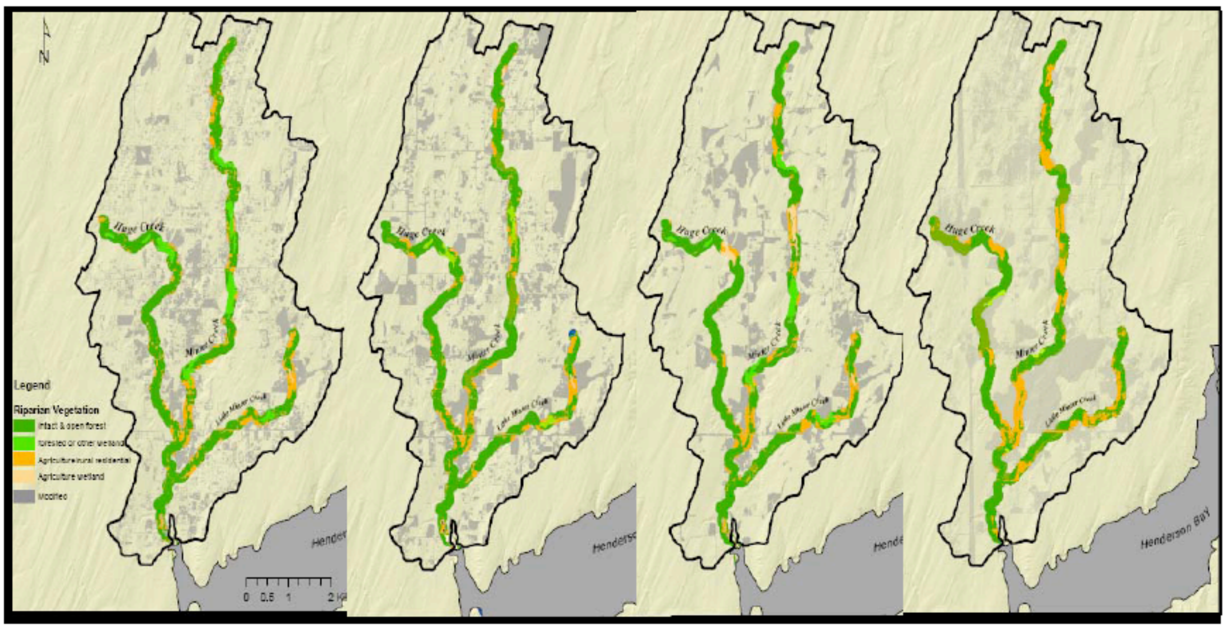
Recovery Implementation Science Team

Review of Monitoring and Evaluation Plans for ESA listed salmon and steelhead



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The Recovery Implementation Science Team (RIST) is an independent science team formed by the NMFS Northwest Fisheries Science Center and Northwest Regional Office to help provide scientific advice on salmon recovery implementation. Information from the RIST is scientific or technical and is intended to inform policy and management decisions: not to prescribe or make decisions.

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More information on the RIST, as well as an electronic copy of this report, can be found at http://www.nwfsc.noaa.gov/trt/index.cfm.

Cover page graphic was produced by Mindi Sheer.

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Introduction and Background

In June, 2008, the National Marine Fisheries Service (NMFS) Northwest Region's Salmon Recovery Division asked the Recovery Implementation Science Team (RIST) to review several draft monitoring and evaluation plans for ESA listed salmon species. Monitoring data are critical for several aspects of ESA recovery implementation, including conducting mandatory 5-year status reviews, conducting biological assessments and opinions of federal actions, implementing adaptive management of recovery plans, and ultimately making delisting or change-of-listing-status decisions. In requesting that the RIST provide a scientific review of several plans, NMFS intended that the review would be helpful to the plan authors as they update, revise, or implement the plans, and would assist others developing monitoring plans by promoting the successful elements of existing plans. The specific plans the RIST was asked to review were:

- The Shared Strategy's Monitoring and Adaptive Management Plan for Puget Sound Chinook salmon;
- The Lower Columbia Fish Recovery Board's Research, Monitoring and Evaluation Plan for Lower Columbia Salmon and Steelhead; and
- The Upper Columbia Salmon Recovery Board's Upper Columbia Spring Chinook Salmon and Steelhead Monitoring and Evaluation Plan

This review provides comments on each plan organized by the NMFS management questions. In addition, the document identifies several key areas that could benefit from greater attention in all plans.

The basic purpose of a monitoring and evaluation (M&E) plan for ESA listed salmon (NMFS 2007, 2008) is to provide information for NMFS and others to determine:

- The status and trend of the listed species
- The status and trend of limiting factors and threats to the species
- Whether the elements of the recovery plan have been implemented
- Whether the recovery actions achieved their intended effects

With these overarching goals in the mind, the RIST reviewed the three M&E plans with respect to the following specific questions:

If implemented, will the plan(s):

1. Provide the information necessary to evaluate both status and trends of the listed species and the threats identified in the recovery plans?
2. Provide a means for validating the initial hypotheses regarding limiting factors, and have a formal evaluation of alternative hypotheses?

3. Provide the information necessary to assess compliance and implementation progress? Specifically, will information be readily available to determine a) what the intended recovery actions are, b) whether, when and where and how they were carried out?
4. Have mechanisms for evaluating the effectiveness of recovery actions, and of changing strategies if initial hypothesis regarding effectiveness are not validated? (i.e., adaptive management?)

In addition to these strategic questions, the RIST also reviewed plans with respect to several 'nuts and bolts' type questions:

Do the plans:

5. Describe the current ongoing monitoring and evaluation efforts and the gaps between current efforts and the proposed M&E plan?
6. Identify the highest priority monitoring and evaluation needs?
7. Provide sufficient statistical power to determine the effectiveness of implemented recovery actions at various spatial scales?
8. Establish performance targets against which to measure progress or improvements?
9. Provide a mechanism to develop the necessary information from the data generated? In particular, is a mechanism provided to convert raw data into the metrics necessary to evaluate the recovery goals identified by the plans or associated Technical Recovery Team viability criteria?
10. Provide a mechanism to ensure that the information collected by the plan is made available for use in decision processes for NMFS, other agencies, and the general public in a useable form?

Response to NMFS questions

Puget Sound MAMA

1. Does the plan provide the information necessary to evaluate both status and trends of the listed species and the threats identified in the recovery plans?

The draft MAMA plan provides a framework for monitoring the status of individual populations against VSP elements on an annual basis (Vol. II, chap. 2). That framework describes specific monitoring questions and objectives relative to each of the basic VSP elements (abundance, productivity, spatial structure and diversity). Examples of indicators, data, sampling tools and analytical approaches for generating information on status and trends against those objectives are also provided.

The draft MAMA plan recognizes that tracking changes in the status of major limiting habitat factors is an important element of the adaptive approach embodied in the Puget Sound Chinook Recovery Plan. The draft MAMA habitat elements are designed to build on ongoing monitoring efforts and sources of guidance, providing more explicit recommendations for coordinated implementation at several scales. Examples of region-wide monitoring strategies are provided, along with a template for designing population specific habitat monitoring programs. The template provides specific management questions and the associated data/analytical needs organized by major tributary/nearshore marine habitats. The draft highlights the importance of estuarine and nearshore marine habitats given the basic life history patterns exhibited by Puget Sound Chinook salmon – extended first year juvenile rearing in these key areas. A general set of key monitoring/evaluation questions is also provided for harvest and hatchery elements of the recovery plan, although details are deferred to regional management documents.

The framework to consider status and trends of the focal species and threats is outlined with benchmarks represented by five questions. The first two of these address viability of individual populations and limiting or listing factors relevant here (the other three questions consider the availability of resources for outreach, implementation, integration). Limiting factors are defined more broadly than just the 4Hs and includes predation, disease, climate, and ocean, although monitoring of these additional limiting factors is not well developed. The MAMA provides a strong collaborative framework for monitoring and evaluation of these first two elements.

The plan is hierarchical with efforts in each watershed contributing to the regional assessment. As a result some information should exist for every population and MPG representing the ESU. Given the hierarchical nature of the recovery goals this could be key to any inference about status.

Despite the strong framework there is relatively little detail or guidance for monitoring design related to status and trends and limiting factors that clarifies the translation of monitoring data to actual information. There is an excellent discussion of design issues in the section on effectiveness monitoring. The same issues are relevant for status and limiting factors. Although the plan references the need for monitoring design within each area it seems that some (arbitrary?) decisions have already been made about the number and representation of populations that might be included. For example, The Plan proposes fish in:fish out for at least one population in each MPG. Spawner abundance will be monitored in each population via existing or “representative” approaches. In Table 1 abundance is based on the use of “representative” populations and estimates of “relative” or “absolute” abundance. Without further detail on the nature of the effort and data associated with counts of live salmon, redds, carcasses, or methods for estimating juvenile abundance it will be impossible to conclude whether adequate “information” can be gained. Because there are no details on the utility of existing data, a logical first step for implementation will be to summarize existing data, determine statistical characteristics and limitations of those methods, and identify gaps and needs for further development or issues for sampling design or refinement. Additional details are tied to the Governor’s Forum on Monitoring and the roll out schedule provides some assurance that the critical evaluation will occur in a timely fashion. It would be helpful to provide further discussion of the problems and anticipated solutions associated with the final designs and translation of data to information as soon as possible.

2. Does the plan provide a means for validating the initial hypotheses regarding limiting factors, and have formal evaluation of alternative hypotheses?

The Puget Sound MAMA is organized around regional recovery plan strategies, using a general framework, the Ecosystem Management Initiative (EMI) approach (draft attributes the University of Michigan as source). Using that framework, the MAMA is constructed around four stages, each summarized by a general question cycle; A) What are you trying to achieve?; B) How will you know if you are making progress?; C) How will you get the information you need?; and, D) How will you use the information in decision making?

As in other regions, achieving recovery objectives relies on implementation and tracking across multiple jurisdictions. Given that framework, the explicit linkages between monitoring and evaluation elements and the regional recovery plan strategies incorporated into MAMA promote efficiencies and enhance the potential for generating information that would trigger adaptive improvements.

The section on effectiveness monitoring provides an excellent overview of uncertainty in the link between recovery actions and habitat or biological responses. It outlines two basic approaches: 1) level of evidence or correlative studies linked to ongoing monitoring and 2) intensively monitored watersheds (IMW) or control/test experimental studies. The plan recommends development of at least one IMW study to consider the effects of habitat actions on salmon viability and one level of evidence study for each strategy deemed most critical to the success of the recovery plan. The critical strategies and associated hypotheses are not defined. Additional approaches include communicating priorities to research scientists and other collaborators to prioritize effectiveness research relevant to issues of recovery.

3. Does the plan provide the information necessary to assess compliance and implementation progress? Specifically, will information be readily available to determine a) what the intended recovery actions are, b) whether, when and where and how they were carried out?

The MAMA Plan provides guidance and a framework for implementation monitoring. It does not mandate a single approach. It does anticipate monitoring within each watershed, on an annual basis. The Plan provides a Master Implementation Monitoring Schedule with triggers and dates for noncompliance. It also identifies responsible parties. Priorities for implementation monitoring will depend on available funding and guidance from the recovery council and individual watershed groups.

4. Does the plan have mechanisms for evaluating the effectiveness of recovery actions, and changing strategies if initial hypothesis regarding effectiveness are not validated? (i.e., adaptive management?)

The draft MAMA plan provides specific guidance on designing and implementing effectiveness monitoring directly related to the population specific recovery strategies. The draft MAMA recognizes that the adaptive approach called for in the Puget Sound Recovery plan will require directed monitoring and evaluation efforts to determine responses to particular strategies along with programs that are specifically designed to validate key assumptions. The draft MAMA calls for coordinated efforts to identify and implement sampling strategies aimed at determining if particular categories of actions are resulting in the physical habitat changes expected given the underlying hypotheses. Insights from these monitoring efforts will contribute to validating the hypotheses underlying the current recovery strategies. In addition, the draft MAMA recommends developing more directed evaluation strategies for key hypotheses, employing combinations of watershed specific and coordinated project monitoring efforts. The draft discusses different experimental designs for validation, highlighting some of the practical considerations associated with evaluating response through field sampling. The need to consider life history patterns of the species targeted by the recovery plans in the design of validation strategies is explicitly discussed. The draft MAMA recommends setting up a combination of regionally coordinated sampling efforts to evaluate responses to key habitat strategies including Intensively Managed Watershed studies targeting specific populations representative of particular categories and coordinated 'Levels of Evidence' approaches designed to take advantage of sampling across the region at several scales.

The framework for data collection, review and decision making is established with timelines and coordination through strong governance and coordination mechanisms linked through a "Recovery Council". Reporting on the progress and status of benchmarks is intended to assess the ESU's progress toward recovery and ensures "that adaptive management decisions are made on a regular basis at both the watershed and regional scales". The framework will clearly support passive adaptive management with a 5 year reporting review and timeline at each level of organization. The effectiveness monitoring process outlines a program for prioritization and testing of important assumptions and hypotheses that presumably could support more *active* adaptive management, but that is not outlined in the Plan.

5. Does the plan describe the current ongoing monitoring and evaluation efforts and the gaps between current efforts and the proposed M&E plan?
Existing or planned monitoring for spawner abundance and juvenile outmigrants has been summarized and important gaps are considered in two appendices of the current plan. An assessment of existing habitat monitoring has not been completed but is anticipated early in the plan implementation. The need to identify and resolve monitoring gaps for habitat and other monitoring elements are recognized, but remain to be completed. The roll out anticipates that a summary of the current monitoring and the design or refinement of proposed monitoring will be completed in the first two years of implementation by watershed. This should provide the ideal framework to recognize and address important gaps.

6. Does the plan identify the highest priority monitoring and evaluation needs?
The plan does not directly consider priorities in monitoring, but does acknowledge the need. It is anticipated that the Recovery Council will make decisions about where to allocate resources and support, as well as decisions about whether strategies in the Recovery Plan should be continued, modified or abandoned over time. In general the plan indicates that monitoring must "provide for the measurement of progress for all populations, and must also specifically allow a focus on populations at the highest risk of extinction."

7. Does the plan provide sufficient statistical power to determine the effectiveness of implemented recovery actions at various spatial scales?
The framework is very strong, but the details of the sampling methods and design are not sufficient to answer this question. The general methods outlined throughout the plan have been

used to gather useful information and characterize accuracy and precision in other systems, but in many cases these kinds of data have important limitations or the limitations are simply unknown. Redd counts, for example, are a common tool used throughout the region as an index of adult abundance and presumably will be important here. The errors and limitations of redd counts have rarely been evaluated. Studies comparing results from standard redd expansion approaches with mark/recapture or other methods of estimating chinook spawning abundance have recently been done on a small number of river systems (e.g., Weeks et al., 2003; Gallagher & Gallagher, 2005; Sharpe et al. 2009). The results to date indicate that precision and accuracy of abundance estimates based on redd expansions can vary substantially between locations depending on river specific factors (sampling approach, environmental conditions, confounding with intermingled species, etc). Work with other large salmonids (e.g., bull trout) would indicate that problems with precision and bias can be quite important under some circumstances. Similarly, precise measures of juvenile abundance can be logistically difficult and expensive to obtain. Without further guidance for a rigorous assessment or periodic review of statistical characteristics and sampling issues it is impossible to know whether the results will provide sufficient statistical power. The plan acknowledges that "traditional monitoring programs have lacked the critical elements of replication, randomization, independence and reference/controls, have collected data at the wrong spatial or temporal scales, or have lacked sufficient institutional controls to maintain the integrity of the monitoring design over a period sufficient to generate reliable results". The section goes on to suggest that "never the less existing monitoring programs can be adjusted or new programs can be developed that should provide the information necessary to detect changes at the appropriate spatial and temporal scales". This section on effectiveness monitoring has an excellent discussion of design issues and alternatives that may guide refinement. It could be noted that similar issues exist with status/trend monitoring. A formal review of existing data and periodic review of the information actually gained through monitoring of status and trends could be important. The strong governance section and coordination among parties involved in the plan and the process outlined for reporting and analysis should provide a good forum for discussion and review of the quantitative issues associated with monitoring. Periodic evaluation of the monitoring results, the limitations of metrics and sampling schemes will be an important element of that review.

8. Does the plan establish performance targets against which to measure the progress or improvements?

The MAMA Plan describes a series of key questions or benchmarks as a framework for gauging progress. It recommends that specific "targets" which describe the desired level of implementation actions and VSP characteristics and limiting factors be established. The plan proposes targets for hatcheries and harvest factors, but only recommends that similar targets for habitat and VSP characteristics be developed by the Recovery Council and individual Watersheds.

9. Does the plan provide a mechanism to develop the necessary information from the data it generates? In particular, is a mechanism provided to convert raw data into the metrics necessary to evaluate the recovery goals identified by the plans or associated Technical Recovery Team viability criteria?

A section on *data collection and management* provides some guidance that standardized operating procedures will be used and based on existing monitoring programs. The section on *data analysis and reporting*, has general statements about synthesis to address the central questions guiding monitoring and evaluation. It is emphasized that uncertainty and assumptions need to be clear, but a mechanism for translating diverse sources of data to common metrics is not clear. A process for agreeing on the data to be reported based on existing harvest management strategies is outlined with a similar process proposed here. This process would seem to depend on an analysis of the utility of different data or sources of data. A formal process of review to refine the translation of data to information will be important early in the implementation.

10. Does the plan provide a mechanism to ensure that the information collected by the plan is made available for use in decision processes for NMFS, other agencies, and the general public in a useable form?

A centralized program of data management is anticipated but has not been developed. This will be a critical step and is anticipated early in implementation. This has been a serious problem in past efforts, largely because of inconsistencies in methodology and design among groups with different objectives or capacities. The principles for Verification and Accountability articulated in this section are helpful, but this process will remain a challenge until it can actually be demonstrated. A serious commitment to coordination and periodic review of the data collection and management issues is an important step toward resolution of a classic problem. An overall coordination through a common "council" provides a mechanism for technical and financial support and some assurance of implementation and accountability. The available infrastructure for conducting the needed work also appears to be strong. Important elements of this plan include the hierarchy of organization and governance that shows a mechanism for coordination and accountability and roles and responsibilities of participants for implementation. The coordination provides an important assurance that the plan will be implemented and oversight/support will exist to identify and resolve issues in a collective fashion. A strongly coordinated effort for data development, standardization, management, analysis and reporting of the data and resulting information could prove critical to success where a wide range of groups with distinct goals and capacities are involved in the process. The framework and governance portions of this plan provide a great template to guide the data management process, but implementation remains a challenge.

Lower Columbia Plan

1. Does the plan provide the information necessary to evaluate both status and trends of the listed species and the threats identified in the recovery plans?

The plan identifies and defines criteria and metrics for characterization of status and trends of species and threats linked primarily to habitat. There is a framework for status and trend monitoring that includes three levels of detail (intensive, inventory, indicator), two life history stages (adults, juveniles), and metrics relevant to the four attributes of viable populations. Habitat status monitoring includes three "scales": stream corridor, landscape and water quantity/quality. The attributes, metrics and example statistics are outlined in general terms. Sampling activities and considerations of sampling frequency and stratification are mentioned as well. Benchmarks are established to guide some determination of the adequacy of the anticipated effort and interpretation of results.

Whether the *information* necessary to draw clear conclusions will be available is more difficult to answer. The current level of detail does not address the quality of the monitoring and data that exist or that will be collected in attempts to fill existing gaps. The analytical framework that will bring those data together to create information is also not fully developed. It does seem clear that gaining useful information across four species and three eco-regions each with multiple populations under the diverse responsibilities of multiple agencies, tribes and other participants will be a huge challenge. The plan identifies responsible partners for different elements, but seems to have a relatively weak governance structure in relation to the other plans (Puget Sound, Upper Columbia) and seems to emphasize flexibility in approach or maintenance of the status quo among existing programs maintained by collaborating participants. While this is probably an important concession to the disparate responsibilities and goals of the collaborators it also seems that it could make consistency and interpretation of data at the higher levels of organization in monitoring difficult to achieve. The plan emphasizes integration of ongoing efforts, the need to identify data reporting schedules, identify constraints and uncertainties and identify considerations for coordination. These represent substantial tasks that must be accomplished before effective coordinated monitoring can occur. Until much of that occurs it's not clear what challenges really exist and whether that integration will be effective.

2. Does the plan provide a means for validating the initial hypotheses regarding limiting factors, and have formal evaluation of alternative hypotheses?

The section on Uncertainty and Validation Research provides a clear statement of the value and need for such work. It also provides an impressive list of ongoing research and anticipated research needs associated with the major elements of the monitoring program. In the current form the lists of research activities and needs seem to reflect existing activities and a wish list of proposals without the prioritization or refinement based on the issues or critical needs that emerged in development of this plan. One might anticipate that a central issue for effective monitoring at the scales addressed in this plan would be uncertainty in status and trends based on data collected with limited or disparate resources and methods. The utility of existing information and integration of mixed data sources seems like an important issue that may limit many possible inferences.

The plan focuses on habitat status as the primary limiting factor. As the plan points out habitat monitoring is "complicated by issues of multiple and overlapping objectives, scales, information needs, and jurisdictional responsibilities". Other efforts to summarize and interpret such diverse information have shown this can be a substantial problem even within a single jurisdiction such as the Forest Service. Until the effort is made to integrate and analyze the data it seems impossible to conclude that the different sources of data are consistent, comparable, or even useful. Given that a large body of information already exists in ongoing programs it would seem useful (critical?) to evaluate the utility of the existing information as a basis for continued monitoring as early in implementation as possible. Can trends be resolved with the kind of information that will be available? It's clear that resources are limited and that monitoring every watershed or population of every species with efforts to provide precise measures of productivity is well beyond the capacity of any realistic program. Rather than simply extending existing efforts, however, it may be important to evaluate and identify which existing projects are effective and which are non-informative, and take appropriate action.
The basic model of how the system works (e.g. threats influencing status) also must lead to some critical uncertainties. There is a sense of that in the consideration of status and threats, but the critical assumptions and relationships that link status and threats are not strongly articulated. Certainly EDT, which has been used extensively in this region, articulates some critical relationships/process linking habitat and population response. Some of the information used in EDT is based on judgment, however, and some of the relationships are poorly understood. Perhaps a sensitivity analysis could be used to identify the critical uncertainties for further work as a foundation for monitoring and adaptive management to validate or refine the underlying models. The point is not that the current lists are inappropriate, but simply that a scheme for prioritization based on critical limitations, sensitivities, or uncertainties that may emerge through the planning and initial monitoring process could be important given the almost certainly limited resources available to the effort.

3. Does the plan provide the information necessary to assess compliance and implementation progress? Specifically, will information be readily available to determine a) what the intended recovery actions are, b) whether, when and where and how they were carried out?

The plan does provide a strong foundation to address progress in recovery compliance and implementation actions. Responsibility for coordination is assigned to the LCFRB and a coordinated data base will be implemented via SalmonPort . A 2-year assessment interval should provide a regular and early check on progress, compliance, and any limitations across the program.

4. Does the plan have mechanisms for evaluating the effectiveness of recovery actions, and changing strategies if initial hypothesis regarding effectiveness are not validated? (i.e., adaptive management?)
The plan provides a framework for evaluation of action effectiveness and identifies indicators for stream, water, and watershed characteristics. The plan adopts monitoring design and protocols developed by the Washington Salmon Recovery Board. The plan also proposes an adaptive

evaluation framework with decision points and direction to guide future actions. It is not clear whether this implies formal adaptive management with the intent to probe and experiment as a mechanism for actually learning or whether the intent is for a passive approach with periodic reevaluation. Given that detailed validation research may be limited by available resources, some active adaptive management would seem important to support any capacity for learning. The uncertainty and validation research section provides a long list of proposed or ongoing research projects, but there is not a prioritization based on an underlying model with recovery actions linked to anticipated response and no clear link between monitoring and critical hypotheses that might be tested through adaptive management. The application of adaptive management explicitly linked to critical uncertainties or important limitations that emerge through further work could strengthen the effort.

5. Does the plan describe the current ongoing monitoring and evaluation efforts and the gaps between current efforts and the proposed M&E plan?
The plan provides a clear discussion of ongoing sampling/monitoring efforts and the gaps in coverage associated with each element of the monitoring program. The gaps do no necessarily reflect issues in data quality or sampling limitations that could limit interpretation or utility of specific data sets. A comprehensive assessment of *information* gaps (e.g. constraints and uncertainties) as outlined in the implementation actions will still be important as specific datasets and efforts are evaluated.

6. Does the plan identify the highest priority monitoring and evaluation needs?
The plan identifies priorities based on populations targeted for high viability or large improvements in status. The plan identifies a biological sampling program over every population, but allocates varied sampling effort or intensity among populations. The plan provides a general discussion of salmon recovery priorities and four tiers of stream reaches that could serve as a basis for prioritization in habitat monitoring. It is not clear whether habitat monitoring will or can actually be managed to meet such priorities.

7. Does the plan provide sufficient statistical power to determine the effectiveness of implemented recovery actions at various spatial scales?
The plan outlines statistical concepts such as stratification and probabilistic sampling to ensure representation and replication to quantify variation. There is relatively little guidance to evaluate the details and whether the resulting data can provide useful information. Clearly a broad framework is needed to guide monitoring efforts across such a large and diverse region, but it is not possible with the existing plan to conclude whether the information necessary to evaluate status or detect trends based on characteristics of accuracy and precision will exist. Some effort to evaluate the adequacy of existing data and revise, refine, replace or even simply recognize inadequate or non-informative efforts is implied and will be important to gain some assurance that efforts provide useful information. Efforts to standardize data collection or interpretation to some common metrics with known limitations will eventually be critical to insure success.

8. Does the plan establish performance targets against which to measure the progress or improvements?
The plan develops benchmarks for evaluating progress in population status (viability criteria) and general habitat conditions. Statistical criteria for recognizing trends or change are not discussed,

but quantitative values represented by estimated probabilities of persistence linked to adult abundance and productivity are proposed. Qualitative criteria are defined for other population and habitat characteristics (Table 4).

9. Does the plan provide a mechanism to develop the necessary information from the data it generates? In particular, is a mechanism provided to convert raw data into the metrics necessary to evaluate the recovery goals identified by the plans or associated Technical Recovery Team viability criteria?

Population and habitat status will be evaluated through a series of attributes, metrics, and summary statistics. A series of benchmarks are outlined as a framework to translate those data to information about status that can be summarized and mapped for direct evaluation. The Plan indicates that the assessments of habitat suitability for fish and the effects of habitat changes will rely on quantitative and qualitative interpretations of indicators. Interpretations should be based on changes in indicators over time as well as comparisons with benchmark values. Benchmarks are not intended to represent goals but rather reference points or standards for comparison.

The plan also has sections on sampling and analytical design that outline different types and levels of sampling and benchmarks that suggest the types or amount of information needed for different levels of inference, but at present those seem somewhat arbitrary. The plan identifies gaps in existing sampling efforts based on coverage, but it makes only general reference to issues of statistical design and the utility of information to detect trends or draw a valid inference about status. Because the plan attempts to address multiple and potentially conflicting objectives it isn’t clear that existing data can be translated to information required for each purpose or how different types of information might pass through that filter. Some synthesis and evaluation of available data will be important early in the monitoring program to actually test, refine or revise the process used to standardize and analyze data and interpret it in the context of the benchmarks outlined here. Although the plan has a section on programmatic evaluation there was not a clear mechanism for review, and adjustment of future work that might be needed once the utility of existing and planned data collection and interpretation methods are understood.

10. Does the plan provide a mechanism to ensure that the information collected by the plan is made available for use in decision processes for NMFS, other agencies, and the general public in a useable form?

The data management and reporting process for the plan has only limited development. The plan cites guidance directly from the recovery plan and proposes to assess data management needs as a precursor to development of a more detailed data management process. The plan references existing data systems and infrastructures, but because data will be assembled from existing monitoring efforts sometimes with disparate objectives, interests and capacities, it is not clear that those systems will actually work. This will be an important element of the plan to develop relatively soon. Many agencies have struggled with the limited utility of data collected for varied objectives without a common design. One solution has been to develop a single centralized, program of information management, coordination and analysis with support contributed by all participants, but that often needs to be done before the fact of monitoring implementation not after, to be effective.

Upper Columbia Plan

1. Does the plan provide the information necessary to evaluate both status and trends of the listed species and the threats identified in the recovery plans?

The plan explicitly outlines two major questions to determine if the Recovery Plan is working:

(1) Is the status of the population/ESU/DPS improving?

(2) Are the primary factors limiting the status of the population/ESU/DPS increasing or decreasing?

Status and trends in populations will be evaluated in reference to 10 objectives and a series of "benchmarks" developed to address four elements of VSPs outlined in the recovery plan. Details of the data collection are outlined in a separate appendix. Threats considered by the monitoring plan are limited to the condition in key habitat limiting factors and the plan assumes that evaluation of other limiting factors (e.g. harvest, hatcheries, hydro., predation) will be evaluated by other entities. Trends and progress will be based on monitoring of limiting factors identified in the Recovery Plan with a series of benchmarks based on the NOAA fisheries concept of Proper Functioning Condition.

For the elements that are addressed this is a clearly written and comprehensive monitoring plan. The questions related to population status are listed with details on the specific metrics, representation of precision, and the benchmark associated with recovery that will be measured or estimated for each population. The parties responsible for implementation, coordination and existing or potential funding are identified which should help insure that key elements are adopted. One potential issue may be with the interpretation of results across the 10 objectives addressed through population monitoring. It is not clear how those results will be integrated to a comprehensive or overall evaluation of status and trend for each population.

The monitoring anticipated to evaluate threats associated with trends in habitat is more vague, based primarily on ongoing efforts such as PIBO, AREMP, State agency programs, and the basin level work of ISEMP projects. The methods for monitoring and evaluation will rely on ISEMP and OBMEP protocols and the specific analytical methods for deriving and evaluating different habitat variables used in those programs. These efforts should provide an excellent foundation if they can be extended across the areas and populations required in the plan, but that implementation will depend on adequate funding and the coordination of methods among diverse groups

If successfully implemented, this plan should provide important information necessary to evaluate status and trends of both the listed species and limiting factors. Many of the methods, however have considerable uncertainty and it is not clear that the detailed design and sampling associated with ISEMP for example, can be effectively extended to other populations and basins. Few of the methods outlined in these programs have been implemented at the scale intended here.

2. Does the plan provide a means for validating the initial hypotheses regarding limiting factors, and have formal evaluation of alternative hypotheses?

The Recovery Plan defines "critical uncertainties" as "unknown aspects of environmental conditions vital to salmonid survival" and indicates that these uncertainties are a focus of research in the Upper Columbia region. That work however, is not part of the plan developed here.

The plan divides limiting factors into broad categories (habitat, hydro, harvest, etc) but directly addresses only those associated with habitat. It does not outline any explicit hypotheses or formal evaluations of implied hypotheses, but it does consider a process for identifying important questions in the effectiveness monitoring section. The generally implied hypothesis seems to be that improvement in habitat should lead to improvement in VSP characteristics for individual populations though mechanisms are undefined. For other potential limiting factors the plan outlines general questions, but anticipates that other entities will be responsible for monitoring and evaluation of those effects.

The monitoring plan does not reference back to specific limiting factors identified in the recovery plan on a population by population basis. It does recommend that effectiveness monitoring be implemented for habitat actions that are anticipated to have large treatment effects, key assumptions linking habitat and landscapes, key assumptions in population habitat models, and general linkages between physical and biological process. Given that those projects are not yet defined it is not possible to anticipate whether they will resolve important or competing hypotheses. Based on the monitoring that is defined it does seem that any conclusions about limiting factors must be based on a general association of trends in habitat conditions with trends in populations. Because the monitoring strategy does propose a wide range of habitat characteristics that could be associated with the status and trends of individual populations, it may be possible to refine understanding through the differential effects in empirical/statistical models, but such analyses are not expressly considered and issues of appropriate statistical power and design are beyond the scope of the current plan.

The plan does outline a series of possible results in the general association and the general conclusion that might emerge (e.g., "If there are negative trends in VSP parameters toward an increase in extinction risk for each fish population, but there is a positive trend in habitat quality and quantity for each subbasin (section 2.4.3), then it is unlikely that changes to the Habitat Work Schedule, Implementation Schedule or Recovery Plan will be effective in addressing the negative trends in VSP parameters."). It seems likely that the anticipated level of monitoring will be sufficient to test or validate the very general hypothesis regarding overall habitat limitation, particularly when combined with the effectiveness monitoring component of the plan, but it may not be possible to resolve whether failure in recovery could be due to any specific factor or an interaction with other factors outside of the local habitat.

3. Does the plan provide the information necessary to assess compliance and implementation progress? Specifically, will information be readily available to determine a) what the intended recovery actions are, b) whether, when and where and how they were carried out?

The plan has a well developed implementation monitoring component that focuses on two primary questions: *were actions implemented according to the implementation schedule*? And *were the actions implemented correctly*? An Implementation Team with broad representation from the stake holders and agencies should help insure that coordination is effective and timely and that individual responsibilities are clear and accountable. This governance structure should also provide effective context for the local Watershed Action Groups and help to resolve issues in funding or other resources that may limit implementation and implementation monitoring.

Because project sponsors will be responsible for collecting information needed to assess implementation progress effective coordination will be critical. The plan suggests that the management of that information will be through "regional tracking systems", but it is not clear that those systems can be effectively coordinated to develop a consistent and comprehensive evaluation of implementation. Some further detail on where the implementation information that is collected would be housed and how it would be accessible would be useful. .

4. Does the plan have mechanisms for evaluating the effectiveness of recovery actions, and changing strategies if initial hypothesis regarding effectiveness are not validated? (i.e., do the plans practice adaptive management?)

Like the rest of the document, the discussion of effectiveness monitoring is brief and clear, but covers all the essentials. The plan relies on several ongoing intensive monitoring programs (e.g., ISMEP) for the effectiveness monitoring component, particularly for habitat actions. We did not review these programs in detail, so cannot comment on how likely they will be to be successful.

Throughout, the plan relies on a statistical null hypothesis testing framework for evaluation. In general, we are not sure that a null hypothesis testing framework is the best approach for monitoring and evaluation. Such an approach seems appropriate if an investigator wishes to be conservative about rejecting a null hypothesis, but seems less useful if the goal is to estimate the size of an effect (or slope of a trend). We are concerned that a strict null hypothesis testing framework creates knife edge criteria and focuses solely on the question "is there an effect" rather than "what is the distribution of effect sizes consistent with the data?"

Even for simple metrics such abundance, it would be useful for the adaptive management plan to provide some more discussion of what is meant by an increasing or decreasing trend. Based on the recovery criteria, this is presumably the running average of a 12 year geometric mean in either abundance or natural recruits/spawner.

Hatchery monitoring. Although there is a section on hatchery monitoring, there is no specific mention of monitoring relative reproductive success of hatchery fish, but there are ongoing studies in the Upper Columbia and this has been identified as an important component of hatchery M&E in several forums (FCRPS BiOp, Upper Columbia FERC agreement, Ad Hoc Group on Supplementation Monitoring). In addition, the plan also seems to imply that there will be only one treatment and one reference stream per population, which may not work as an experimental design.

5. Does the plan describe the current ongoing monitoring and evaluation efforts and the gaps between current efforts and the proposed M&E plan?

There is already a significant body of monitoring occurring within the Upper Columbia Basin. Attachment 1 provides a very useful summary of ongoing monitoring, data gaps and limitations or issues with existing efforts. The attachment provides important guidance for validation of existing work and resolving currently apparent gaps or limitations. The plan also anticipates a comprehensive state-of-the-science review, facilitated by the Regional Technical Team every 5 years identify any information gaps that emerge through implementation.

6. Does the plan identify the highest priority monitoring and evaluation needs?

The plan states what will be monitored with the focus clearly on monitoring the status and trend of VSP parameters (abundance, productivity, spatial structure, and diversity), and changes in habitat and restoration implementation. The plan outlines monitoring for other limiting factors and provides a framework for effectiveness monitoring and research. The priorities at this level are clear.

The monitoring requirements for status and trends in VSP criteria and habitat conditions are considerable and some consideration for further prioritization may become important. A set of questions guiding the interpretation of VSP characteristics was translated into 10 monitoring objectives each with a general sampling design for each population. Habitat sampling will rely on ongoing programs and design provided through ISEMP and OBMEP with statistical framework linked to rotating panel designs based on the GRTS master sample of sites for WA. Presumably ongoing work will not provide the full detail outlined in this plan for each population or all streams. Much of the VSP monitoring will rely on redd counts to estimate adult abundances, but other information (genetics, sampling of adults for morphometric characteristics) are included as well. Given that funding is uncertain and the intensity of sampling undefined, there could be a lot of room for variation in frequency, intensity and distribution of effort, selection among overlapping or potentially redundant or non-informative metrics and selection of critical or indicator streams or populations that could represent important tradeoffs in cost and potential information gain across metrics, streams, and populations. Unless funding is unlimited further guidance could prove useful to guide consideration of those tradeoffs and prioritization of available funding as opportunities to leverage specific projects becomes apparent.

7. Does the plan provide sufficient statistical power to determine the effectiveness of implemented recovery actions at various spatial scales?

The plan will rely on design considerations from ongoing intensive monitoring efforts associated with ISEMP, OBMEP, and the EMAP sampling frame that should provide an important foundation to characterize the precision and power of the monitoring that results. The plan also provides general guidance for reporting the precision of some metrics. Without evaluation of existing results and some knowledge of the limitations associated with existing sampling methods and metrics, however, it will be impossible to know what precision and power is actually possible. Many of the objectives associated with status and trend monitoring for VSP characteristics rely on redd counts, which can have important limitations. Attachment 1 outlines important questions and the need for validation of some metrics and sampling approaches including the validation of redd counts. It will be important to carefully consider/reconsider the precision, power, and utility of the monitoring efforts as those validation efforts and the actually monitoring information become available.

8. Does the plan establish performance targets against which to measure the progress or improvements?

For the population metrics, the plan provides a link the recovery goals identified by the ICBTRT and the Upper Columbia Recovery Plan, which are the obvious targets against which to measure improvement. Success will be evaluated by considering the individual trends in a series of VSP defined parameters for each population. We did not find any framework for a synthesis or composite evaluation of the multiple metrics; presumably the framework developed by the ICBTRT will be used. For the habitat related limiting factors the Plan proposes to use the NMFS indices of Proper Functioning Condition as benchmarks for measuring success and progress (i.e. are conditions trending toward PFC). Given current direction in recovery planning and consultation PFC may represent one possible benchmark for habitat monitoring. It will be important to consider its limitations, however, as well. The PFC concept has been criticized because it does not represent the spatial and temporal dynamics of natural landscapes (e.g. ISAB 2003). The range of conditions considered to reflect PFC also may be derived from streams and landscapes that are not representative or characteristic of the systems in question. There are no simple solutions to these problems, but the broad distribution of monitoring anticipated in this plan might be used to consider the range and variability of natural conditions in reference watersheds as more appropriate criteria.

9. Does the plan provide a mechanism to develop the necessary information from the data it generates? In particular, is a mechanism provided to convert raw data into the metrics necessary to evaluate the recovery goals identified by the plans or associated Technical Recovery Team viability criteria?

The plan provides a list of metrics for population and habitat status and trends and references specific established protocols to guide collection of data. There is a strong framework for data management and a clear outline of the responsibilities and general protocols for the flow of data. For population status and trends the plan outlines a general procedure for analysis of the anticipated data and a general statistical comparison with recovery criteria. The plan is less clear on how the habitat data will be compiled and analyzed to actually evaluate or draw conclusions on status and trends. Tables 1 and 2 provide a comprehensive list of habitat metrics that will be monitored, and there is discussion in Appendix Q about expectations for trends in improvement in these metrics. It is not clear how, or if trends based on many different metrics can be resolved from these data. In both cases the lists of metrics, are something of a ‘check list’, and do not provide a specific way to report an overall ‘trend’ in status.

This seems to be a limitation of all three plans, and may reflect the state of the science more than any specific failure of the plans. This could be an area where a decision support system could be very useful, at least for structuring how ‘trends’ will be evaluated when the trend of interest is complex, multivariate phenomena such as habitat quality. There is a reference to NMFS (1996) concept of "properly functioning conditions" (PFC) (p. 141) which may serve as a crude sort of multivariate reference point for habitat quality, but there is important scientific debate whether PFC is a useful concept in landscapes that are driven by spatially and temporally variable watershed and habitat forming processes (see above).

The lack of comprehensive overall metrics is hardly the fault of the M&E plan, which is using the criteria provided to it, but it is an area that will likely require more work. It may be useful for the adaptive management plan to provide more discussion of what is meant by an increasing or decreasing trend and how that might be resolved. It might also be useful to highlight this issue with the anticipated state-of-the-science data analysis at the Regional Technical Team Analysis Workshops as an important venue for further consideration and the resolution of issues like this.

10. Does the plan provide a mechanism to ensure that the information collected by the plan is made available for use in decision processes for NMFS, other agencies, and the general public in a useable form?

This plan provides a very strong framework for the coordination and management of data developed through the monitoring process across multiple entities and levels of organization. The incorporation of data bases from established efforts (ISEMP and OBEMP) and the identification of a regional data base format are important steps providing some assurance of success. Responsibilities for collection, sharing, management, and reporting of data are identified. The hiring of a data steward to coordinate local data management efforts should insure that both monitoring results and information from any analysis will be effectively preserved and shared with stakeholders.

The plan provides a reporting schedule that is explicitly tied to the NMFS review schedule (p. 31). Appendix Q lays out a governance structure with roles for all key players.

Some issues in common to all three RP M&E programs

Compilation, standardization, and management of information from multiple/diverse data sources

Coordination of the diverse and extensive data sets associated with salmon recovery will be a challenging task. Ideally it could be accomplished through a centralized data management sysem developed specifically for the problem at hand. The compilation and coordination of a diversity of existing and ongoing efforts, often developed to answer other questions, however, will be necessary for many salmon recovery programs. The Lower Columbia plan points out that use of ongoing work is "complicated by issues of multiple and overlapping objectives, scales, information needs, and jurisdictional responsibilities", and we agree.

This is not a new problem. Bisbal (2001) noted in an earlier review of monitoring and evaluation in the Columbia River Basin that different mandates, designs, objectives, environments, funding and technical capacity can lead to disagreement, inconsistency in approach, metrics, data quality, frequency and extent of monitoring. Massive amounts of information may not mesh well and will not necessarily support clear inference over confusion. A 2003 report by SAIC cited by Crawford and Rumsey (2009) indicated that information system development in the region is largely ad-hoc; that different agencies, institutions or projects manage information independently, creating their own databases, collection methods and reports; that existing efforts at consolidation or standardization have not yet succeeded across the region as a whole and that existing individual information systems are disparate because they often don't share the same operating system or language, don't collect data of uniform quality or description and usually cannot "talk" directly to each other.

The existing plans all cite one or more ongoing efforts to coordinate, standardize, and manage monitoring information (e.g., WA Govenor's Salmon Recovery Board, PIBO, AREMP, PNAMP protocol manager, USFWS Bull Trout RME, USFS R1/R4, Johnson et al. 2001, Johnson et al. 2007; CSMEP, ISEMP). These efforts can provide important guidance and some experience to help refine the work at hand. But still there are few examples of successful implementation in coordination monitoring and management of information at the scale and of the complexity required under the current draft plans.

There are reasons for concern. Cost and complexity of compiling diverse sources of information and utility of existing data associated with such programs are often poorly anticipated. The Interior Columbia River Basin Ecosystem Management Project (Lee et al. 1997) is an example of a major effort to compile data from stream reach inventory and monitoring developed using traditional Forest Service protocols. The project worked to compile and standardize stream data collected on Forest Service districts throughout much of Washington, Oregon, Idaho, and Montana representing three different administrative Regions. Data for thousands of reaches were potentially available, but because of problems in definition of the variables, variability in or documentation of methodology, location of sites, reporting of information, only a fraction of the data (e.g. 600 of 6000+ observations) could be analyzed and important uncertainties about the source of variation in the final observations remained. None of these issues were anticipated in the design of the project because Forests throughout the basin share similar (but subtly different) objectives and methodologies. Until the effort is made to integrate and analyze available data it will remain virtually impossible to know whether the different sources of data are consistent, compatible, or even useful. An effort to compile, interpret and analyze existing data very early in the plan implementation will be key to resolving similar issues with diverse data sets in each of the recovery domains. The Technical Recovery Teams have already done some of this work for adult abundance data, but it will be important to make similar efforts for habitat data.

The current harvest management system for Pacific salmon provides another example of an operational monitoring and evaluation program. An examination of this program also is useful for getting an idea of the level of effort and coordination required to address even a focused set of questions.

Harvest management of Pacific salmon is coordinated by both international (Pacific Salmon Commission), regional (Pacific Fisheries Management Council) and basin-scale (e.g., Columbia River Compact, Point No Point Treaty Council) forums, each with associated technical committees that analyze monitoring data on an annual basis (see recent overview/review by the Independent Science Advisory Board (ISAB 2005) and the Pacific Salmon Commission (PSC 2005)).

The monitoring program that feeds this process is based on a distributed (California to Alaska) system of catch-accounting, escapment monitoring, and a mark-recapture program of, primarily, hatchery fish using coded-wire tags (CWTs). CWT releases and recoveries are reported in a standardized way to a publically available database run by the Pacific States Marine Fisheries Commission (http://www.rmpc.org/). Catch and escapement information is compiled annually by multiple coordinated technical committees to develop pre-season forecasts and post-season reviews. Some aspects of the process are highly coordinated and structured. For example, the Chinook Technical Committee of the Pacific Salmon Commission conducts and publishes its analysis using a set of agreed upon procedures, and other 'downstream' technical committees (e.g., the PFMC's Salmon Technical Team) make use of the CTC outputs in a structured way. Other aspects of the process, in particular the spawning ground surveys or other methods to develop annual escapement estimates, are highly decentralized, however, and are coordinated only at the level of information sharing.

It is informative to consider the level of effort required to make this monitoring system work, and sobering to consider that it only partially addresses one of the many risk factors identified for ESA listed salmon. Some of the elements that make this an operational system include (see Johnson 2004 for a comprehensive review):

- Agreement by over 50 organizations (states, countries, tribes) to develop and use the CWT program to monitor fisheries.
- Development of detailed protocols for sampling fisheries, reporting and using data and settling disputes.
- A centralized coordinating body to store and distribute data and work with the data collectors to resolve reporting problems.

- Protocols for coordinating tag codes, and an agreement (now abandoned) to use an adipose fin clip solely to indicate the presence of a CWT.
- The effort is very large scale: ~50M tags are implanted annually, and ~275000 tags are recovered annually (Johnson 2004).

Achieving this level of coordination in monitoring takes considerable resources: approximately $20M annually are spent implementing just the tagging and recovery aspects of the program, not including the costs of data analysis, data management and coordination of harvest management (Johnson 2004).

Despite the resources and efforts that are devoted to the CWT program, it is proving to be inadequate to meet current information needs (PSC 2005). In particular, coordination has become more difficult because some parties have started using the adipose fin clip as a mark for selective fisheries rather the CWT placement. As a result samplers must now use expensive electronic wands or tubes to detect CWTs, and more tags are missed, especially in smaller or more remote fisheries. In addition to this added inefficiency, ESA listings and other conservation concerns have greatly increased the total number of individual stocks that managers wish to assess (PSC 2005). The program is adaptive, however, and genetic stock identification (GSI) is increasingly being used to augment the CWT data.

In principle, the goals of the M&E plans for ESA recovery are much more comprehensive than the CWT program, in that they involve monitoring and evaluation of a larger group of disparate risk factors by a much larger group of agencies than is the case for salmon harvest monitoring. Indeed, even spending $20M or more a year, the current CWT program covers only a fraction of the ESA listed stocks, and in general struggles to provide sufficiently fine scale information to evaluate the effects of harvest actions on individual populations of interest (see, e.g., Ford et al. 2007).

Each of the draft plans generally acknowledges the issues, but it is not clear that the plans recognize the scope of the potential problem or have developed ways of dealing with it. The Puget Sound plan, for example, provides for coordination through a governance structure and standardization of methods, protocols and metrics based on monitoring direction of the Washington Governor's Salmon Recovery Board. This Puget Sound plan outlines a two year timeline for implementation and initial review and indicates that a data management system will be developed in 2008. The details of that system are not apparent, but it is intended to be applied and accessible across existing and anticipated programs, to support regular, timely reporting and to be independently reviewed and graded on a regular basis. The implementation schedule implies regular coordination, but does not provide specifics on development of the data base, data management framework, or piloting of the process.

The Lower Columbia plan calls for identification of "constraints" and "uncertainties" and acknowledges the need to establish a database and adopt "compatible" protocols. The plan acknowledges the need for assessment of data management needs, standardized data sets and regional data storage taking advantage of existing infrastructure. The Lower Columbia plan outlines a programmatic evaluation that calls for 2 year "check points" with regular reporting and coordination, but details are still vague or undeveloped.

The Upper Columbia Plan explicitly emphasizes coordination in data collection, submission and management, standardized protocols, metadata and storage and management. Responsibilities and a governance structure are clearly defined and coordination should be facilitated by a standing Monitoring and Data Management Committee of the RTT and a data steward hired by the Upper Columbia Salmon Recovery Board. The ongoing Integrated Status and Effectiveness Monitoring Program (ISEMP), provides a foundation for piloting data management methodology, monitoring protocols, and support for centralized data management. Data storage and management will be facilitated through the existing STEM databank developed through NOAA. The plan outlines a data management strategy that includes QA/QC and a 5 year evaluation cycle with scientific analysis and identification of information gaps that should facilitate recognition of data and information management problems.

Steps Forward

Failure to address data standardization, compilation, and management, to do this well and to do it early has the potential for costly false starts. When Recovery Planning groups actually do begin to accumulate data they may find it inadequate or excessive, wasting time, money and delaying or disrupting the process (ISAB/ISRP 2004); it has proven easy to suggest standardization and coordination, but difficult to accomplish. Efficient programs will in most cases require an iterative process of design, test, and refinement that begins as early as possible. Some of the plans have taken important steps in this process, others are just beginning. We suggest the following points for consideration in each program to help insure the process of compilation, standardization and management of data to generate useful information will be as effective and efficient as possible.

- Define Objectives. Clarify the questions and anticipated outputs to insure data and data base structure will be compatible with and support the analyses required to answer them.
- Simulate analyses in advance. It is valuable to figure out what analyses you plan to do on the data in advance, then do a few dry runs on a subset of data or made up data before starting to collect or compile anything. This will help identify which data are actually useful. It will also help clarify the appropriate structure of the data base.
- Clarify the needs of participants. Plan for coordination, communication, and buy in among participants. The governance section of the Puget Sound plan and the identification of protocols and responsible parties in the Upper Columbia plan provide excellent guidance to ensure that scientists, resource managers, NOAA analysts, and decision makers understand and agree on what data will be collected and what information is required, and assembled to answer the questions and meet the objectives.
- Define roles and responsibilities of the participants. Identify timelines and deadlines for data collection and data entry and sharing.
- Identify funding sources. Determine stability and adequacy of funding for individual and common objectives. Seek collaborative solutions for individual and program wide short falls or limitations.
- Agree on protocols and terminology (e.g., a data dictionary). Resolve method and data standardization vs. information standardization.

- Establish consistent and thorough metadata requirements. Metadata should, at a minimum, include details of the scale and grain of sampling, spatial and temporal references, standardized field methods and units of measure, and the organization and personnel responsible for the data.
- Define the processes for filtering, proofing and correction, translation and reporting of existing data to common format.
- Establish the framework and infrastructure for data entry, management, storage and retrieval. Clarify where it will be, what data management system and formats will be used, and how it will be maintained. The data management framework could be centralized or modular and dispersed with a relational structure. In either case it will be important to insure that all participants can access and summarize information for local needs without duplication of effort or conflict with local objectives. The decision regarding structure may depend on existing programs or other resources available for support. In many cases there may be some advantage to work within or adopt an existing data base structure rather than starting from scratch. There are a variety of ongoing monitoring coordination and data management efforts within the Columbia River basin that might be explored (*Reference the table summarizing existing data management efforts*).
- Provide for long term maintenance and security.
- Implement, review and refine. It will be virtually impossible to anticipate all of the issues in compilation, coordination and data management. An iterative process of implementation and review as soon as possible could be key to recognizing and resolving critical problems, minimizing wasted resources and maximizing the utility of resulting information.

Analyses of bias, precision, power and information content in monitoring data

Monitoring that does not produce new information, does not allow detection of change with an acceptable level of power, or that produces higher precision than necessary will be a waste of resources. Because funding for monitoring is limited and the needs for monitoring are extensive it will be important to develop and apply methods that provide acceptable limits of accuracy and precision and to allocate and prioritize that effort effectively and efficiently. Evaluations of accuracy and precision in existing methods and the design of monitoring to maximize information will be the responsibility of scientists, biologists and technicians that implement specific elements of each monitoring program. Much can be done to evaluate the utility and limitations of current or proposed methods and considerable information exists in the scientific literature and ongoing evaluations to guide that process. A determination of whether the monitoring provides an acceptable level of power to detect change, however, is a matter of policy. No formal guidance on the required confidence currently exists, but Crawford and Rumsey (2009) propose that monitoring for VSP criteria should *"Incorporate a robust unbiased adult spawner abundance sampling design that has known precision and certainty*" that "*the agencies and tribes should strive to have adult spawner data with a coefficient of variation (CV) on average of 15% or less for all ESA populations*" and "*Agencies and tribes should conduct a* *power analysis for each natural population being monitored within an ESU to determine the power of the data to detect a significant change in abundance and provide that information to all interested parties.*" This guidance is preliminary and may not be useful in all applications. It also reflects policy guidance but not necessarily the confidence required for all management decisions. It does provide a useful reference point.

It is clear that recovery monitoring will have to build on a diverse set of existing programs and collaboration among multiple jurisdictions that have responsibility for and interests in salmon recovery. This can be problematic. In a 2005 report the Coordinated System Monitoring and Evaluation Project (CSMEP, SWOT report) noted that:

> most current monitoring programs were designed to provide information at smaller spatial scales (population and smaller); at large scales, there are fairly thorough index programs, but how well these index areas represent the whole is undetermined; most index areas have not been randomly chosen, there may be some trend value but little value for estimating total population; very rarely do we have the ability to estimate variance (precision) or bias (accuracy) associated with monitoring activities; and we don't have a widespread ability to make inferences at larger spatial scales using most existing monitoring designs, because they are not statistically-based (i.e. simple random sampling, GRTS/EMAP, census, etc.).

Each of the plans acknowledges concepts of, and problems associated with, precision, accuracy, and information content. They mention the need for standardization and QA/QC in sampling protocols and reference concepts such as stratification, replication, probability based sampling and the need for an appropriate sampling design. The Puget Sound plan for example advocates a statistical sampling approach based on design and guidance in the WA Governor's Forum and probabilistic sampling framework adapted from the U.S. EPA EMAP program. This plan explicitly recognizes the need for standard operation procedures and protocols and a need to prioritize new effort based on the important gaps in existing work. The Lower Columbia plan outlines statistical concepts such as stratification, replication, probability based sampling and the need for an appropriate sampling design in efforts to insure collection of appropriate data, a capacity to detect meaningful change and the tradeoffs between precision and effort. The Lower Columbia plan emphasizes the use of standard protocols as outlined by PNAMP and Johnson et al. 2001 and mentions the need for QA/QC. Guidance on sampling intensity and representation is linked to recovery goals and mentions the need to address uncertainty. The Upper Columbia plan provides specific detail on protocols with the metrics and general elements of the sampling design identified for each species and stock. The Upper Columbia plan identifies some information that must be developed to calculate derived variables or metrics and emphasizes standardization of habitat protocols based on ISEMP and long list of protocol documents available there. The plan requires calculation of standard errors and confidence intervals for estimates, outlines specific analyses and calls for variance decomposition for some estimates (e.g. limiting factors or habitat conditions). The effectiveness monitoring section of the Upper Columbia plan identifies observer error as an issue and emphasizes strong protocols as a solution. A biennial workshop-based review of implementation results and 5 year science review could also provide an opportunity to evaluate the utility of the information.

The current plans do leave important uncertainty about the capacity to develop meaningful information. Each of the draft plans must necessarily allocate effort based on the diverse mix of existing monitoring efforts and gaps in representation of populations prioritized in recovery efforts. Each of the plans incorporates annual estimates of spawning abundance generated at the TRT population level. In most cases those estimates are based on expanded redd counts. In many cases current estimates are based on a census of redd counts or live counts across spawning habitats within a population (descriptions of current sampling approaches: Puget Sound Chinook, Appendix E of the Puget Sound Harvest Plan; Lower Columbia; Appendix ; Upper Columbia, ICTRT (2008). In general, the draft monitoring and evaluation plans propose stratification to insure coverage of populations representative of species or regions of importance to recovery, but it is not clear that this will create the most effective statistical representation or design based on scales of variability and knowledge of the underlying statistical characteristics of the data. Understanding whether the initial allocation and distribution of sampling effort is efficient and effective at providing the information needed to detect change will require further evaluation of sampling design following implementation. Many of the metrics proposed or anticipated for monitoring also are based on commonly accepted methods (e.g. redd counts) that may not have had a serious evaluation of sampling variability and bias or the inherent variation associated with the systems of interest.

Understanding precision and bias in monitoring data will be key to further refinement. Precision will influence sample size and the effort needed to determine effect size or power to detect change. Bias can be a systematic error or the result of non-random sampling leading to a under or overestimation of the element, process or condition of interest. Both may depend on environmental context, observers and methods and can vary through time and space; essentially there are two sources of error, observation or measurement error and process variability. Process variation may represent important information, measurement error contributes to bias, but can also confound detection or measurement of process variation. Critical work has been done on the repeatability, precision, and bias associated with some methods and that experience might be used to select, prioritize, or refine methods that are currently proposed. Where critical evaluations are not available or not appropriate for the anticipated application, however, it also will be important to implement, review, revise and refine sampling methods as data become available. Consideration of other research or other resources dealing with these issues also could be useful.

Steps Forward

Quantify variation and validate methods- Quantification of temporal/spatial variation in the systems of interest can be used to guide monitoring design through consideration of stratification, and the grain, extent, replication and/or frequency of sampling (e.g., Courbois et al. 2008). Given the limited funding available for most monitoring programs, however, it also may be important to validate planned or existing methods and either abandon or modify methods that provide little useful information or require unrealistic effort. Several of the studies or reviews referenced above provide some perspective on many of the habitat and population methods that are commonly used. Some local validation should be considered, however, because the conditions influencing measurement errors are not easily generalizable.
Validation might include work to apportion variation and to consider the magnitude of potential of bias by comparing methods against the "truth" (e.g. Dunham et al., 2001; Parken et al., 2003); Peterson et al. 2004; Roper et al. 2007) when the truth can be measured or reasonably

approximated. Insight into potential bias can be gained by simply comparing results across several different methods (Gallagher & Gallagher, 2005); Weeks et al. 2003) Some efforts are underway to evaluate bias and variability of population or drainage level escapement estimates for chinook in Puget Sound and the Lower Columbia regions. The Puget Sound Harvest Management Plan includes a summary of conclusions from studies designed to evaluate accuracy of redd count based abundance estimates in the selected river systems in Puget Sound. The Pacific Salmon Commission has recently initiated a five year study plan to obtain comparative information to evaluate current escapement estimates in the Snohomish and Skagit River systems in Puget Sound. The WDFW has an ongoing effort to evaluate chinook spawning escapement estimation in the Lower Columbia River. Initial results include a comparison spawning escapement estimates for the Coweeman River generated by three different methods.

Standardize Standard methods and protocols along with careful coordination among programs developing information and careful training of field crews can reduce measurement error. A strong program of QA/QC with oversight and review of a coordinating body will be helpful. Considerable effort has been devoted to sharing and standardizing protocols throughout the region and useful guidance can be found with several ongoing projects or programs (e.g. PNAMP; CSMEP; ISEMP, Johnson et al. 2007).

Design: Effective monitoring design will require more than simply filling apparent gaps in the coverage of stocks or limiting factors. It will require the explicit recognition of scale, sources of variation and bias relevant to the methods and systems of interest (e.g. Roni et al. 2005). Pilot projects can help define limitations and refine the design and application of existing protocols, but they can be expensive and time consuming. It can be useful to revisit the monitoring design as data become available and presumably the review schedules built into the plans will facilitate some of that work. It may also be possible to build on existing programs to identify critical tradeoffs in design or generalize from analyses of models or extensive data sets. Courbois et al., (2008) provide an important example based on a long term census of Chinook salmon redds across the entire Middle Fork Salmon River basin. CSMEP is implementing systematic processes for developing and evaluating integrated designs that address key anadromous and resident fish management questions. A limited set of standard designs with different costs and levels of reliability are anticipated based on the simulation of population processes.

Review and Revise: Early and periodic evaluation review and revision of methodology will be important. The sooner methods with important limitations can be refined or abandoned the sooner resources can be focused in more effective or more appropriate ways.

Remote sensing based habitat assessments

The Puget Sound and Lower Columbia River plans both rely on remote sensing as a method of monitoring trends in habitat quality, but provide few details on how this will be done. The emphasis on remote sensing is not surprising. Common problems in field-based habitat monitoring are limited power requiring large sample sizes to detect change, and logistical constraints that impose tradeoffs between local intensity and spatial extent of sampling. Field based monitoring must often struggle to balance cost, precision, and the scales of possible inference. Each of the plans makes some reference to the utilization of remote sensing as potential solutions to these problems, but the identification of critical metrics and the potential utility of remote sensing tools is still unclear. Existing and emerging remote sensing tools represent possible advances where intensive (even continuous) data can be obtained over broad regions at costs comparable to or even less than existing methods. Remote sensing approaches can be limited, however, in the nature of the data or metrics they can measure (e.g. pool characteristics, but not substrate characteristics). Development of standard protocols for using widely available remote sensing data should therefore clearly be a high priority for all recovery plans.

Steps Forward

There is a wide variety of remote sensing options available with a range of spatial coverage, spatial and temporal resolution, and data types (e.g., Mollot and Bilby 2008; Lane and Carbonneau 2008; Burnett et al. 2007). One thing they all have in common is the need for sophisticated processing and interpretation of large quantities of data. Each plan should therefore more completely articulate its expectations from remote sensing based habitat assessment. This should include a survey of the remote sensing technologies available, the information provided by the various technologies, the cost, and integration with ground-based survey information.

The regional natural resource management community should be engaged to deliver remote sensing based information that can be used in Recovery Plan evaluations; however, this will only be possible if Recovery Planning groups clearly articulate their needs in terms of metrics, spatial and temporal extent and resolution, and the acceptable uncertainty in the information (e.g. classification error, or interpolation/imputation error).

Data Analysis Frameworks

Analytical frameworks that are most relevant and useful for Recovery Plans will need to explicitly support decision making with respect to the design, implementation and evaluation of Recovery Plan actions. In general, all Plans reviewed have chosen to organize the feedback between action implementation and evaluation around the concepts of Adaptive Management. This is a logical choice that is well supported by the scope and scale of all Salmonid Recovery Plans since an adaptive management plan links results (intermediate or final) to feedback on design and implementation of actions. The linkage in an Adaptive Management driven approach comes from:

(1) a clear statement of the metrics and indicators by which progress toward achieving goals will be tracked
(2) a monitoring and evaluation plan for tracking such metrics and indicators, and
(3) a decision framework through which new information from monitoring and evaluation is used to adjust strategies or actions aimed at achieving recovery goals.

However, a strategy and a monitoring program is not sufficient; key to the concept and implementation of AM is learning. At its heart, an AM strategy is one of knowledge flow – from predictions to actions to observations to updated action plans and predictive methods – and is underlain at every step by quantified expectations and decision criteria. Therefore some form of modeled relationship between management actions and their predicted impacts on the Recovery Plan targets is required. No one single existing modeling approach will suffice, but there are a number of useful approaches to follow.

Fish - habitat models -- Relating fish population processes to "habitat condition" is a basic analytical need of many Recovery Plan actions. The approach of estimating population productivity or individual condition as a function of environmental conditions is relevant for all Listing Factors. Traditionally, these relationships have been developed for population processes as functions of freshwater physical habitat characteristics, but the methodology is not limited to these environments or lifestages. Several broad categories of modeling work have proven valuable in this regard: Leslie matrix models, Beverton-Holt population capacity models and Individual Based Modeling methods. All of these approaches to data analysis go well beyond the simple linear model of fish numbers as a function of environmental condition because they contain fundamental population process mechanisms – stage specific survival based demographics, density dependent population regulation and individuals' behavioral and physiological response to environmental conditions. All of these analytical methods are data intensive, so are rarely amenable to post hoc action evaluation. However, all of the data requirement of methods map directly to standard monitoring metrics, so it is possible to design management action evaluation processes that make use of these analytical tools.

Integrative (ecosystem, All-H) models -- Existing examples of quantitative "all-H" modeling have not been able to develop strong management recommendations (Hoekstra et al. 2007). The lack of management direction arises primarily from the models inability to unambiguously distinguish between threats, or "Hs". Taking an explicit ecosystem approach might be more appropriate from a biological mechanisms perspective (Harvey, C. J., P. Kareiva. 2005), but the trophic level results may be not translate well into the single species based management direction.

Large scale experimental designs -- Producing biological benefit, in terms of improvements in salmonid population processes such as stage specific survival, population growth rate, or population productivity is the goal of most Recovery Plan actions. Determining population-scale responses depends on the coordinated implementation of actions, the collection of population, habitat, and action tracking data, and an analytical approach that can predict a population-scale response from project-scale actions. Although the basic guidelines for monitoring management actions have been established, the details of implementation strategies, project prioritization processes, and data analyses remain undetermined. What we do know from previous work is that:

- Status and trends monitoring of background population and habitat condition is necessary to establish baseline conditions and to develop a reference data set for large-scale, long-term patterns that may confound population-scale analyses.
- Population-level responses to mitigation actions can only be detected at the appropriate spatial and temporal scales—generally at the spatial scale of populations, or at least that of major life-cycle components, and occurring over multiple years or generations.

- Individual management action responses can best be detected at the scale of the action itself—generally occurring at a reach or habitat unit scale and only after the objective of the action has been reached.
- Individual management actions generally do not directly impact population processes—their direct effect is to modify physical or biological habitat condition.
- Individual management actions generally occur at too fine a scale to generate population level responses.

Recognizing these underlying precepts, the task of developing a strategy for demonstrating the biological benefit of Recovery Plan actions is one of coordinating implementation of actions and monitoring to optimize a modeling approach to estimate the benefit rather than designing a monitoring program or set of monitoring tools to directly measure the benefit.

Why models, why not directly measure the biological benefit of Recovery Plan actions? No matter how well designed, on some level Recovery Plan implementation will be a disparate suite of actions scattered across a wide range of ecoregions and ESUs and as such will be difficult, if not impossible, to assess in a programmatic fashion, particularly if the response variable is population productivity or life-stage specific survival. Therefore, the only way to assess the overall impact of Recovery Plan implementation will be to estimate the biological benefit with a modeling approach that is dependent on on-the-ground monitoring of projects and watersheds to generate the mechanistic basis of the model and estimates for model parameters. Therefore, the challenge in designing and implementing Monitoring and Evaluation of Recovery Plan actions has four components: first to estimate, from whatever method, data and expert opinion is currently available the biological benefit of the actions; second, to specify an improved, more mechanistically based modeling approach from which subsequent progress and benefit evaluations will be done; third, to specify the data collection necessary to test the hypotheses posed by the initial and subsequent quantitative evaluation frameworks; and finally, to specify the adaptive process by which refinements on the monitoring and evaluation components are accomplished such that the balance between cost, timeliness, and certainty is maintained.

Decision Support System / Bayesian Belief Networks –These are modeling approaches that include quantitative evaluation of fish-H relationships but also directly support management decisions. DSS are potentially the ideal compromise between the need for transparent, consistent quantification of decision data and the ability to model the complexity of recovery plan implementation. Such systems need to have sufficient technical rigor that management support is justified, but also need to be accessible enough to be useful in a broad, changing context. DSS, and BBNs in particular, have a long history of application in natural resource management decision-making in Europe and Australia, but are only beginning to be applied to similar settings in North America (Pourret et al. 2008). Using these tools may greatly facilitate implementing the Adaptive Management plans each Recovery Plan describes. Recent examples of DSS/BBNs that recovery planning groups could consider are the DSS used by the Oregon Coast Coho TRT, the Lower Columbia Lisiting Factor, and BBNs developed for invasive species (e.g. Peterson et al 2008).

Steps forward

As a series of nest steps, we suggest that the Recovery Plan groups implement an analytical compilation of methods, just like trying the data compilation to evaluate the coverage of methods and data. It would also be helpful for each group to fully diagram the work-flow for all decision-making in the respective Recovery Plans – which data sets are necessary for which decision step, what work needs to be done on thresholds and criteria, where are gaps in information flow that will critically impact the entire evaluation cycle?

It would be of use to Recovery Plan groups to consult with the Northwest Forest Plan monitoring program (AREMP) and the Oregon state recovery program for input on assembling past monitoring data, building evaluation tools and testing the process in order to learn what was planned and worked, where the unexpected hurdles appeared, and how the experience was used to move monitoring and evaluation programs into the future.

All of the Recovery Plans need to carefully treat all limiting factor / listing factor decisions as hypotheses; as a result, the aggregate list of questions to be addressed will overwhelm the data collection and reduction steps, so a prioritization process is necessary.

- Not all limiting factor / listing factor dependent actions must be tested, but evaluation of implementation effects must consider the possibility that the lf/LF targeted was in fact not limiting
- Some plan for explicit testing of lf/LF should be developed that clearly states the assumed relationships between actions and habitat/population processes and the relationships to be tested.
- Data collection prioritization steps should be connected to the decision making work-flow and the assumption set to clearly communicate what is known, assumed or being measured.

Large-scale critical uncertainties

The M&E plans reviewed here were generally developed based on known, actionable threats to salmonid populations. Each plan was organized with these threats in mind. However, additional factors, issues, and processes could potentially overwhelm or at least undermine recovery efforts. Here we discuss several "critical uncertainties" that are generally applicable to all Recovery Domains. For the most part, these are not directly addressed in the reviewed M&E plans, although aspects of all of them may be dealt with in other parts of the associated recovery plans.

Four classes of such uncertainties were considered:

i. Habitat changes in large rivers and estuaries
ii. Human population growth
iii. Climate change, including regional variation
iv. Ecosystem state, integrity, and integration

Some details about coverage in each plan follow. Overall, the RIST concluded that two critical uncertainties – human population growth and climate change – could be particularly important to consider when developing monitoring plans. These uncertainties are especially noteworthy given findings of the Northwest Independent Scientific Advisory Board (ISAB 2007a,b), who concluded that climate change would cause negative environmental changes, particularly increased winter flooding; decreased summer and fall streamflows; and elevated stream, river, estuary and ocean temperatures. All could affect salmon recovery via influences on spawn timing, redd destruction, habitat alterations, larval and smolt development, oceanic survival, and food web disruption, among other impacts. Human population projections predict growth of 40% or more in the next 40 years, leading to increased demand on resources critical to salmon recovery, especially water availability and quality; accelerated land conversion; and loss, degradation, and fragmentation of habitat. Climate change and population growth will combine to increase pressure on fish habitats. Although it is difficult to plan for unknown future events, all recovery plans need to be sufficiently adaptable to adjust to emerging trends and appropriate monitoring will be an important part of this adaptability.

Processes in large rivers and estuaries (and nearshore coastal nursery habitats) can also influence the outcome of plan implementation and may deserve greater monitoring attention and resources. In the plans we reviewed, few specifics were provided as to how estuarine habitats will be sampled, monitored, and evaluated.

An ecosystem-based perspective is increasingly valued among managers in general (NRC 1999; NMFS 1999; Helfman 2007). Just as none of the identified listing factors operates alone to delay salmon recovery, all biological, ecological, hydrological, and physical aspects of salmon life history interact to affect populations. Integration of an ecosystem perspective into the plans, including communication/integration among agencies and workers throughout each basin would appear to be important.

What follows is a very brief summary of how each of the reviewed M&E plans addresses these uncertainties. This provided for information only; we do not intend this to be a criticism of any particular plan.

A. Puget Sound Monitoring And Adaptive Management (MAMA) Plan

Large rivers and estuaries. The plan emphasizes the importance of mainstem and estuarine habitats and calls for Landsat analysis of mainstem rivers to analyze land use and vegetative cover, instream habitat, road density, and floodplain connectivity and mainstem channel structure. Landsat analysis will be similarly applied to loss or degradation of estuarine habitat.

Major improvement of habitat conditions within mainstem rivers is considered necessary to attain recovery goals, especially for Chinook. Because the development footprint is most intense around mainstem rivers, recovery actions that improve mainstem conditions will also benefit many other species. The long-term strategy is to reduce further degradation of the mainstem rivers by protecting existing healthy habitat, and restoring wetlands and the connections of rivers and floodplains.

Human population growth. The Shared Strategy acknowledges that population growth will continue in the area and relies on existing growth management plans, emphasizing encouragement of growth in existing urban areas and no expansion of the urban growth boundary. The recovery plan concludes that the impacts of growth and development are a "major source of uncertainty in the Recovery Plan and must be addressed in the detailed adaptive management plan" (Chap. 7, p. 454). Otherwise, the issue is not addressed, neither here nor in the adaptive management plan (Volume III).

Climate change / patterns / variation. The plan acknowledges that a changing climate directly affects listed salmonids via impacts to water temperature, ocean cycles and currents, migration and abundance of predators, food chain dynamics, precipitation and snowpack relative to seasonal streamflow, and other habitat features. A brief discussion focuses on some research findings and sources of additional information, emphasizing. "the need to maintain . . . populations through conservation and restoration of freshwater and estuarine habitat" (Chap. 3, p. 123), which is to say that changing climate will exacerbate existing problems and only increase the need for active, adaptive management and conservation. However, "none of the watershed plans have proposed means of monitoring climate change or its impacts" (Chap. 7, p. 455). Benchmark 2A of MAMA deals with current and potential effects of climate change on achieving viability criteria. This section is incomplete, however, requiring NOAA "to provide this information for completion of the final draft."

Ecosystem state / integrity / integration. An emphasis on an ecosystem approach to recovery is clear throughout the document, repeatedly emphasizing actions focused on "protection, enhancement, and restoration of naturally-functioning ecosystems" for salmon and species that depend on salmon (Chap. 1, p. 20; Chap. 5, pp. 212, 307). The MAMA plan incorporated the Ecosystem Management Initiative (EMI) approach to ecosystem-based adaptive management developed at the University of Michigan. As above, Monitoring Data and Reporting Systems apparently await input from NOAA.

B. Lower Columbia Fish Recovery Board: Research, Monitoring and Evaluation Program for Lower Columbia Salmon and Steelhead

Large rivers/estuaries. The LC plan focuses on the estuary and mainstem as a combined unit, referring to a pre-existing comprehensive estuary recovery plan module (NMFS 2007) and a dedicated research, monitoring, and evaluation program (Johnson et al. 2008). An extensive list of variables and indicators follows, but no details of actual methods or sampling schedules are provided. A list of 22 "research needs" follows, but again few specifics are provided.

Specified monitoring of mainstem and estuarine habitats includes: passage, habitat protection and restoration, and mitigation-related impacts at Bonneville Dam; PIT tags to estimate project and reach survival rates throughout the mainstem Columbia and in the estuary; and harvest impacts on representative index stocks in the mainstem. Attributes, metrics, example statistics, and sampling methodologies for ecological interactors (e. g., predators and introduced competitors) are presented, noting that these topics represent significant information gaps.

Human Population Growth. The valley and foothill portions of the Lower Columbia region -- historically the most productive habitat for fall Chinook and chum salmon -- are most likely to absorb much future population growth. No other mention of human population trends occurs.

Climate change/patterns/variation. Identification of long term trends in global factors affecting salmon production including climate is identified as a research need. No other mention of climate change occurs.

Ecosystem state / integrity / integration. The topic is not directly addressed.

C. Upper Columbia Spring Chinook Salmon and Steelhead Monitoring, Evaluation, and Adaptive Management Plans, Appendix P and Q

Large rivers/estuaries. An extensive mainstem and tributary sampling regime is ongoing and planned for adults and smolts, focused on possible changes in life history characteristics. UC is depending on the Lower Columbia River Estuary Partnership to implement and coordinate estuary monitoring activities.

Human population growth. The topic was not directly addressed.

Climate change/patterns/variation. A protocol for assessing drought trends is presented, contingent on resources becoming available.

Ecosystem state / integrity / integration. The Upper Columbia approach is based on the University of Michigan Ecosystem Management Initiative, as in the Puget Sound MAMA, but the topic does not appear to be addressed directly beyond that.

References

AREMP (Aquatic and Riparian Effectiveness Monitoring Plan) http://reo.gov/monitoring/watershed-overview.shtml

Bisbal, G. A. 2001. Conceptual design of monitoring and evaluation plans for fish and wildlife in the Columbia River Ecosystem. Environmental Management. 28(4):433-453.

Burnett, K.M., G.H. Reeves, D.J. Miller, S. Clarke, K. Vance-Borland, and K. Christiansen**.** 2007. Distribution of Salmon-Habitat Potential Relative to Landscape Characteristics and Implications for Conservation. *Ecological Applications*.17(1):66-80.

Courbois, J.-Y.; Katz, S.L., Isaak, D.J., Steel, E.A., Thurow, R.F., Rub, A.M.W., and Jordan, C.E. 2008. Evaluating probability sampling strategies for estimating redd counts: an example with Chinook salmon (Oncorhynchus tshawytscha). Canadian Journal of Fisheries and Aquatic Sciences 65: 1814-1830.

Crawford, B.A. and S. Rumsey. 2009 (Draft). Guidance for monitoring recovery of salmon and steelhead listed under the Federal Endangered Species Act (Idaho, Oregon, and Washington). National Marine Fisheries Service, Portland, OR.

CSMEP (Collaborative System Wide Monitoring and Evaluation Project) http://www.cbfwa.org/csmep/web/Content.cfm?ContextID=1

Dunham, J.B., Rieman, B.E., and Davis, K. 2001. Sources and magnitude of sampling error in redd counts for bull trout. North American Journal of Fisheries Management. 21:343-352.

Ford, M. J., N. J. Sands, P. McElhany, R. G. Kope, D. Simmons, P. Dygert. 2007. Analyses to Support a Review of an ESA Jeopardy Consultation on Fisheries Impacting Lower Columbia Tule Chinook Salmon. National Marine Fisheries Service, Northwest Fisheries Science Center, Conservation Biology Division; National Marine Fisheries Service, Northwest Regional Office, Sustainable Fisheries Division.

Gallagher, S.P. and C.M. Gallagher. 2005. Discrimination of Chinook salmon, Coho salmon and steelhead redds and evaluation of the use of redd data for estimating escapement in several unregulated streams in Northern California. North American Journal of Fisheries Management. 25:284-300.

Harvey, C. J., P. Kareiva. 2005. Community context and the influence of non-indigenous species on juvenile salmon survival in a Columbia River reservoir. Biological Invasions, 7:651-663.

Helfman, G. S. 2007. *Fish Conservation: A Guide to Understanding and Restoring Global Aquatic Biodiversity and Fishery Resources*. Washington, DC: Island Press.

Hoekstra, J. M., K. K. Bartz, M. H. Ruckelshaus, J. M. Moslemi, T. K. Harms. 2007. Quantitative threat analysis for management of an imperiled species-Chinook salmon (Oncorhynchus tshawytscha). Ecological Applications, 17:2061-2073

ISAB (Independent Scientific Advisory Board). 2005. Report on Harvest Management of Columbia Basin Salmon and Steelhead. ISAB 2005-4. Northwest Power and Conservation Council, Portland, OR. (www.nwcouncil.org/fw/isab/)

ISAB. 2007a. Climate change impacts on Columbia Basin fish and wildlife. ISAB Report 2007-2. Portland, Oregon: Independent Scientific Advisory Board for the Northwest Power and Conservation Council, Columbia River Basin Indian Tribes, and National Marine Fisheries Service.

ISAB. 2007b. Human population impacts on Columbia Basin fish and wildlife. ISAB Report 2007-3. Portland, Oregon: Independent Scientific Advisory Board for the Northwest Power and Conservation Council, Columbia River Basin Indian Tribes, and National Marine Fisheries Service.

ISAB and ISRP 2004. A joint ISAB and ISRP review of the Draft Research, Monitoring and Evaluation Plan for the NOAA-Fisheries 2000 Federal Columbia river Power system Biological Opinion. ISAB&ISRP 2004-1.

ISEMP (Integrated Status and Effetiveness Monitoring program) (http://www.nwfsc.noaa.gov/research/divisions/cbd/mathbio/isemp/index.cfm

Johnson, D. H.; Pittman, N.; Wilder, E.; Silver, J. A.; Plotnikoff, r. W.; Mason, B. C.; Jones, K. K. ; Roger, P.; O'Neil, T., and Barrett, C. 2001. Inventory and Monitoring of Salmon Habitat in the Pacific Northwest: Directory and Synthesis of Protocols for Management/Research and Volunteers in Washington, Oregon, Idaho, Montana, and British Columbia. Olympia, WA: Washington Department of Fish and Wildlife; 2001.

Johnson, D.H., Shrier, B.M., O'Neal, J.S., Knutzen, J.A., Augerot, X., O'Neil, T.A. 2007. Salmonid field protocols handbook: Techniques for assessing status and trends in salmon and trout populations. American Fisheries Society, Bethesda, MD.

Johnson, G.E, Diefenderfer, H.L., Ebberts, B.D., Tortorici, C., Yerxa, T., Leary, J. and, J.R. Skalski. 2008. Research, Monitoring, and Evaluation for the Federal Columbia River Estuary Program. Dept. of Energy Report to Bonneville Power Administration. PNNL-17300.

Johnson, J.K. 2004. Regional review of coded wire tagging of anadromous salmon and steelhead in northwest America. Paper updated from 1989 to current year 2004. Available on line: http://www.psc.org/pubs/CWT/CWTWebPapers/SpecificForWorkshop/johnson2004.pdf

Lane, S.N and P.E. Carhonneau. 2008. High Resolution Remote Sensing for Understanding Instream Habitat. In: *Hydroecology and Ecohydrology.* Editor(s): Paul J. Wood, David M. Hannah, Jonathan P. Sadler. John Wiley & Sons, Ltd

Lee, D., J. Sedell, B. Rieman, R. Thurow, and J. Williams. 1997. Assessment of the condition of aquatic ecosystems in the Interior Columbia River Basin . Chapter 4. Eastside Ecosystem Management Project. Pacific Northwest Research Station, PNW-GTR-405, Portland, OR.

Mollot, L. A. and R. E. Bilby. 2008. Use of remote sensing data and habitat suitability models to identify riparian areas where restoration would have the greatest benefits for anadromous fishes. Restoration Ecol. 16: 336-347.

NMFS (National Marine Fisheries Service). 1996. *Making ESA determinations of effect for individual or grouped actions at the watershed scale.* National Marine Fisheries Service, Portland, Oregon, USA.

NMFS (National Marine Fisheries Service). 1999. Ecosystem-based fishery management. A report to Congress by the Ecosystems Principles Advisory Panel. Silver Spring, MD: US. Dept Commerce.

NMFS (National Marine Fisheries Service). 2007. Proposed Columbia River Estuary ESA Recovery Plan Module for Salmon & Steelhead. http://www.nwr.noaa.gov/Salmon-Recovery-Planning/ESA-Recovery-Plans/Estuary-Module.cfm

NRC (National Research Council). 1999. *Sustaining marine fisheries*. Washington, DC: National Academy Press.

Parken, C.K. , R.E. Bailey and J.R. Irvine. 2003. Incorporating uncertainty into area-under the curve and peak count salmon escapement estimation. North American Journal of Fisheries Management. 23:78-90.

Peterson, D.P., Rieman, B.E., Dunham, J.B., Fausch, K.D. and M.K. Young. 2008. Analysis of trade-offs between threats of invasion by nonnative brook trout (Salvelinus fontinalis) and intentional isolation for native westslope cutthroat trout (Oncorhynchus clarkii lewisi). Can. J. Fish. Aquat. Sci. **65**:557-573.

Peterson, J.T., Thurow, R.F., and Guzevich, J.W. 2004. An evaluation of multipass electrofishing for estimating abundance of stream dwelling salmonids. Transactions of the American Fisheries Society. 133: 462-475

Pourret, O., Naim, P., and B. Marcot. 2008. *Bayesian Networks: A Practical Guide to Applications.* 446pp. J. Wiley, New York, NY.

PSC (Pacific Salmon Commission) 2005 Expert Panel on the Future of the Coded Wire Tag Program for Pacific Salmon. 2005. Report. Pacific Salmon Comm. Tech. Rep. No. 18: 230 p. http://www.psc.org/pubs/psctr18.pdf).

PIBO (PacFish/InFish Biological Opinion Effectiveness Monitoring Program). http://www.fs.fed.us/biology/fishecology/emp/

PNAMP (Pacific Northwest Aquatic Monitoring Partnership). http://www.pnamp.org/web/Content.cfm?SectionID=8

Roni, P., Liermann, M.C., Jordan, C.E., and E.A. Steel. 2005. Steps for designing a monitoring and evaluation program for aquatic restoration. Pages 13-34. In Roni and Quimby (eds) 2005. *Monitoring stream and watershed restoration*. American Fisheries Society Press. Bethesda, MD.

Roper, B. B., J. M. Buffington, E. Archer, C. Moyer, and M. Ward. 2007. The Role of Observer Variation in Determining Rosgen Stream Types in Northeastern Oregon Mountain Streams. Journal of the American Water Resources Association (JAWRA) 44(2):417-427.

Sharpe, C.S., B.G. Glaser and D.J. Rawding. 2009. Spawning escapement, juvenile production, and contribution to fisheries for Coweeman River fall Chinook salmon: A completion report for work in 2007 and 2008. Washington Dept. of Fish and Wildlife. 61p.

Weeks, H., B. Riggers and J. White. 2003. Fall Chinook salmon in the Siuslaw River: spawner escapement, run reconstruction and survey calibration 2001-2002. Cumulative Progress Report. Oregon Dept. of Fish and Wildlife. Coastal Chinook Research and Monitoring Project. 36 p.