CHAPTER 9. MONITORING AND EVALUATION

Our conceptual foundation for the Fish and Wildlife Program 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.

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 Progam in achieving the Council's goals of doubling the runs of salmon and steelhead in the basin. The 1994 Fish and Wildlife Progam states that there will be an evaluation path as well as an implementation path (Northwest Power Planning Council, 1994). 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 Progam 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. In essence, adaptive management recognizes that many actions related to fish management must occur continually (e.g., river flows), whether ideal or not. 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. Everson et al. (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 (Northwest Power Planning Council, 1988) and recommendations have been obtained from a peer group established by the Council (Monitoring and Evaluation Group of the Northwest Power Planning Council, 1988). Monitoring and evaluation elements of the Fish and Wildlife Progam are periodically reviewed as part of the Council's System Planning Process (an effort under the lead of the fish 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 Progam. 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 (letter of May 24 from G. Drais to R. Whitney).

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 is given special attention. The Program suggests a regional center for biological analysis (3.2F.1). 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). 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 will be an evaluation project to test the relative benefits of two modes of fish passage--in-river and transportation (barging and trucking).

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), and a biennial evaluation of the Program on its scientific merits (by the Independent Scientific Group)(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 a the Coordinated Information System, as well as oral presentation of project reports at symposia (3.2G).

The Fish and Wildlife Progam 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 Progam. 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 the Lower Snake River Compensation Plan (Corps of Engineers, 1975).

Perspectives on Monitoring and Evaluation

There are two perspectives on "monitoring and evaluation" in the Fish and Wildlife Progam, 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., §s 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 Progam (in both social and biological terms) as a basis for evaluating whether to continue them as part of the Fish and Wildlife Progam or to develop alternatives through adaptive management (e.g., § 3.1B). Programmatic monitoring and evaluation are highly dependent on the biological monitoring for measures of success (or failure) of the Fish and Wildlife Progam 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, are separate processes, sometimes occurring together but often not. Linkage of the two terms and failure to differentiate the perspectives behind their use have 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 towards Fish and Wildlife Progam goals. Whether we have environmental monitoring or not, the Fish and Wildlife Progam needs evaluation of all projects and

programs. We believe that there should be a clearer distinction between the two terms in the conduct of the Fish and Wildlife Progam.

This section of the review of science 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 programmatic approaches for monitoring and evaluation the Fish and Wildlife Progam were provided by Coutant and Cada (1985). We previously provided additional guidelines for programmatic monitoring and evaluation.

Issues in Monitoring and Evaluation

Numerous issues have concerned those planning monitoring and evaluation. Many 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 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. MEG (1988) clearly stated the main scientific issue: a measure of progress for the Program should not only determine progress (such as toward doubling goals), but should also provide information to increase understanding, decrease uncertainty, and permit the Program to be refined over time. The recent issue is a 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 belief structure may be more productive than previous ones.

• 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 Progam 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 Progam (Northwest Power Planning Council, 1992). 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 Progam 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 (Monitoring and Evaluation Group of the Northwest Power Planning Council, 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.

• Index life stage(s). The point in salmonid life cycles that counts should be made to best represent success is uncertain (Monitoring and Evaluation Group of the Northwest Power Planning Council, 1988). Counts of juvenile emigrants has the appeal of being a rapid and direct measure of the effects of many Fish and Wildlife Progam actions in the freshwater part of the life cycle. This avoids survival problems in the ocean over which the Fish and Wildlife Progam 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 seen as a better "bottom line" for evaluation, but it is difficult to separate the effects of Program actions from other factors. 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 can be used to discern relationships between variables such as run size and flow during emigration. A life-cycle approach uses a computer model as a conceptual basis for explaining trends displayed by the observational indices. Each has its appropriate uses and drawbacks (Monitoring and Evaluation Group of the Northwest Power Planning Council, 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. Thus was spawned a flurry of models by different agencies aimed at integrating all of 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.

• 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 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 valuation 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 factor was recognized in the 1987 Program {§ 206(d)(C)} and a Coordinated Information System (CIS), now called StreamNet was implemented. Items for CIS attention 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 lead to information being unavailable, not provided in a timely manner, provided by informal routes susceptible to misinterpretation, 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 monitoring data on demand. For example, the Corps is now placing daily fish count and environmental data from its projects on the Web. Others, such as the University of Washington, have life cycle models (CRiSP) on its Web site. 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 (*in press*) 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 Progam 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 Progam from the outset to provide information on the migrational characteristics of the various stocks of salmon and steelhead with in the Columbia Basin. This program has included monitoring 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 Progam, 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, as the dam-counts of adults is standardized and familiar. Results of monitoring to date, such as trends in fish numbers, are discussed in Section III and elsewhere in this report.

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 provided, or 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, 1950; Parkhurst, 1950). 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; Northwest Power Planning Council, 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 Progam. The habitat surveys include the Umatilla, Tucannon, Asotin, and Grande Ronde river basins (McIntosh et al., 1995), the Clearwater, Salmon, Weiser, and Payette river basins (Mcintosh et al., 1995), the Willamette River basin (McIntosh et al., 1995), the Cowlitz River basin (McIntosh et al., 1995), and

the Yakima River basin (McIntosh et al., 1995). 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 (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 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 (CIS), the Fish and Wildlife Progam 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 CIS offices at the Columbia River Inter-Tribal Fish Commission (Hymer, 1992; Hymer, 1992; Kiefer et al., 1992; Olsen et al., 1992; Olsen et al., 1992). The CIS 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 Progam.

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 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 Progam.

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., 1988). 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.

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., 1995; 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 ISG 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., 1995; 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; e.g., (Achord et al., 1995; 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 require 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. Transportation normally collects downstream migrants at upriver dams (Lower Granite, Little Goose, and Lower Monumental) and barges or trucks them to the river below Bonneville Dam (see section of this report dealing with transportation). All bypassed (and thus PIT-tag-detected) fish would, under this scenario of operations, be transported and thus not available for PIT-tag detection at downstream dams. The obstacle that fish transportation would thus present to information gathering has caused bypasses 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. 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

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). 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. They have also documented the onset of spawning and intervals of peak spawning activity. This monitoring has documented a dramatic increase in returns of fall chinook to Hanford reach in recent years. The relative contribution of this stock to fall chinook runs in the Columbia River increased from about 24% in the early 1980s to 50-60% of the total in the late 1980s. 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 metapopulation consist of about 40 breeding units from 11 river systems that are more-or-less discrete and segregated temporally and/or geographically, based on a NPPC presence/absence database. Eight index rivers and stocks were identified by the BRWG (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 includes 1954-1993 (and continuing) redd counts, adult age composition from carcass surveys, and scale analyses to determine hatchery/natural origin. Monitoring has been according to the Grande Ronde Subbasin salmon and steelhead production plan (Oregon Dept. of Fish and Wildlife, 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 1954-1993 data series is available (and continuing). Monitoring has been according to the Grande Ronde Subbasin salmon and steelhead production plan (Oregon Dept. of Fish and Wildlife, 1990). The river characteristics are similar to the Minam, although there is localized riparian and instream habitat degradation from grazing.

c) Catherine Creek, tributary to Grande Ronde River (spring chinook). Monitoring has been according to the Grande Ronde Subbasin salmon and steelhead production plan (Oregon Dept. of Fish and Wildlife, 1990). No data are presented in BRWG (1994).

d) Mainstem Imnaha River (spring/summer chinook). A data series 1952-1993 (and continuing) includes redd counts, adult age composition, from carcass surveys, and scale analyses to determine hatchery/natural origin. Monitoring has been according to 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 1957-1993 (and continuing). Monitoring has been part of the Lower Snake River Compensation Plan. 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 1957-1993 (and continuing) data set 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 Progam (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 1959-1993 (and continuing) 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 1957-1993 (and continuing) 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 anadromous fish, evaluate habitat improvement projects under the Program, and develop a record for off-site mitigation projects.

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 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 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 (Evermann, 1895) made observations on the presence and abundance of sockeye salmon in the Stanley Basin lakes. Parkhurst (1950) 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 Reservation (Conf. 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 (Conf. Tribes of the Umatilla Indian Reservation, 1984; Oregon Dept. 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) is in operation 1992-1997. Phases 2 & 3 are scheduled to begin intensely in 1997 and 2004, respectively. Results have been published only for the 1992-1993 season.

Downstream Migrants

1. Basinwide Smolt Monitoring Program. Downstream migrants are monitored primarily through the Smolt Monitoring Program (SMP) coordinated by the Fish Passage Center of the Columbia Basin Fish and Wildlife Authority (and mandated by the 1994 Program, § 5.9A). The SMP is overseen by a peer review group, the Fish Passage Advisory Committee. The SMP is a major component of the Fish and Wildlife Progam and has been a part of the Council's program since its inception in 1982. The SMP has undergone a series of changes since its inception. Since the 1987 version of the Program, the SMP 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. Monitoring data are collected at three dams on the Snake River, three dams on the lower Columbia River, one dam on the mid-Columbia, and at five river trap sites on the Snake River and tributaries.

The SMP consists of five major projects, each of which contain several specific projects. The five major projects are: Project 85-323 which funds Idaho Department of Fish and Game to operate the Lewiston, Clearwater , and Salmon River taps and to tag salmon and steelhead at these traps; Project 84-014 which funds NMFS to collect samples of fish at John Day and Bonneville dams; Project 87-401 which funds the USFWS to collect information on smoltification and the prevalence of disease for marked groups of salmon and steelhead used in the SMP and to develop an index of smolt condition for real-time use in water management and evaluation; Project 87-127 which funds smolt

monitoring at Rock Island Dam, tagging of fish at Idaho hatcheries, tagging and monitoring at Lower Granite Dam by WDFW, tagging and monitoring at McNary Dam and the Hanford Reach by WDFW, monitoring at Lower Monumental Dam by WDFW, tagging and monitoring at Little Goose Dam by ODFW, tagging in the Grande Ronde and Imnaha rivers by ODFW, and monitoring in the Imnaha by the Nez Perce Tribe; and Project 91-029 which funds NMFS to tag spring/summer chinook parr in their natal streams in Idaho and monitor their emigration as smolts. These projects are discussed in more detail below.

We concluded a review of the SMP in March 1995 (Independent Scientific Group, 1995). From a programmatic standpoint, the ISG 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., 1995). 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. Lindsay (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. (1995) 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 readers 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; e.g., (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. However, only one report, covering 1991 tagging and 1992 detections, has been issued (Achord et al., 1995). Wild spring and summer chinook salmon were collected by seining and electrofishing and PIT-tagged in July to October from areas of know 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 Fish 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 indicate 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; 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 open 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 has 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). Tha 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 (McConnaha 1990). These methods have been criticized as not being consistent with actual data collected by Raymond (1974), 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. (Achord et al., 1995) 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 normative river.

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 period 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 mapped and qualitatively evaluated major alluvial reaches of the Columbia River system that most closely match reaches of known high productivity (e.g., the Hanford Reach, Figure 2.6). (Map of alluvial reaches was unavailable in a form suitable for this publication at time of printing) Some of these appear to be reasonably intact and potentially functional, others are degraded. Nonalluvial, 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 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 use the normative river condition, to the extent we know it, as the standard of measure.

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. Curently, few detectors are in place where habitat evaluations are most needed. Detectors in each of the major fish bypass systems at dam and in adult samplings (terminal fisheries and fishladders at dams) is essential.

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 Under the Normative River Concept

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 Progam goals will require reestablishment of metapopulation integrity in subbasin watersheds and mainstem areas. Under the Normative River concept, 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, e.g., (Sedell and Luchessa, 1981; Lichatowich and Mobrand, 1995; McIntosh et al., 1995) must be undertaken to establish a normative river template against which progress toward the normative river can be measured.

Monitoring under the Normative Ecosystem conceptual foundation will differ in 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 the Normative Ecosystem concept, 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 4,3C in the Fish and Wildlife Progam (population monitoring) should be modified to take into consideration the metapopulation structure of salmonids in the basin.

Under the Normative Ecosystem concept, the following needs should be addressed by a 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 Progam) 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). Restoration of extinct life history patterns will probably be an early indication of habitat restoration and indicate progress toward redevelopment of metapopulation structure.
5) Identification, protection, and reestablishment of key physical linkages among local populations and between core and satellite populations to facilitate dispersal.

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, the migrational behavior patterns in a normative river. Migration "habitat" at dams needs to be evaluated carefully in the context of the normative river. 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 normative river atre 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 effectivenes 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 has been funded by the Fish and Wildlife Progam 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 Progam that requires all ecological research, monitoring and evaluation results that are funded by the Fish and Wildlife Progam be published in juried formats. Also, the Fish and Wildlife Progam 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 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.

As noted above we have previously provided a guidance document for conducting peer review of proposals (Independent Scientific Group, 1995). These guidelines should be used. Only through the mechanism of peer review will progress toward resolving key uncertainties in the recovery of Columbia River fisheries proceed effectively and cost-efficiently. We recognize that agencies and tribes have a legal mandate to manage fisheries resources, but that does not mean that new information should be just the purview of management entitlements. Rather, management, monitoring, evaluation and research should be interactive and adaptive as new information is forthcoming to resolve uncertainties in an ecosystem context (e.g., Stanford and Poole, in press). The solution is for the Fish and Wildlife Progam to be revised to clearly articulate priorities and protocols for management, monitoring and evaluation and research funding and all funding, with the exception of actions that are clearly policy related and based on clear implications of scientific analyses, should be based on peer review.

Conclusions (level of proof)

1. A large amount of effort is being expended in monitoring of salmonids in the Snake and mid-Columbia basins in conformance with high Fish and Wildlife Progam emphasis on monitoring and evaluation including various index life stages (adults, redds, fry/smolt emigration, adult-equivalent production, life-cycle productivity) through a variety of state, federal, and utility programs and these efforts appear to be directed toward valid technical needs (1);
2. Monitoring data are generally compiled and made available in databases (e.g., FPC and CIS) and written reports, although user-friendliness and suitability for specific needs further attention (1);
3. The focus of monitoring and evaluation has evolved to be larger than just the hydrosystem (befitting life cycles that extend from mountain streams to the ocean, and resident fishes in storage reservoirs) (1);
4. Observations generally exceed analyses (evaluation) (2);
5. Monitoring effort has been heavily focused by current beliefs and oriented toward establishing relationships among volume of flow, water travel time, and fish travel time, usually between dams and most commonly in the lower Snake River (1)
6. Current beliefs that focus the monitoring effort do not always have explicit statement, rigorous examination of the evidence in support of those beliefs (evaluation), framing of alternative hypotheses, and design of monitoring and evaluation to fairly test all reasonable hypotheses (1);
7. Population models have become a popular analytical (evaluation) method, but models have pitfalls because results are determined to a large extent by beliefs built into their structure (1);
8. Both collection of long-term data sets and monitoring with an experimental design to test hypotheses are being conducted in the basin (2);
9. Despite considerable effort, monitoring and evaluation are not adequate for the present needs, especially the level of evaluation and assessment (1).

Critical uncertainties

1. Importance of alternative hypotheses to design of routine monitoring and monitoring experiments are not well articulted.
2. Thoroughness and validity of evaluation (need for scientific synthesis) of monitoring results are not emphasized in the Fish and Wildlife Progam.
3. Information on life stages are not now monitored or integrated well with existing monitoring (e.g., in ocean and estuary).
4. The degree to which beliefs bias evaluation of monitoring results.

Recommendations

1. Maintain monitoring and evaluation as a major objective for the Fish and Wildlife Progam and include new metrics that permit monitoring of normative river conditions (e.g, effectiveness of peak flows in maintaining habitat structure; ground water controls on surface temperatures and productivity; integrity of riparain 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. Install and operate PIT 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 based on our normative river conceptual foundation.
6. 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.
7. 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.

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