $1-b$). Six alternative tests of compliance were initially compared; these were as follows:

Rule #1

Joint decision rule using

Test 1 $\quad H_{o1}\text{: } m_{Post} - m_{Pre} \le 0$

$\quad\quad\quad\; H_{a1}\text{: } m_{Post} - m_{Pre} > 0$

and

Test 2 $\quad H_{o2}\text{: } m_{Post} - m_{Pre} \ge \Delta$

$\quad\quad\quad\; H_{a2}\text{: } m_{Post} - m_{Pre} < \Delta$

Compliance would be concluded if H_{o1} is rejected and H_{02} is not rejected, each at a significance level of a. The value Δ is the required improvement in survival between pre- and post-2000 periods specified in the BiOp.

Rule #2
Simple decision rule using

Test 1 $H_o: m_{Post} - m_{Pre} \leq 0$
$H_a: m_{Post} - m_{Pre} > 0$

Compliance would be concluded if H_o is rejected at a significance level of a.

Rule #3
Simple decision rule using

Test 1 $H_o: m_{Post} - m_{Pre} \leq \Delta$
$H_a: m_{Post} - m_{Pre} > \Delta$

Compliance would be concluded if H_o is rejected at a significance level of a.

Rule #4
Joint decision rule using straight-line regression of survival versus year during the post-2000 period.

Test 1 $H_{o1}: a + b(2010) - m_{Pre} \leq 0$
$H_{a1}: a + b(2010) - m_{Pre} > 0$
and
Test 2 $H_{o2}: a + b(2010) - m_{Pre} \geq \Delta$
$H_{a2}: a + b(2010) - m_{Pre} < \Delta$

Compliance would be concluded if H_{o1} is rejected and H_{02} is not rejected, each at a significance level of a.

Rule #5
Simple decision rule using

Test 1 $H_o: a + b(2010) - m_{Pre} \leq 0$
$H_a: a + b(2010) - m_{Pre} > 0$

Compliance would be concluded if H_o is rejected at a significance level of a.

Rule #6
Simple decision rule using the asymptote (g) of a hyperbolic function fit to the post-2000 data. The test would be based on the hypotheses

Test 1 $\quad \mathrm{H_o}:\ g - m_{\mathrm{Pre}} \le \Delta$

$\qquad\quad\ \mathrm{H_a}:\ g - m_{\mathrm{Pre}} > \Delta$

Compliance would be concluded if $\mathrm{H_o}$ is rejected at a significance level of a .

Monte Carlo Results
Table 1 presents results of Monte Carlo simulations to estimate the observed a -level and statistical power $(1 - b)$ of the various compliance tests. All tests were performed at a = 0.05. A null case of no recovery was simulated where pre- and post-2000 survival estimates had the

Table 1. Estimated probabilities of concluding compliance for a yearling Chinook salmon smolt survival improvement of Δ = 0.09 from Lower Granite to Bonneville Dam at a = 0.05. Simulations were conducted under no improvement (i.e., $\Delta = 0$) and prescribed improvement (i.e., Δ) from 1 to 10 years after the year 2000. Decision Rules 1 through 6 were evaluated.

		Probabilities of Concluding Compliance						
Scenario		**Rule 1**	**Rule 2**	**Rule 3**	**Rule 4**	**Rule 5**	**Rule 6**	**Expectation**
No improvement		0.0025	0.000	0.000	0.306	0.000	0.000	a = 0.05
Recovery by year of size Δ	2010	0.200	0.200	0.000	0.481	0.028	0.010	1-B increasing ↓
	2009	0.220	0.220	0.000	0.514	0.038	0.018	
	2008	0.268	0.268	0.000	0.593	0.055	0.033	
	2007	0.331	0.331	0.000	0.567	0.052	0.031	
	2006	0.387	0.387	0.000	0.569	0.062	0.036	
	2005	0.434	0.434	0.000	0.566	0.059	0.036	
	2004	0.504	0.504	0.000	0.566	0.048	0.045	
	2003	0.601	0.601	0.000	0.540	0.051	0.044	
	2002	0.665	0.665	0.000	0.481	0.043	0.035	
	2001	0.738	0.738	0.000	0.478	0.034	0.023	

Same mean and variance. This scenario corresponds to the situation where the tests shall reject the hypotheses of no recovery at a = 0.05. Few of the tests had observed a-levels near the nominal level tested. For Rule #2, the results under no recovery reflect the fact the two-sample t-test is not nominally distributed when the pre-2000 data are treated as fixed values. For Rules 1, 3, 4, 5, and 6, the no-recovery state of nature (i.e., $m_{\text{Post}} = m_{\text{Pre}}$) does not produce a centrally distributed test situation. Instead, the no-recovery state of nature is in the tail of the acceptance zone of the null hypotheses. As such, observed a-levels are far below the nominal value of a = 0.05.

Under full recovery, Monte Carlo simulations were performed where the expected survivals equaled target BiOp values 1, 2, …, 10 years after 2000. Immediate recovery in year 1 (i.e., 2001) is the most favorable condition, with typically the highest statistical power for concluding recovery (Table 1). A recovery trajectory that achieved its target goal only in year 10 (i.e., 2010) would typically have the lowest statistical power for concluding compliance (Table 1). Comparison of the performances for Rules 1 and 2 indicate the first rule is largely governed by the first set of hypotheses, i.e.,

$$\text{H}_{o1}:\ m_{\text{Post}} - m_{\text{Pre}} \leq 0$$
$$\text{H}_{a1}:\ m_{\text{Post}} - m_{\text{Pre}} > 0.$$

Hence, the test of recovery in Rule #1 is not comparing post-2000 survivals to a standard of $m_{\text{Pre}} + \Delta$ but only to the pre-2000 mean (i.e., m_{Pre}). Rule #3 had no chance of concluding recovery (i.e., H_a) even when smolt survivals equaled the target goal in expectation. The reason, to reject

$$\text{H}_o:\ m_{\text{Post}} - m_{\text{Pre}} \leq \Delta$$

the observed mean for m_{Post} needs to exceed $m_{\text{Pre}} + \Delta$ by an amount $t\sqrt{s^2\left(\frac{1}{6}+\frac{1}{10}\right)}$ to be statistically significant. If the post-2000 survivals at best have an expectation of only $m_{\text{Pre}} + \Delta$, it is unlikely the null hypothesis will be rejected in favor of concluding compliance.

Rules 5 and 6 have a similar difficulty. Under recovery of size Δ, the expected values of the linear [i.e., $a + b(2010)$] and nonlinear regression (i.e., g) projections are equal to $m_{\text{Pre}} + \Delta$. However, to reject H_o and conclude compliance, the projections need to be appreciably above the recovery target to be declared significant. This situation, however, occurs rarely under Rules 5 and 6. Behavior of Rule #2 is analogously affected, resulting in a maximum power of only 50 percent (Table 1).

From the behavior of the above rules, a quite different attack to compliance testing is required. Typically, observed values need to exceed the stated target goals for standard statistical methods to conclude compliance. The inherent difficulty with existing tests is trying to demonstrate compliance when full recovery is expected to be at best (and at worst) exactly equal the target goals.

Alternative Decision Rules for Compliance

Establishing a Multidimensional Decision Rule

Instead of using existing statistical tests which have proven ineffectual for compliance testing (i.e., Table 1), statistical tests tailored to the purpose were constructed. The test criteria were based on reasonable properties for the annual survival estimates post-2000 under compliance. It seemed reasonable to expect under compliance, the post-2000 data may have some or all of the following properties:

1. The slope of a linear regression of annual survival versus year of the form

$$\hat{S}_i = a + bt_i$$

1. would have a positive slope (i.e., $b > 0$).
2. The mean survival post-2000 would be greater than the mean survival pre-2000 (i.e., $m_{\text{Post}} > m_{\text{Pre}}$).
3. Some of the annual survival estimates $(\hat{S}_i, i = 1, \ldots, 10)$ during the post-2000 period would equal or exceed the target performance level of $m_{\text{Pre}} + \Delta$.
4. The asymptote (g) of a hyperbolic curvilinear line

$$\hat{S}_i = \frac{g\,t_i}{\Psi + t_i}$$

   describing the relationship between survival over time would equal or exceed the target performance level, i.e., $\hat{g} \geq m_{\text{Pre}} + \Delta$.

5. Mean survival during the period 2006-2010 would equal or exceed mean survival during the period 2001-2005, i.e., $m_{2006+} \geq m_{2001+}$.

A multivariate decision rule was empirically constructed using these multiple criteria which had a probability of a of rejecting the null hypotheses of no compliance when true but a high power of concluding the alternative hypothesis of compliance if compliance was indeed achieved.

In constructing the multivariate decision rule, a multidimensional critical area of size a had to be specified under the null hypothesis of no improvement (i.e., $m_{\text{Post}} = m_{\text{Pre}}$). To construct the a-critical field, Monte Carlo simulations were performed. Two sets of simulations were conducted, (1) under H_o: Noncompliance (i.e., $m_{\text{Pre}} = m_{\text{Post}}$) and (2) under H_a: Compliance when the target for survival of $m_{\text{Pre}} + \Delta$ was achieved in year 2010. For each simulation, 6 years of fixed pre-2000 survivals and 10 years of random survivals under compliance were generated and the test statistics computed. These multivariate test results were when binned into mutually exclusive and exhaustive cells within the hyperspace defined by the ranges of the individual test criteria. A minimum of 10,0000 simulations were done under both H_o and H_a conditions for a given set of test criteria. The test criteria were so written that they were monotonically increasing in value as H_a became more realized (i.e., nonrecovery versus recovery, recovery by year 10 versus recovery by year 1). Hence, one "corner" of the hypercube was distinctly associated with strong evidence for compliance. Starting in that corner, bins were summed from the most frequently occurring cells under H_a to the least frequent. This summary was allowed to continue until α 100 percent of the area of the H_o hypercube had been achieved. In so doing, a critical field has been established that has the probability of α of occurring under H_o but has a high probability of occurring under H_a. The critical field is then defined by the individual test conditions that define that multidimensional space.

Several alternative test criteria were considered in devising this multidimensional test of compliance. The test criteria correspond to the five data characteristics considered to be reasonable properties of a system in compliance. The test criteria were as follows:

1. Test of $\begin{array}{l} H_o: \ \beta \le 0 \\ H_a: \ \beta > 0 \end{array}$

   using $t_1 = \dfrac{\hat{\beta} - 0}{\sqrt{\hat{Var}\left(\hat{\beta}\right)}}$ and where $P_1 = P\left(t_{n-2} \le t_1\right)$. A weighted linear regression was performed for the model $\hat{S}_i = \alpha + \beta t_i$. The mean survival of the pre-2000 year was used for $\hat{S}_0$ at $t = 0$ with a weight of n_{Pre}, then number of pre-2000 years of annual survival estimates. For the post-2000 annual survival estimates, they were given equal weights of one.

2. Test of $\begin{array}{l} H_o: \ \mu_{\text{Post}} \le \mu_{\text{Pre}} \\ H_a: \ \mu_{\text{Post}} > \mu_{\text{Pre}} \end{array}$

   using $t_2 = \dfrac{\hat{\bar{S}}_{\text{Post}} - \hat{\bar{S}}_{\text{Pre}}}{\sqrt{\dfrac{s_2^2}{n_2} + \dfrac{s_1^2}{n_1}}}$ and where $P_2 = P\left(t_{n_1+n_2-2} \le t_2\right)$.

3. Count (C_3) of the number of post-2000 survival estimates whose values are $\ge \hat{\bar{S}}_{\text{Pre}} + \Delta$. The value C_3 has the range $0,1,\ldots,10$.

4. Test of $\begin{array}{l} H_o: \ \gamma \le \hat{\bar{S}}_{\text{Pre}} \\ H_a: \ \gamma > \hat{\bar{S}}_{\text{Pre}} \end{array}$

using $Z_4 = \frac{\hat{g} - \hat{\bar{\bar{S}}}_{\text{Pre}}}{\sqrt{\widehat{Var}(\hat{g}) + \frac{s_2^2}{n_2}}}$ and where $P_4 = P(Z \le Z_4)$. Here, g is the asymptote of a hyperbolic curve fit to the post-2000 data.

5. Test of $\begin{array}{l} \text{H}_{\text{o}}\text{: } m_{2006+} \le m_{2001+} \\ \text{H}_{\text{a}}\text{: } m_{2006+} > m_{2001+} \end{array}$

using $t_5 = \frac{\hat{\bar{\bar{S}}}_{2006+} - \hat{\bar{\bar{S}}}_{2001+}}{\sqrt{\frac{s_1^2}{n} + \frac{s_2^2}{n}}}$ and where $P_5 = P(t_{2n-2} \le t_5)$ when

m_{2001+} is the mean for year 2001-2005 and m_{2006+} is the mean for years 2006-2010.

Letting P_1', P_2', C_3', P_4', and P_5' be the critical values for an a -level test of compliance based on Monte Carlo simulations, compliance would be concluded if

$$\begin{array}{l} P_1 \ge P_1', \\ P_2 \ge P_2', \\ C_3 \ge C_3', \\ P_4 \ge P_4', \\ P_5 \ge P_5'. \end{array}$$

Each of the individual criteria would need to exceed their separate critical values to conclude compliance significant at a = 0.05.

Monte Carlo Results

Monte Carlo simulations were performed using a variety of test criteria combinations (i.e., 1, . . ., 5 of Section 2.2.1). The purpose of the simulations was to determine whether various multidimensional rules provided greater statistical power than the univariate compliance tests already examined (Table 1). A sample of possible rule combinations and their statistical power to detect compliance when it indeed occurs is presented in Table 2. For comparison, power of these new tests is presented along with Rule 1 from Section 2.1.1 based on the specifications in the BiOp. To date, a combination of criteria 1, 2, and 4 (i.e., last column of Table 2) provides uniformly greater power than the BiOp rule and any other univariate methods tested. For example, should compliance in yearling Chinook salmon survival between Lower Granite and Bonneville dams be achieved in the year 2010, the BiOp rule had a power of $1-b$ = 0.200 versus the new multivariate rule with a power of $1-b$ = 0.655. Should compliance be achieved in year 2001, statistical power is 0.810 versus 0.738 for the new multivariate rule versus BiOp rule, respectively. The critical values for the joint rule using criteria 1, 2, and 4 are, respectively,

$$P_1' = 0.85$$
$$P_2' = 0.74$$
$$P_4' = 0.82.$$

Observed P-values have to exceed each of these respective critical values to conclude compliance using this multivariate rule.

Results to date suggest this multivariate approach to compliance testing can provide objective criteria with known Type I error rates. Furthermore, the multivariate testing criteria, by using more information, can provide more statistically powerful tests of compliance than any univariate tests alone. Additional simulations are being performed to determine whether additional statistical power can be achieved by incorporating 4 or 5 of the test criteria.

Progress Rules

Initial Approach Using Standard Statistical Methods

Decision Rules

Statistical progress testing in years 2005 and 2008 were again initially conceptualized as standard statistical tests of one or more null hypotheses. Standard tests would be performed at some α -level to draw conclusions concerning progress in ultimately achieving compliance with

Table 2. Statistical power to conclude compliance in 2010 for yearling Chinook salmon survival from Lower Granite to Bonneville at α = 0.05 under various recovery scenarios.

Scenario		Original BiOp Test	Multiple Test Criteria				
			1,2,5	1,4,5	2,4,5	1,4	1,2,4
No improvement		0.0025	0.05	0.05	0.05	0.05	0.05
Recovery by year	2010	0.200	0.575	0.534	0.569	0.621	0.655
Of size Δ	2009	0.220	0.620	0.578	0.619	0.678	0.715
	2008	0.268	0.657	0.610	0.657	0.725	0.766
	2007	0.331	0.676	0.625	0.679	0.760	0.805
	2006	0.387	0.671	0.615	0.678	0.784	0.834
	2005	0.434	0.628	0.567	0.634	0.797	0.851
	2004	0.504	0.573	0.511	0.580	0.798	0.858
	2003	0.601	0.513	0.450	0.521	0.789	0.855
	2002	0.665	0.450	0.387	0.456	0.767	0.841
	2001	0.738	0.388	0.323	0.388	0.725	0.810

BiOp performance measures. As in the previous section on compliance testing, a good progress rule would have a low probability of concluding progress if the system was not improving but a high probability of indicating progress if improvement has indeed occurred. Therefore, standard statistical tests were evaluated in the hopes of identifying satisfactory progress rules.

Five alternative tests of progress were initially evaluated; these tests were as follows:

Rule #1

Simple decision rule using

Test 1 $H_o: b \le 0$

$H_a: b > 0$

Progress would be concluded is H_o is rejected at a significance level of a. In performing this test, three forms of linear regression were considered:

1a. Ordinary linear least squares on years 2001+ (OLS).

1b. Linear regression, fixing the intercept at the value of $\hat{\hat{S}}_{Pre}$ (FA).

1c. Weighted linear least squares where data for year 0 was set at $\hat{\hat{S}}_{Pre}$ with weight 6; all post-2000 years were given identical weights of 1 (WR).

Rule #2

Joint decision rule using

Test 1 $H_{o1}: m_{Post} - m_{Pre} \le 0$

$H_{a1}: m_{Post} - m_{Pre} > 0$

Test 2 $H_{o2}: a + b\left(2005 \text{ or } 2008\right) \le 0$

$H_{a2}: a + b\left(2005 \text{ or } 2008\right) > 0$

Progress would be concluded if H_{o1} is rejected and H_{o2} rejected, each at a significance level of a.

Rule #3

Joint decision rule using

Test 1 $H_{o1}: m_{Post} - m_{Pre} \le 0$

$H_{a1}: m_{Post} - m_{Pre} > 0$

Test 2 $H_{o2}: a + b\left(2005 \text{ or } 2008\right) \ge 0$

$H_{a2}: a + b\left(2005 \text{ or } 2008\right) < 0$

Progress would be concluded if H_{o1} is rejected and H_{o2} not rejected, each at a significance level of a.

Rule #4
Joint decision rule using

$$\text{Test 1} \quad H_{o1}:\ m_{\text{Post}} - m_{\text{Pre}} \geq 0$$
$$H_{a1}:\ m_{\text{Post}} - m_{\text{Pre}} < 0$$
$$\text{Test 2} \quad H_{o2}:\ a + b\,(2005 \text{ or } 2008) \leq 0$$
$$H_{a2}:\ a + b\,(2005 \text{ or } 2008) > 0$$

Progress would be concluded if H_{o1} is not rejected and H_{o2} is rejected, each at a significance level of a .

Rule #5
Simple decision rule using

$$\text{Test 1} \quad H_{o}:\ m_{\text{Post}} - m_{\text{Pre}} \leq 0$$
$$H_{a}:\ m_{\text{Post}} - m_{\text{Pre}} > 0$$

Progress would be concluded is H_o is rejected at a significance level of a .

Monte Carlo Results
Monte Carlo simulations were performed to evaluate the Type I error rate under no recovery and the statistical power of concluding progress when the performance standards would ultimately reach compliance by year 2010. Tests of progress were conducted for years 2005 and 2008 under different trajectories for compliance. Scenarios were simulated where survival rates reached mean compliance levels $1,2,\ldots,10$ years post-2000. In testing for progress, only the data to 2005 or 2008 were used in the analyses.

Tables 3 and 4 provide Monte Carlo results on Rules 1-5 for progress using data through 2005 to test for progress. Of all the rules evaluated, Rule 1 using weighed regression had the highest statistical power to correctly identify progress when it was indeed occurring. Even for that rule, statistical power never exceeded 0.673. Across the rules, weighted regression outperformed ordinary least squares or fixing the intercept (i.e., a) at the pre-2000 mean.

Tables 5 and 6 provide Monte Carlo results on Rules 1-5 for progress testing using the survival data through 2008. Of all the decision rules evaluated, Rule 1 with weighted regression had the highest chance of correctly identifying progress in 2008. Rule 1 had a maximum power of 0.749 of correctly identifying progress where the survivals were improving at a rate that would reach compliance by year 2002. Power dropped to 0.433 of correctly identifying progress if the survivals were on a trajectory of reaching compliance by the year 2010. Rules 3 and 5 had the exact same performance because testing hypotheses H_{02} in Rule 3 contributed nothing to the performance of Rule 3. That left Rules 3 and 5 identical in specification.

Maximum powers of 0.673 and 0.749 of correctly identifying progress in year 2005 and 2008 by classical means suggest alternative decision rules for assessing progress are needed.

Multidimensional rules for assessing progress will therefore be investigated analogous to those reviewed for compliance testing.

Alternative Decision Rules for Progress

Establishing a Multidimensional Decision Rule

A similar multidimensional approach to progress testing was used as was proposed for compliance testing. At the 2005 and 2008 "check-in," it might be expected that if progress has been achieved, several traits should be exhibited in the monitoring data. Among the traits anticipated of the post-2000 data include the following:

Table 3. Estimated probabilities of concluding progress in yearling Chinook salmon smolt survival from Lower Granite to Bonneville Dam at a = 0.10. Simulations were conducted under no improvement (i.e., $\Delta = 0$) and prescribed improvement (i.e., Δ) from 1 to 10 years after the year 2000. Decision Rules 1 and 2 were evaluated at the 2005 "check-in."

Scenario		Rule 1 OLS	Rule 1 FA	Rule 1 WR	Rule 2 OLS	Rule 2 FA	Rule 2 WR	Expectation
No improvement		0.126	0.013	0.069	0.010	0.012	0.002	a = 0.10
Recovery by year	2010	0.228	0.084	0.256	0.038	0.053	0.056	1-B increasing ↓
of size Δ	2009	0.216	0.083	0.271	0.045	0.060	0.061	
	2008	0.230	0.077	0.274	0.043	0.055	0.056	
	2007	0.261	0.093	0.332	0.054	0.077	0.078	
	2006	0.285	0.125	0.415	0.074	0.102	0.105	
	2005	0.293	0.161	0.480	0.145	0.172	0.178	
	2004	0.314	0.207	0.586	0.168	0.202	0.208	
	2003	0.257	0.268	0.673	0.242	0.290	0.297	
	2002	0.178	0.228	0.646	0.276	0.360	0.367	
	2001	0.126	0.212	0.628	0.298	0.393	0.407	

Table 4. Estimated probabilities of concluding progress in yearling Chinook salmon smolt survival from Lower Granite to Bonneville Dam at a = 0.10. Simulations were conducted under no improvement (i.e., Δ = 0) and prescribed improvement (i.e., Δ) from 1 to 10 years after the year 2000. Decision Rules 3-5 were evaluated at the 2005 "check-in."

		Rule 3			Rule 4				
Scenario		**OLS**	**FA**	**WR**	**OLS**	**FA**	**WR**	**Rule 5**	**Expectation**
No improvement		0.015	0.015	0.015	0.062	0.044	0.049	0.015	a = 0.10
Recovery by year	2010	0.075	0.075	0.075	0.178	0.145	0.173	0.075	1-B increasing ↓
of size Δ	2009	0.075	0.075	0.075	0.194	0.162	0.187	0.075	
	2008	0.072	0.072	0.072	0.231	0.179	0.203	0.072	
	2007	0.095	0.095	0.095	0.231	0.203	0.227	0.095	
	2006	0.124	0.124	0.124	0.306	0.284	0.315	0.124	
	2005	0.198	0.198	0.198	0.405	0.384	0.419	0.198	
	2004	0.237	0.237	0.237	0.443	0.451	0.493	0.237	
	2003	0.329	0.329	0.329	0.469	0.515	0.548	0.329	
	2002	0.430	0.430	0.430	0.447	0.522	0.548	0.430	
	2001	0.537	0.537	0.537	0.376	0.489	0.515	0.537	

Table 5. Estimated probabilities of concluding progress in yearling Chinook salmon smolt survival from Lower Granite to Bonneville Dam at a = 0.10. Simulations were conducted under no improvement (i.e., Δ = 0) and prescribed improvement (i.e., Δ) from 1 to 10 years after the year 2000. Decision Rules 1 and 2 were evaluated at the 2008 "check-in."

		Rule 1			Rule 2			
Scenario		**OLS**	**FA**	**WR**	**OLS**	**FA**	**WR**	**Expectation**
No improvement		0.113	0.007	0.044	0.001	0.002	0.002	a = 0.10
Recovery by year	2010	0.266	0.123	0.443	0.016	0.033	0.033	1-B increasing ↓
of size Δ	2009	0.292	0.157	0.469	0.037	0.051	0.051	
	2008	0.384	0.243	0.582	0.035	0.057	0.057	
	2007	0.378	0.274	0.656	0.048	0.075	0.074	
	2006	0.387	0.346	0.712	0.068	0.101	0.097	
	2005	0.315	0.334	0.715	0.101	0.134	0.132	
	2004	0.272	0.391	0.745	0.109	0.163	0.156	
	2003	0.218	0.374	0.735	0.203	0.273	0.266	
	2002	0.160	0.349	0.749	0.217	0.321	0.311	
	2001	0.113	0.358	0.741	0.238	0.395	0.385	

Table 6. Estimated probabilities of concluding progress in yearling Chinook salmon smolt survival from Lower Granite to Bonneville Dam at a = 0.10. Simulations were conducted under no improvement (i.e., Δ = 0) and prescribed improvement (i.e., Δ) from 1 to 10 years after the year 2000. Decision Rules 3-5 were evaluated at the 2008 "check-in."

		Rule 3			Rule 4				
Scenario		**OLS**	**FA**	**WR**	**OLS**	**FA**	**WR**	**Rule 5**	**Expectation**
No improvement		0.014	0.014	0.014	0.034	0.023	0.027	0.014	a = 0.10
Recovery by year	2010	0.061	0.061	0.061	0.298	0.287	0.315	0.061	1-B increasing ↓
of size Δ	2009	0.077	0.077	0.077	0.372	0.359	0.393	0.077	
	2008	0.082	0.082	0.082	0.418	0.414	0.453	0.082	
	2007	0.101	0.101	0.101	0.472	0.481	0.522	0.101	
	2006	0.144	0.144	0.144	0.493	0.530	0.551	0.144	
	2005	0.180	0.180	0.180	0.526	0.592	0.606	0.180	
	2004	0.231	0.231	0.231	0.514	0.624	0.638	0.231	
	2003	0.348	0.348	0.348	0.530	0.645	0.643	0.348	
	2002	0.408	0.408	0.408	0.510	0.684	0.678	0.408	
	2001	0.537	0.537	0.537	0.416	0.657	0.646	0.537	

1. The slope of a linear regression of annual survival versus year of the form

   $\hat{S}_i = a + bt_i$

   would have a positive slope (i.e., $b > 0$).

2. Mean survival post-2000 would be greater than the mean survival pre-2000 (i.e., $m_{\text{Post}} > m_{\text{Pre}}$).

3. Some of the annual survival estimates $(\hat{S}_i; i = 1, \ldots)$ during the post-2000 period would equal or exceed the pre-2000 mean of m_{Pre}.

4. The projection of survival at time of check-in under a linear model of the form

$$\hat{S}_i = a + bt_i$$

   would be greater than the pre-2000 mean (e.g., $a + b(2005) > m_{\text{Pre}}$).

A multivariate decision rule was empirically constructed using these multiple criteria which had a probability of a of rejecting the null hypotheses of no improvement when true but a high power of concluding progress if progress was indeed occurring.

Monte Carlo methods were used to construct an a-critical field under the null hypotheses of no improvement but which had a high probability of concluding progress if it occurred. The test criteria were so written that they were monotonically increasing under the state of survival improvements. One "corner" of the hypercube was therefore associated with strong evidence of progress. The critical field used in rejecting the null hypothesis of no progress was therefore in this "corner."

Several alternative test criteria were considered in devising this multidimensional test of progress. The test criteria correspond to the four data characteristics considered to be reasonable properties of a system in progress. These test criteria were the following:

1. Test of $\begin{array}{l} H_o: \ b \le 0 \\ H_a: \ b > 0 \end{array}$

   using $t_1 = \dfrac{\hat{b} - 0}{\sqrt{\widehat{Var}\left(\hat{b}\right)}}$ and where $P_1 = P\left(t_{n-2} \le t_1\right)$. A weighted linear regression was performed for the model $\hat{S}_i = a + bt_i$. The mean survival of the pre-2000 year was used for $\hat{S}_0$ at $t = 0$ with a weight of n_{Pre}, the number of pre-2000 years of annual survival estimates. For the post-2000 annual survival estimates, they were given equal weights of one.

2. Test of $\begin{array}{l} H_o:\ m_{Post} \le m_{Pre} \\ H_a:\ m_{Post} > m_{Pre} \end{array}$

   using $t_2 = \dfrac{\hat{\bar{S}}_{Post} - \hat{\bar{S}}_{Pre}}{\sqrt{\dfrac{s_2^2}{n_2} + \dfrac{s_1^2}{n_1}}}$ and where $P_2 = P\left(t_{n_1+n_2-2} \le t_2\right)$.

3. Count (C_3) of the number of post-2000 survival estimates whose values are $\ge \hat{\bar{S}}_{Pre}$. The value C_3 has the range $0,1,\ldots$.

4. Test of $\begin{array}{l} H_o:\ g \le \hat{\bar{S}}_{Pre} \\ H_a:\ g > \hat{\bar{S}}_{Pre} \end{array}$

   using $Z_4 = \dfrac{g - \left(\hat{\bar{S}}_{Pre}\right)}{\sqrt{\hat{Var}\left(\hat{g}\right) + \dfrac{s_2^2}{n_2}}}$ and where $P_4 = P\left(Z \le Z_4\right)$. Here, g is the asymptote of a hyperbolic curve fit to the post-2000 data.

Letting $P_1', P_2', C_3', \text{and } P_4'$ be the critical values for an a -level test of progress based on Monte Carlo simulations, progress would be concluded if

$$P_1 \ge P_1',$$
$$P_2 \ge P_2',$$
$$C_3 \ge C_3',$$
$$P_4 \ge P_4'.$$

Each of the individual criteria would need to exceed their separate critical values to conclude progress significant at a = 0.10.

Monte Carlo Results

Initial simulation studies indicate that multivariate decision rules do provide greater statistical power than any univariate test alone. Table 7 presents the statistical power of combined Rules 1, 2 and 4 in progress testing in years 2005 and 2008. Comparison of results reported in Tables 3 and 4 versus the 2004 check-in results of Table 7 indicate across-the-board improvements with the multivariate tests. Similarly, comparison of results reported in Tables 5 and 6 versus the 2008 check-in results of Table 7 indicate across-the-board improvements with the use of the multivariate decision rules. Actual improvements are even more dramatic, for the univariate test were performed at a = 0.10 while the multivariate tests were performed at a = 0.05. Additional studies will be conducted with Rules 1-4 to assess whether statistical power can be further improved.

Recommendations
The multivariate decision rules for progress and compliance testing are based on common-sense properties of the data expected on the road to recovery. Annual survival estimates should exceed baseline conditions (i.e., Pre-2000), show upward trends, and asymptote or equal target goals over time. By using these various properties, decision rules were built that could better detect progress or compliance than any simple criterion.

The purpose of this initial work was to demonstrate the feasibility of developing reasonable decision rules that have better statistical properties than existing criteria in the BiOp. The next step in the process should include the following.

1. Repeat analyses using updated information on baseline survival estimates.

Table 7. Estimated probabilities of concluding progress in yearling Chinook salmon smolt survival from Lower Granite to Bonneville Dam at a = 0.05. Simulations were conducted under no improvement (i.e., $\Delta = 0$) and prescribed improvement (i.e., Δ) from 1 to 10 years after the year 2000. Decision Rules 1, 2, and 4 were evaluated at the 2005 and 2008 “check-ins.”

		Rules 1, 2, and 4 for Check-Ins		
Scenario		**2005**	**2008**	**Expectation**
No improvement		0.048	0.050	a = 0.05
Recovery by year	2010	0.192	0.440	1-B increasing ↓
of size Δ	2009	0.213	0.506	
	2008	0.246	0.580	
	2007	0.283	0.652	
	2006	0.352	0.710	
	2005	0.439	0.750	
	2004	0.523	0.781	
	2003	0.584	0.789	
	2002	0.627	0.794	
	2001	0.597	0.755	

2. Expand the investigation to examine the performance of 4- or 5-dimensional rules.
3. Establish critical values for each of the in-river smolt survival performance measures listed in the BiOp.
4. Upon approval of the approach by the RM&E - Hydro Working Group, these tasks will be performed, beginning 2003.

4. Hatchery/Harvest RME Plan

Introduction

This plan addresses hatchery- and harvest-related RME called for in the BiOp . Specifically, this plan covers actions 182 and 184, which focus on hatcheries or hatchery fish, and on action 167, which relates to harvest.

This document is organized into four sections. Following this introduction, each of the next three sections addresses one of the three actions covered in this plan. Section II addresses action 182, Section III addresses action 184, and Section IV addresses action 167. Each section begins with the action as presented in the BiOp, followed by a discussion of the key questions that the action was intended to address and how those questions relate to implementation of the BiOp. The next subsection identifies relevant performance indicators that will be evaluated at the scheduled BiOp check-ins, and any applicable performance standards pertinent to future assessments. The next subsection presents an overview of the actions underway in the basin that may contribute to addressing the stated needs. This overview encompasses the AA's BiOp implementation plans. An initial analysis of the degree to which current or anticipated actions meet the requirements is presented for the purpose of identifying gaps in program/project coverage. Finally, each section outlines the workgroup's strategy for addressing these gaps.

Action 182: Relative Reproductive Success of Hatchery Spawners

A. Action 182 is presented in Section 9.6.5.3.2 of the BiOp, and states:

> *The Action Agencies and the NMFS shall work within regional priorities and congressional appropriations processes to establish and provide the appropriate level of FCRPS funding for studies to determine the reproductive success of hatchery fish relative to wild fish. At a minimum, two to four studies shall be conducted in each ESU. The Action Agencies shall work with the Technical Recovery Teams to identify the most appropriate populations or stocks for these studies no later than 2002. Studies will begin no later than 2003.*

Artificial production of anadromous salmonids has occurred on a large scale for many years in the Columbia River Basin to mitigate for development and support fisheries. Recently, artificial production has been seen as a tool that might be useful to contribute to recovery of depressed populations, particularly those listed under the ESA. One result of artificial production, intentional in some cases and inadvertent in others, is that many populations in the basin are a mix of natural-origin and hatchery-origin spawners. This circumstance presents two kinds of problems, one biological and one data related, that combine to mask the true status of natural populations in the basin and is referred to here as the "masking problem." A description of the masking problem is described in McClure et al. 2000:

> One of the greatest uncertainties does not involve the biology of salmonids; it is a simple counting problem. Hatchery fish spawn with wild fish to varying degrees throughout the Columbia River Basin. In some cases we have virtually no rigorously collected samples to indicate what percentage of the wild spawners are from a hatchery. In virtually all cases, even if we knew what fraction of spawners were hatchery fish, we do not know to what extent those hatchery fish are

> successful at spawning, or even if they were successful at all. The foundation of the most basic population analysis for any fish stock involves counts of spawner and recruits per spawner. When dealing with wild fish that mix with hatchery fish on the spawning ground, ignorance about the **number of hatchery fish** and **their reproductive success** means that estimates of recruits per spawner are compromised. Without **widespread quantitative estimates of hatchery spawning contributions** and more selective estimates of **relative reproductive fitness of hatchery fish**, our analyses (and for that matter anyone's quantitative analyses of salmonid populations) are highly uncertain… (emphasis added)

The immediate objective of action 182 is to ensure that studies are in place in 2003 that would begin to address the issues described above to improve the status assessments called for in the BiOp at the 2005 and 2008 check-ins. As noted above, the masking issue can be broken into two components, each requiring a different response.

The biological aspect of the masking problem stems from peer-reviewed studies indicating that hatchery-origin spawners have lower reproductive success when they spawn in the wild than natural-origin spawners. The causes of the differences in reproductive success of wild-spawning hatchery fish are attributed largely to genetic effects. Uncertainty about parameter estimation required the status assessments contained in the BiOp to rely on a large range (e.g., 20 percent to 80 percent) for the relative reproductive success of wild-spawning hatchery fish compared to natural-origin fish. This parameter greatly affects conclusions regarding the status of the wild population and the improvement needed to meet ESA survival and recovery criteria. The BiOp calls for studies designed to address the critical uncertainty regarding the relative reproductive success of hatchery fish spawning in the wild.

The data-related, or "counting," aspect of the masking problem stems from uncertainty about the numbers of hatchery fish spawning in the wild and their spatial and temporal distribution. Estimates of the numbers of fish spawning in the wild in many cases are based on extrapolations of hatchery- and natural-origin fish counts at dams or weirs rather than on field surveys of the spawning grounds. Or, they are based on surveys of spawning ground index areas where the hatchery- and natural-origin spawners are not readily distinguishable because the hatchery fish were not marked (a practice that continues to some degree still), or these data simply are not recorded. Where the spatial and temporal distribution of hatchery- and natural-origin spawners may differ, errors can be introduced because index data are erroneously expanded to the larger population.

Together with spatial structure and diversity, abundance and population growth rate are key parameters of population viability and extinction risk analysis. The population growth rate, or "lambda," represents productivity over time, i.e., a measure of how well a population is performing in its environment. Its accuracy depends in part on the accuracy of counts of natural- and hatchery-origin fish in the spawning populations. Unfortunately, for reasons noted above, it sometimes has been difficult or impossible to separately estimate the natural- and hatchery-origin components of the spawning populations. As a result, estimates of recruits per spawner for the naturally reproducing component of the population can be inflated.

These uncertainties affect estimates of the degree of improvement needed to achieve ESA survival and recovery objectives for listed populations. Table 9-2-4 of the BiOp provides estimates of the percentage improvement in survival rates needed for each ESU addressed by the action to achieve survival and recovery criteria. For the listed Snake River steelhead ESU, this range is from 44 percent to 333 percent. This range is due largely to the masking problem, and explains why the BiOp identifies it as a "critical uncertainty" that must be resolved to enable reliable assessments of population status and better inform recovery planning activities.

B. Performance Indicators and Standards Relative to Action 182

The performance standard applicable to this action requires resolution of the masking issue, which must address the biological question regarding the relative reproductive success of hatchery fish spawning in the wild and the counting question concerning the spatial and temporal distribution and extent of hatchery fish spawning in the wild. Resolution of the biological question would lead to a substantial narrowing of the range of relative spawning effectiveness of hatchery fish used in the BiOp (e.g., 20 percent to 80 percent). Assuming the counting question also is resolved with an improved status monitoring program, this would enable better future assessments of the status of listed populations and better inform estimates of the extent of improvement in survival rates necessary to achieve ESA survival and recovery criteria. This information may also prove useful to recovery planning in that it might inform decisions about whether, under what circumstances and to what extent artificial production may provide a demographic benefit to populations.

For the purpose of implementation of the BiOp, the applicable performance indicator is the initiation and continuance of a sufficient number and quality of studies by the 2003 check-in. The studies must be designed to produce quantitative results usable in life cycle models to facilitate future assessments of the status of the listed ESUs addressed in the action.

Overview of requirements of Action 182
As noted previously, the masking problem has two components, dubbed herein as the "counting" component and the "biological" component. Each must be addressed in the RME plan. The text of action 182 prescribes two to four studies per ESU but is non-specific as to what constitutes a "study" in this context.

Counting component. This issue is encompassed in the broader effort to improve status monitoring; additional RME projects may be needed to address this aspect of the masking problem. In addition, because the counting problem stems in part from the inability to distinguish hatchery from natural-origin fish, a comprehensive marking strategy is under development pursuant to action 174 to ensure that hatchery- and natural-origin fish can be more reliably distinguished in the spawning escapement. Failure to externally mark all hatchery production will make answering this question extremely difficult and/or expensive.

Biological component. As noted above, action 182 calls for a minimum of 2-4 studies in each ESU to be underway in 2003 but provides no guidance of what constitutes a "study" in this context. It is unclear, for example, whether a tally of studies would include investigations into the counting component of the masking problem. A robust, scientific approach would involve studies focused on more than one population within each multi-population ESU to determine the extent to which reproductive success may vary among populations, as well as to replicate results. For the purpose of determining the minimum level of RME necessary to meet the intent of action 182, this plan assumes there must be, at a minimum, one tier study directed at the relative reproductive success of hatchery fish underway in 2003 for each of the listed ESUs addressed by the action, other than Snake River Sockeye.[19] An action 182 study focused on Columbia River Chum may be unnecessary to address the masking issue because of the relatively minor amount of artificial production in the past but could contribute greatly to recovery planning. Existing studies in an ESU, though possibly relevant to the critical question, will not automatically count toward this minimum if they are not designed to provide the kind of quantitative results envisioned by the action. However, it may be feasible to modify existing studies to meet requirements of action 182.

C. General description of current projects (or expected to be funded) relevant to Action 182

Numerous studies are underway in the basin and elsewhere that will provide information relevant to the relative reproductive success of hatchery fish. While these studies may be useful, many do not provide the kind of specific and quantitative results required to fulfill BiOp purposes. In addition, not all ESUs are addressed by the current studies, and some of the studies are directed at populations not pertinent to the action. State-of-the-art, pedigree-based (DNA or chemical progeny marker) research on relative reproductive success of hatchery- and natural-origin salmon and steelhead (see Table 182-A) is being conducted on, or has been proposed for, five populations of steelhead, seven populations of spring Chinook, two Coho populations, and one Sockeye populations, as follows.

[19] Given the minimal number of natural-spawning fish in this ESU, and considering that most of those fish are the progeny of artificial production, an action 182 study directed at this ESU is considered non-essential.

Species	Esu	Population	Province
A. Steelhead			
	Olympic Peninsula	Forks Cr.	WA Coast
	Snake STHD	Little Sheep Cr.	Blue Mt.
	MCR STHD	Umatilla	Col. Plateau
	LCR STHD	Abernathy	L. Columbia*
	LCR STHD	Hood	Col. Gorge
B. Spring Chinook			
	Snake SSCH	Lostine R.	Blue Mt.
	Snake SSCH	Catherine Cr.	Blue Mt.
	UCR SCH	Wenatchee	Col. Cascade*
	LCR SCH	Kalama	L. Columbia*
	Snake SSCH	Tucannon	Blue Mt.*
	MCR SCH	Yakima	Col. Plateau
C. Coho			
	Puget Sound	Minter Creek	Puget Sound
	L. Col. River	Abernathy	L. Columbia*
D. Sockeye			
	Lake Ozette	Lake Ozette	Wash. Coast

* proposed in Mainstem/Systemwide solicitation

DRAFT! **Table Action 182-A: List of Projects Investigating Relative Reproductive Success of Hatchery Fish** ***DRAFT!***

Ref. Code	Project #	Title	Province Subbasin	Species ESU	Comments
182-A	HSRG	Interactions Between Wild and Hatchery Steelhead – Key Assumptions	WA Coast Forks Creek	Olympic Peninsula Steelhead	Use msDNA to reveal origin of juvenile steelhead for relative reproductive success of hat. and nat. fish; interbreeding
182-B	198909600	M&E Genetic Characteristics of Supplemented Salmon and Steelhead	Blue Mt Grande Ronde Imnaha, Tucannon, Salmon, Clearwater	Snake SSCH Snake STHD	MsDNA Pedigree-based research on Little Sheep Cr. Steelhead and Lostine and Catherine Cr. spr Chinook. Estimate selection gradients.

DRAFT! **Table Action 182-A: List of Projects Investigating Relative Reproductive Success of Hatchery Fish** ***DRAFT!***

Ref. Code	Project #	Title	Province Subbasin	Species ESU	Comments
182-C	35041	Reproductive Success of Hatchery & Natural Spr. Chinook in Wenatchee, Tucannon, and Kalama Rivers	Col. Cascade Blue Mt. Lower Col. Wenatchee Tucannon Kalama	UCR SCH LCR SCH Snake SSCH	MsDNA-based pedigree research on relative reproductive success of naturally spawning hatchery and natural origin fish.
182-I	200204700	Develop Progeny Maker for Salmonids to Evaluate Supplementation	Col. Plateau Umatilla	MCR STHD	Develop and test chemical progeny marker. Apply to female steelhead to test relative reproductive success of hatchery-origin fish
182-N	HSRG	Differences in Natural Production Between Hatchery and Wild Coho – Influence of Hatchery Ancestry	Puget Sound Minter Cr.	Puget Sound Coho	Use msDNA to evaluate reproductive competence between hatchery and wild coho.
182-O	35027	Evaluation of Two Captive Rearing Methods for Assisting Recovery of Naturally Spawning Steelhead and Coho	Lower Col. R Abernathy Cr.	LCR STHD LCR Coho	Evaluate captive rearing of steelhead and Coho and then relative reproductive success of HOR v. NOR
182-R	199506325	Yakima/Klickitat Project M&E	Col. Plateau Yakima	Spr. Chinook	Evaluate reproductive success of HOR and NOR spring Chinook
182-W	199005200	Performance/Stock Productivity Impacts of Hatchery Supplementation	Mt. Snake Clearwater	Snake STHD	Evaluate HxH, HxW, WxW in streams and hatchery. Survival in migration and to adult
182-D-G	198909800 198909801 198909802 198909803	Idaho Supplementation Studies	Mt. Snake Clearwater Salmon	Snake SSCH	Evaluate 31 streams of supplemented versus control populations. Measures survival, genetic structure, individual and population parameters
182-H	199005500	Idaho Supplementation Studies – Steelhead	Mt Snake Clearwater Salmon	Snake STHD	Evaluate steelhead supplementation. Genetic database on 72 wild and 5 hatchery stocks. Measure abundance, trends, genetic attributes

DRAFT! Table Action 182-A: List of Projects Investigating Relative Reproductive Success of Hatchery Fish DRAFT!					
Ref. Code	**Project #**	**Title**	**Province Subbasin**	**Species ESU**	**Comments**
184-R	HSRG	Genetic Characterization of Lake Ozette Sockeye	WA Coast Ozette	Ozette SOCK	Use otolith marking and genetic data to monitor HOR and NOR abundance and interactions
184-DD	200001900	Tucannon Spr. Chinook Captive Broodstock Rearing and Research	Col. Plateau Tucannon	Snake SSCH	Uses genetic data to determine source of returning spawners
182-U	198805304	Hood River Production Program M&E	Col. Gorge Hood	LCR STHD	Use msDNA analysis on archived steelhead scales from 1991 on
182-X	OWEB	Non-Parieal Pedigree Project	OR Coast Umpqua	OR Coastal Coho	Use msDNA on HOR and NOR coho. Status uncertain

D. Gap assessment: what more is needed

Despite existing and proposed (and likely to be funded) studies, there are research gaps relative to minimal BiOp needs for action 182. Additional studies designed to produce quantitative results on the relative reproductive success of hatchery fish spawning in the wild are needed for the following ESUs or populations: Upper Columbia steelhead ESU, Mid-Columbia River steelhead ESU[20]; an ocean-type Chinook ESU (either directly involving the Snake River fall Chinook ESU or a suitable representative population of ocean-type fall Chinook) and Columbia River Chum ESU, the latter primarily to better aid the development of recovery options.

E. Action plan for meeting RME needs for Action 182

Guidelines for Action 182 RME projects

The fundamental, biological question encompassed in action 182 requires that any differences in reproductive success of hatchery and wild fish spawning naturally in the same population be quantified. (As noted previously, the counting question is addressed in the tributary status monitoring plan.) Therefore, action 182 studies must be designed to directly measure these differences. Parentage analysis using molecular genetic techniques is likely to be the most robust method to measure reproductive success, but other methods will be considered if they address the questions of interest in a sufficiently thorough manner. (The development of promising new methods, such as chemical progeny markers, also should be pursued, but their value for the purposes of this action is more speculative at this time.) Reproductive success needs to be evaluated in terms of the ability of wild-spawning hatchery fish to produce progeny that complete the entire life cycle, i.e., to produce F2 spawners. The pertinent question is

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[20] The workgroup notes that a reproductive success study exists for this ESU, but the study depends on the successful development and application of a new methodology (chemical progeny marker). Thus, the workgroup believes an additional study is warranted for this ESU that utilizes relatively more proven genetics-based methods.

- Do hatchery-origin fish reproduce in the wild less successfully than natural-origin fish and, if so, what is the extent of this difference, measured in terms of F2 productivity?

The lower reproductive success of hatchery-origin spawners may well be a function of several mechanisms, such as reduced genetic fitness, behavioral deficiencies, hatchery domestication, intentional and unintentional selection during hatchery broodstock collection and the accumulation and maintenance of deleterious alleles in the hatchery population. Some hatchery practices have been reformed in recent years in attempts to reduce deleterious effects and/or improve the potential for positive contributions of hatcheries. Many reforms have been in place for only a few years, and the putative benefits have not been empirically demonstrated with peer reviewed scientific studies. Nevertheless, it is probable that at least some widely implemented reforms have reduced deleterious effects, improved hatchery fish performance and/or conferred demographic benefits on natural populations. For the purpose of providing the most relevant information for action 182, studies directed at the relative reproductive success of wild-spawning hatchery fish produced by "reformed" hatchery practices are preferred; it will be of less value, for example, to study the relative reproductive success of wild-spawning hatchery fish produced using out-of-basin stocks.

Plans for addressing gaps in Action 182.
As a result of the gap analysis described in Section a.3 above, the need has been identified for additional studies directed specifically at certain ESUs. To obtain these studies, a technical description of the needed studies was included in a targeted solicitation, the Request for Studies (RFS). BPA issued the RFS on March 14, 2003. Proposals submitted in response to the RFS have been preliminarily evaluated by the ISRP and the FCRPS Hatchery/Harvest RME Workgroup. Most of the entities that submitted a proposal have been asked to respond to the ISRP and Workgroup technical comments by June 3, 2003. The ISRP and the Workgroup will complete a final evaluation by early July 2003, and selection of proposals for implementation is expected by early August 2003.

Action 184: Effectiveness of Hatchery Reforms and Conservation Hatcheries

A. Action 184 is presented in Section 9.6.5.3.4 of the BiOp, and states:

> *The Action Agencies and the NMFS shall work within regional priorities and congressional appropriations processes to establish and provide the appropriate level of FCRPS funding for a hatchery research, monitoring, and evaluation program consisting of studies to determine whether hatchery reforms reduce the risk of extinction for Columbia River basin salmonids and whether conservation hatcheries contribute to recovery.*

As noted previously, artificial production of salmonids occurs on a large scale in the Columbia River Basin to mitigate for development and support fisheries and is also seen today as a potential tool to help ESA species recovery. Artificial propagation activities can impart deleterious genetic, ecological or management effects on natural populations. In recent years, many reforms have been enacted or proposed that are designed to reduce these deleterious effects and improve the performance of hatchery fish used in conservation programs, thereby contributing to the recovery effort. The hypothesis is that deleterious effects of artificial production on listed populations can be reduced, thereby contributing to a reduction in extinction risk for affected natural populations. For conservation activities, the hypothesis is that properly designed intervention with artificial production, under certain circumstances, can make a net positive contribution to recovery of listed populations.

As noted in the BiOp, the fundamental premise underlying hatchery reforms is that artificial production programs can be operated consistent with and complementary to the goals of the ESA while still achieving their fishery mitigation objectives (BiOp at 9-152). A list of artificial production reforms designed to reduce ecological, genetic and/or management risks to listed species, and/or to improve the performance of hatchery fish, is identified in Section 9.6.4.2 of the FCRPS BiOp. Many of the reforms on this list have been implemented in recent years for some hatchery programs. Unfortunately, many reforms flow from hypotheses that are difficult to test with limited empirical data. A comprehensive RME approach is needed for evaluating hatchery reforms, particularly in terms of their ultimate efficacy in reducing extinction risk of listed species and contributing to recovery.

For the purpose of implementing action 184, two separate, but related topics are considered here: the efficacy of hatchery reforms in reducing extinction risk and of conservation hatcheries in contributing to recovery.

Efficacy of hatchery reforms in reducing extinction risk. Many hatchery reforms are designed to reduce the deleterious ecological, genetic or management effects of artificial production on listed ESUs using various approaches. For example, to minimize deleterious genetic effects, acclimation ponds are constructed and used to manage unwanted straying and/or increase homing fidelity of hatchery fish, inappropriate broodstocks are replaced and/or hatchery broodstocks are more routinely infused with fish from locally adapted populations. Rearing and release strategies designed to minimize ecological interactions of hatchery juveniles with natural-origin fish (e.g., predation, competition) are utilized. Reforms designed to improve survival of hatchery fish produced for fishery mitigation purposes could result in the need to produce less of them to achieve fishery objectives, thereby reducing costs and potentially the extent of unwanted ecological interaction with juvenile listed fish. Or, the reforms may result in hatchery fish used in supplementation programs that perform better in the wild. The challenge in evaluating reforms lies in isolating the effect of the reform in a controlled study and quantifying it in terms of effect on population viability.

Efficacy of conservation hatchery activities in contributing to recovery. Conservation hatchery activities, as loosely defined herein, can take many forms, some of which are touted even in the absence of scientific justification. They include many (but not all) supplementation and reintroduction programs (egg, fry/fingerling, smolt, or adult plants), captive brood- and captive-rearing strategies, steelhead kelt reconditioning and similar types of activities distinguished as a group by their focus primarily on conservation and recovery rather than fishery objectives (at least in the near term). Conservation may be the sole purpose of a particular hatchery facility, or it may be one of several activities conducted at a particular facility. This aspect of action 184 seeks to determine the efficacy of these conservation hatchery activities, i.e., the extent to which they provide a net positive effect on survival of listed species, thereby contributing to recovery. Positive effects may result from any number of mechanisms. For example, reforms may seek to improve the survival of hatchery fish that are used to provide a demographic boost to a listed population while not undermining its genetic diversity. Or, they may be designed to enable a facility to produce multiple, separate lots of fish for supplementation of specific tributaries thereby reducing the homogenization effect of supplementation.

B. Performance Standards Relative to Action 184

Action 184 prescribes RME activities directed at determining the effectiveness of hatchery reforms at reducing extinction risk and conservation hatchery activities at contributing to recovery. This action is part of a class of RME items referred to in the BiOp as AER. Because the subject matter involved in this action is hatchery reform and conservation hatchery activities that strive to accomplish certain substantive results consistent with performance standards applicable to hatchery programs, it is easy to confuse those desired results with the performance standards applicable to this action. The subject matter here involves performance standards applicable to effectiveness research rather than to hatchery programs and activities. Thus, the applicable performance standard here relates to the ability of the study(s) to detect changes in survival resulting from reforms or conservation hatchery activities. Detecting survival changes at the level of individual fish or a production lot may be relatively straightforward; detecting it at the population or the ESU level can be daunting. At these levels, it may be necessary to evaluate the effect of groups of reforms to achieve the necessary statistical power to adequately test hypotheses involving hatchery reforms and conservation hatchery activities.

A thorough discussion of performance standards and indicators relevant to AER studies is provided in the AER section of this RME plan. Though focused particularly on the effectiveness of habitat actions, that section is also relevant to effectiveness research prescribed by this action. Like habitat effectiveness studies, hatchery reforms and conservation hatchery activities are management actions, meaning they are purposeful manipulations of the environment. As such, effectiveness studies should be viewed as experiments that should be conducted consistent with good, scientific research methods, including clearly stated hypothesis, controlled experimentation, replication and peer review.

Overview of requirements of Action 184

Action 184 requires an unspecified number of studies designed to determine the efficacy of hatchery reforms in reducing extinction risk and whether conservation hatchery activities contribute to recovery. No specific schedule is provided for initiating or completing such studies, but the BiOp requires that priority studies be undertaken by the 3-year check-in (BiOp Appendix F). Thus, to determine adequacy of action 184 efforts relative to BiOp needs, the underlying intent of this action was used to determine whether sufficient RME is underway or whether gaps exist.

On this basis, action 184 requires studies focused particularly on the efficacy of problematic reforms and conservation activities that are being proposed for implementation in many hatchery programs and/or are likely to be proposed in connection with the basinwide HGMP process established pursuant to action 169. Of less immediate interest are studies that focus on evaluating the efficacy of programmatic reforms (e.g., clarification of a hatchery's goals and objectives) or generally agreed operational reforms (e.g., phasing out of non-local broodstocks). The rationale for this approach is that priority should be afforded to studies of those reforms or conservation hatchery activities that are most likely to be advocated and/or challenged by regional interests on the basis of their assumed (rather than proven) beneficial effects.

C. General description of current projects underway relevant to Action 184

A large number of hatchery reforms and conservation hatchery activities involving many facilities and populations are being evaluated across the basin. Many will provide results pertinent to action 184, but many of those will require modification and/or additional analysis to address the specific questions identified in the action. For example, studies exist that consider the effect of a particular reformed hatchery practice on the fish produced in the hatchery or on other populations affected by the hatchery fish, but these effects are seldom evaluated in terms of extinction risk for an ESU. Some conservation activities, such as supplementation programs, are evaluated for their effectiveness in returning F1 spawners, an important consideration but fewer focus on F2 spawners or the other questions pertinent to the recovery of viable populations, such as genetic diversity and population structure.

The following list of potentially relevant projects underway or likely to be funded represents a first step in evaluating the sufficiency of the current suite of activities applicable to action 184 and to facilitates the identification of gaps relative to BiOp needs. The list includes potentially relevant projects outside the Columbia River Basin. For research directed at reforms intended to reduce extinction risk, the nature of evaluated effects was identified, e.g., genetic, ecological interaction or management effects (Table 184-1, below). For conservation activities, the type of activity and life stage involved was identified (e.g., supplementation approach) and summarized in Table 184-2. The second step is as evaluation of these lists relative to the likely effects and significance of various reforms on the status of natural populations to identify apparent gaps in priority research.

DRAFT Table Action 184-1: Studies of Hatchery Reforms to Reduce the Risk of Extinction

Type of reform	Ref. Code	Project #	Title	Province/ Subbasin	Species/ ESU	Comment
Ecological	184-A	HSRG	Development of Methods on Effects of Hatchery Release Methods on Residualism and Interactions in Relation to Stream Carrying Capacity			Competition for food and space. Methods development.
Ecological	184-B	HSRG	Development of BKD Vaccine			Disease transmission. Control incidence in hatchery and environment
Ecological	184-C	HSRG	Residualism in Wild Broodstock Steelhead	Lower Col. River Kalama	LCR STHD	Residualism. Assess factors; develop methods to reduce.
Ecological	184-F	35039	Influence of Hatcheries on Health and Physiology of Naturally Rearing Fish	Col. Gorge Big White Salmon	Spr Chinook Steelhead	Disease transmission. Effects of hatcheries on BKD in environment and health of natural fish.
Ecological Genetic	184-G	199105500	Natural Rearing Enhancement Systems – NATURES	Systemwide	Chinook, coho, sockeye, steelhead	Domestication. Competition and Survival. Evaluate natural-like

DRAFT Table Action 184-1: Studies of Hatchery Reforms to Reduce the Risk of Extinction						
Type of reform	**Ref. Code**	**Project #**	**Title**	**Province/ Subbasin**	**Species/ ESU**	**Comment**
						culture facilities and method
Ecological Genetic	184-P	200203800	Physiological Assessment of Wild and Hatchery Juvenile Salmonids	Col. Plateau Yakima	MCR SCH	Domestication Competition and Survival. Evaluate natural-like culture facilities and method
Ecological	184-H	199901800	Characterize and Quantify Residual Steelhead in the Clearwater	Mt. Snake Clearwater	Snake STHD	Residualism. Quantify interactions with wild steelhead. Assess rearing practices
Ecological	184-J	199801004	M&E Snake Fall Chinook Released above Lower Granite	Blue Mt.	Snake FCH	Competition. Evaluate post-release behavior
Ecological	184-M	35063	Compare Bacterial Fish Pathogen Populations in Hatchery and Adjacent Creek, Evaluate Disease Transfer	Lower Col. River Abernathy	LCR Coho LCR STHD Cutthroat	Disease Transmission. Determine two bacterial pathogens in hatchery and creek; examine fish for diseases
Ecological	184-N	200101	LSRCP-Dworshak Spring Chinook	Mt. Snake Clearwater	Spr. Chinook	Disease Transmission. Evaluate erythromycin for FDA registration to reduce BKD incidence
Genetic	184-D	HSRG	Olfactory Imprinting in Hatchery Salmon	Puget Sound	Puget Sound Coho	Out-breeding depression. Develop molecular and electrophysiological assessment tools for homing – reduce straying
Genetic	184-E	35012	Spatial Scales of Homing and Efficacy of Hatchery Supplementation of Wild Pops.	Col. Plateau Yakima	MCR SCH	Out-breeding depression. Examine patterns of imprinting, homing, spawning per acclimation.
Genetic	184-I	199801003	Spawning Distribution of Snake Fall Chinook	Blue Mt. Hells Canyon	Snake FCH	Out-breeding depression. Determine homing with acclimation facilities
Genetic Ecological	184-K	199805303	Hood River Production M&E	Col. Gorge Hood	MCR SCH LCR STHD	Out-breeding depression. Domestication. Evaluate supplementation effects on natural pops.
Genetic	184-L	199805304	Hood River	Col. Gorge	MCR SCH	Out-breeding

DRAFT Table Action 184-1: Studies of Hatchery Reforms to Reduce the Risk of Extinction						
Type of reform	**Ref. Code**	**Project #**	**Title**	**Province/ Subbasin**	**Species/ ESU**	**Comment**
Ecological			Production M&E	Hood		depression. Domestication. Evaluate supplementation effects on natural pops.
Genetic	184-O	199005200	Performance/Stock Productivity Impacts of Supplementation	Mt. Snake Col. Plateau Clearwater Deschutes	Snake STHD MCR SCH	Domestication. Evaluates hatchery practices on growth and survival of steelhead and Chinook.
Genetic	184-S	HSRG	White River Acclimation Pond Evaluation	Puget Sound White River	Puget Sound Coho	Out-breeding depression. Evaluates spawning distribution of acclimated fish
Management	184-Z	200001700	Kelt Reconditioning-Enhance Iteroparity in Col. Steelhead	Col. Plateau Yakima	MCR STHD	Broodstock collection. Reduce effects of broodstock collection on population.
Management	184-WW	29007	Okanogan Kelt Reconditioning	Col. Cascade Okanogan	UCR STHD	Broodstock collection. Reduce effects of broodstock collection on population.

Table Action 184-2: Studies of the Effectiveness of Conservation Hatcheries						
Type Of Conservation Action	**Ref. Code**	**Project #**	**Key Words Or Title**	**Province/ Subbasin**	**Species ESU**	**Comments**
Supplementation	184-R	HSRG	Genetic Characterization of Lake Ozette Sockeye	Wash. Coast Ozette	Lake Ozette Sockeye	Fingerling plant
Supplementation	184-S	HSRG	White River Acclimation Pond Evaluation	Puget Sound White River	Spring Chinook	Smolt plant
Supplementation	184-T	HSRG	Snow Creek Coho Recovery	Puget Sound Snow Creek	Puget Sound Coho	Egg plant Fingerling plant
Supplementation	184-U	HSRG	Hamma Hamma Steelhead Evaluation	Puget Sound Hamma Hamma	Puget Sound Steelhead	Smolt plant
Supplementation Altered Stream	184-V	HSRG	Development of Engineered Streams	Puget Sound Dungeness	Puget Sound Coho	Egg plant
Supplementation NATURES	184-W	HSRG	Rearing Coho with NATURES Raceways	Puget Sound Several hat.	Puget Sound Coho	Control v. test raceways
Supplementation NATURES	184-X	HSRG	Semi-natural Habitat to Increase Chinook Survival	Puget Sound Nisqually	Puget Sound Chinook	Test structures added to rearing pond on survival
Supplementation	184-EE	199000500	Umatilla Hatchery M&E	Col. Plateau Umatilla	MCR STHD	Assess survival and

Table Action 184-2: Studies of the Effectiveness of Conservation Hatcheries						
Type Of Conservation Action	**Ref. Code**	**Project #**	**Key Words Or Title**	**Province/ Subbasin**	**Species ESU**	**Comments**
						contribution to natural pop.
Supplementation Captive Brood	184-FF	199800702	Grande Ronde Supplementation – Lostine	Blue Mt. Grande Ronde	Snake SSCH	Suppl. and captive smolts
Supplementation Captive Brood	184-GG	199800703	Grande Ronde Supplementation M&E	Blue Mt. Grande Ronde	Snake SSCH Snake STHD	Suppl. and captive smolts
Supplementation	184-JJ	199805301	Grande Ronde/Imnaha Spr, Chinook Supplementation	Blue Mt. G.R./Imnaha	Snake SSCH	Plan, implement, and M&E recovery-smolt
Supplementation	184-KK	200105300	Lower Col. River Chum in Duncan Creek	Lower Col. Duncan Cr.	Col. River Chum	Fry plant
Supplementation	184-LL	200107	LSRCP-NPT Evaluation	Blue Mt G.R./Imnaha	Snake SSCH Snake STHD	Smolt plant. Survival of hat. and nat. fish
Supplementation	184-MM	200108	LSRCP – NPT Evaluations	Mt. Snake Salmon	Snake SSCH	Smolt plant. Spawner composition Genetic analysis. Contribution of hatchery origin adults
Supplementation	184-NN	200109	LSRCP – ODFW Evaluations	Blue Mt. G.R./Imnaha	Snake SSCH Snake STHD	Smolt plant. Survival of hat-origin fish
Supplementation	184-OO	200117	LSRCP-Grande Ronde Steelhead and Fall Chinook Evaluation	Blue Mt. G.R./Snake	Snake STHD	Smolt plant. Survival, genetics, distribution
Supplementation	184-PP	200118	LSRCP-Evaluation of Salmonids	Blue Mt. Hells Canyon	Snake FCH	Fingerlings. survival, genetics, life-history
Supplementation	184-QQ	200116	LSRCP-M&E Asotin Creek	Blue Mt. Asotin	Snake SSCH Snake STHD	Smolt plant. Survival, genetics, distribution of hat. and nat fish.
Supplementation NATURES	184-RR	200119	LSRCP-Hatchery M&E - Idaho	Mt. Snake Salmon	Snake SSCH Snake STHD	Smolt plant. Survival of hat. and nat. Life-history. NATURES
Supplementation Captive Brood	184-SS	200120	LSRCP-Reintroduction of	Blue Mt. Grande Ronde	Snake SSCH Snake STHD	Smolt plant. Survival of hat.

Table Action 184-2: Studies of the Effectiveness of Conservation Hatcheries						
Type Of Conservation Action	**Ref. Code**	**Project #**	**Key Words Or Title**	**Province/ Subbasin**	**Species ESU**	**Comments**
			Spr. Chinook and Study Steelhead in Lookingglass Cr. - proposed			and nat. fish. Genetics
Supplementation	184-TT	200121	LSRCP-Evaluation of Salmonids	Col. Plateau Snake River	Snake FCH	Fingerling plant. Survival, genetics, distribution
Supplementation	184-UU	200122	LSRCP-Walla Walla Steelhead Evaluation	Col. Plateau Walla Walla	MCR STHD	Smolt plant. Survival of hat. and nat. Genetics
Supplementation	184-VV	200123	LSRCP-Tucannon Spr. Chinook and Steelhead Evaluation	Co. Plateau Tucannon	Snake SSCH Snake STHD	Smolt plant. Survival of nat. and hat. Genetics, Life-Hist.
Supplementation	184-XX	199701500	Imnaha River Smolt Monitoring	Blue Mt. Imnaha	Snake STHD	Smolt plant. Survival of hat. and nat fish thru dams
Supplementation	184-YY	198902401	Juvenile Salmonid Out-migration in Lower Umatilla River	Col. Plateau Umatilla	MCR STHD	Smolt plant. Survival of hat. and nat. fish
Supplementation	182-D	198909800	Idaho Supplementation Studies	Mt. Snake Salmon, Clearwater	Snake SSCH	Smolt plants. 31 streams evaluated; test v. control streams
Supplementation	182-E	198909801	Idaho Supplementation Studies	Mt Snake Clearwater	Snake SSCH	Smolt plants. Data collected on 2 tribs.
Supplementation	182-F	198909802	Idaho Supplementation Studies	Mt Snake Salmon, Clearwater	Snake SSCH	Smolt plants. Data collected in 9 tribs.
Supplementation	182-G	198909803	Idaho Supplementation Studies	Mt Snake Salmon	Snake SSCH	Smolt plants. Data collection in 6 tribs.
Supplementation	182-H	199005500	Idaho Supplementation Studies - Steelhead	Mt. Snake Salmon, Clearwater	Snake STHD	Gathering info on wild steelhead pops. Genetic data on 72 wild and 5 hat pops
Captive Broodstock	184-Y	199305600	Assess Captive Broodstock Technologies	Mt. Snake Salmon	Snake SOCK Snake SSCH	Develops and improves tech.
Captive Brood Supplementation	184-FF	199800702	Grande Ronde Supplementation – Lostine	Blue Mt. Grande Ronde	Snake SSCH	Suppl. And captive smolts

Table Action 184-2: Studies of the Effectiveness of Conservation Hatcheries						
Type Of Conservation Action	**Ref. Code**	**Project #**	**Key Words Or Title**	**Province/ Subbasin**	**Species ESU**	**Comments**
Captive Brood Supplementation	184-GG	199800703	Grande Ronde Supplementation M&E	Blue Mt. Grande Ronde	Snake SSCH Snake STHD	Suppl. and captive smolts
Captive Brood	184-AA	199107200	Redfish Lake Sockeye Captive Broodstock Program	Mt. Snake Salmon	Snake SOC	Evaluate survival of various strategies
Captive Brood	184-BB	199204000	Redfish Lake Sockeye Captive Broodstock Rearing and Research	Mt. Snake Salmon	Snake SOC	Evaluate captive brood propagation
Captive Brood	184-DD	200001900	Tucannon Spr. Chinook Captive Broodstock Program	Col. Plateau Tucannon	Snake SSCH	Survival, Genetics, Evaluate propagation
Captive Brood	184-HH	199801001	Grande Ronde Spr, Chinook Captive Broodstock Program	Blue Mt. Grande Ronde	Snake SSCH	Evaluate G.R., Lostine, Catherine populations
Captive Brood	184-II	199801006	Captive Broodstock Artificial Propagation	Blue Mt. Grande Ronde	Snake SSCH	Evaluate rearing regimes
Captive Rearing	184-CC	199700100	Idaho Chinook Captive Rearing Program	Mt. Snake Salmon	Snake SSCH	Adult plants. Develop and test propagation and field performance
Captive Rearing	182-O	35027	Evaluate 2 Captive Rearing Methods for Steelhead & Coho	Lower Col. R. Abernathy Cr.	LCR STHD LCR Coho	Steelhead adult plants Coho smolt plants
Kelt Recondition	184-Z	200001700	Kelt Reconditioning – Enhance Iteroparity in Columbia Steelhead	Col. Plateau Yakima	MCR STHD	Adult plants. Develop and test propagation. Evaluate field performance; options
Kelt Recondition	184-WW	29007	Okanogan Kelt Reconditioning	Col. Cascade Okanogan	UCR STHD	Adult plants. Develop and test propagation. Evaluate field performance

D. Gap assessment: What more is needed

Based on an assessment of ongoing research relative to BiOp needs, it appears that sufficient studies directed at the effectiveness of conservation hatchery activities are underway. However, several issues were identified as gaps relating to the effectiveness of hatchery reforms in reducing extinction risk. They fall into two categories, the first being more urgent than the second:

Category 1 (most urgent, i.e., needed for 2003 check-in):

- Methodologies or analytical models (e.g., growth rate and extinction risk models) for synthesizing the results and detecting the effects at the population and ESU levels of a myriad of hatchery reforms and conservation hatchery activities in terms of their effects on extinction risk and/or recovery. As noted previously, most studies of hatchery reforms necessarily will focus on effects on individual lots of fish at a particular life stage. Therefore, the degree to which a reform reduces extinction risk at the population or ESU level will have to rely on models developed outside the particular study and/or as-yet unavailable information relating populations to ESUs. Similarly, many conservation hatchery activities will rely on imputed effects on recovery, i.e., on analysis of the contribution of the conservation hatchery to a particular life stage and, in turn, on effects at the population and ESU levels. (There will be cases, however, where the effects of conservation hatchery activities can be measured for the entire life cycle of a fish group.) This reliance on models and analyses extraneous to specific studies to detect changes in extinction risk or recovery will have to be considered in the design and selection of action 184 effectiveness studies and in applying any conclusions reached. Because no methodology exists for this kind of analyses, effective compliance with the intent of action 184 requires the development of suitable methodologies for synthesizing the results of reforms and conservation activities.

- Benefit/risk of steelhead kelt reconditioning, including evaluation of the relative reproductive success of steelhead kelts, as compared to standard broodstock collection and smolt supplementation techniques, with particular focus on effects on small, natural steelhead populations.

Category 2

- Predation by steelhead smolts on emerging steelhead, Chum, or Chinook fry

- Predation by spring Chinook smolts on emerging steelhead, Chum, or Chinook fry

- Short-term (but perhaps intensive) competition for food and space between hatchery releases of steelhead smolts and Chinook smolts and fingerlings and natural-origin fish in the tributary spawning and rearing habitat.

E. Action plan for meeting RME needs for Action 184

Guidelines for Action 184 projects
The purpose of action 184 is to determine the efficacy of hatchery reforms in reducing extinction risk and of conservation hatchery activities in contributing to recovery. This places this action in the category of Tier 3 AER, guidelines for which are generally described in Section 9.5.6.3 of the BiOp, and in more detail in the Tributary Monitoring section of this RME Plan.

Generally, these studies should involve controlled scientific experiments designed and replicated sufficiently to provide statistically and biologically meaningful results pertinent, preferably, to multiple programs. For studies of specific reforms, efficacy must be evaluated in terms of the specific fish affected by the study, and ultimately, in terms of their effects on extinction risk and/or recovery. In some cases, particular hatchery reforms or conservation hatchery activities already have been implemented, and the question is whether extinction risk was actually reduced or whether the action contributed to recovery. The potential may exist that useful information could be derived *post hoc* from actions taken in one area to inform reforms in other areas, assuming the reforms were accompanied by pertinent M&E. Whether studies are designed as new, controlled experiments to provide new information, or information is derived *post hoc,* from previously implemented actions, the overriding objective is to determine the efficacy of reforms in reducing extinction risk for the affected populations and ESUs, or the efficacy of conservation hatchery activities in contributing to recovery under a given set of circumstances.

Action 184 studies should outline the method employed to isolate and estimate the effects of a particular hatchery reform or conservation hatchery activity on survival, and how it is proposed that these effects will be extrapolated to extinction risk and/or recovery of the affected listed populations or ESUs. The focus should be on the effect of reforms and programs as they are actually conducted in the Basin, rather than on discontinued practices. Most listed salmonid ESUs comprise multiple populations, making direct measures of effect on extinction risk or recovery difficult. Certain indicators (e.g., survival rates for particular life stages), therefore, will probably be utilized, coupled with life-cycle models or new quantitative methodologies, to estimate the effect on population growth rates (lambda or other appropriate population parameter) and to evaluate effects of reforms on extinction risk (see Sections 1.3.1.2.1 and 1.3.1.2.2 of the BiOp for further guidance).

Studies involving hatchery reforms must be designed to address, at a minimum, the following questions:

- What is the nature of the hatchery program's deleterious effects or its potentially positive effects on listed populations?
- What is the efficacy of the hatchery reform in reducing deleterious effects or increasing potentially positive effects?
- To what extent and with what certainty will reduction of deleterious effects or increase of potentially positive effects reduce extinction risk for affected populations, and how is this determined?
- What effect will the reform have on other objectives, such as mitigation or harvest?

Studies involving conservation hatchery activities must be designed to address, at a minimum, the following questions:

- By what mechanism does the conservation hatchery activity being evaluated seek to contribute to recovery? (Best expressed in terms of the four population-viability criteria of abundance, productivity, distribution/population structure and genetic/life-history diversity.)

- What indicators will be evaluated to determine efficacy?

- How will net effect on recovery be evaluated (e.g., by direct measure of survival changes, extrapolation, modeling)?

Plans for addressing gaps in Action 184
As a preliminary result of the gap analysis described above, the need has been identified for additional studies directed at specific topics pertinent to this action. Two topics (noted previously) are most urgent, i.e., projects to address them should be initiated in 2003; the others will be solicited in the next round of provincial reviews. To obtain the most urgent of the new studies, a technical description of the needed studies was included in a targeted solicitation, the Request for Studies (RFS). BPA issued the RFS on March 14, 2003. Proposals submitted in response to the RFS have been preliminarily evaluated by the ISRP and the FCRPS Hatchery/Harvest RME Workgroup. Most of the entities that submitted a proposal have been asked to respond to technical comments by June 3. 2003. Final evaluations will be completed by early July 2003, and proposals selected for implementation are expected by early August 2003.

Action 167: Improving Estimates of Incidental Mortalities in Fisheries

A. Action 167 is presented in Section 9.6.3.2.2 of the BiOp and states:

> *The Action Agencies shall work with NMFS, USFWS, and Tribal and state fishery management agencies to develop improved methods for estimating incidental mortalities in fisheries, with particular emphasis on selective fisheries in the Columbia River basin, doing so within the time frame necessary to make new marking and selective fishery regimes feasible.*

A major, biological issue pertinent to managing fisheries is the extent of incidental mortality imparted on other species or runs. Incidental mortality estimation is particularly critical to the development and implementation of new types of selective fisheries necessitated by the presence of listed species throughout the year in the Columbia River Basin. For catch-and-release fisheries, accurate estimates of mortality rates of nontargeted fish are difficult to obtain yet are essential to determining whether a particular gear or method is suitable for its intended purpose, i.e., in catching the target species while limiting impacts on listed fish. Many variables impact these mortality rates, including encounter rates, gear type, handling techniques, temperature and recapture rates. Though gear development studies pertinent to the Columbia River Basin and elsewhere typically focus on immediate and short-term mortality, the critical question relates to effect on ultimate spawning (reproductive) success.

The purpose of action 167, therefore, is to improve estimates of incidental mortality rates (in terms of impact on spawning success) for existing fisheries and to determine or verify rates in new or experimental fisheries utilizing new kinds of selective gear and/or methods. The AAs are required to have initiated studies and/or developed methods by the 3-year check-in.

The AA address action 167 in their IP under Harvest Substrategy 1.2: Research to address incidental mortality in selective fisheries. That plan identifies incidental mortality studies underway in the Lower Columbia River in experimental tooth-tangle net fisheries and “ghost net” recovery efforts in Zone 6 that might lead to estimates of incidental mortalities from that source (and ultimately to reducing these mortalities if they are significant and location/removal proves feasible).

B. Performance Indicators and Standards

NMFS sets performance standards for allowable incidental mortality of listed fish in fisheries. The performance standard relevant to this action is the estimate of incidental mortality levels, in particular fisheries, expressed in terms of the effect on spawning reproductive success, using scientific studies capable of providing sufficiently accurate and precise estimates as needed to make fishery management decisions in the context of listed fish.

For the purpose of implementation of the BiOp, the applicable performance indicator is the initiation and continuance of a sufficient number and quality of studies by the 2003 check-in. The studies must be designed to produce quantitative results applicable to cohort and harvest models used in harvest management. In addition, accurate estimates of direct and indirect harvest mortality are needed in other forums addressing adult passage survival performance and stock-status monitoring.

C. RME needs assessment

General description of BiOp requirements
Action 167 does not identify a specific number or type of studies. Rather, it identifies the need to address uncertainties surrounding incidental mortality rates generally, while highlighting the question for fisheries involving new selective gear or methods, particularly those under development per the closely related action 164 (Development of Selective Fishing Methods and Gear).

General description of current projects underway relevant to RPA 167
In 2003, the AA will enter their third year of providing funding to test the feasibility of tooth-tangle nets applied in commercial fisheries for Chinook in the Lower Columbia River. These tests are intended to estimate the extent of incidental mortality in these fisheries to determine whether the commercial gill net fishery using this gear and method can target abundant hatchery fish while constraining incidental impacts on listed fish within established ESA limits. These tests have been refocused in light of results to date, particularly the high numbers of steelhead caught and released during 2002 fishery.

D. Gaps assessment

Incidental mortality studies have been undertaken for the selective fisheries being evaluated in the basin. Thus, no specific gap has been identified at this time. This conclusion is premised on continued funding of the incidental mortality studies associated with existing selective fishery evaluations and for any additional selective fishery proposals that may emerge.

E. Action Plans for Meeting RME Needs for Action 167

In addition to continuing existing studies, further incidental mortality studies should be undertaken coincident with the development of new selective fishery methods or gear prior to widespread deployment. Greater harvest selectivity will provide the greatest survival benefit to listed species if and when it is brought to fisheries with large impact on listed species. Accordingly, the approach to implementation of new action 167 studies would be to act opportunistically to new selective fishery proposals as they emerge, and to promote such studies through the co-managers, particularly for high-impact fisheries like the Zone 6 gill net fishery or selective mark recreational fisheries, including steelhead.

References

McClure, M.M. et al. (2000) ??

6. Data Management RME Plan

Introduction

The 2000 NMFS FCRPS BiOp has specific research, monitoring and evaluation requirements to support periodic assessments of the adequacy of RPA implementation . The AAs have completed an IP for the BiOp, including an RME section. This Data Management Plan specifically addresses the RME section of the IP; however this description of data management is a subset of the overall information needs for the BiOp. Furthermore, the BiOp data-management requirements as a whole are a subset of the fish and wildlife data requirements for the Columbia River Basin natural resource management process. This data-management plan directly addresses the data requirements for BiOp Actions 179-199 and complements regional fish and wildlife data-management requirements. It surveys other data- and information-management activities in the basin and proposes ways to integrate the proposed opinion process with these basinwide activities.

Data management in the IP is primarily aimed at satisfying action 198:

> *"The Action Agencies, in coordination with NMFS, USFWS, and other Federal agencies, NWPPC, states, and Tribes, shall develop a common data management system for fish populations, water quality, and habitat data."*

Data-system development cannot proceed in the abstract without detailed knowledge of precisely what, where and when data will be collected, and with what methods and standards it will be collected. Not all of this information is final because it depends on funding decisions. Therefore, final decisions on data-collection deliverables cannot be made. The data needs of the IP will, however, be based on detailed program plans made to implement actions 179-197 and 199. The Tributary Monitoring, Hydro, Hatchery/Harvest and Estuary/Ocean RME plans must specify their data-management requirements, including the data attributes, collection protocols, methods, standards, users, reporting requirements, etc. The data-management plan must detail the development of a data-management system to support these identified data needs, including an intensive effort to standardize data collection and reporting methods[21].

The BiOp RME data-management plan will also be developed within the proposed Columbia Basin Cooperative Information System (CBCIS) process. Important, high-level decisions need to be made on administrative responsibility and funding for CBCIS and the extent to which information system standards and protocols will be uniformly adopted across all RME programs throughout the region.

Data-quality issues are of particular importance to BiOp RME efforts and present particular challenges for the development of BiOp RME data-management products. In addition, there are data-quality issues arising from the Data Quality Act that applies to all Federal agencies.

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[21] This will require agreement from all RME action groups to adopt common standards and deploy them, action that has not yet occurred and for which there would need to be dedicated program and funding.

Overall RME Data Management Objectives

Systemwide Data Management

A common system will be developed for the efficient and effective collection, management and distribution of information relating to RME needs as specified in BiOp for actions 179-199. The system will be verified for compatibility with the fish and wildlife data-management requirements for the Columbia River Basin. The BiOp RME database will be incorporated into a regional data-management system when such a system is developed.

Specific recommendations are:

- Develop an overall RME information system architecture—a detailed blueprint of the design of the RME system.
- Take advantage of existing, potential data centers. Include information portals/distributed database-management system tools as necessary to consolidate data and communicate using the Internet.
- Develop a datamanagement cost-sharing approach to achieve BiOp requirements.
- Promote the free exchange of information and development of a systems view of the Columbia River Basin.

Subbasin Data-Management Prototype)

Develop a data-management program to meet research monitoring and evaluation data-management needs for subbasin specific BiOp RME pilot implementation projects.

- Recognize the need to develop an information system(s) in a modular fashion so that the system(s) meets the practical needs of the local users while meeting the legal and administrative requirements of the region.
- Perform a scoping exercise. Develop specific objectives, deliverables, timelines and budgets for a prototype.
- Develop and use common protocols and techniques for data collection, development, storage and distribution.
- Ensure that data can be shared as needed for timely analysis.
- Ensure properly documented metadata for published data and information. Include data pedigree and metadata and clearly distinguish primary data and derived information.
- Adopt geospatially reference standards using repeatable standard methods. Where possible make the data available as spatial data layers.
- Provide security for data, systems and participant information where necessary.

- Work collaboratively and cooperatively to obtain necessary data and improve data quality.

Identify Implementation Plan Strategies and associated actions.

Background
To support the decision-making process, the BiOp RME Data Management Team solicited input from regional experts with experience in developing or managing large-scale regional information systems. The strategic findings of the group were as follows:

- A key discussion concerned how to meet the BiOp short-term needs and how to do this efficiently and in a way that allows integration and compatibility of the information with other regional data-management efforts. In particular, an interim repository is needed for the upcoming field season. We agreed to pursue prototypes.

- A key point was not to focus or decide on technology/database solutions until after the specific needs, data outputs and data inputs of the planned user group have been thoroughly defined in a detailed needs assessment with the creation of a data dictionary.

- The team agreed that data analysts should perform the data dictionary/needs assessment.

- Following the creation of a prototype data dictionary for pilot RME projects, the team would evaluate the specific data-management needs and determine if existing data-management systems are adequate. If not, a more formal system analysis would be conducted to make decisions about how best to meet those needs through 1) augmentation of existing management systems, 2) the establishment of a new centralized data-management systems, or 3) the creation of a distributive system of subbasin databases and portal efforts. Emphasis was placed on the benefits of achieving the results in an iterative and modular fashion rather than through a large-scale development process that might solve all problems at one time, but at the risk of not meeting critical time and functional needs.

- The team agreed that with respect to the hydrological foundation for the BiOp RME effort the 1:24,000 GIS–enabled data from the USFS/BLM/state hydrographic effort will be used where available and when it has passed sufficient regional review. This process involves the use of a shared data set based on common standards with built-in quality control and quality assurance. It supports the mounting of verified and validated field data on a common server for widespread use, a function similar to that needed for BiOp RME.

- Finally, there was discussion about how the BiOp RME data collection effort relates to the CBCIS initiative.

The Columbia Basin Cooperative Information System in relation to BiOp RME Needs.
Science Applications International Corporation (SAIC) has now completed a high-level, information management needs assessment in the Columbia River Basin[22]. At the May 2003 meeting, the NPCC, with NOAA Fisheries agreement, proposed to move forward with the following action: to receive public comment on the CBCIS report, to propose a draft administrative structure for CBCIS, to identify a budget and cost-sharing agreement, and to approach the stakeholders about commitments for a CBCIS-style regional information system.

The AA propose to meet action 198 with the proposed CBCIS project. However, with current funding for the CBCIS project (approx $250K), and without further commitment from the AA, the CBCIS project will not satisfy the scope and deliverables in action 198. An estimate of overall costs, not all of which would be for BiOp RME needs, is identified below. It is also important to understand that funding alone will not create a common data management system. Commitments (probably through Memoranda of Agreement) to develop and apply regional standards are also necessary.

Performance Indicators and Standards

Identify performance indicators.
Programmatic performance indicators for data-management programs will include

- Meeting defined user needs as specified in the design documentation for each deliverable.
- On-time delivery based on the data-management project plan.
- On-budget delivery based on the data-management project plan.
- Satisfies Internal Validation and Verification (IV&V) reporting requirements.
- Meets overall BiOp RME system requirements as in action 198.
- Meets applicable quality and reporting standards.

Identify Performance Standards or plans for development and any issues (if applicable).
Neither the Columbia River Basin as a region nor the AA have adopted standards, for information system development, for example, for completing metadata, for data collection methods, for GIS spatial data, or for compliance with a common data dictionary.

Data-quality issues are of particular importance to the efforts of BiOp RME implementation projects. There are new data-management quality issues arising from the Data Quality Act that apply to the Federal agencies. For example, NOAA Fisheries[23] has obligations, under the Data

[22] SAIC, April 30th 2003. Recommendations for a Comprehensive and Cooperative Columbia River Information Management System. SAIC, Battlebro, VT. A press release and a copy of the SAIC report are available on the NPCC web site http://nwcouncil.org/.
[23] The data-management group does not have details of all action agency DQA policies.

Quality Act[24] to qualify data when it is used in NOAA decisions and reports. This has implications for all ESA decisions and programs in the BiOp RME plan. For example, the Data Quality Act applies to the use of third-party information and most planned BiOp RME efforts depend on third-party information to some extent.

The NOAA Data Quality Act policy details the following general standard and language for third party data:

> *"<u>General Standard</u>: Information is presented in an accurate, clear, complete, and unbiased manner, and in proper context. The substance of the information is accurate, reliable, and unbiased; in the scientific, financial or statistical context, original and supporting data are generated and the analytical results are developed using sound, commonly accepted scientific and research methods. "Accurate" means that information is within an acceptable degree of imprecision or error appropriate to the particular kind of information at issue and otherwise meets commonly accepted scientific, financial and statistical standards.*
>
> *If the information is "influential," i.e., it is expected to have a genuinely clear and substantial impact on major public policy and private sector decisions, it is noted as such and is presented with the highest degree of transparency. If influential information constitutes an assessment of risks to human health, safety or the environment, indicate whether the risk assessment was qualitative or quantitative…*
>
> *…Use of third party information in the product (information not collected or generated by NOAA) is only done when the information is of known quality and consistent with NOAA's Section 515 Guidelines; any limitations, assumptions, collection methods, or uncertainties concerning the information are taken into account and disclosed"*

The Data Quality Act creates a regional data-management challenge because each Federal entity is required to develop its own standard for compliance with the Data Quality Act. Therefore, it will be important to evaluate whether or not the Data Quality Act can be uniformly applied within the Columbia, at least with respect to BiOp RME.

The federal government also has a set of "best practices" or guidelines for application and use by agencies involved in enterprise-level system development[25], which will be used to inform ongoing, high-level BiOp RME planning.

RME needs assessment

Detailed professional level assessments are necessary for prototype BiOp RME programs and for overall BiOp RME data-management planning. A detailed needs assessment is a process undertaken by information system data analysts to identify and document, at a fine level of detail, the attributes of the information that will be collected, the products that will be produced, and the business (or administrative) rules that will govern system operation.

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[24] Section 515 of the Treasury and General Government Appropriations Act for Fiscal Year 2001 (Public Law 106-554). Links to DQA information are at http://www.noaanews.noaa.gov/stories/iq.htm and http://www.whitehouse.gov/omb/inforeg/agency_info_quality_links.html

[25] "Federal Enterprise Architecture Framework version 1.1 Sept 1999."

General description of FCRPS Opinion RME requirements
Under BiOp RPA action 198 the AA are charged with addressing the data requirements for actions 179-199 of the BiOp in the context of a common regional data-management system. The integration of the BiOp requirements into a common data management system is addressed in the following work plan.

The BiOp requirements for data management must support the RME Plan's principle components of Population/Environmental Status Monitoring, AER and CUR associated with the needs of check-in assessments and actions 179-199. Specific descriptions of these assessments and actions can be found in Chapter 9 of the BiOp.

General description of current projects and programs addressing these needs

General reviews of current programs and projects:

- The May 2000 Independent Scientific Review Panel's Review of Databases Funded through the Columbia Basin River Fish and Wildlife Program identified specific information system development needs and was critical of the current system.

- In November 2000, the National Science and Technology Council Committee on Environment and Natural Resources concluded in its From The Edge - Science to Support Restoration of Pacific Salmon that "Current monitoring will need to expand and, data storage/retrieval, and evaluation processes will need to evolve in complexity and increase capacity. Monitoring and data systems need to keep pace to facilitate improved quantitative approach to salmonid recovery and restoration."

- The 2001 Inaugural Annual Report of the Columbia Basin Fish and Wildlife Program 1978-1999 noted that "Since 1978, Bonneville's fish and wildlife expenditures total $3.48 billion" and made this major conclusion: "While we report on Bonneville's fish and wildlife expenditures, our report also notes the confusing state of fish and wildlife data collection and reporting in the basin. This must improve. When it does, accountability to the public for the Council's program and Bonneville's expenditures will also improve."

- Recently, the GAO-02-612 reported: "Columbia River Basin Salmon and Steelhead – Federal Agencies' Recovery Responsibilities, Expenditures and Actions" noted that [While] Federal agencies have undertaken many types of recovery actions and, although these actions are generally viewed as resulting in higher numbers of returning adult salmon and steelhead, there is little conclusive evidence to quantify the extent of their effects on returning fish populations…The data to quantify the effects of these actions on fish populations are generally not available…" While the GAO report did not comment directly on the capability of the regional information system to manage available data, the implication of the GAO report is that critical data, essential for determining the effectiveness of recovery actions is not being collected.

Regional data-management development projects underway in the Columbia basin include the following:

- The funding process for the FY 03 Columbia Basin Mainstem and other funding proposals that include proposals for RME data collection, analysis and management. Significantly, there is no regional information plan or regional information architecture to guide these decisions. Only a few proposals address RME needs.

- The CBCIS project has identified regional needs for information system development for the Columbia River Basin (of which RME is considered a highly relevant subset). The CBCIS initiative results from a memorandum of agreement between the NPCC and the NMFS.

- The Regional Ecosystem Office (REO) effort, an interagency support effort to develop and manage regional data sets, for example 5th and 6th HUC watershed delineation data and 1:24,000 forest and watershed data.

- Data Access in Real Time (DART). DART provides access to current and historic information from sources such as StreamNet, the Fish Passage Center and others. As such, it is considered a "second tier" database. DART uses a report generator to allow users to select one or more routinely prepared documents, graphs, etc., for viewing and printing.

- The Fish Passage Center (FPC). The center provides specific analysis of alternatives for fish passage, such as those used for decisions on flow augmentation, spill, adult passage and the like. It provides analysis and reports to state water quality agencies. The FPC designs and oversees the Smolt Monitoring Program and manages the Comparative Survival Study.

- StreamNet is the Northwest Aquatic Resource Information Network. StreamNet operates a PC-based database containing fully referenced data and an online query interface. It maintains a library and reference system for use in monitoring and evaluation of Columbia River fish stocks. StreamNet prepares an annual report on status of runs, including some data on environmental conditions that could affect status. StreamNet does not evaluate the implications of published data.

- PIT-Tag Information System (PTAGIS) is a program to provide database systems management and operations for the collection and distribution of PIT tag data to all interested parties. It collects data from tag detectors on hydroelectric dams on the Columbia and Snake Rivers and provides user training and support.

- The Coded Wire Tag Recovery (CWT) and Regional Mark Information System (RMIS). The CWT program provides for a joint Washington and Oregon sampling effort for coded wire tags, while the RMIS provides for the recovery and management of data from the tags that are made available through the Pacific States Marine Fisheries Commission Regional Mark Information System.

Needs Assessment

Summary:

The BiOp sets programmatic and project reporting obligations at years 3, 5, and 8. RPA action 198 calls for a common data-management system for the region that is sufficient to meet these obligations. No existing regional data-management system meets the data-management BiOp requirements.

General data-management needs for the BiOp are well understood. They include a need to communicate via the Internet, geo-spatially reference data for use with GIS tools, a data quality–control program that includes data-collection standards, information portals or other tools for the purpose of consolidating key data sets, and employment of current information system technologies (for example, GIS spatial data technology, integrated database technology, such as Oracle, and web-enabled data exchange and information system enterprise management). These needs are not met by any existing regional data-management system. Specific data management needs of the BiOp RME Plan, as outlined with each technical section of the Plan, are presented in Table 6.1.

Since data management standards do not exist for the BiOp RME process, Table 6.1 represents the first attempt to standardize across RME action implementation planning. The following general recommended actions reflect the needs assessment within the BiOp RME Plan, as well as across the region to support and facilitate implementing a BiOp RME data management system.

- A more comprehensive scoping of existing regional data-management projects/goals/needs.

- A formal comparison of regional data-management goals/needs compared to the FCRPS BiOp goals/needs.

- The development of an BiOp RME information system architecture or blueprint that is consistent with regional needs.

- The development/organization of information system capability in a modular fashion so the system(s) meets the practical needs of the local users while meeting the legal and administrative requirements of the region.

There are also important overall architectural choices with at least two approaches (and combinations thereof) to information system design:

- <u>A Distributed Database Management System (DDBMS).</u> A DDBMS provides the tools and protocols to connect multiple users and databases into a coherent information system and provides considerable advances over the informal resources currently available through the Internet. Users have the benefit of using common protocols for information sharing, data inventory, data transfer and interchange, metadata, data recovery, data collection, data distribution, confidentiality and version control. Users also would be able to use the new system without needing expert knowledge in computer networking and data transformation.

However, a DDBMS system with weak or diffuse central control over the institutions involved in data collection and distribution[26] presents many challenges. DDBMS systems rely on consistent, repeatable application of common technologies and data-management tools. Given this reality, there may be circumstances where portal development offers a more efficient and effective architecture. Moreover, it is possible to use combinations of DDBMS and portals, depending on actual user needs and the maturity of existing systems. Designers of RME architecture need to stay open to all these possibilities. There are also legal issues. Because of legal requirements of "maintaining a record" of administrative decisions under a Section 7 ESA consultation, the AA and regulatory agencies cannot rely entirely on existing, ad-hoc regional arrangements for data management.

- A Centralized Information Management System. A centralized system provides some advantages over a DDBMS. These advantages include central control over user access and security, standardized formats for managing data and accessing it and the ability to provide a consistent approach to managing different versions of documents. There may also be efficiencies arising from economies of scale and staffing. However, they also have disadvantages: they require a very high level of agreement between participants to join such a system. Where the participants have different mandates, constituents and/or business objectives the operational agreements and cost-sharing arrangements can be difficult to overcome. A further weakness is that entire centralized systems can become dependent on a single (or limited) set of technologies that can restrict opportunity to take advantage of improved technology.

The BiOp RME data-management plan proposes an iterative pilot process in parallel to CBCIS where regardless of the architectural solution (about which there are legitimate differences of opinion), detailed and exacting RME needs assessments are necessary to ensure consistency, completeness and integrity of a regional system.

There are pitfalls to be considered when developing a regional database concurrently with pilot implementation programs. For example, standards can be developed in advance of pilot programs, or they can be developed concurrently with the expectation that at least some of the prototypes will need reengineering if different standards are adopted. Data-management system and RME program managers need to be aware of the consequences of such tradeoffs. Because the most probable consequence of reengineering is substantial, increased early attention to standards is critical.

Ultimately, regional data management should be conducted within a formal information system built at an enterprise level, for example as described in the Federal Enterprise Architecture Framework. A formal approach would systematically develop awareness of the problem, build consensus on the approach, assess the extent and details of the project, undertake renovation and

[26] As is the case for current data-management arrangements among institutions in the Columbia Basin.

rebuilding of existing information infrastructure, test the solutions, and deploy the preferred solutions. The CBCIS effort may meet the scoping requirements for a formal architecture. However, an early commitment and deliberate action plan will be necessary if the CBCIS effort will meet RME obligations under the BiOp.

Table 6.1. RME Workgroup Data Management Needs Summary - Derived From The RME Implementation Plan (RME Plan 12-20 draft. Doc) and updated information from some workgroups.

RME Workgroup	RPA	Role of the Workgroup	Status of RME workgroup plan including dates, contacts, deliverables, etc)	What is the data-management task for the different workgroups?	Are needed data adequately identified and defined?	Is source/location of existing /new data adequately identified?
Data management Workgroup.	Compliance Monitoring	Coordination.	The AA have proposed and are developing an Implementation Planning (IP) database in Microsoft Access.	Track all action agency projects for salmon recovery in Columbia. There is also a proposal from the Federal Habitat Team for a "Habitat Tracking Initiative" to track all project data for habitat-related projects in the Columbia.	AA have defined their own needs. The Federal Habitat Team has also developed a draft list of data needs.	The AA are sourcing data from internal project files. The Federal Habitat Team will need to consolidate data from across multiple federal agencies, and from the AA IP data base. Source of needed habitat data needs to be determined.
	180-181	Coordination.	Pilot Habitat data management plan depends on programmatic refinement from the P/E Status monitoring group.	The current data task is to support data management for the 3 P/E status monitoring projects.	See below.	See below.
	198	Coordination with Regional lead entity.	Not known.	Not known.	A preliminary data inventory has been completed.	Partly complete.
P/E Status Monitoring Workgroup	180,181	Primary.	The scientific goals and objectives are complete. Programmatic details of data collection are not known (Who what, when, how).	Manage the data for three pilots habitat and population monitoring projects: John Day, Wenatchee and Upper Salmon.	Most attributes are identified, but not sufficiently defined.	Historical data sources have been identified. Management for new data is not known.

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	183 (AER) Project Based	Coordination	Programmatic details are not known.	Some data collected by AER and P/E status will be used by both.	Particular indicators and protocols will be developed cooperatively with AER. (Which ones?)	Not known.
	183 (AER) Watershed	Primary.	No planned program implementation before 01-04.	Manage the data for three pilots habitat and population monitoring projects: John Day, Wenatchee and Upper Salmon.	Most attributes are identified, but not sufficiently defined.	Historical data sources have been identified. Management for new data is not known.
	182 (H/H)	Coordination.	Programma tic details not known.	Assess extent of naturally spawning fish.	No.	No.
	198	Coordination.	The draft status monitoring RME plan discusses importance of action 198.	The P/E Status group identifies that Data management is the overall key for coordination of the many sub-projects.	No.	No.
Action effectiveness Workgroup	183	Primary.	The scientific goals are developed. Programmatic details are not fully developed. There is a draft schedule with field collection beginning June 03. There are some broad data collection and project costs.	The data management needs of AER are not known. The draft states that "data collected would go to repositories….this needs much additional thought and discussion." The nominal project scope is initially to complete 3 pilot data collection efforts (John Day, Wenatchee, Upper Salmon) beginning 03 with 3 additional pilots in 04.	Sample sites and responsibility for data collection at sites are yet to be determined. Experimental design includes lists of physical and environmenta l indicators to be collected.	No.
	198	Coordination.	To be determined.		No.	No.

Table 6.1. RME Workgroup Data Management Needs Summary - Derived From The RME Implementation Plan (RME Plan 12-20 draft. Doc) and updated information from some workgroups.

Hydro	185, 186, 187,188,189, 190,191,192, 193,195,199	Primary.	There appears to be substantial reliance on existing program.	Few data collection needs are identified. There is a single reference in the Action Plan for status monitoring that for each ESU the HWG will "Determine what data or estimates are needed for each demographic unit in order to conduct the tests….."	Not known.	Not known.
	198	Coordination.	To be determined.		No.	No.
Estuary Ocean Work Group	158	Primary.	Estuarine Habitat Inventory.	No data collection needs are identified for the RME data management group. There is a single reference to two mapping efforts in the Estuary partnership Program providing comparative data and a Task…. to "review existing data and assess limiting factors".	Not known.	Not known.
	161	Primary.	Estuary RME Program.	There are tasks to "develop performance indicators and standards" and to "Coordinate with the <u>data-management subgroup</u> to establish data-management protocols to ensure access and usability of the data." There are data-management tasks in Table xx for the Estuary partnership to develop database capability using "STORET," to implement a short-term approach to managing data using networked databases and to seek funding for a "totally interactive data management system."	Not known.	Not known.
	162	Primary.	Conceptual Model of Estuarine Ecological Relationships.	Reference to a need for data and information to fill gaps…but no specificity as to who will provide it.	Not known.	Not known.

Table 6.1. RME Workgroup Data Management Needs Summary - Derived From The RME Implementation Plan (RME Plan 12-20 draft. Doc) and updated information from some workgroups.

	196	Primary.	Salmon Use of Estuary.	No reference to needed data – Project is in appropriation stage.	Not known.	Not known.
	197	Primary.	Salmon Use of Plume.	No reference to needed data – Project is in appropriation stage.	Not known.	Not known.
	194	Primary.	Physical Model of Lower Columbia River and Plume.	Reference to a need for data and information for CORIE (pilot environmental observation and forecasting system), but no specificity as to who will provide it.	Not known.	Not known.
	198	Coordination.	To be determined.		Not known.	Not Known.
Hatchery Harvest Workgroup	182	Coordination.	Data reliance appears to be with existing collection and management programs. Unspecified additional studies are needed, but no specific data gaps are identified. A new hatchery program database, developed by Mobrand Biometrics will be a data source.	More work is needed to define data needs. There are no references to needed data, except for a "counting component" data need that will be managed by the P/E status monitoring group …see above.	Not Known.	Not Known.
	184	Coordination	Data reliance appears to be with existing collection and management programs. Unspecified additional studies are needed, but no specific data gaps are identified. A new hatchery program database, developed by Mobrand Biometrics will be a data source.	The work group is still identifying the scientific questions that need to be addressed. Once these details are decided data needs will be considered.	Not Known.	Not Known.

Table 6.1. RME Workgroup Data Management Needs Summary - Derived From The RME Implementation Plan (RME Plan 12-20 draft. Doc) and updated information from some workgroups.

	167	Not Known	Data reliance appears to be with existing collection and management programs.	No scientific or data needs have been identified. More work is needed.	Not Known.	Not Known.
	198	Coordination	To be determined.		Not known.	Not Known.

Action Plans for meeting RME Needs

RME Data Management Work Plan

Note: At this point, no dedicated funding has been allocated to the BiOp RME Data Management Plan, beyond that required one of the data management tasks below. Therefore, in terms of work products, BiOp RME data management is restricted to a limited coordination effort. Programmatic commitment to and funding for BiOp RME data management is a critical current gap.

The following table outlines the recommended BiOp RME Data Management efforts to be completed. While the list enumerates current needed data management support tasks, it is likely that additional needs will emerge as the IP process transitions from scientific and technical guidance to the implementation of data collection efforts.

A generic outline for planning and development of a systemwide information system is included below, following the RME Data Management Work Plan.

RME Data Management Work Plan			
Strategy	**Objective**	**Task**	**Estimated Schedule[27]/Costs[28]**
Systemwide Data Management – especially Action 198	1. Review existing data management projects/ goals/needs and compare to FCRPS goals/needs. Includes: development of cost sharing arrangements and MOAs between the agencies.	1. See 1-3 below table.	1. This task requires a detailed needs assessment and scoping. The task is estimated to take 3-6 months for a regional coordinator /project manager and 2-3 data analysts.
	2. Develop common FCRPS RME information system plan together with architecture, standards and protocols.	1. See 4-7 below table.	Time, detailed tasks and costs depend on scoping above. However, significant progress on a project of this scale and complexity will require a substantial information system development team for a 2-3 yr effort[29].

27 The schedule for habitat subbasin strategy is based on the "Schedule for Tributary Effectiveness," which states that compilation of survey information will occur in October '03. This proposal assumes that the Population and Status Monitoring group adopts a parallel schedule for the purpose of database development.

28 The estimates provided here are based on best professional judgment based on experience of what database consolidation and web/GIS development /deployments at these scales typically cost.

29 The SAIC report has identified some 46 steps that would be necessary for the Columbia region to develop and adopt a common data management system. Preliminary labor estimates of this effort derived from SAIC time estimates approximate $4.3M.

RME Data Management Work Plan			
Strategy	**Objective**	**Task**	**Estimated Schedule[27]/Costs[28]**
Habitat Pilot Data Management for three sub basins[30]	1. Scoping pilot data-management project and project management	1. Fully scope data resources. Prioritize needs and develop detailed project plan. Manage project.	Data analyst, 2 months, $15K[31]. Project Management (except deployment), 12 months at 0.25 FTE, $25K. All project travel $15K.
	2. Pilot data-management needs assessment.	1. Validate data needs outputs and model inputs. 2. Identify data protocols, needed spatial data layers, QA/QC methods, etc. Identify standard data reporting protocols for the three subbasins. 3. Review needed data for compatibility. 4. Develop initial data dictionary for needed data. 5. Identify initial business rules for operating pilot information system.	Data Analysts, 3 months, $30K.
Total Planning and Design			**$85K**
	3. Go-NoGo decision	Client to review and make decision	
	4. Develop pilot information management system.	1. Confirm needs. 2. Design and develop information management solution. 3. Build, test and document the pilot system.	Web Developer, 6 months, $55K. Database Developer, 6 months $60K. Documenter, 2 month, $12K. Tester, 3 month, $18K.
Total Development			**$145K**
	5. Pilot Deployment (for 1 year)	1. Provide user training. 2. Populate the data system with available data. 3. Maintain pilot database and access and perform backups and database maintenance.	Deployment project management 0.1 FTE/yr, $9K. Data Specialists-Application Administrator, 1.0 FTE/yr, $70K, Data Base Administrator, 0.2 FTE, $20K. Trainer, 1month $6K.
Total Deployment			**$105K**

[30] Note: these estimates were developed for the unsupported 35048 Proposal, which included in-kind contributions.

[31] For data needs for the John Day pilot.

RME Data Management Work Plan			
Strategy	**Objective**	**Task**	**Estimated Schedule[27]/Costs[28]**
	6. Monitor and Evaluate	1.Independent Validation and Verification.	Senior analyst, 1 month $15K.
Total Monitoring and Evaluation			**$15K**

Outline of RME Data Management Systemwide Work Plan

1. Include general participant goals for each participating agency
(This example is for NMFS, other participants would have their own):

- Recover protected fish species, build sustainable fisheries and protect and restore critical fish habitat;
- Identify risks and opportunities for ecosystem protection and restoration;
- Make data and information accessible, compatible, and usable to support defensible and scientifically sound decision-making related to the necessary protection, and maintenance, of Columbia River Basin fishery resources.

2. Develop background information
This information sets the stage for considering and making system changes to meet RME goals and provides a basis for understanding the consequences of the changes.

<u>Identify FCRPS BiOp data-management roles and responsibilities for RME data management:</u>

- National Marine Fisheries Service
- Bonneville Power Administration
- Corps
- BOR
- USFWS

<u>Recognize other potential data sources and users:</u>

- Columbia Basin Tribes
- CBFWA
- Northwest Power and Conservation Council
- Local governments
- State agencies
- Other Federal agencies
- Federal Caucus or other interagency entity
- Existing data management programs (Dart, StreamNet FPC, CWT, PITAGIS, etc.)
- Regional Assessment Advisory Committee
- Independent Science Advisory Board
- Citizen/environmental groups

Identify relevant information management system reports or documents (for example):

- 2000 FCRPS BiOp
- Fish & Wildlife Program 2000 Plan Amendments
- ISRP report
- Subbasin Assessment Template
- All-H paper
- Other reports

Identify critical legal issues (for example):

- Are there intellectual property rights or other information ownership issues?
- What are the FOIA and other legal obligations for data management?
- Do all users have equal legal rights to the information?

Identify budget and staffing needed for RME

- What are the current funding arrangements for information system management?
- What are the current staffing and information skill levels?
- Are there critical staffing gaps? Is there adequate funding for the development? For deployment?

Identify current organizational and system infrastructures

- System infrastructure detail would include descriptions of operational databases, hardware, software and networking resources, analytical tools and would identify dependencies on other systems.

3. Define Required Data-Management System Functions and Needs

Support collection of scientific data

- Support collection of RME data.
- What data will be collected, when, where and by whom?
- What input devices technologies will be supported?
- If the data are already being collected but need to be used for analysis, where will it come from and how will it be managed prior to analysis?
- Are data-collection standards in place and what are they?

Support the collection of metadata.

- What standards will be used?
- Who will maintain metadata?

Support access to collected data and other information

- Who will have access, at what times, and for what reasons?
- Who will the gatekeeper(s) be?
- What security system is needed? Would public key infrastructure, digital signatures or other methods be used?
- How important is the timeliness of access?

Support information use

- Will the RME data-management system provide access to these data and/or provide or develop tool sets that enable data analysis?
- Will the access be provided online, through dial up, through the web or both?
- Will paper documentation and reports be provided?

Support system maintenance

- For example, how will users be registered, and firewalls maintained?
- What firewalls are necessary?
- How will records be maintained and archived?
- What master data will be maintained, for example, species lists?
- Who will have authority to update, delete, copy or archive records?

Support archives

- How will the archive/legacy function be provided?

4. Define Necessary Operational Processes

What are the critical operational processes that must be included in the information system design? For example, if secure access to the information system is needed, the system design must accommodate this. If security needs dictate encryption of data transmission, then an additional operational layer is needed at the system design level. These issues relate directly to necessary functions and needs detailed in 3.0 above.

5. Define System Architecture

Evaluate options for an RME system architecture. What would the RME system architecture look like? Would it be a subset of a Columbia regional information system architecture, or would it stand alone? How would it relate to existing architectures?
Standards for overall system dependability, needed development of linkages to existing distributed databases, support of web enabled access, analytical capability, metadata and responsibilities for system maintenance need to be considered and developed.

The design would need to specify the way (at least) each of the following system components interact and combine to satisfy the stated functional/operational needs:

- Database(s)
- Communication
- Tools
- Security layer and firewalls
- Web application
- Transactions
- Data Archiving
- Internet Services,
- GIS Repository

6. Define Reporting Standards

The plan should include specific standards for
- Metadata
- Geospatial information
- Scientific reporting and sampling (unless otherwise specified)
- Regional data consistency (how are the data going to be used by other data users)

7. Complete Design Review or Develop Prototype

A design review should be completed or a prototype built and tested to see whether the system can meet defined functional and operational needs. NMFS prefers prototypes.

8. Define System Specifications and Documentation

These specifications and the design should be sufficiently developed and detailed to fully support the system build by a third party through an RFP or other similar process.

- Database Specification
- Security and Access Specification
- Communication Protocol Specification
- GIS Specification
- Administration Specification
- System Maintenance
- Web Site and Form (page) Specifications
- Prescriptive Performance Standards
- Master Data Specifications

The plan should include cost and time estimates for all component parts for each of the following:
- System Project Planning
- System Design
- System Build
- System Testing
- System Deployment
- System Maintenance and Upgrading

9. Develop Administrative/Organizational arrangements (logistics)

The plan should include a review of administrative/organizational arrangements, to ensure adequacy of staffing, funding and planning for equipment purchases for deployment. The plan allow understanding of what system will be built, what the system will do, what skills and resources are necessary to deploy and maintain the system and what if any will be the implications for the pre-existing organizational arrangements identified in 2.0 above. The plan will address how current problems will be solved and emerging needs will be met.

Alternatives should be addressed in the planning process. For most system components, there will be alternatives.

The plan should include details of administrative/organizational responsibility and funding arrangements for each part of the plan to address at least the following questions:

- Project Planning - a detailed project plan is necessary,
- Approving Design,
- System build,
- Deployment,
- Maintaining the system,
- Operating the system, and
- Training for operators and users.

Because many groups may have particular and potentially different interests in the data-management system, the plan would need to establish clear mechanisms through which system operation would serve to meet all interests' needs. Memoranda of understanding or operational agreements may be necessary.

10. Build and Deploy

The project plan should include time schedules for all components and deliverables (near and longer term) and cost estimates for each part of the development, including deployment. A full life-cycle approach to project planning and cost analysis is needed. Instead of a formal design review (in section 7 above), prototypes may be built to fully test the system and provide a more realistic basis for creating documentation and overall design. Validation and verification should be completed following deployment.