Return to Table of Contents
Go to Next Chapter

CHAPTER 11. MONITORING AND EVALUATION: THE MISSING LINK

"That in view of the lack of definite assurance as to the degree of success to be anticipated from the plan as proposed, its experimental character should be recognized; and it follows that the adoption of the plan for trial should not be understood as implying an indefinite commitment to its support, but only for so long as the results may reasonably appear to justify its continuance."

Calkins, R. D., H. F. Durand and W. H. Rich. 1939. Report of the Board of Consultants on the fish problems of the upper Columbia River. Sections 1 and 2. Stanford University, California.

Monitoring and evaluation has been a long-standing issue of concern in the Columbia River basin, as well as for the Council's Fish and Wildlife Program. The importance of the monitoring and evaluation functions has been recognized for some time (Calkins et al. 1939) including the necessary linkage of monitoring and evaluation with adaptive management (Lee 1993; Volkman and McConnaha 1993; McConnaha and Pacquet 1996). Nevertheless, system-level monitoring and evaluation remains an elusive goal (MEG (Monitoring and Evaluation Group) 1988; Independent Scientific Review Panel 1997)

Peer review of the Council's Fish and Wildlife Program and the projects funded under it were formally initiated in 1997 through an amendment to the Northwest Power Act. The amendment directed the Council to form an Independent Scientific Review Panel (ISRP) to make recommendations to the Council on project priorities within the Columbia River Basin Fish and Wildlife Program (FWP) and to review the projects proposed for funding for their scientific merit and consistency with the program. The ISRP reports its findings annually by June 15 before the Council adopts its annual funding recommendations.

Incorporating independent peer review and altering the project selection process into a smoothly functioning process has been a challenge to the region (Independent Scientific Review Panel 1997; 1998; 1999). One of the benefits of this process has been increased attention and rigor for monitoring and evaluation at the project level. However, little progress toward a meaningful system-level monitoring and evaluation program has occurred.

Our alternative conceptual foundation for the Fish and Wildlife Program (Chapter 3) necessitates revisiting the program's monitoring and evaluation functions. New metrics more appropriate to this view of the system need to be found or forged from existing activities. For example, the restoration or simulation of key ecological features known to support salmon may be more readily monitored than the salmon themselves in some cases.

Monitoring and Evaluation in the Program

The Council is committed to monitoring and evaluation to promote sound investments in salmon and steelhead projects (1994 Program sections 1.3A; 1.4; 3.2E.1). Although implied from the earliest planning under the Northwest Power Act, a monitoring and evaluation role was made explicit in the 1987 amended program with inclusion of a System Monitoring and Evaluation Program to track progress of the Fish and Wildlife Program in achieving the Council's goals of doubling the runs of salmon and steelhead in the basin. The 1994 Fish and Wildlife Program states that there will be an evaluation path as well as an implementation path (NPPC 1994a). This path will "monitor overall program implementation, evaluate the effectiveness of actions taken, and judge their scientific merits." The key is ensuring feedback so that the Fish and Wildlife Program can be modified as needed to reach goals. Learning from implementation is the essence of "adaptive management," which has been adopted as a guiding philosophy for the program. Adaptive management requires a deliberately designed experiment to manipulate factors, such as river flow, then to monitor and evaluate the effects on salmon. Appropriate data gathering during these events should lead to recognition of their value and to refinement of any subsequent actions. The Program also states that base-line information is needed, which will improve management and conservation of wild and naturally spawning populations (7.1C).

Monitoring and evaluation activities have been assessed periodically for the program. Everson et al. (1989) summarized the history of habitat monitoring and evaluation in the Program up to 1986. Monitoring and Evaluation has been the subject of a NPPC staff issue paper (NPPC 1988) and recommendations have been obtained from a peer group established by the Council (MEG (Monitoring and Evaluation Group) 1988). Monitoring and evaluation elements of the Fish and Wildlife Program are periodically reviewed as part of the Council's System Planning Process (an effort under the lead of the fisheries agencies and tribes to plan fisheries actions in 31 subbasins related to production objectives, constraints and opportunities). A Coordinated Information System has been developed for collection and dissemination of information produced as part of the Fish and Wildlife Program. BPA has tried to include decision science in its efforts to use the value of information as a means to focus and prioritize potential monitoring activities.

There has been a significant change in the monitoring and evaluation aspects with the 1994 program, reflecting these assessments. Specifically, more emphasis has been placed on the use of indicator stocks tied to rebuilding schedules which are, in turn, tied to program goals (framework). High priority populations are to be identified as indicator stocks (4.3C) and long-term monitoring strategies developed for them. Rebuilding targets and performance standards are to be established wherever possible as explicit means for measuring progress (Section 4). If progress toward standards and targets falls significantly short, the Council will revisit all aspects of the Program (3.1B). Effects on resident fish and wildlife are to be monitored to avoid indiscriminate shifting of environmental problems from salmon to these species as a result of using upstream reservoirs to supply water for downstream migrants (1.4). Periodic assessment of the ecological health of the Columbia River Basin is called for (introduction to Section 2). Measures of ecosystem health are to be selected to simplify this evaluation (2.1A.1). The annual emigration of smolts is to be monitored by the Smolt Monitoring Program of the Fish Passage Center (5.1B).

One way the Council has moved to ensure monitoring and evaluation is to structure projects so that they test quantitative hypotheses wherever possible (3.2; 5.0). These quantitative hypotheses are to be prioritized according to key uncertainties identified by the Independent Scientific Group (3.2). To narrow the focus of monitoring to a manageable level, the Program calls for identification of index stocks (indicator populations) and their monitoring needs (3.2A.1; 4.3C). Analytical tools for monitoring and evaluation are in need of development (3.2F; 4.3C.1) to link program actions to survival targets, rebuilding schedules, and rebuilding targets. The tools are to reflect the span of legitimate scientific differences and approaches. Computer models and their uses are given special attention. The Program suggests a regional center for biological analysis (3.2F.1), although this has yet to be seriously considered or implemented. Effective compilation of data and their availability are essential to monitoring and evaluation, and the Program assigns these tasks to the Coordinated Information System (3.3; 4.3C.1), now known as StreamNet. The most explicit foray by the Program into a specific monitoring and evaluation exercise is the mainstem passage experimental program, which requires extensive monitoring and evaluation (Section 5). This experiment is intended to be an evaluation project to test the relative benefits of two modes of fish passage--in-river and transportation (by barge or truck). The long-term experiment is underway and periodic reports have been published (Bugert et al. 1997).

Despite good intentions, the 1994 Program recognizes that there has been unsatisfactory progress in coupling actions (taken with the best available information) and evaluation to allow learning from implementation (2.2H). The Program now couples an annual implementation work plan, an annual monitoring report on meeting targets and standards (by the Coordinated Information System/StreamNet), and a biennial evaluation of the Program on its scientific merits (by the Independent Scientific Group, now called the Independent Scientific Advisory Board) (3.1B; 3.2A.2; 3.2B.1; 3.3A.2). Reflecting the need for the Program actions to be implemented and monitored in a coherent, well-organized, and carefully disciplined manner, the Council has requested a management consultant's analysis of the management of the Program (3.1E.1). This analysis would include development of measurable benchmarks and workable mechanisms for measuring progress. The Program also calls for attention to the endangered species consultation process to ensure consideration of monitoring and evaluation (3.2D.1). Coordination of monitoring and evaluation is to be fostered by publication of summaries of results of all studies funded by the Program and incorporation of them into the electronic database of the Coordinated Information System/StreamNet, as well as oral presentation of project reports at symposia (3.2G).

The Fish and Wildlife Program recently included 58 projects categorized by BPA as "monitoring and evaluation" (Lohn 1995). The Fiscal Year 1995 planned cost for these projects was $22,471,432. Many of these projects involve data collection whereas others are mainly consultative (the funding for the Independent Scientific Group is one such project). The management agencies also conduct extensive monitoring of their resources within the general umbrella of the Fish and Wildlife Program. For example, the U. S. Army Corps of Engineers monitors the passage of adult fish past each of its projects, while the mid-Columbia public utility districts do so at most of their projects. States have had monitoring programs underway with a different impetus, such as fulfillment of the 1975 Lower Snake River Compensation Plan (US Army Corps of Engineers 1975). All fish and wildlife projects funded by the Bonneville Power Administration are now listed on the Internet at the StreamNet site (www.streamnet.org). Data queries allow searching for monitoring projects.

Recently, the Columbia Basin Fish and Wildlife Authority (Columbia Basin Fish and Wildlife Authority 1997) has included specific recommendations for monitoring in its Multi-Year Implementation Plan. An initial set of index populations and their associated watersheds form the basis of this program. Key parameters to be monitored are included. These are discussed further below.

Perspectives on Monitoring and Evaluation

There are two perspectives on "monitoring and evaluation" in the Fish and Wildlife Program, biological inventory and program evaluation. The two are often inadequately distinguished. Biological inventories are the counting of salmon, steelhead, resident fishes, and wildlife within migrations or water bodies and from year to year (e.g., 4.3C and 7.1C) to establish a numerical basis for evaluating trends in population sizes and needs for (and results of) water and habitat management and improvement. The programmatic perspective is the monitoring of the success of specific projects and programs within the Fish and Wildlife Program (in both social and biological terms) as a basis for evaluating whether to continue them as part of the Fish and Wildlife Program or to develop alternatives through adaptive management (e.g., ß

3.1B). Programmatic monitoring and evaluation are highly dependent on the biological monitoring for measures of success (or failure) of the Fish and Wildlife Program in terms of salmonid population sizes.

This distinction is not universally applied, and there is often confusion about what is meant by "monitoring" and "evaluation" (terms that are usually given inseparably). Monitoring is often reserved for the environmental measurements (biological and physical-chemical), whereas evaluation is thought of as programmatic. Monitoring and evaluation, both environmental and programmatic, should be separate stepwise processes, sometimes occurring together but often not. Linkage of the two terms and failure to differentiate the perspectives behind their use has contributed to numerous false starts at both environmental and programmatic efforts. Monitoring of selected environmental features is essential if we are to keep track of overall progress toward Fish and Wildlife Program goals. Whether we have environmental monitoring or not, the Fish and Wildlife Program needs evaluation of all projects and programs. We believe that there should be a clearer distinction between the two activities in the conduct of the Fish and Wildlife Program.

The need for better distinction and for further resolution of monitoring and evaluation activities prompted the authors of Wy-Kan-Ush-Mi-Wa-Kish-Wit (Columbia River Inter-Tribal Fish Commission (CRITFC) 1995). The tribal recovery plan to offer five levels for attention: (1) project accountability, (2) project effectiveness, (3) resource status, (4) strategy effectiveness, and (5) program effectiveness. These levels and their application are discussed more fully in the CBFWA Multi-Year Implementation Plan (Columbia Basin Fish and Wildlife Authority 1997). The additional resolution is good, but the distinction betwen biological and managerial (programmatic) monitoring and evaluation still remains blurred. Items two and three may be considered biological inventory as both attempt to record the project-specific or resource-wide changes (hoped to be benefits for salmonids) from restoration actions. The other three items are predominantly programmatic assessments--evaluations of the management processes at either the project or program level.

A major problem over the years has been a relative lack of evaluation of the results of biological monitoring. A significant reason has been the lack of identified forums responsible for making evaluations and acting on the results. Among existing groups, there has been confusion generally about the proper roles and responsibilities of technical groups (evaluation) and policy groups (deliberation and decision). Evaluation by technical specialists has often been derided as improper excursions into policy formulation. Consequently, critical technical evaluations have not been done or have not been fully incorporated into management decisions. A clearer role is needed for technical/scientific evaluation in the pathway to management and policy decisions. The ISG suggests a definition of roles in Figure 11.1. It would be useful if all groups in the basin related to fish and wildlife monitoring, evaluation, and policy located themselves explicitly on such a flowchart.

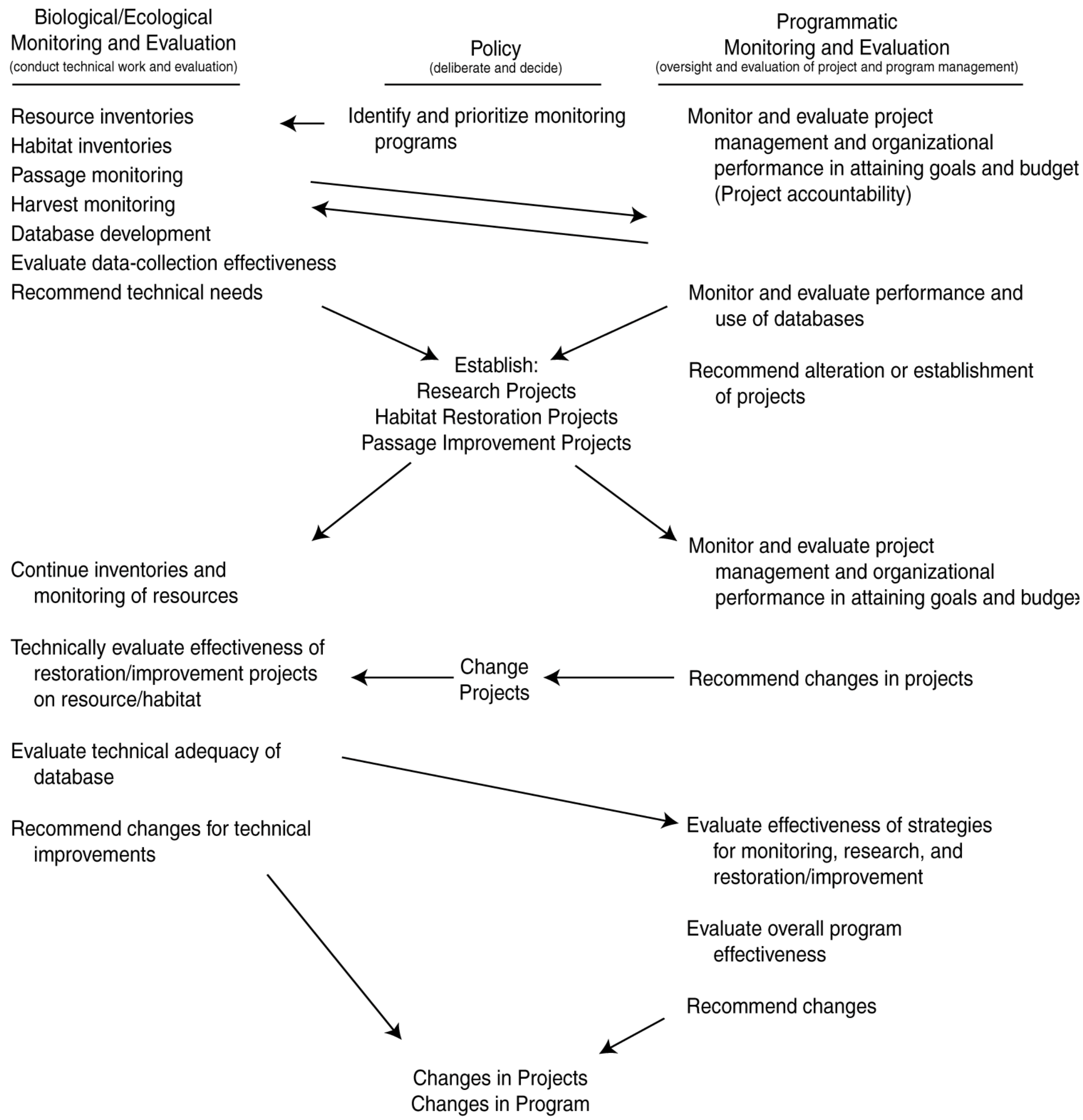

Figure 11.1. Relationships among three aspects of "monitoring and evaluation" (a) technical work of biological/ecological monitoring and data analysis, (b) oversight of programs (programmatic monitoring and evaluation), and (c) policy deliberation and decisions regarding projects to conduct and adaptive management based on the results. All three are important for an effective monitoring program.

This review focuses on biological-environmental monitoring rather than programmatic monitoring. Monitoring and evaluation of the biological successes of implementation actions are usually built into specific project plans. Some approaches for monitoring and evaluation in the Fish and Wildlife Program were provided by Coutant and Cada (1985). The ISG previously provided fish and wildlife program managers with additional guidelines for monitoring and evaluation. These guidelines included a formal review of all projects every 3-5 years by a review team of professional peers. The review would include evaluations of published material, an administrative briefing for project context, a project overview, technical presentations, site tours, discussions with staff, discussions among the review team members, and a written report usually accompanied by a close-out briefing to project managers and staff.

Issues in Monitoring and Evaluation

Numerous issues have concerned those people responsible for planning monitoring and evaluation activities. Many issues have been procedural (i.e., What is the "flow chart" of information and decision-making?). Others have focused on what to measure. As we consider a new conceptual foundation, it is important to recognize the evolution of ideas that has already occurred.

• Policy. That there should be monitoring and evaluation is uncontested and well supported by the 1994 Program. The issue is whether it has been sufficient. Lists of things to monitor have grown longer and the need for prioritization became evident. Notions of the relative value of information became a criterion for project selection, without answering the question of what makes information valuable.

• Scientific. The Monitoring and Evaluation Group (MEG 1988) clearly stated the main scientific issue: a measure of progress for the Program should not only determine progress (such as toward a doubling goal), but should also provide information to increase understanding, decrease uncertainty, and permit the Program to be refined over time (i.e., adaptive management). A recent issue is the matter of how the Program and its monitoring and evaluation have been focused by prevailing beliefs. Ideally, there should be an objective analysis of all information, aided by alternative hypotheses. A critical issue is whether current beliefs are sufficiently supported by the evidence. This review suggests that a new ecological belief structure may be more productive that previous ones guided principally by technology.

Identification of results from actions taken under the Fish and Wildlife Program has been difficult because evaluations have relied primarily on before/after or treatment/control comparisons, which were not designed to account for temporal variations in other portions of the salmon life cycle. Newer approaches suggest a method of disaggregating the salmon life cycle into suitably small temporal and spatial segments where a cause and effect approach can be better applied (Columbia Basin Fish and Wildlife Authority 1997).

• Program focus. With a multitude of influences and management efforts related to fish and wildlife in the Columbia River basin, especially salmonids, identification of positive results from actions derived specifically from the Council's Fish and Wildlife Program is difficult. There are factors beyond human control, such as cycles of ocean productivity and temperature (El Nino), management of harvest rates outside the Program, and programs funded by other agencies (such as the Corps of Engineers) that affect total populations, but may not be fully integrated into the Fish and Wildlife Program (NPPC 1992a). Assigning credit for accomplishments is not just an administrative exercise, for it is germane to estimating whether specific actions have been effective and which have not.

• Observation vs. analysis. Sufficiency of numerical fish counts for evaluating overall Program success is questionable. Although the Fish and Wildlife Program goal is stated simply as a doubling of runs, what and where to measure is not straightforward. Observational methods are insufficient without analytical methods that use these data in population-level models to estimate trends and correlations with environmental factors (MEG 1988). Analytical methods build upon numerical observations to increase information content by integrating environmental indices, research results and monitoring data into mathematical expressions that are hypotheses for explaining trends in observational data. But the critical question of what constitutes the population to be modeled remains to be determined.

The Northwest embarked on a massive analytical effort when it initiated in 1995 a multi-agency process termed PATH--Plan for Analyzing and Testing Hypotheses (Marmorek and Parnell 1995). This project has attempted to synthesize observational monitoring data in the context of models for fish population dynamics. Final results are expected in 1999.

• Index life stage(s). The point in salmonid life cycles that best represents success and should be monitioried is uncertain (MEG 1988). Counts of juvenile emigrants have the appeal of being a rapid and direct measure of the effects of many Fish and Wildlife Program actions in the freshwater part of the life cycle. This avoids survival problems in the ocean over which the Fish and Wildlife Program has no control and the delay to maturity of up to five years in the case of chinook salmon. Yet smolt monitoring has logistical difficulties, it contributes to a continued fragmented approach; it fails to consider smolt quality; and tells only part of the salmonid story. In lieu of direct counts, however, there is the opportunity to use various smolt indices, such as those collected by the Fish Passage Center. Adults are often seen as a better "bottom line" for evaluation, but it is difficult to separate the effects of Program actions from other factors, particularly those in the estuary and ocean. MEG recommended four indices: (1) a measure of annual juvenile production, (2) an estimate of annual adult equivalent production, (3) a life-cycle analysis of stock productivity, and (4) a program to monitor genetic effects of management actions.

• Analytical tools. The best analytical tools are not evident. Statistical methods might be used to discern relationships between variables. A life-cycle approach uses a computer model of population dynamics as a conceptual basis for explaining trends displayed by the observational indices. Each has its appropriate uses and drawbacks (MEG 1988). MEG concluded that, because no single measure of Program progress could be found to identify effects of the Program from non-Program effects(either existing or that could be developed) the effects would have to be isolated by analytical methods such as life-cycle models. This conclusion spawned a flurry of model generation by different agencies aimed at integrating parts of the life cycle (CRiSP, FLUSH, SLCM). Recent evaluations of alternative life-cycle models indicates that they are very sensitive to initial assumptions ("belief systems") and that, as such, they can be better used to frame and test hypotheses (different beliefs) than to make predictions about the future (Barnthouse et al. 1994). This weakness of models is often overlooked in the search for an objective means of selecting management options. The PATH process, noted above, is an attempt to reconcile several models and the monitoring data (Marmorek and Parnell 1995). Unavoidably, PATH suffers from some of the same weaknesses as the models it attempts to reconcile.

• Experimental design. The costs of monitoring can exceed benefits unless attention is paid to the likely use of information. Monitoring can be seen as an "experiment" in which key information is needed to verify (or not) certain hypotheses (although it is not really an experiment, but a way of obtaining information useful in testing hypotheses). The hypotheses can be coded in the life-cycle models. MEG (1988) proposed monitoring of subbasin plans and specific additional research to fill information gaps. An important issue is how to maintain long-term data collections (often extending for 30 years or more) while also focusing on key parameters that need evaluation for population models.

• Information system. Coordination and organization of large amounts of monitoring information are as important as the program to collect it. The information must be made available to decision makers in a timely and effective manner. This was recognized in the 1987 Program {206(d)(C)} and a Coordinated Information System, now called StreamNet,was implemented (Anderson 1995; Anderson et al. 1996). Items for attention by the Coordinated Information System/StreamNet were not just data archiving, but documentation of data sources, procedures and quality; consistency of data collection to ensure comparability of data sets; and development of ways to communicate data and analytical results in a timely and clearly understandable way.

Hard-copy reports often have been inadequate for effective adaptive management. Although BPA publishes progress and final reports, there is often a lag of several years between completion of the manuscript by the authors and the actual publication date (as indicated by the date given with the document number on the back cover). The publication mechanisms have led to information being unavailable, not provided in a timely manner, provided by informal routes susceptible to misinterpretation and bias, and with a variety of citation formats. The Fish Passage Center provides weekly reports of smolt monitoring data and relevant management actions that are mailed to those who request them.

Recent availability of the World Wide Web on the Internet has opened the way for rapid communication of reports and monitoring data on demand. For example, the Corps is now placing daily fish count and environmental data from its projects on the Web, as is the Fish Passage Center. Others, such as the University of Washington, have life cycle models (CRiSP) on their Web sites. Many of these sites can be accessed through the home pages of the Council (www.nwppc.org) and Bonneville Power Administration (www.bpa.gov). An emerging issue is how to make effective use of this new mode of accessibility for data and analytical tools.

• Effective adaptive management. Monitoring and evaluation are justified as being needed for "effective adaptive management." The reality is, however, that we have few documented examples of adaptive management. Until examples are collected and discussed, the skeptics with regard to adaptive management will remain reluctant to test and use it. McConnaha and Paquet (1996) have summarized adaptive strategies for management of ecosystems in the perspective of the Columbia River experience.

• Overall assessment of monitoring and evaluation. The bottom line is whether the monitoring and evaluation portion of the Fish and Wildlife Program is providing an accurate and thorough scientific basis for actions that improve salmon populations. The key criterion by which the effort is judged is whether salmonid stocks improve. They have not. Monitoring and evaluation of a downward spiral in fish numbers signals that we did not learn enough from the data collection and analysis to reverse the trend of decline.

Monitoring of fish populations

Monitoring of fish migrations has been part of the Fish and Wildlife Program from the outset to provide information on the migrational characteristics of the various stocks of salmon and steelhead within the Columbia Basin. This program has included counting of adults passing through fish ladders, index counts of redds in spawning areas, and monitoring of outmigrating juveniles principally at dams. The monitoring was not initiated with the Fish and Wildlife Program, but was a continuation, extension and refinement of adult counting conducted by dam operators and state agencies at fish ladders, redd counting by agencies, and other monitoring programs. The emigrant monitoring effort has been standardized and coordinated in recent years by the Fish Passage Center of the Columbia Basin Fish and Wildlife Authority. Considerable effort has been made to shift smolt monitoring from a role of merely documenting numbers for the historical record to one of rapid data processing so that the numbers can be used during migrations for management purposes, such as adjusting river flows with the intent of assisting peak migrations.

We reviewed the process of monitoring and the evaluation of monitoring data and we examined the development of techniques for monitoring, the types and intensity of monitoring in the basin, and the ways data are handled and evaluated. We concentrated on monitoring of juveniles. The ISAB reviewed adult passage issues in 1999 as part of a larger review of the US Army Corps of Engineer's capital construction program (Independent Scientific Advisory Board 1999d). The counting of adults presents some problems, such as double counting, fallback, migration through the navigation channels where they are not counted, and others. The ISAB recommended that PIT tag detectors for adults, and/or radio tracking be employed to adjust the counts in the fish ladders to take these factors into account.

Monitoring Spans a Spectrum from Research to Management

The topic of "monitoring" is claimed by many adherents to salmon recovery. When one sorts out the many voices calling for more monitoring, a spectrum of approaches and actions is apparent. The spectrum runs from predominantly research at one end to predominantly management at the other. It is useful to understand that the spectrum exists and to attempt to place a proposed action within it.

At the ends of the spectrum are two distinctly different, but linked, tasks. At one end is the routine compliance monitoring of stocks, habitats, and environmental variables. At the other end is the scientific research needed to develop monitoring techniques and technologies. There is a gradation between these ends that is often confusing. Routine monitoring usually cannot be established without many other elements in the spectrum.

<u>Research on monitoring techniques</u>. This is often rather basic research (perhaps more physics, chemistry and electronics than biology), without any particular monitoring plan in mind. Basic questions of how one measures items of interest are pursued, usually in a laboratory. Even as monitoring technologies are deployed after development, a percentage of effort usually is devoted to improvements in the basic underpinnings of the technology to make it better.

<u>Research to test monitoring technologies</u>. Lab-bench-scale developments need to be tested on fish or other relevant target. Again without any specific monitoring objective, initial

deployments are made in the field with the objective of evaluating the technology, not the monitoring target. Pond-scale or similar limited scale efforts are common.

Experimental monitoring programs. With the objective again to test the *technology*, nearly full-scale monitoring may be undertaken with fish stocks or environmental variables in the field. Although useful management information may come from these monitoring tests, management decisions are not the main objective.

Experimental management using monitoring. At this point, the focus turns more toward management objectives, although the management tools are being researched. An established monitoring technology and protocol (or several of them, to establish which is most useful) is used to test or study whether the management approach will work on the target resource, usually on a limited scale.

Monitoring for Adaptive Management. Having shown through management research that a management technique or approach seems to work, broader application of the approach is instituted. Monitoring technologies are selected and put in place to consistently measure the relevant outcomes (e.g., fish numbers, redds, temperatures, etc.) over a specified period of time. This is management with a long-term information-gathering character, in which management strategies are periodically scrutinized and anticipated to change depending on the results of the monitoring.

Routine compliance monitoring. With less emphasis on anticipated changes in strategy, many biological and environmental factors are routinely measured over long periods. This measurement may be truly for compliance with some pre-set standard or limit. Alternatively, it may simply be conducted to document long-term trends, some of which may be unanticipated.

Feedback loops and multiple interactions are the norm for this seemingly linear spectrum. Many activities occur simultaneously at different levels in the spectrum. Nonetheless, those carrying out a project in the name of monitoring should have clear objectives that define their project in the spectrum between research and management.

Historical Record

The Fish and Wildlife Program is documenting the historical record of salmonids and their habitats in the Columbia River basin. The federal Bureau of Fisheries (now the National Marine Fisheries Service) conducted stream habitat surveys in parts of the basin from 1934 to 1942. These surveys were intended to cover streams in the Columbia River Basin that then provided, or once had provided, spawning and rearing habitat for salmon and steelhead to evaluate their condition, availability and usefulness for migration, breeding, and rearing of migratory fishes (Rich 1948). Most of the quantitative records of those surveys had been lost.

Surviving material consisted of summaries or brief, qualitative accounts (Rich 1948; Bryant 1949; Bryant and Parkhurst 1950; Parkhurst 1950c; Parkhurst 1950b; Parkhurst 1950a). Despite their brevity, these summaries have formed the basis for estimating habitat losses and conditions in the Columbia River Basin (Fulton 1968; 1970; Thompson 1976; NPPC 1986).

Recently, field notebooks from the early fishery surveys were discovered. The data are now archived and stored in the Forest Science DataBank at Oregon State University and have been published as exact replicates of the originals as part of the Fish and Wildlife Program. The habitat surveys include the Umatilla, Tucannon, Asotin, and Grande Ronde river basins (McIntosh et al. 1995a), the Clearwater, Salmon, Weiser, and Payette river basins (Mcintosh et al. 1995), the Willamette River basin (McIntosh et al. 1995c), the Cowlitz River basin (McIntosh et al. 1995b), and the Yakima River basin (McIntosh et al. 1995d). These records, as noted by the compilers of the present publications, are the earliest and most comprehensive documentation available of the condition and extent of anadromous fish habitat before hydropower development in the Columbia River Basin. They are unique because they are the only long-term data set that quantifies fish habitat in a manner that is replicable over time. Other surveys, such as Thompson and Haas (1960) inventoried extensive areas but in a manner that was mostly qualitative. Knowledge of past and present quantity and quality of habitat for anadromous fishes is essential to evaluating our efforts to enhance fish populations. Habitat condition has to be recognized as a key element in monitoring and evaluating progress toward the Council's restoration goals.

The data sets include detailed information on the character of the watershed and station, marginal vegetation and extent of erosion, elevations and slopes, observed flows and fluctuations, water and air temperatures, pool and riffle characteristics, character of the bottom, areas available that were suitable and unsuitable for spawning, obstructions, diversions, pollution, fish observations (redds, run sizes and timing, juvenile rearing), non-salmonid fish observed, extent of sport fishing, and miscellaneous field observations and opinions of the surveyors.

Stock Summary Reports

Under the Columbia River Coordinated Information System (now StreamNet), the Fish and Wildlife Program has attempted to compile summaries of tributary stocks of salmonids in the river basin. Draft, hard-cover reports were published in 1992 and the material is stored in retrievable electronic form at the StreamNet offices (www.streamnet.org) (Hymer and ten co-authors 1992a; Hymer and ten co-authors 1992b; Kiefer et al. 1992; Olsen et al. 1992c; Olsen et al. 1992d; Olsen et al. 1992b; Olsen et al. 1992a). The effort to develop stock summaries of major tributaries is a valuable guide to information that is available. Many of the stocks for which information has been compiled have not been systematically monitored but have scattered records. In the sections that follow, we have concentrated on stocks with long-term records or current studies that are specifically part of the Fish and Wildlife Program.

Use of Passive Integrated Transponder (PIT) fish tags

Adaptation of passive integrating transponder (PIT) tags for fisheries applications (Prentice 1990) has been a major advancement in smolt monitoring. These are small electronic packages (about the size of a large grain of rice) that are inserted into a fish's body cavity. They are programmed with a unique code that is matched to information such as tagging date, location, fish size, and other information. This code is formatted in a tiny radio-frequency transmitter. The PIT tags can be detected and the code "read" at any later time and location by a radio transmitter-receiver that, when placed near the fish, energizes the tag, causes it to send its information, and records it. PIT tags have been developed for fish monitoring over the past decade at the National Marine Fisheries Service, Northwest Science Center, Seattle, largely with funding through the Fish and Wildlife Program. Detectors have gradually been added to the fish bypass systems at Snake River and mainstem dams. Currently, full-service PIT-tag detectors are in place at Lower Granite, Little Goose, Lower Monumental, and McNary dams. There is currently the ability to detect at the John Day gatewell site, also. This is a monitoring point that has existed for many years. A single gatewell is sampled via an airlift pump. All fish sampled in this facility are checked for PIT tags. The sample rate, however, is very low and so it is of limited value compared to the other sites.

Development of fish-migration information from PIT-tag detections at dams is complex. Not all fish are guided away from turbines and into bypass systems, and the proportion that are guided varies with flow, time of day, and degree of smoltification of the migrating fish (Giorgi et al. 1988a). Numbers of fish detected can be corrected to give an estimate of total numbers by use of a fish guidance efficiency for the particular dam's configuration of turbine screens and bypass system. Release of water at a dam's spillways (spill) further reduces the percentage of fish, including those tagged, that pass through the fish-bypass detectors. Spill does not affect fish guidance efficiency at the turbine; spill does affect the fish passage efficiency, however. This is the proportion of fish approaching the project that pass by means other than through the turbines. The volume of water spilled, both mandated spills during low flows and involuntary spills during high flow times, must be taken into account when the fish guidance efficiency is calculated for the time of collection. These relationships are discussed in detail in Whitney et al. (1997).

Because some PIT-tagged fish that are not detected at one dam (for the above reasons) could be detected at the next dam, and also possibly at one or more dam detectors thereafter, detection totals, percentages, and timing need to be calculated thoughtfully. An experiment has been underway for three years at Lower Granite Dam to test several statistical models to relate different combinations of detection to location and timing of releases of specially marked fish (Iwamoto et al. 1994; Muir et al. 1995b; Muir 1996). This study followed a detailed evaluation of statistical methods for estimating smolt survival (Dauble et al. 1993) and consultation of state-of-the-art statistical documents (Burnham et al. 1987). The study has, with great attention to detail, field tested and evaluated the single-release, modified single-release, and paired-release models for estimating survival probabilities of migrating juvenile salmonids, identified operational and logistical constraints to collection of data for the models, and collected some useful information on smolt travel time and survival under the extant river conditions and dam operations. Although the statistical procedures have been questioned, a separate peer review led by the Independent Scientific Group established that the methods, though not perfect, are the best available and are appropriate for obtaining survival estimates (Independent Scientific Group 1996).

The Snake River monitoring experiment (Iwamoto et al. 1994; Muir et al. 1995b; Muir 1996) has incrementally obtained information of immense value to future monitoring efforts. Nonetheless, it has limitations. Estimates of survival from this study can be made only for specific reaches of the river. A problem with mixing of fish in the river has not yet been overcome (fish under the single release model seem to mix satisfactorily, however fish released under paired or multiple releases do not always mix as well). In 1993, only hatchery yearling chinook salmon were tested over a fraction of the migration period. In 1994, the research was expanded to include releases of wild yearling chinook salmon and hatchery steelhead. The 1994 studies covered a longer duration of the migration period and a greater length of the Snake River. Primary release sites for test fish were in the Snake River about 37 km upstream of Lower Granite Dam (this simulates fish coming downriver from upstream PIT-tagging operations at index traps and in tributaries (Achord et al. 1995b; Buettner and Brimmer 1995). Test fish also were released in forebays, turbine intakes, collection channels of juvenile bypass facilities, and bypass flumes (downstream of the PIT-tag detectors) to quantify effects within portions of the dam and bypass system. While the NMFS studies appear to provide a good means of assessing reach survival, they only address a limited portion of the river system currently covered by PIT tag detectors and so answer only a portion of the overall problem. Fully instrumenting the river system is needed and requires a major commitment of funds and effort.

Use of marked fish for monitoring and estimating in-river timing and survival is made more complicated by the fish transportation system in place on the Snake River. Downstream migrants are normally collected at upriver dams (Lower Granite, Little Goose, and Lower Monumental) and transported by barges or trucks to the river below Bonneville Dam (see section of this report dealing with transportation). All bypassed (and thus PIT-tag-detected) fish under this scenario of operations, would be transported and thus not available for PIT-tag detection at downstream dams. This constraint has caused bypass systems to be equipped with slide gates to selectively return PIT-tagged fish to the river to continue their migration and allow for multiple dam detections (Muir et al., 1995). Currently, transport does not appear to affect PIT tag studies because of this ability to put PIT-tagged fish back in the river and not transport them. Alternatively, detectors at the bypasses can account for those tagged fish that were transported.

The Snake River monitoring experiment has shown that assumptions of the single-release and paired-release models are generally satisfied (Iwamoto et al., 1994; Muir et al., 1995; 1996). Detection of fish at an upstream site did not influence the probability of its subsequent detection downstream or its survival. Fish mixed across the river downstream of a dam as expected. There was no significant mortality after a fish was detected and its remixing with fish using other passage routes. Thus, the single-release model was deemed appropriate for estimating survival probabilities for the primary release groups. A surprising result of these detailed monitoring trials has been quantification of survival much higher than estimated in earlier years (Raymond 1979) and relatively little mortality in Lower Granite Reservoir (Muir et al., 1995). Based on the 1993 and 1994 research, it is anticipated that existing models can be used with selective tagging and releases to make precise estimates of juvenile salmonid passage survival through individual river sections, reservoirs, and hydroelectric projects in the Columbia and Snake rivers.

A monitoring program is being developed to detect PIT-tagged adults returning to the basin (Newman 1995). Lower Granite Dam is the sole facility on the Columbia River system that possesses a PIT-tag detector for returning salmon and steelhead. Because of small sample sizes so far, the work has concentrated on *how* to analyze returns, with emphasis on statistical approaches. PIT tags have been implanted in juvenile wild and hatchery emigrants since 1985, with the first substantial numbers released in 1987, primarily to assess their emigration and survival (see monitoring of downstream migrants, below). Detections of adults at Lower Granite Dam have begun, and the data are stored in the PTAGIS2 information system maintained by the Pacific States Marine Fisheries Commission (www.psmfc.org/pittag/). Adult PIT-tag returns will be important to monitor to evaluate the river conditions that not only provide for downstream passage but ultimate survival of spawning adults.

Spawning Stocks

<u>Long-term data series have been developed for spawning by several index stocks. Diverse methods have been used, including aerial redd counts and carcass surveys.</u>

1. Hanford. The Hanford reach of the Mid-Columbia River has been monitored annually for spawning fall chinook salmon ("upriver brights") since 1948 (Dauble and Watson 1990; 1997). Aerial redd counts have been made in the 90-km reach between Richland, Washington and Priest Rapids Dam to provide an index of relative abundance among spawning areas and years as well as to document the onset of spawning and intervals of peak spawning activity. Fall chinook numbers have dramatically increased in the Hanford reach in recent years. The relative contribution of the Hanford stock to fall chinook runs in the Columbia River increased from about 24 percent in the early 1980s to 50-60 percent of the total in the late 1980s according to Dauble and Watson (1997), although it was back to about 38 percent in 1992 (the last year for which they analyzed data). Estimated numbers of visible redds ranged from a low of 65 in 1955 to a high of 8630 in 1987. Aerial counts have limitations due to visibility, so it is believed that a large, but unknown, proportion of total redds are not detected.

2. Snake River spring/summer chinook salmon index stocks. An ad hoc, interagency Biological Requirements Work Group (Biological Requirements Work Group 1994) evaluated Snake River spring/summer chinook salmon stocks to identify which ones had been monitored sufficiently well that data are available on spawning adults for developing historical population profiles. Populations within the Snake River basin consist of about 40 breeding units from 11 river systems that are more-or-less discrete and segregated temporally and/or geographically from each other, based on a presence/absence database developed by the Council. Eight index rivers and stocks were identified by the work group (Biological Requirements Work Group 1994), and are briefly presented below. Spawner and recruit data for index stocks consist of time series of indices for spawning escapements (redd counts) and age composition of spawners. Time series for the index stocks include observations from the 1950s and 1960s to the present.

a) Minam River, tributary to Grande Ronde River (spring chinook). The data series covers 1954 to present and includes redd counts, adult age composition from carcass surveys, and scale analyses to determine hatchery/natural origin. Monitoring followed procedures described in the Grande Ronde Subbasin salmon and steelhead production plan (Oregon Department of Fish and Wildlife et al. 1990). The Minam River is managed for native stock, but stray hatchery fish from nearby Lookingglass Hatchery (upstream of the Minam River) have been recovered on the spawning grounds. The drainage is mostly in wilderness and contains excellent quality spawning and rearing habitat.

b) Lostine River, tributary to Grande Ronde River (spring chinook). A data series from 1954 to the present is available. Monitoring has followed procedures described in the Grande Ronde Subbasin salmon and steelhead production plan (Oregon Department of Fish and Wildlife et al. 1990). The river characteristics are similar to the Minam, although the Lostine suffers from localized riparian and instream habitat degradation from grazing.

c) Catherine Creek, tributary to Grande Ronde River (spring chinook). Monitoring has also followed the Grande Ronde Subbasin salmon and steelhead production plan (Oregon Department of Fish and Wildlife et al. 1990). No data are presented in Biological Requirements Work Group (1994).

d) Mainstem Imnaha River (spring/summer chinook). A data series from 1952 to the present includes redd counts, adult age composition, from carcass surveys, and scale analyses to determine hatchery/natural origin. Monitoring procedures have followed the Imnaha River Subbasin salmon and steelhead production plan (Nez Perce Tribe, 1990). The riverine habitat is relatively pristine with headwaters in wilderness. Both hatchery and wild fish are present, but hatchery contributions are accounted for (Biological Requirements Work Group 1994).

e) Marsh Creek, tributary to Middle Fork Salmon River (spring chinook). Redd counts and adult age composition from carcass surveys are available from 1957to the present. Monitoring has been part of the Lower Snake River Compensation Plan (US Army Corps of Engineers 1975). The entire Middle Fork Salmon River is managed for wild, native spring/summer chinook salmon and steelhead (Kiefer et al. 1992). Overall habitat quality in Marsh Creek is good, although cattle grazing occurred until 1993. High quality habitats occur in most tributaries.

f) Bear Valley/Elk creeks, tributary to Middle Fork Salmon River (spring chinook). A data set from 1957 to the present exists for redd counts and adult age composition from carcass surveys. Monitoring has been part of the Lower Snake River Compensation Plan. Major habitat impacts from grazing, mining, and logging have been reduced through habitat improvement projects of the Fish and Wildlife Program (Andrews and Everson 1988). The entire Middle Fork Salmon River is managed for wild, native spring/summer chinook salmon and steelhead (Kiefer et al. 1992).

g) Sulfur Creek, tributary to Middle Fork Salmon River (spring chinook). The data series covers 1959 to the present for redd counts and adult age composition from carcass surveys. This is a wilderness drainage with excellent riparian and instream habitat, although there are occasional stray cattle.

h) Poverty Flats area, tributary to the South Fork Salmon river (summer chinook). A data series 1957 to the present is available for redd counts and adult age composition from carcass surveys. Monitoring has been part of the Lower Snake River Compensation Plan. The South Fork Salmon river is managed for natural and hatchery summer chinook and wild steelhead (Kiefer et al. 1992). The Poverty Flats area is located 13 miles downstream from the McCall Hatchery weir, but appears to be minimally affected by dropout of unmarked hatchery spawners. The drainage has been degraded through erosion and sedimentation, but there has been subsequent rehabilitation since 1966 (Megahan et al. 1980). Complete habitat recovery has not occurred.

Tributary Production

Certain monitoring and evaluation projects were established in the Program by tributary basins to monitor natural production of juvenile anadromous fish, evaluate habitat improvement projects under the Program, and develop a record for off-site mitigation projects. The sites were selected on a project-by-project basis and do not represent a specific index set for the whole Columbia River basin.

1. Stanley Basin (Idaho) Sockeye Salmon. The Idaho Department of Fish and Game and the Shoshone-Bannock Tribe established a sockeye salmon monitoring program for historically important salmon spawning and rearing areas in the Stanley Basin in 1991 (Kline 1995). The program has several objectives. One is to estimate, annually by age class, the population size, density, and biomass of sockeye and kokanee in four Stanley Basin lakes (Redfish, Alturas, Pettit, and Stanley). Another is to evaluate emigration characteristics of smolts from two locations (Redfish and Alturas lakes) including run sizes and the travel time and survival of PIT-tagged fish to lower Snake River dams. A third is to establish location and timing of spawning for natural sockeye salmon production in Redfish and Alturas lakes. The program also includes work of a less monitoring nature, including estimates of predator populations and determination of the origin of Stanley Basin sockeye salmon through otolith chemistry.

The recent Stanley Basin monitoring efforts follow a history of fragmented data collection at these sites that partially document the ups and downs of the stock (Kline 1995). In the late 1800s, Evermann (1895) made observations on the presence and abundance of sockeye salmon in the Stanley Basin lakes. Parkhurst (1950b) recorded the return of sockeye salmon to Redfish Lake in 1942 after decades of local extirpation by small dams. Bjornn et al. (1968) presented the most thorough assessment of Redfish Lake sockeye salmon for the period of 1954 to 1964. Chapman et al. (1990) recount the history. Hall-Griswold (1990) chronicled Redfish Lake spawners in the 1980s.

2. Crooked River/Upper Salmon River. One monitoring and evaluation project involves spring chinook salmon and summer steelhead in the Crooked River and upper Salmon River in Idaho (Kiefer and Lockhart 1995). There, the Idaho Department of Fish and Game (1) estimates egg deposition using weir counts, redd counts, and carcass surveys, (2) uses parr counts developed by snorkeling and stratified random sampling to estimate parr abundance and egg-to-parr survival, (3) PIT tags representative groups of parr and uses PIT-tag detections at the lower

Snake and Columbia river smolt-collecting dams to estimate parr-to-smolt survival, and (4) used adult outplants into tributary streams to estimate carrying capacity. The agency uses these data to (1) estimate parr production attributable to habitat projects, (2) quantify relationships between spawning escapement, parr production, and smolt production, and (3) use smolt production as a basis for assessing habitat improvement benefits. Habitat features that may relate to smolt productivity include substrate, riparian vegetation, and channel quality.

3. Umatilla River Basin. The Umatilla River basin salmonid resources are monitored by the Confederated Tribes of the Umatilla Indian Reservation (Confederated Tribes of the Umatilla Indian Reservation 1995). Monitoring and evaluation are part of Umatilla River Basin Fisheries Restoration Plan to rehabilitate runs in this heavily impacted basin that had once had abundant summer steelhead and spring chinook salmon (Confederated Tribes of the Umatilla Indian Reservation 1984; Oregon Department of Fish and Wildlife 1986). Irrigation and agricultural development throughout the basin in the early 1900s is believed to be the primary causes for decline of steelhead and extinction of chinook salmon. Results of watershed enhancement and rehabilitation, hatchery construction and operation, juvenile and adult passage facilities, holding and release facilities, trapping and hauling of fish around irrigation-dewatered reaches, and flow augmentation actions are being monitored and evaluated. Three phases of monitoring and evaluation have been established: (1) collection of baseline data relating to life histories, distribution, abundance, survival, natural production, habitat, and production potential of salmonids; (2) intensive adaptive management and the development of a streamlined monitoring program using the results of phase 1, and (3) risk-containment monitoring after the major remaining risks are identified. Phase 1 (baseline data collection) occurred for 1992-1997. Phases 2 and 3 was scheduled to begin intensely in 1997 and 2004, respectively.

Downstream Migrants

There has been a concerted effort to sample and enumerate juvenile salmonids that migrate downriver in the mainstem Snake and Columbia rivers. Monitoring sites have been chosen to provide broad geographic coverage.

1. Basinwide Smolt Monitoring Program. Downstream migrants are monitored primarily through the Smolt Monitoring Program coordinated by the Fish Passage Center of the Columbia Basin Fish and Wildlife Authority (and mandated by the 1994 Program, ß 5.9A). The Smolt Monitoring Program is overseen by a peer review group, the Fish Passage Advisory Committee. It is a major component of the Fish and Wildlife Program and has been a part of the Council's program since its inception in 1982. The program has undergone a series of changes since its inception. Since the 1987 version of the fish and Wildlife Program, the Smolt Monitoring

Program has focused on monitoring characteristics of the smolt migration for in-season water management and post-season analysis of smolt movement in relation to runoff conditions(NPPC 1987; NPPC 1992a; NPPC 1994a). Monitoring data are collected at three dams on the Snake River (Lower Granite, Little Goose, and Lower Monumental), three dams on the lower Columbia River (McNary, John Day, and Bonneville), one dam on the mid-Columbia (Rock Island), and at five river trap sites on the Snake River and tributaries. Summary data are provided on the Fish Passage Center's web site (www.fpc.org) and in StreamNet (www.streamnet.org).

The SMP consists of several major components, each of which contain several specific projects. The Idaho Department of Fish and Game operates traps to tag salmon and steelhead at Lewiston on the Snake River and on the Clearwater and Salmon rivers. The National Marine Fisheries Service collects samples of fish at John Day and Bonneville dams and tags spring/summer chinook parr in their natal streams in Idaho and monitors their emigration as smolts. The U.S. Fish and Wildlife Service (now the Biological Resources Division of the U.S. Geological Survey) has collected information on smoltification and the prevalence of disease for marked groups of salmon and steelhead used in the monitoring program and develops an index of smolt condition for real-time use in water management and evaluation. The Washington Department of Fish and Wildlife monitors smolts at Rock Island Dam, tags fish at Idaho hatcheries for recapture downstream, tags and monitors fish at Lower Granite Dam, tags and monitors fall chinook salmon at McNary Dam and the Hanford Reach, and monitors fish at Lower Monumental Dam. The Oregon Department of Fish and Wildlife tags and monitors fish at Little Goose Dam and tags fish in the Grande Ronde and Imnaha rivers. The Nez Perce Tribe monitors fish in the Imnaha River. These projects are discussed in more detail below.

The Independent Scientific Group concluded a review of the Smolt Monitoring Program in March 1995 (Independent Scientific Group 1995). From a programmatic standpoint, the review found the program to be well operated and to have relatively clear goals and objectives. Several recommendations were made to improve the scientific content of the program. These included (1) establish closer contact with data users to review kinds of data collected and technologies for getting them; (2) review and possibly adjust the sampling rates and numbers of fish collected to meet scientific objectives; (3) provide similar quality control among sites; (4) reevaluate the number of monitoring sites to meet program needs; (5) determine ways to minimize handling of fish, especially weak stocks, at collector dams; (6) increase evaluation efforts to find relationships among survival, travel time, and various river and operational variables; (7) reexamine the Fish Passage Index and alternative measures for utility for fish and water management decisions; (8) identify promising new monitoring technologies for study and potential application; and (9) improve communication among monitoring staff and researchers about the overall goals of the program and to generate useful feedback for planning.

2. Snake River Basin above Lower Granite Dam. One goal of monitoring is to characterize the emigration timing and pattern of different wild stocks from spawning tributaries of the Snake River Basin and to relate migration timing to environmental factors (Achord et al. 1995a; Achord et al. 1995b). Before 1989, data on the timing of individual populations of wild fish as they passed through the lower Snake River were limited. Raymond (1979) reported timing of smolts (mostly wild) arriving at Ice Harbor Dam from 1964 through 1969, based on gatewell sampling by the Bureau of Commercial Fisheries (predecessor of NMFS). The migration period spanned early April through mid-June, with peak migrations varying from late April to late May. Raymond (1979) distinguished between timing of individual tributary populations from Eagle Creek, and Imnaha, Grande Ronde, and Wallowa rivers in Oregon and the Lemhi and East Fork of the Salmon rivers in Idaho using marked fish. Sims and Ossiander (1981) summarized migrations of juvenile chinook salmon and steelhead in the Snake River from 1973 to 1979. Lindsey et al. (1986) monitored wild smolts from the John Day River as they entered John Day Dam from 1979 through 1984. Although patterns of migration were evident, sample rates for individual tributaries were low at the dams and the results were unsatisfactory.

Achord et al. (1995b) reviewed Raymond's unpublished field notes and data to determine if there was unpublished material of value for present questions. They concluded that his results do not provide the scope or precision that is currently required. Individual tributary populations received minor attention. Methods were primitive by today's standards. The marking methods (hot brands, alcohol/dry ice and liquid nitrogen cold brands) used to mark small parr in the fall would not have produced many marks identifiable the following spring. Marked fish were not representative of the entire stream population, and numbers were low. As hatcheries in the basin became operational, branded hatchery fish recaptured at index traps and dams provided much of the migration data.

To provide information on smolt movement prior to arrival at the lower Snake River reservoirs, the Idaho Department of Fish and Game (IDFG) has monitored the daily passage of smolts at the head of Lower Granite Reservoir since 1988 (Buettner 1991; Buettner and Brimmer 1993; Buettner and Brimmer 1995). Three locations are used for trapping fish for counting and marking. A Snake River trap is located approximately 40 km downstream from the interstate bridge between Lewiston, Idaho and Clarkston, Washington (see Figure 1 of Buettner 1991). This location is at the head of Lower Granite Reservoir, 0.5 km upstream from the confluence of the Snake and Clearwater rivers. The exact location of the trap was established based on information from radiotelemetry of juvenile steelhead which suggested a significant proportion passed the specific trap site (Liscom and Bartlett 1988). A Clearwater trap is installed 10 km upstream from the convergence of the Clearwater and Snake rivers. It is 4.5 km upstream of slack water in Lower Granite Dam at normal pool elevation. A Salmon River trap is installed 1.6

km downstream from the White Bird Gauge, 86.6 km upstream of the confluence with the Snake River.

The IDFG monitoring project collects data on daily fish numbers, relative species composition, hatchery and wild ratios, travel times and migration rates. It applies freeze-brands and PIT-tags for subsequent detection of juvenile migrants at the Snake River trap, Lower Granite Dam, and subsequent Snake and Columbia River dams with detectors (and of adults returning past Lower Granite Dam when adult detectors are in place). It provides a detection site at the Snake River trap for PIT-tagged smolts, marked on other projects, at the end of their migration in a riverine environment and at the beginning of their migration in reservoirs. Water temperature and turbidity are measured at each trap daily. River discharges were available at nearby USGS gauges and at Lower Granite Dam for correlation with fish movements.

NMFS began a cooperative study with the U.S. Army Corps of Engineers in 1988 to PIT tag wild spring and summer chinook salmon parr for transportation research. This project continued through mid-1991. Tagged emigrating smolts were monitored during spring and summer 1989-91 as they passed Lower Granite, Little Goose, and McNary dams where detectors were installed in the fish bypass systems (Matthews et al. 1990; Achord et al. 1992; Matthews et al. 1992). The study allowed evaluation of the juvenile fish collection, transportation, and bypass facilities (Monk et al. 1992). Aside from the transportation applications, these studies demonstrated that timing of various stocks through Lower Granite Dam differed among streams and also differed from patterns for hatchery fish (Achord et al., 1995). Generally, the emigrations of wild spring chinook salmon were later and more protracted than for hatchery fish, and timing patterns were variable over the three years. Summer wild chinook salmon were, conversely, earlier than hatchery fish, although also more protracted.

From the summer of 1991 to the present, the PIT-tag monitoring program on the Snake River by NMFS has been funded by Bonneville Power Administration (Achord et al. 1995a; Achord et al. 1995b). Wild spring and summer chinook salmon were collected by seining and electrofishing and PIT-tagged in July to October from areas of known high parr concentrations in 13 streams in Idaho and 3 streams in Oregon. Surviving PIT-tagged fish migrated volitionally through the hydroelectric complex of the Snake and Columbia rivers. Of eight dams passed, three were equipped with complete smolt collection and PIT-tag monitoring systems in 1992: Lower Granite, Little Goose, and McNary. At collection dams, all smolts guided away from the turbine intakes and into juvenile bypass systems are electronically interrogated for PIT tags as they pass through the system. All detected data are transferred daily to a computer operated in Portland, Oregon by the Pacific States Marine Fisheries Commission.

3. Lower Snake River. One of the critical questions regarding juvenile emigrants that has emerged over the past two decades is the relationship between river flow and migration speed

in the lower Snake River, which is presumed to lead to better survival at higher flows. Monitoring by NMFS first provided evidence that rate of migration through certain segments of the Snake and Columbia rivers was influenced by prevailing discharge volumes (Giorgi 1993). NMFS investigators measured and reported indices of travel time for the period 1973 through 1983 (Sims and Ossiander 1981; Sims et al. 1984), with their last synthesis including data acquired only through 1982 (Sims et al. 1983). The Fish Passage Center has continued to add to this smolt travel time data set since 1984. Their most comprehensive synthesis was published in the peer-reviewed literature (Berggren and Filardo 1993). The gradual accumulation of data for years of different flows during the main yearling smolt migrations is showing an increase in travel time through the lower Snake River with lower flows. There is little change at flows above about 80-100 cfs but a major slowing of movement as flows decline below this level. Confidence in these results has been impaired by the relatively small number of data points at lower flows, although the drought of the early 1990s added more important data.

Smolt survival estimates initially accompanied NMFS annual calculations of smolt travel times, and continued through the 1960s, most of the 1970s, and early 1980s (Giorgi 1993). The annual system survival estimates, or indices, represented overall smolt survival from the upper dam on the Snake River where marked fish were released to a lower Columbia River sampling site, usually John Day or The Dalles dams. The indices represented the combined effects of reservoir residence and dam passage. Results seemed to reflect the travel time estimates (Sims et al. 1983). The reliability and relevance of these survival estimates (especially lack of statistical properties) was questioned in the early 1980s, and travel time replaced survival as the key performance measure for juvenile passage.

Moving more toward evaluation than direct monitoring is the estimation of reservoir mortality. During the late 1980s, the fisheries community suggested that estimates of reservoir mortality would presumably reflect mortality associated with the speed of migration, apart from direct dam passage effects (Giorgi 1993). Dam passage mortality depended upon the route of passage, which has been estimated at representative sites, whereas reservoir mortality is difficult to determine. Thus, standard estimates of passage-route-specific dam mortality were used to subtract dam mortality from system survival estimates from 1970, 1973-79, and 1980 to yield reservoir mortality estimates apportioned evenly throughout the system on a per-mile basis. These methods have been criticized as not being consistent with actual data collected by Raymond (1979), for example (Giorgi, 1993). Rather than being informative, these estimates have hidden the important details regarding the location and magnitude of mortality in reservoirs, the mechanisms causing smolt mortality, and thus the opportunities for correcting specific mortality problems.

Adult returns have been used as measures of flow effects, as another way to evaluate monitoring data, especially for the lower Snake River (Petrosky 1993). Annual numbers of adults in index populations in Marsh Creek and Rapid River have been compared to yearly emigrant river flow for several years. Because of the numerous covariates with flow such as spill (known to be more benign than turbine passage), these estimates have little power to establish flow, per se, as the cause of mortalities (Giorgi, 1993). Remedial measures might better be aimed at increasing spill, even in low-flow years, than at augmenting flow.

Monitoring of Environmental Data

Efforts to correlate salmonid migration behavior and other population features with environmental variables has been made difficult by lack of environmental monitoring. Achord et al. (1995a; 1995b) reported that many of the formerly active hydrological stations of the U. S. Geological Survey (USGS) used to record flow information in the upper Snake River basin were no longer operational. No continuous water temperature information was available from any of the five operational USGS sites. Our review found that habitat variables are generally not well monitored. Rather than dwell on specific deficiencies of the current program, we concentrated our review on environmental features that need to be monitored under a new paradigm, the ecosystem perspective described in our conceptual foundation.

New Metrics for the Normative River and Ecosystem

An integrated ecosystem monitoring and evaluation program with emphasis on suitable habitat is badly needed, in addition to monitoring of fish. In Chapter 5, we describe how habitats have been degraded in spawning and rearing areas by various land uses such as logging, mining, agriculture (including riparian grazing) and urbanization. We also describe mechanisms, such as reregulation of hydrographs to allow periodic flooding, to restore habitat and to provide enhanced salmonid food production that occurs during periods of high water. We have also shown that dams and reservoirs can be built and operated in ways that can better simulate the natural habitat of salmonids and thus foster increased survival. Monitoring of quantity and quality of available habitat and utilization of habitat by various stocks is essential to the objective of conserving or increasing the productivity of each life history stage.

However, uncertainty exists as to what constitutes quality habitat. We qualitatively evaluated major alluvial reaches of the Columbia River system that most closely match reaches of known high productivity (e.g., the Hanford Reach). Some of these appear to be reasonably intact and potentially functional, others are degraded. Non-alluvial, constrained reaches also must support migrants during their passage. A more precise inventory of habitat types is needed and coupled with research that demonstrates a suite of variables that can be used to describe habitat quality (McCullough and Espinosa 1996). Considerations include:

- the degree of channel and flood plain connectivity via surface and groundwater pathways
- locations of groundwater influent or upwelling
- availability of microhabitat types (e.g., deep pools, shallow riffles, undercut banks, point bars, eddy bars, back bar channels and other slack water environments)
- availability of flow cues, such as turbulence and wave phenomena, as well as thalweg flow
- substratum size distribution, including woody debris
- suspended and deposited fine particulate inorganic and organic matter
- water quality conditions (baseline; point and nonpoint pollution sources)
- riffle and slack water food web conditions and community ecology (e.g., indices of biotic integrity including species composition, forage and predatory categories, production rates; percent non-natives)
- riparian conditions (e.g., successional state, species composition; percent canopy; production rates; indices of grazing use and resilience to grazing; percent non-natives; seasonality of flooding).

Best management practices (e.g., reregulation of flows; forestry and riparian grazing prescriptions, pollution abatement; crop rotation) have been fostered to reduce habitat degradation, but few if any of these practices have been empirically (experimentally) evaluated. They need to be examined in terms of the habitat variables given above or in terms of cumulative catchment effects, such as water and fine sediment and organic matter yield. Long term comparisons of undisturbed and managed areas (small catchments) are needed to properly evaluate BMPs and should be required of all land management agencies and corporations with salmonid production zones. Evaluations should focus on documenting improvements in ecological attributes known to be critical to salmonids and where possible, to make inferences about historical conditions in order to better place the monitoring and evaluation process into an ecologically meaningful context.

Stock status (wild and cultured) in mapped habitat types is needed for each sub-basin, including annual determinations of spawners, redds, life history growth patterns from scales and otoliths and juvenile recruitment in rearing habitats (e.g., sloughs, shorelines, eddies and other shallow or slack waters). Much of this work can be a logical extension of monitoring already underway.

Mortality estimates for each life history stage are needed. Such estimates require well-planned tagging programs. PIT tags are effective if detectors are located at the right places to determine mortality (or survival) by habitat type and life history stage. Currently, few detectors are in place where habitat evaluations are most needed. It is essential to have detectors in each of the major fish bypass systems at dams and in adult samplings (terminal fisheries and fish ladders at dams).

We need a measure of migrant vitality to assess bottlenecks associated with reservoir and dam transit and food web variations in different habitat types. Perhaps a measure of energy reserves (whole body lipid content) would suffice, but research on this subject is required.

Metapopulation Monitoring

In developing this section, we assumed that 1) metapopulation processes are important in maintaining regional persistence and abundance of Columbia basin salmonids, and 2) accomplishment of the Fish and Wildlife Program goals will require reestablishment of metapopulation integrity in subbasin watersheds and mainstem areas. Under these assumptions, a central question that a monitoring program must be designed to address is, "How is restoration of metapopulation organization progressing within subbasins and region-wide?" From a metapopulation perspective, monitoring and evaluation should focus on systems of local populations or subpopulations; their spatial arrangement or distribution within watersheds and the relationship of this distribution to spatial and temporal variation in habitat conditions; and connectivity among local populations which is related to their proximity and the favorability of connecting habitats. Thus, monitoring metapopulation organization necessarily must be linked to habitat monitoring in an integrated habitat-metapopulation monitoring system appropriate at watershed scales. Moreover, where possible, reconstruction of historic habitat conditions and life history distributions (Sedell and Luchessa 1981; Lichatowich and Mobrand 1995; Mcintosh et al. 1995) must be undertaken to establish a template against which progress can be measured.

Monitoring under the normative ecosystem conceptual foundation will differ to some degree from present monitoring programs within the basin. Present monitoring efforts focus primarily on life stages of individual stocks extant in the basin today. Under our alternative conceptual foundation (Chapter 3), not only the status of individual stocks, but also their spatial association and diversity would be emphasized. Furthermore, stocks and life histories that were extirpated in the past may need to be restored to reestablish metapopulation integrity and ensure the opportunity for operation of metapopulation processes. Thus, monitoring programs will need to assess not only the status of extant stocks and their life histories, but also the progress of reestablishment of extinct stocks, their life histories, and their habitats. To ensure that recovering metapopulations are adequately protected, the local populations or subpopualtions making up a metapopulation should be monitored at critical points during their migration through the mainstem Columbia and Snake rivers. Measure 4.3.C in the Fish and Wildlife Program (population monitoring) should be modified to take into consideration the metapopulation structure of salmonids in the basin.

The following needs should be addressed by an ecosystem-based monitoring program:

1) Identification and protection of healthy core and satellite populations throughout the region. This includes the Hanford stock of fall chinook, as well as other healthy populations spawning in mainstem and headwater areas. To facilitate the design and implementation of metapopulation monitoring, the subregional process (measure 3.1D in the Fish and Wildlife

Program) should be organized so that the geographic range of a metapopulation is not split among two or more subregions.

2) Restoration of core populations and their habitats at critical locations within each physiographic region in the Columbia basin. Reestablishment of metapopulation organization will require restoration of vital core populations that are presently extinct (Rieman and McIntyre 1993; Schlosser and Angermeier 1995). Areas where core populations were historically abundant need to be identified as high priority areas for restoration. Many of these areas likely were extensive alluvial reaches of rivers. Monitoring will need to assess the progress of restoration of both core populations and their habitats.
3) Improved survival of extant satellite populations and reestablishment of some extinct satellite populations. This is especially critical in the Snake River Basin where chinook salmon metapopulation integrity appears to have been severely compromised.
4) Development of measures of spatial diversity of local populations and life history types within watersheds (Rieman and McIntyre 1993). Reexpression of extinct life history patterns will probably be an early indication of habitat restoration and indicate progress toward redevelopment of metapopulation structure.
5) Develop the ability to monitor individual salmon and steelhead stocks or representative stocks during significant portions of their life history. This means estimating the numbers of smolts in the outmigration and tracking the catch of adults throughout their ocean and in-river lives, as well as accounting for them as they pass the dams. This should lead to a full accounting for all fish that are produced in the individual subbasins.
6) Identification, protection, and reestablishment of key physical linkages among local populations and between core and satellite populations to facilitate dispersal.
7) Develop monitoring protocols to evaluate improvements in habitat, such as mapping areas where reregulation has improved spawning and rearing conditions (such as the Hanford Reach), mapping areas opened up by improved passage, areas improved by screening of irrigation diversions, by fencing out livestock, improved forest practices, zoning to provide setbacks for developments near water bodies, etc.

Dam-Passage Evaluation

We have shown that the ability of juvenile salmon to pass downstream through dams is now constrained by passage routes that defy, rather than simulate, evolved migrational behavior patterns. Consequently, migration "habitat" at dams needs to be evaluated carefully in the context of fish behavior. Monitoring will be required to establish that redesign of passage facilities to mimic natural mechanisms actually does provide better passage. Specifically, we need to:

1) Develop estimates of smolt mortality rates assignable specifically to mortality in turbines, tailraces, reservoirs, and forebays, to identify areas of highest mortality and to be able to treat them individually with the most appropriate measures. Initial studies should be followed by monitoring as bypass measures to better simulate the natural conditions are taken.

2) Further evaluate the surface ice and trash sluiceways as a passage route for juvenile salmonids. Studies should be designed to compare relative numbers of fish passing through the turbines relative to the sluiceways at spill levels and powerhouse loads chosen to obtain measurements at specified intervals, covering an appropriately wide range, rather than depending on observations made under normal operating patterns. The purpose is to develop a regression equation that can be used to predict sluiceway and spill effectiveness at different levels of spill. Secondarily, the information can be used to evaluate engineering changes that might be made in the sluiceways to improve their effectiveness as collectors of surface-oriented fish, such as modifications in the upstream openings or flow volumes.

3) Further evaluate the procedure used to determine spill levels required at the Snake and lower Columbia river projects to achieve the fish passage goals set by the Council and NMFS. These should be done to contrast normal spill and surface spill (which more closely approximates the surface orientation of downstream migrants). The purpose is to refine the amount of spill required at each project (by using surface spill, the amount of water should decrease). To accomplish this requires evaluation of data used at each project to predict the mix of species and stocks expected to occur at various time periods during the emigration, data on FGE for those species and stocks, and data on spill effectiveness.

4) Evaluate new designs for spill deflectors or other gas abatement measures at dam spillways that minimize gas supersaturation in water that is spilled. The purpose would be to design an abatement method that is effective over a wide range of spill levels, particularly high levels associated with flood events.

Relation of basic research and peer review to routine monitoring and evaluation

This review of monitoring and evaluation underscores the need for basic research to resolve uncertainties associated with the ecology of the Columbia River. Many of these uncertainties are revealed from routine analysis of monitoring data. Actions to recover fisheries have not been successful in the Columbia River largely due to lack of scientific synthesis and peer review as key attributes of the funding process for recovery efforts. Moreover, the General Accounting Office noted that very little basic research had been funded by the Fish and Wildlife

Program prior to 1992 (General Accounting Office 1992) and we note little, if any, change in that trend to date.

Recent scientific syntheses (see Table 1.1), coupled with conclusions from various sections of this report, have identified the primary uncertainties in the ecosystem science of the Columbia River. These uncertainties have to be resolved through basic research. That research currently is not being effectively accomplished and will not be under the current mechanism of program implementation.

The standard of science is publication of research results in scholarly journals that have rigorous peer review protocols. Publication of research results is much easier and credible if the research that is being reported is derived from a peer reviewed research plan. Successful competitive grants programs, as administered for example by the National Science Foundation, National Atmospheric and Space Administration and the National Institutes of Health, require detailed and well planned research proposals and honest and constructive peer review prior to funding. This provides credibility to research and the funding process and generally increases the likelihood of the study producing significant results.

A new or at least a revised mandate is needed in the Fish and Wildlife Program that requires all ecological research, monitoring and evaluation results that are funded by the Fish and Wildlife Program be published in juried formats. Also, the Fish and Wildlife Program should provide for a competitive grants program for funding research to resolve uncertainties in management actions to recover salmonid populations. No research organization or individual should be locked out of research funding due to agency management jurisdictions. Funding of research and monitoring and evaluation projects should be based on the quality and innovation expressed by the proposal and the professional expertise of the proposers as evaluated and ranked through peer review. The solution is for the Fish and Wildlife Program to be revised to clearly articulate priorities and protocols for management, monitoring and evaluation and research. Funding for all projects should be based on peer review, with the exception of those actions that are clearly policy related, which should still be based on clear implications of scientific analyses.

PATH Evaluation of Monitoring Data

Perhaps the most extensive use of biological monitoring data has taken place with the current PATH process (Plan for Analyzing and Testing Hypotheses) (Marmorek and Parnell 1995; Marmorek and C. N. Peters (editors) 1998). An interagency group of fishery scientists has evaluated redd-count data on the index stocks described earlier in an attempt to reconstruct past run sizes and to project into the future the trends of abundance expected from hypothetical changes in operating characteristics of the Columbia-Snake river system. A key aspect of the process has been comparisons of the population trajectories of index stocks monitored in the upper Snake River basin, tributaries and mainstem of the lower Columbia River, and the Mid-Columbia above the confluence with the Snake River. A principal objective of this evaluation phase has been to establish the role of mainstem dams in population declines and, through computer simulations, to test alternative strategies for reducing sources of mortalities. Lower Columbia index stocks are presumed to be more affected by ocean and other non-hydropower conditions that either of the upper-river sets of stocks. Analyses of monitoring data are most complete for spring-run chinook salmon, although additional analyses have been undertaken for fall-run chinook salmon and steelhead.

The PATH process has coupled advanced computer models of population dynamics, such as the mechanistic CRiSP and the empirical FLUSH models, with sophisticated statistical analyses of the monitoring data. The statistical analyses have yielded estimates of the relevant population parameters needed by the population-dynamics models.

The entire PATH evaluation exercise has pushed the use of these monitoring data to the limit. Analytical tools not used previously have been brought to bear on a limited range of actual data. It seems clear to both participants and critics that there is a fundamental need to reconsider the types of monitoring data that are being obtained. Better measures of population success are needed. Although redd counts for the current index stocks must still be obtained for temporal inter-comparisons, additional measures are needed.

A major post-PATH deficiency is agreement on what those additional monitoring measures should be. When the basin accepts a new paradigm for salmon restoration--one that emphasizes life-cycle protections, integration and connectivity of habitats, natural riverine processes, metapopulation dynamics, and the like, as proposed in this review--it will need to establish new types of metrics to monitor the results of management actions. How traditional fish-oriented data collection will be merged with more ecosystem-oriented measures and genetically based stock evaluations has yet to be determined. How statistical analyses such as those used by PATH will be augmented by new data resources remains to be established. Even the advisability of pursuing those analytical directions needs to be re-evaluated.

Recommendations

1. Maintain monitoring and evaluation as a major objective for the Fish and Wildlife Program and include new metrics that permit monitoring of improved river conditions (e.g, effectiveness of peak flows in maintaining habitat structure; ground water controls on surface temperatures and productivity; integrity of riparian communities; composition and dynamics of slack water communities, including but not limited to salmonid populations).

2. Maintain basic collection, archiving and dissemination of index data;.

3. Encourage explicit statement of current beliefs that affect monitoring programs, rigorous examination of evidence for beliefs, framing of alternative hypotheses, and design of monitoring and evaluation to fairly test all reasonable hypotheses (through basic data collection and/or conduct of monitoring experiments);

4. Encourage integration of other agency efforts (and funding) to extend the monitoring and evaluation for salmonid populations beyond the hydropower system to the estuary and ocean.

5. Rather than try to design a complete and comprehensive monitoring program (which it probably cannot afford), the region should identify and develop consensus about how much and what type of monitoring is needed and can be afforded for managing an effective salmon restoration program.

6. Install and operate PIT tag detectors at key monitoring points and implement a tagging program that is statistically valid to estimate mortality of all life history stages of salmonid stocks.

7. Mandate peer review using guidance documents for competitive research and management proposal evaluation previously produced by the ISG and require that studies and evaluations be submitted to professional journals for review and publication.

8. Implement a competitive grants program for research that is responsive to uncertainties derived from periodic syntheses of monitoring data and general ecological science pertaining to the Columbia River Ecosystem.

Return to Table of Contents
Go to Next Chapter