# *Draft* Columbia River Basin Research Plan

**NOTE: This DRAFT document has not been reviewed or endorsed by the Council. It is only for internal staff and ISAB and ISRP review.**

**By the**

**Northwest Power and Conservation Council**

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# I. Introduction

## Objectives of the Research Plan

The purpose of the Research Plan is to identify the critical management uncertainties within the region that need to be resolved to conserve and recover native fish and wildlife. The intent of the Research Plan is to facilitate prioritization and implementation of research that addresses those uncertainties as they affect anadromous fish, resident fish, and wildlife and the ecosystems that support them. Despite a large body of knowledge about the needs of fish and wildlife, there remain instances in which the region lacks the information to fully understand which mitigation or restoration actions will be most effective. Over time, research completed under the plan will reduce critical management uncertainty by increasing scientifically based knowledge. The Research Plan will help the Council manage the Fish and Wildlife Program by informing decision-making, facilitating scientific review, focusing project selection, providing a basis for redirecting future research, and most importantly, making restoration projects more effective. Specific objectives of the Research Plan include:

1. Increased accountability for the annual expenditures of research funds.

2. Improved input from independent scientists, fish and wildlife agencies and tribes, and other interested parties in the region.

3. Improved coordination among mainstem research programs.

4. Implementation of the research important to subbasin plans.

5. Improved monitoring, evaluation, and the application of results.

6. Improved accessibility to the information generated by the research and restoration projects of the Fish and Wildlife Program.

### Biological Objectives of the Council's Fish and Wildlife Program

In 1980, Congress passed the Pacific Northwest Electric Power Planning and Conservation Act[1] that authorized the states of Idaho, Montana, Oregon and Washington to create the Northwest Power and Conservation Council (Council). The Act directs the Council to develop a program to:

> *"protect, mitigate and enhance fish and wildlife, including related spawning grounds and habitat, on the Columbia River and its tributaries … affected by the development, operation and management of [hydroelectric projects] while assuring the Pacific Northwest an adequate, efficient, economical and reliable power supply."*

[1] Pacific Northwest Electric Power Planning and Conservation Act of 1980 (Public Law 96-501, 94 Stat. 2697 (December 5, 1980), codified with amendments at U.S Code Annotated 16, section 839 (2000)). See Section 839b(h)(6)(B).

The Council's Columbia River Basin Fish and Wildlife Program is one of the largest regional efforts in the nation to recover, rebuild, and mitigate impacts of hydropower dams on fish and wildlife. As a planning, policy-making, and reviewing body, the Council develops and monitors the program, which is funded by the Bonneville Power Administration (Bonneville) and implemented by tribal, state, and federal fish and wildlife managers and others. The Council adopted the first Fish and Wildlife Program (Program) in November 1982. The heart of the Program is a set of immediate actions to improve conditions for listed and non-listed anadromous fish, resident fish, and wildlife that have been impacted by the hydrosystem in the Columbia River Basin.

The latest revision of the 2000 Program marks a significant departure from past versions, which consisted primarily of a collection of measures directing specific activities. In contrast, the 2000 Program establishes a basinwide vision for fish and wildlife along with four overarching biological objectives:

1. A Columbia River ecosystem that sustains an abundant, productive, and diverse community of fish and wildlife.

2. Mitigation across the basin for the adverse effects to fish and wildlife caused by the development and operation of the hydrosystem.

3. Sufficient populations of fish and wildlife providing abundant opportunities for tribal trust and treaty right harvest and for non-tribal harvest.

4. Recovery of the fish and wildlife affected by the development and operation of the hydrosystem that are listed under the Endangered Species Act.

### Rationale for a Research Plan

This plan provides a programmatic framework for research, and associates the research needed for recovery planning under the Endangered Species Act (ESA) with the broader responsibilities of the Program. Research is necessary to provide scientifically credible answers to questions addressing uncertainties pertinent to management. For the purpose of this plan, the term "research" is used broadly and includes more than just dedicated hypothesis testing, e.g., estimation, pattern recognition, observation, categorization, studies involving the collection of data to better quantify important known relationships, and improvements in statistical methods.

For 25 years the Council has supported a diverse range of research efforts to work towards the biological objectives of the program. Hundreds of excellent projects, including dedicated research projects and habitat restoration projects with research elements, have been completed since the inception of the program in 1982. Projects implemented under the Program and others in the Columbia River Basin have substantially advanced the state of scientific understanding of fish and wildlife restoration. Despite this concerted effort, critical management uncertainties have persisted because the relevant research questions are difficult to answer due to: environmental variability; the complexity of the Columbia River Basin environment; and the inherent difficulty in agreeing on specific problem definitions. In addition, over the course of the

development of the Program, the Council has adopted specific measures for research without a research plan that includes clear prioritization of remaining critical management uncertainties. This absence of a plan to coordinate and guide research in the region has contributed to a lack of focus on critical management uncertainties. Consequently, the Council called for development of a Columbia River Basin Research Plan (Research Plan) in the 2000 Program, to guide the development of a research program under the Program, and to foster collaboration with the research programs of the other resource management entities within the region. Specifically, the Basinwide Provisions (D.9) state that:

> "The Council will establish a basinwide research plan, similar to the subbasin plans, which identifies key uncertainties for this program and its biological objectives and the steps needed to resolve them. The plan will identify major research topics, including ocean research, and establish priorities for research funding."

Additional challenges to addressing uncertainties include shared responsibility for funding under overlapping mandates and the challenge of eliciting and sustaining long-term funding commitments to support research. As a result, resource management agencies have been unable to secure, individually or collectively, the funding commitments necessary to mount organized, long-range, and/or large-scale field experiments. These institutional problems in part explain why the feasibility of conducting the research needed to address the critical management uncertainties has not been determined. For this reason, the convocation of a Regional Research Partnership is proposed towards the end of this plan for the Program. The Regional Research Partnership would facilitate the coordination of research within the region; i.e., as well as research conducted outside the Columbia River Basin that is of high relevance to the management of the Program. It would work to identify and remove unnecessary redundancies, facilitate collaborative funding, and redirect savings to new research priorities. The Council is strongly positioned to serve as a sponsor of a collaborative regional research program that encompasses the multiple entities involved in fish, wildlife, and hydrosystem mitigation in the Columbia Basin. In particular, the Council's membership, structure and processes e.g., open public meetings and hearings, provides opportunities to facilitate coordination among the parties involved in research.

Important general objectives of the plan are to facilitate improved communication among scientists, cooperation among institutions, and better coordination of long term biological monitoring. A key dialogue that the Research Plan can facilitate regards the role and use of biological and ecological research to inform decision making on major conflicts in the basin that have profound socio-political implications, such as the persistent disagreements about the relationship of flow and survival of fishes or the influence of hatchery fish on wild stocks. Fundamental issues of fish migration and of the interaction of hatchery and wild fish remain poorly understood, yet the consequences are substantial for both listed species and the economy of the region. In fact, in 2000 the Committee on the Environment and Natural Resources stated that, "Basic scientific information is lacking for many of the remedial actions that must be taken over a longer term." Recognizing that we have limited understanding of how the ecosystem works, it will be important to reach agreement on what parts of the ecosystem we need to better understand, while implementing the plan in a way that fosters and takes advantage of innovative approaches.

## Scope of the Columbia River Basin Research Plan

The primary audience for the Research Plan is policy and decision makers responsible for natural resource management within the Columbia River Basin, such as the Council members and other regional executives. The plan will also provide useful guidance to researchers, project sponsors, and planners. The scope of the content of the plan does not include recounting the factors and events contributing to the decline of fish and wildlife species within the Columbia River Basin, as that history has been previously described by numerous other sources. The geographic scope of the Research Plan is limited to the Columbia River Basin.

Many parties are responsible for fish and wildlife management in the Columbia River corridor and basin, and their interrelationships and responsibilities. For example, Bonneville Power and its funding of the Council program, supports the work of the Army Corp of Engineers (ACOE), NOAA Fisheries, and other entities that manage the landscape e.g., Forest Service, Bureau of Land Management, Environmental Protection Agency. The Tribes, in their role as co-managers, make significant contributions in the areas of hatchery production, monitoring, and habitat restoration. The state resource management agencies also play key roles in the implementation of the Program; i.e., the Oregon Department of Fish and Wildlife (ODFW), the Washington Department of Fish and Wildlife (WDFW), Department of Fish and Wildlife (IDFG), and Montana Department of Fish, Wildlife, and Parks (MFWP). The Columbia Basin Fish and Wildlife Authority (CBFWA) represent the fish and wildlife managers of the states and tribes.

### Interface with Other Research Plans in the Pacific Northwest

The Council recognizes that the status quo for research within the region consists of multiple, separate research plans. These plans make reference to the "need to coordinate" with other similar efforts, but rarely set forth any explicit steps to implement such coordination. Consequently, the Council developed the Research Plan, in part, to enhance current coordination and facilitate future collaboration. This Research Plan recognizes other research plans as important components of a potentially integrated regional research program, and provides a framework for establishing linkages between existing research programs and initiatives. Many of the critical management uncertainties identified in other research plans in the region have been incorporated into this plan. Thus, this plan identifies research that can be funded directly through the Fish and Wildlife Program, as well as recommendations for research that will require collaborative, multi-party funding commitments by the Council and other entities with similar research mandates.

It is not the intention of the Council to subsume other research programs into the Fish and Wildlife Program and then direct their funding. To the contrary, the Council intends to use Program resources to catalyze research requiring long-term commitments, e.g., research supporting the development of a regional approach to monitoring. To the extent possible, the Research Plan will facilitate the coordination of processes already in place. For example, these other plans include the Federal Research, Monitoring, and Evaluation Plan, Anadromous Fish Evaluation Program, the Strategy of the Pacific Northwest Aquatic Monitoring Partnership (PNAMP), and the Washington State Salmon Recovery Plan. (Detailed information about these

other plans and programs are not reiterated in this plan to avoid redundancy and any implication that Program considerations are independent from these other efforts.)

In addition to supporting the Fish and Wildlife Program, the plan forges links to the research activity of the ACOE, the U.S. Bureau of Reclamation, Bonneville, NOAA Fisheries, U.S. Fish and Wildlife Service, U.S. Geologic Survey, U.S. Forest Service, U.S. Environmental Protection Agency (EPA), the Tribes, and other entities. Many other resource management entities share responsibility with the Council for research in support of fish and wildlife stewardship within the Columbia River Basin.

### Relationship of the Research Plan to Subbasin Plans

> *… to ensure that relevant scientific information, including socioeconomic information is available to decision makers in a useful format, a structured process is needed to involve community stakeholders and tribal governments and their issues, values, and priorities.*
>
> -- Committee on the Environment and Natural Resources, 2000

In 2000 the Council initiated subbasin planning in order to help local entities develop their own restoration plans. In 2005, 57 subbasin plans were adopted into the Program that identified coordination needs and opportunities for fish and wildlife restoration by integrating strategies in the Program with other federal, state, tribal, Canadian, and volunteer fish and wildlife restoration programs. The cooperative and inclusive participation of federal, state, tribal, and local stakeholders in subbasin planning created the opportunity for subbasin plans to provide a collective expression of the critical management uncertainties within a subbasin.

The Fiscal Year 2007-2009 project selection process, as well as future funding cycles, will be used to implement the restoration priorities set forth in subbasin plans; the research priorities set forth in this draft Research Plan; and, some of the monitoring priorities identified in the PNAMP Aquatic Monitoring Strategy (PNAMP, 2002). Many subbasin plans identified research needs that are either site specific or a prevalent need within the subbasin or province. The Research Plan encompasses the critical management uncertainties identified in subbasin plans that have broad application to other provinces, or to the entire Columbia basin. In the project selection process for the Program, research projects that help more than one subbasin will be given preference.

## Organization of Critical Management Uncertainties

Critical management uncertainties arise from the most important policy issues facing the region. In 1993 the Scientific Review Group (SRG) defined critical uncertainties:

> "*…as questions concerning the validity of key assumptions implied or stated in the Fish and Wildlife Program. Critical uncertainties identify important gaps in our knowledge about the resources and functional relationships that determine fish and wildlife productivity. Resolution of uncertainties will greatly improve chances of attaining recovery goals in the Fish and Wildlife Program.*"

The Research Plan divides scientifically important, but complex issues, into critical management uncertainties. The Plan provides a rationale for why the critical management uncertainties are important, but does not include extensive background beyond that necessary to establish significance of the issue. Full syntheses of current knowledge on each research topic are not provided as doing so would require a much longer Plan. The critical management uncertainties are described at a high level to preserve flexibility of implementation and to prevent the plan from quickly becoming dated. The critical management uncertainties were compiled from the Fish and Wildlife Program, various reports of the Independent Scientific Advisory Board (ISAB) and the Independent Scientific Review Panel (ISRP), regional fish and wildlife managers, subbasin plans, recommendations from national science groups, biological opinions, and other research plans within the region (*see* Appendix A. Sources of Critical Management Uncertainties).

By articulating and organizing these uncertainties, the plan will help the region agree upon research priorities, address knowledge gaps, and avoid duplication of effort. To be effective, the Research Plan describes the critical management uncertainties in terms that are intended to elicit the development of specific research hypothesis and project proposals. Therefore, each overview combines a brief reference to the literature with a profile of the topic and why it is important. This approach highlights the central issues while preserving the challenge for investigators to develop more innovative or integrative approaches. The ISAB and ISRP recommend against an overly detailed rendition of research needs pointing out that it might inadvertently diminish innovative responses; preclude flexibility to incorporate new information and techniques; and result in early obsolescence of the Plan. Further, the ISAB and ISRP cautioned that too many research recommendations could precipitate difficulty in reaching consensus on priorities. Consequently, the inventories of all the potential research topics identified during the public review of the plan are presented in the appendixes for each research topic.

Chapters II and III of the plan introduce long-standing and contemporary critical management uncertainties important to the Program and the region. These were identified through the distillation and synthesis of scientific uncertainties identified in Appendix A. Taken together, these two elements of the Research Plan, the critical management uncertainties and the inventories, provide a framework for guiding more detailed discussions of research funding allocation. (Prior efforts to identify research priorities for the region are described in Appendix B.).

It is intended that the critical management uncertainties identified in the plan will inform and help shape the research agenda for the region, with the more specific details to be developed over time as the plan is implemented. The life of the plan is six years with three-year work plans to be developed by Council staff in collaboration with Bonneville and the fish and wildlife managers. The work plan should be responsive to advancements in science and technology and help guide project selection process. The work plans could be peer reviewed, potentially by the ISAB and ISRP.

## II. Critical Management Uncertainties: The Four Hs Plus

The critical uncertainties identified in this document were generated from evaluation of independent science group reports, recommendations from national science groups, the fish and wildlife program, the biological opinions, and other regional research plans (*see* Appendix A.).

The ISRP and ISAB recommended that special emphasis should be placed on critical management uncertainties that cut across the four Hs, for example, the interaction of hatchery releases and habitat quality on wild salmon populations. Designing research studies without recognizing that these multiple H interactions may be occurring and accounting for these interactions in the experimental design could cause serious problems in interpretation of results.

### Hatcheries

### Overview

There is an urgent need for fundamental information on the interactions of hatchery-produced fish with wild populations (Return to the River, 1996, *see* also Williams, 2005; CENR, 2000, NPPC 99-15, NPPC 99-4, 2000 Columbia River Basin Fish and Wildlife Program). Effects of hatchery-produced fish on wild stocks potentially include genetic alteration, competition, predation, and disease. Sufficient attention must be given to evaluating ecological interactions, so that it will be possible to determine whether the anticipated increases in natural-origin adult recruits were constrained by the intrinsic biological attributes of the species being supplemented, biotic interactions, or habitat limitations. Many hypotheses concerning supplementation are largely unevaluated. (For the purpose of this plan, relevant terms such as "stock, population, etc." are defined in Appendix D., under Definition of Hatchery Terms.)

**Defining the Problem -** Supplementation (with unmarked hatchery fish) can introduce uncertainty through masking the numbers of natural-origin fish, making a determination of reproductive success difficult (for both natural-origin and hatchery-origin fish). The immediate net demographic benefit or harm to population abundance from supplementation depends on three things: intrinsic biological parameters of the stock in its environment, policy constraints, and management control variables. The integration of these factors, much less their measurement, has not been adequately considered in supplementation evaluations to date. For hatchery programs where the hatchery and natural population are integrated, the current scientific understanding is inadequate for determining the cost to the natural population. The impacts of these hatchery programs on the extinction risk to, or recovery of, the remaining natural populations have not been determined empirically, and these knowledge gaps need to be addressed (*see* ISAB, 2003-3, Review of Salmon and Steelhead Supplementation).

A major uncertainty associated with the use of supplementation is the condition of the habitat that will receive the hatchery-produced fish. The ecological conditions required to achieve benefits from supplementation have received little conceptual development or programmatic

experimentation. The explicit connections between species survival, habitat, and water quality improvements are uncertain.

In the ocean, the combined hatchery production of the entire Columbia River Basin may decrease viability of wild production under less than optimal ocean conditions. Work in Alaska on pink salmon suggests that the ocean is limited and increased hatchery production can displace wild production. If there is evidence that freshwater interactions are imposing density dependence on natural production, the region may want to consider decreasing hatchery production when ocean conditions are optimal, increasing opportunities for rebuilding natural stocks.

The ecological interactions of hatchery fishes are not well understood. The timing of "imprinting" of juveniles on their natal tributaries and how imprinting influences straying when adults return to spawn needs further assessment. Assured imprinting on a specific water source will reduce the potential for straying when fish are planted to establish a new wild spawning run.

**Multiple Roles for Hatcheries? -** Can hatchery programs provide harvest opportunities, restore natural production and conserve wild populations at the same time? Are there combinations of habitat and hatchery practices that can be employed so self-sustaining spawning runs can be reestablished where natural fish populations have been extirpated or in newly restored or reconnected habitat? Hatcheries currently provide significant harvest opportunities. Yet there is uncertainty about whether risks to wild fish caused by these production hatcheries are being effectively and appropriately managed. There is also uncertainty about how hatcheries can and should be used in restoring natural production and conserving wild populations. There is general consensus among experts that individual hatchery programs likely cannot do both at once; therefore, it is necessary to identify very precise hatchery program objectives. Conservation programs should require exacting implementation designs focused on solving the specific conservation problem.

Some scientists and managers believe that it is likely that supplementation will produce an increased abundance of natural-origin fish, and that reformed hatchery practices can reduce the risks from supplementation to acceptable levels. Other scientists and managers not only doubt that the expected increases in abundance will be realized, but also believe that there is a high probability that supplementation will cause significant harm, reducing the genetic diversity, productivity and abundance of the natural-origin component of the integrated population. The essential issue for hatcheries is how detrimental are the releases from "segregated" mitigation and harvest augmentation programs to wild fish, owing to ecological interactions and interbreeding, and how detrimental are the supplementation programs to target and non-target natural populations, from ecological interactions and interbreeding.

In essence, Columbia River Basin supplementation projects are being used to reduce near term management risk, yet may be precipitating long-term biological risks. In recent years three major reviews have been critical, and the science on this issue is far from settled, see Artificial Production Report (Council Document 99-15), the Artificial Production Review and Evaluation issued in 2004 (Council Document 2004-17), and the ISAB Review of Salmon and Steelhead Supplementation (ISAB 2003-3).

**Fish and Wildlife Program Goals -** The Council's 2000 Program recommends that supplementation and habitat restoration should be linked with the goal of reestablishing self-sustaining natural salmon populations. Although research has demonstrated detrimental effects of some hatchery programs on wild salmon, hatcheries, if operated properly, may be important and useful tools for restoring salmon populations. Wild stock information, such as the degree of hatchery introgression, is difficult and expensive to acquire, particularly at the stream reach level. Yet if wild stocks are to be used for recovery hatcheries, or wild stock sanctuaries are to be set aside for future uses, this type of information must be obtained. Geneticists should be employed to develop broodstock collection, spawning, rearing and acclimation/release protocols that will eliminate or reduce the detrimental effects of hatchery programs.

The hatchery system has become institutionalized within the Columbia River Basin and can be used to produce fish for harvest, maintain natural runs, and, address responsibilities under the ESA. This Research Plan provides a vehicle for addressing how hatchery operations can be integrated into the total production system and assist in the recovery efforts in the subbasin. The purpose and objectives of each hatchery should be established within the context of the subbasin where the hatchery operates, consider non-target species, take into account the linkages between salmonids and their habitats, and allow for the potential for metapopulation rebuilding.

The 1996 amendment to the Northwest Power Act charges the ISRP with providing scientific review of projects funded through the Fish and Wildlife Program, including scientific review for artificial production (AP or "hatchery") projects. New artificial production initiatives are evaluated through a formal three-step review process, first implemented in 1999. The three-step review includes an evaluation of whether a Master Plan is consistent with the ten Artificial Production Review policies (APR; NWPPC 99-15) adopted by Council into the 2000 FWP. A recurring ISRP criticism in their three-step reviews of hatchery projects is a failure to adequately address the second APR policy: artificial production must be implemented within an adaptive management framework including:

- a rigorous experimental design to evaluate the risks and benefits of the proposed project and address the associated scientific uncertainties; and,
- a set of decision rules for adjusting management in response to the experimental results.

Furthermore, the 2000 FWP explicitly directs an experimental approach to all projects (see page 29, Final 2000 Fish and Wildlife Program):

> *In recognition of the risk and uncertainty associated with artificial production, each artificial production activity must be approached experimentally with a plan detailing the purpose and method of operation, the relationship to other elements of the subbasin plan, including associated habitat and other projects within the subbasin plan, specific measurable objectives for the activity, and a regular cycle of evaluation and reporting of results. This approach will allow the region to address the remaining uncertainties on a case-by-case basis and quickly make adjustments in artificial production activities where warranted.*

In the report, Monitoring and Evaluation of Supplementation Projects (2005-15),

the ISRP and ISAB identify for the Council, Council staff, and regional managers, the critical uncertainties of supplementation, outline monitoring data needed to evaluate supplementation, and provide options for coordinating projects throughout the basin to produce an experimental design sufficient to resolve these uncertainties.

**Hatchery Reform -** The Council has been a leader, along with NOAA Fisheries , in assembling and advocating principles of hatchery reform. Hatchery reform requirements are in all of NMFS' more recent biological opinions including the 2000 FCRPS opinion. The Council has been a participant in requiring Hatchery Genetic Management Plans (HGMPs) for all artificial propagation programs, an effort that is driving rapid reforms of hatchery operations. Local brood stocks and genetic management are being emphasized in new and reformed artificial propagation programs. Risks of genetic and ecological interactions are being considered in hatchery programs. Because of the Council and NMFS efforts, the ecological and genetic affects of artificial propagation are being addressed in research and in hatchery operations.

The concepts of hatchery realignment and reform only came into application for most ESUs about five years ago, and many of the actions that have been initiated have not yet generated enough adult returns to evaluate the impacts. Many of the experiments like the Idaho Supplementation Study (ISS) are long-term operations that will affect hatchery operations in the future e.g., in the Salmon River (ISS) and the Clearwater (Nez Perce Tribal Hatchery).

Biological and physical facility constraints are factors, and it takes one or two generations to get an artificial propagation reform program operating, at least one or two more generations to evaluate and adapt, then one or two more generations to put improved operations into general use.

Initial steps of this reform are currently being undertaken through the Council's Artificial Production Review and Evaluation (APRE) initiative and its integration with the recent subbasin planning effort, yet there remain enormous challenges. For example, there is a need for greatly increased coordination among the major Council and BPA-supported supplementation programs in the Yakima, Hood, Grande Ronde, Imnaha, Salmon, and Clearwater rivers subbasins in order to answer basic questions about the efficacy and potential limitations of supplementation as a rebuilding tool. The need can be met through development of coordinated monitoring protocols and standardized "common currency" data that allow retrospective comparisons between programs, stocks, and geographic locations.

**Monitoring -** Because current monitoring and evaluation efforts are inadequate to estimate either benefit or harm from ongoing supplementation projects, it is important to establish reference populations and adequate levels of monitoring and evaluation as part of the basinwide adaptive management experiment. Specifically, multiple supplementation projects should be coordinated across the Columbia River Basin so that in aggregate they constitute a basinwide adaptive management experiment, maximizing the information collected and attempting to reduce uncertainty. For example, the ISS project includes controlled supplementation with hatchery-origin fish as well as natural production control areas such as Cle Elum and the Yakima Fishery Project. Although there is limited coordination among the projects at the implementation stage, the diverse supplementation strategies being tested in streams like the Yakima, Grande

Ronde/Imnaha, and Salmon Rivers are being evaluated and will be compared among the projects with nearby natural populations. The results of these projects will help identify knowledge gaps. Future investment should be in establishing robust experiments with un-supplemented reference streams and rigorous monitoring.

**Critical Management Uncertainties**

1. *What are the range, magnitude, and rates of deterioration of natural spawning fitness of integrated (supplemented) populations and the relationship of the deterioration with management rules, including the proportion of hatchery fish permitted on the spawning grounds, the broodstock mining rate, and the proportion of natural origin adults in the hatchery broodstock is undetermined?*

2. *Is it possible to isolate and reduce interactions between production hatchery fish and naturally produced wild fish e.g., by predicting and partitioning a balance of natural and artificial production at the subbasin, province, basin, and regional scale?*

3. *Is it possible to integrate natural and artificial production systems in the same basin to achieve sustainable long-term productivity?*

4. *What is the relationship between basin-wide hatchery production and the productivity (growth and recruitment to older age classes) of naturally produced salmon for a given level of ocean productivity e.g. a carrying capacity ?*

5. *Is the habitat capable of supporting salmonids at levels of survival that will bring about restoration?*

(Additional research recommendations are presented in Appendix C.)

**Hydrosystem**

**Overview**

**Return to the River -** Various attributes of the hydrosystem such as slow moving reservoirs, mainstem habitat degradation, power peaking affects, elevated temperatures, turbines and screen bypass systems have contributed to fish mortality. The report Return to the River (Williams, 2005) extensively reviewed scientific literature and provided hypotheses regarding fish migration behavior e.g., “spiraling” Chinook migration, diel differences in behavior, effects of size and smoltification on travel time and depth of migration, and makes comparisons between free flowing rivers and impoundments, and their differing hydraulic characteristics. The report suggests that major alterations to the hydrosystem, such as drawdown, are necessary to achieve conditions suitable for juvenile salmonid migration as part of an adaptive management framework.

Under the Fish and Wildlife Program, the Council has an interest in emphasizing research in the areas of mainstem operations including spill, flow augmentation and fish transportation. The Council has adopted two important biological principles to guide decisions on fish passage and mainstem research:

1. Protect biodiversity, by designing passage solutions that benefit the range of species, stocks and life-history types in the river (which may require multiple passage solutions at a project); and,

2. Favor passage solutions that best fit natural behavior patterns and river processes.

These two principles are linked and provide the fundamental conceptual framework necessary for restoration of salmon and other anadromous fish stocks as described in Return to the River (Williams, 2005) and the ISAB's Review of the Corps of Engineers' Columbia River Juvenile Fish Mitigation Program (ISAB 1999). Technologies that most closely approximate the natural physical and biological conditions of migration would most likely accommodate diverse species/stocks. Multiple passage systems are needed to fully protect all anadromous stocks that pass through dams and impoundments. For example, surface orientated bypass systems take advantage of the natural tendency for yearling smolts to pass dams near the surface, while passage systems other than screens and turbines must be developed to pass juvenile lamprey and subyearling Chinook that pass dams lower in the water column.

**Mainstem Amendments -** In April 2003, following a two-year public process, the Council adopted the Mainstem Amendments to its Columbia River Basin Fish and Wildlife Program that provide a broad range of recommended policies, operations and specific recommendations for future research. These amendments describe an experimental approach to many of the long-standing uncertainties regarding fish survival through different routes of passage and under different hydrosystem operational scenarios. To implement the amendments, a workplan was developed that sets forth 45 different tasks, many of which address specific research issues such as tests of dam operations. In general, the focus of hydrosystem research should not be to evaluate incremental benefits or decreases to direct survival, which will be difficult to measure. Emphasis should be on full life-cycle effects of hydrosystem operations, including effects on resident fish. For example, a more comprehensive look at system survival needs to be undertaken to evaluate benefits of spill. Spill volumes have traditionally been closely tied to total discharge and so the benefits of spill on system survival have been difficult to assess because of the typically high correlation between spill proportion and total discharge. Given the number of removable spillway weirs (RSWs) being considered for installation this relationship could change and, a model of spill efficiency should change as well.

The best passage solutions are those that take into account and work with the behavior and ecology of the species and life history types, that mimic the natural situations and processes that emigrating salmonids encountered in their evolutionary history. Passage standards, objectives, designs and evaluations should focus on protecting the wide array of species and life history types in the river, not just a statistical measure of central tendency for the most abundant species. Passage standards, objectives, designs and evaluations, must be related to increases in adults back to the spawning grounds (smolt-to-adult survival rates), not just the incremental survival of

juveniles or adults through the federal Columbia River hydropower system. River operations significantly different than the status quo should be tested to provide information to resolve key uncertainties about the hydrosystem impacts on anadromous fish.

**Critical Management Uncertainties**

*1. What is the relationship between levels of flow and juvenile and adult salmon survival through the Columbia hydrosystem?*

The present flow management strategy does not take into account the complex migratory behaviors of juvenile salmonids. For example, there is considerable uncertainty about the effects that changes in river flows and water temperatures designed to aid yearling migrants have had on subyearlings. Determine the effects of mainstem flow manipulation on survival through experimental studies of all aspects of flow manipulation, including load following.
(*See* ISAB, 2003-1, Review of flow augmentation: update and clarification.)

*2. What is the role of hydrodynamic features other than mid-channel velocity in fish migration?*

Determining the effects on migration of such features as stage waves and turbulent bursts, or pulsing flows may offer opportunities for water management that might be more effective in moving fish with less water than current procedures. The secondary effects of flow differences on near shore habitat conditions of present-day reservoirs (temperature, flow, and food production) need to be measured and evaluated. The effects of shoreline modifications along reservoirs (rip-rap, erosion, and permanent sloughs) compared to the riverine condition need to be evaluated.

*3. What are the cumulative indirect effects of passing multiple dams during migration?*

*4. What is the efficacy of the current operational measures designed to protect out-migrating juvenile fall Chinook?*

Recent studies on out migrating juvenile fall Chinook indicate that they have a more complex migratory life history than previously thought. These findings may call into question, the estimated juvenile survival through the hydrosystem and the current application of transportation, spill and flow augmentation to protect fall Chinook (*see* ISAB Findings from the Reservoir Operations / Flow Survival Symposium 2004-2).

*5. What are the optimal temperature regimes in impounded mainstem and tributaries to support salmonid survival, and how can hydro operations help meet these optimal temperature regimes*?

Current criteria are based on the 7-day average of daily maximum temperatures over the water body, but other measures of spatial and temporal variability might also be needed for salmonid protection, such as the average daily temperature, minimum daily temperature, and the presence of cold-water refugia.

*6. Can new hydro-operations to improve and increase water quality e.g. temperature, total dissolved gas, toxics, and sedimentation, and fish survival be developed*?

*7. What are the ecological effects of hydro operations on downstream fish and wildlife*

*populations and mainstem habitat?*
It is important to stabilize base flow and temperature fluctuations. The exact magnitude and timing of restored flows and temperature regimes is uncertain and should be empirically determined for specific free-flowing segments, via a broadly multidisciplinary approach.

(Additional research recommendations are presented in Appendix D.)

## Habitat

### Tributary and Mainstem Habitat

### Overview

The fragmentation, degradation, and loss of habitat have been substantially contributed to the depletion of fish and wildlife populations in the Columbia River Basin. Fish and wildlife habitat has been severely degraded by dams and diversions, sedimentation from forestry and agriculture activities, and the introduction of nonnative species. To sustain native fish and wildlife productivity requires a network of complex and interconnected habitats, which are created, altered, and maintained by natural physical processes. Restoration efforts must focus on restoring habitats and habitat connectivity, and developing ecosystem conditions and functions that will allow for expanding and maintaining diversity within, and among, species in order to sustain a system of robust populations in the face of environmental variation.

Major long-term interventions will be required to restore the spawning and rearing sites, migratory corridors, the spatial and temporal diversity of these habitats and to reconnect habitat types important for the continuity in the life cycles of salmonids (CENR, 2000). In response to the recommendation of the independent science groups, the 2000 Fish and Wildlife Program places a greater importance on improved natural habitat for fish spawning and rearing throughout their life cycle, including tributary, estuary and marine stages. The critical ecosystem features for the full life cycle of salmonid species and stocks must be defined (CENR, 2000). The relationship between habitat and fish and wildlife productivity is dynamic. Understanding these relationships is critical to conserving and restoring habitat that will meet population-based restoration, recovery, and conservation. Therefore, a comprehensive life-cycle approach that addresses both natural variability in environmental conditions and human impacts on physical, chemical, and biological processes affecting fish and wildlife populations must be defined. (See ISAB, 2003-2, Review of Strategies for Recovering Tributary Habitat.)

It is often more cost effective to reconnect blocked habitat, than to repair damaged habitat. Habitat reconstruction, however, may be the only option available to replace habitat that was lost due to inundation when storage projects were constructed. A mixture of these strategies should be evaluated to focus mitigation actions on the most effective techniques to restore species of special concern. Habitat projects that benefit terrestrial and aquatic communities should be the highest priority.

Habitat refugia have been identified as an essential part of the ecosystem for anadromous and resident fish. The protection and restoration of important aquatic habitats as refugia for the long-term conservation of anadromous and resident populations within the basin will require research to identify such areas. From a policy perspective, the Council also has an interest in emphasizing research in the areas of rearing and spawning habitat, particularly quantification of benefits from riparian protection, improved screening and increased seasonal water flows. Uncertainty about the effectiveness of present best management practices (BMPs) must be resolved by scientific evaluation at both site-specific and watershed scales.

**Determining Large-scale, Long-term Habitat Trends -** The rate of loss of habitat loss to land use practices, development, water quality degradation, loss of connectivity, etc., has not been quantified. Consequently, we have not determined where the locations of the greatest losses are in relation to where habitat is rapidly recovering, or whether these locations match up with the life history needs of the fish and wildlife.

The Interior Columbia Basin Ecosystem Management Project (ICBEMP) was a significant piece of work at the broad scale, but it was largely limited to federally managed lands. The Council should support a similar initiative to assess the status of habitat throughout the Columbia River basin as this information would be very useful in developing a sound, basin-wide restoration strategy.

**Climate Effects -** Although understanding of the short- and long-term climate patterns and variability of precipitation and temperature in the Columbia River Basin has improved, the effects of climate variability on tributary and mainstem habitats still needs to be assessed. This issue is broader than flow; as floods and droughts will strongly affect many other aspects of freshwater habitat. Climate change lends itself well to modeling and field verification, and should be addressed by a strong research program.

**Natural Disturbances -** In order to identify and conserve aquatic diversity and integrity, it will be necessary to define key ecological processes and key ecological functions of species from both a current and historical perspective. One of the most important concepts emerging from landscape ecology and ecosystem theory acknowledges the dynamic and complex nature of most natural systems and their linkages across scales of space and time. The dynamics of physical process in aquatic ecosystems can be manifested in the form of major events that substantially affect physical environments and associated species. Often, such events are described as "disturbances." Whereas some forms of "disturbance" may be viewed as potential threats to species and ecosystem function e.g., forest roads and associated effects, other forms may indeed be essential to natural ecosystem function. For example, large disturbances such as fire and associated hydrologic events have been obvious forces structuring these systems in recent time, but also in deeper geomorphic and evolutionary history. Disturbances will undoubtedly continue to be important in the future and may even become more pronounced. Predicting the effects of different natural and human related disturbances to freshwater ecosystems and ensuring the resilience of these systems to those disturbances represent central problems in natural resource management. Management that ignores the fundamental physical and ecological processes structuring and maintaining natural systems, and their inherent variability, will likely fail.

**Food Webs -** At this time little is known about the food webs in the Columbia Basin, especially in the tributaries e.g., how have they been altered by land and water use; the introduction of toxics, non-native plants and animals; by harvesting; and by climate change. Scientific understanding of the role of nutrients in the growth of juvenile salmon in freshwater and estuarine conditions is also incomplete. Fewer adult salmon returning to spawn in many streams, has resulted in decreased transport of nutrients such as nitrogen and phosphorus. Research has shown the large reductions in adult returns to the Columbia River system have reduced fluxes of carbon, nitrogen and phosphorus. The upstream transport of nitrogen by salmon has been demonstrated by the differences in the isotopic composition of nitrogen between reaches with spawning salmon and without. However, the conclusions derived from these findings and the practices adopted are not well supported.

**Critical Management Uncertainties**

*1 What pattern and amount of habitat protection is needed to ensure long-term survival of fish and wildlife populations in the face of variable environmental regimes?*

*2. Can the benefits of on-the-ground habitat restoration and protection measures be quantified?*

*3. What are the most effective Best Management Practices for protecting and restoring habitat?*

(Additional research recommendations are presented in Appendix E.)

## Estuary

**Overview**

The Columbia River estuary is an important ecological feature of the Columbia River Basin, constituting the physical and biological interface for salmon and trout as they transition between their freshwater and ocean life stages. Juvenile anadromous fish utilize various areas in the estuary to rear and undergo adaptation to marine conditions. Rearing locations, seasonal timing, residence timing, and migration pathways differ between species and stocks. Wetland and tidal channel habitats are important to the early rearing, survival and growth of chum salmon, sub-yearling Chinook, and smaller salmon in other West Coast estuaries. The Columbia River estuary also provides important rearing habitat for other animal species of marine origin, and year-round habitat for species that have evolved to live solely within an estuarine environment. From a policy perspective, the Council has an interest in emphasizing research in the areas of estuary and near shore ocean habitats.

The estuary has been impacted by local habitat and upriver management actions. Changes in the biological processes vary from a fundamental alteration in the basis of the food web to the exclusion of sub-yearling Chinook and chum salmon from a large portion of the tidal marshes. For example, the effects of change in seasonal flows following the development of the hydrosystem have resulted in changes to estuarine circulation, deposition of sediments, and

biological processes. Although all of the investment and effort in the Fish and Wildlife Program flow through this unique environment, the effects of restoration projects in the estuary have not been evaluated. The ISAB recommended incorporating monitoring of the physical environment, such as that currently under way by the Oregon Graduate Institute, with evaluation of large-scale manipulations of estuarine habitats. The intent of these restoration treatments would be to study changes presumed to have had negative impacts and to conduct these at a scale that can be measured within the natural environment (*see* ISRP, 2003-13, An ecosystem-based restoration plan with emphasis on salmonid habitats in the Columbia River Estuary).

In 2003 the Lower Columbia River and Estuary Partnership (LCREP) and the Army Corps of Engineers sponsored a Lower Columbia River and Estuary Research Needs Identification Workshop. The following list of research recommendations is largely drawn from the proceedings of that workshop and the Bonneville sponsored *Plan for Research, Monitoring, and Evaluation of Salmon in the Columbia River Estuary* (Johnson et al. 2004).

**Critical Management Uncertainties**

1. *Can the effects of anthropogenic impacts in the estuary be partitioned from the effects of numerous other impacts in the basin?*

2. *What is the impact of the significant loss of peripheral wetlands and tidal channels?*

3. *What is the ecological significance of the estuary plume?*

4. *What is the relative importance of estuary and tributary habitat restoration actions?*

5. *What are the highest priority estuarine ecological functions for restoration?*

6. *Which estuarine habitat types should have the highest priority for restoration?*

7. *What are the cumulative effects of multiple restoration projects in the estuary?*

8. *What habitat restoration actions in the estuary are most beneficial in affecting abundance, productivity, spatial structure, and diversity (VSP parameters) that enhance persistence of salmon populations?*

9. *What effects does the Lower Columbia Channel Deepening project pose to habitat, recovery planning, monitoring and evaluation, harvest management, natural variation and ocean productivity, and toxics research recommendation topics?*

(Additional research recommendations are presented in Appendix E.)

## Natural Variation and Ocean Productivity

**Overview**

Global and regional-scale processes in the ocean and atmosphere can regulate the productivity of local marine, estuarine, and freshwater habitats for anadromous species such as lamprey and cutthroat trout. Although managers cannot control these processes, natural variability must be understood to correctly interpret the response of fish to management actions in the Columbia Basin. For example, salmon abundances in the California Current region (off Washington, Oregon, and California) and in the Central North Pacific Ocean domain (off British Columbia and Alaska) respond in opposite ways to shifts in climatic regime. During periods of a strong Aleutian Low, zooplankton and salmon production generally increase in the Central North Pacific and decrease in the California Current, suggesting geographically distinct mechanisms of aquatic production. Climatic shifts characteristic of the strong Aleutian Low regime occurred twice this century: one from about 1925 to 1946 and another in 1976/77 to the present. Both periods were marked by precipitous declines in the coho salmon fishery off Oregon. Opposing cycles of salmon abundance between the Central North Pacific and the California Current regions underscore the importance of stock-specific regulation of ocean fisheries. Even during periods of high marine survival off Oregon, harvest limits must ensure that Columbia Basin stocks are not overexploited by northern fisheries trying to compensate for coincidental decreases in the production of stocks from Alaska and British Columbia.

Thus, while salmon migrations are tied to major ocean circulation systems, salmon life cycles are shorter than the inter-decadal periods of large-scale climatic change. The abundance of salmon tracks large-scale shifts in climatic regime, yet the specific mechanisms of this tracking are poorly understood. Stocks with different life history traits and ocean migration patterns may be favored under different combinations of climatic regime and local habitat characteristics. Such differences afford stability to salmon species over multiple levels of environmental variability.

Decadal cycles of ocean productivity have the potential to mask changes in the survival of salmon during freshwater phases of their life cycle, leading to erroneous interpretation of the performance of restoration efforts and increased losses of some stocks. The dynamics of salmon metapopulations will change under different climatic regimes if, for example, the dispersal of core populations or the rate of extinction of satellite populations is a function of fish density. Conservative standards of salmon protection may be necessary even during periods of high productivity to maintain the genetic slack needed to withstand subsequent troughs in productivity. Habitat fragmentation and loss of local stocks will likely magnify the effects of productivity troughs by also increasing freshwater mortality, inhibiting recolonization of disturbed habitats, and slowing rates of population recovery. (There is also increasing evidence worldwide that ocean fisheries on ground fish and coastal pelagic species such as halibut, Pacific Whiting, squid, sardines, anchovies, etc., may have significant impacts on the food web important for salmonids.) Thus, in concert with large-scale changes in climate, increases in the rates of local extinction and loss of stock diversity may lead to greater synchrony in the dynamics of salmon populations. Regional patterns of salmon decline in the Columbia Basin and throughout much of the Pacific Northwest are generally consistent with this synchronization hypothesis.

**Critical Management Uncertainties**

1. *Should hatchery production be scaled back during periods of low ocean productivity in order*

*to minimize competition in the estuary or marine environments (see also hatchery uncertainty #4)?*

2. *What are the effects of ocean conditions on anadromous fish populations?*

3 *Can inland management actions be evaluated and adjusted in response to ocean conditions?*

4. *Can changes in fish survival be associated with the variable nature of the ocean?*

5. *Can long-term monitoring of ocean conditions and the factors influencing survival of salmon during their first weeks or months at sea improve our limited understanding of the specific causes of inter-decadal fluctuations in salmon production?*

6. *How can information on the stock-specific distributions of Columbia Basin wild salmon in the ocean and the migratory patterns of hatchery versus wild salmon be improved*

7. *Can harvest management programs based on stock recruitment relationships and monitoring of individual species provide adequate indicators of the effects of harvest activities on ocean food webs?*

(Additional research recommendations are presented in Appendix E.)

## Harvest

### Overview

Harvest management has changed substantially since the listing of anadromous salmonids and bull trout. In particular, large changes in recreational fisheries management have occurred since the listing of several steelhead ESUs between 1997 and 1999. Harvest is managed under biological opinions that attempt to ensure fisheries do not pose jeopardy to listed fish species so that harvest is not an impediment to recovery.

Under an ecosystem approach for management and recovery planning (e.g., the All H paper), all mortality sectors must be managed to reduce mortality. Harvest, hydrosystem, habitat, and hatchery management have all failed to consider the relation of abundance to other components of the ecosystem, which are connected by the life cycle of the species. Estimates of production from habitats that are constantly declining in productivity will always be too high. Therefore, harvest regulation is a sufficient means of protecting and increasing production only in the presence of reasonably pristine habitat. Most current harvest management targets fish from mitigation hatcheries. Productivity to support harvest has been largely divorced from production in natural habitat.

**Recommendations from the ISAB -** The ISAB Harvest Management Review addressed the question: what constitutes a sound scientific basis for the management of Pacific salmonids in the Columbia River Basin? The ISAB reviewed the scientific issues associated with harvest

management, including the establishment of biological management goals, the information needs for monitoring and evaluation, and relationship to recovery planning. The ISAB evaluated: the ability to manage for smaller population groups given current methodologies; the concept of over-spawning; the role of salmon in the ecosystem; the treatment of uncertainty in stock assessments and management evaluation; and, the assessment of harvest within a life cycle and recovery context.

The ISAB found that there remains extensive concern for conservation of naturally produced salmonids and the effect of harvest on their conservation. Harvest is only one part of this complicated picture. But harvest is frequently targeted as a first management action because it removes mature salmon that could otherwise return to reproduce.

Significant progress, however, is being made in several areas important to harvest management such as the definition of independent population units (NOAA TRT's and State agencies), definition of population and ESU viability, establishment of the Pacific Salmon Treaty and role of the PMFC in limiting ocean fishing impacts, and the renewed in-river fishing agreements. In spite of these actions, harvest is likely to remain a concern because:

- there has been limited evidence of progress toward recovery (until very recently);
- the basis for annual variability in salmon returns is not well understood or explained to the public;
- hydro and habitat issues are seen as very long term issues and not easily managed;
- hatcheries are commonly used and understood to support harvest, particularly with the recent development of mass marking and selective fisheries;
- ocean mixed-stock fisheries in Canada and the United States continue; and
- harvest management systems are poorly understood.

While the ISAB was favorably impressed with the development of biological science and management processes, they noted significant concern for three fundamental components of harvest management. These include:

1. a paucity of quantitative data for analyses by population units (core data);
2. very limited evidence of assessment analyses by production units to provide a biological basis for production goals and trends in status; and
3. limited evidence of accounting for uncertainty in management plans with the exception of reference to precaution in the National Standard Guidelines.

<u>Recommendation 1. Core Monitoring Data</u>: The ISAB commented previously (ISAB 2003-3) on the essential need for a set of core quantitative data to be monitored annually in all production units or, at least, in representative units that may be used as "indicators" of productivity and trends in abundance over time. Data sets for many production units in the Columbia River proved to be very difficult to locate and frequently involved major assumptions, such as fixed age-at-return or use of constants in the estimation of spawning numbers. With the obvious importance of defining recovery goals and then monitoring progress to recovery, establishing quantitative indicator systems within ESUs is essential for a credible harvest management system.

Recommendation 2. Documented Assessments: While the ISAB reviewed many TRT reports, biological opinions, scientific papers, and management plans, there were very few quantitative and documented assessments of individual production units or ESUs, including both natural and hatchery production. Consequently, the ISAB questioned the basis of biological advice on Pacific salmon that subsequently becomes the basis for harvest management planning. Furthermore, the ISAB strongly cautioned against the collection of data without parallel careful design, use, and evaluation. Collection of the data is, of course, the first priority, but only by using data and assessing the dynamics of a production unit can errors be detected and corrections made. Detailed assessments must be documented and peer reviewed to provide quality control to the scientific basis of management planning.

Recommendation 3. Accounting for Uncertainty: The ISAB recommended that guidelines for the estimation and accounting of uncertainty in management targets and in-season management control be developed and applied in the management of listed ESUs. All sources of fishing mortality must be accounted for and a level of risk tolerance established through public consultation. While the ISAB was impressed with the intensive process used for salmon management, we also recommend analysts review whether current levels of harvest impact are consistent with the quality of data and level of uncertainty in processes, and provide the expected likelihood of recovery for these listed species.

Recommendation 4. Adaptive Management in Salmon Recovery: Given the limitations in historical data, the inherently large uncertainty in salmonid ecosystems, and the complexity of management processes involved in harvest management of Columbia River salmonids, the ISAB recommended application of adaptive management principles in salmon recovery. In developing recovery plans, the ISAB recommended a systematic approach to testing alternative actions with an emphasis on achieving secure spawning escapement levels should again be seriously considered.

The ISAB review also examined the effects of climate variability on the marine environment and the interplay of harvest, hatchery production, and varying ocean regimes. The findings from the report relevant to research are set forth in the Critical Management Uncertainties. If marine survival continues to improve, resulting in large returns of some stocks, then harvest will become an increasingly important scientific issue.

**Critical Management Uncertainties**

1. *Uncertainties exist regarding stock-composition and stock-specific abundance, escapement, catch, and age distribution of resident and anadromous fish. Can harvest be managed in mixed-stock areas like the ocean and mainstem Columbia by ESU or even individual populations?*

2. *Directed and incidental harvest of Columbia River Basin salmon has occurred in the absence of definitive knowledge of harvest impacts on the abundances and viabilities of the majority of the individual native spawning populations. With only specific information available for limited populations, can general knowledge be applied to aggregations of wild populations?*

3. *Uncertainties exist as to the harvest levels that resident and anadromous fish can sustain*

*without impacting the viability and productivity of the population. Can the level and pattern of stock specific mortality due to harvest activities, e.g., of various patterns of mixed-stock fishing, be determined?*

*4. What levels of escapement at the watershed scale are necessary to ensure that over-harvest of anadromous and resident is not taking place?*

*5. Can the equipment and marking techniques necessary to establish selective harvest techniques e.g., adipose fin clips, PIT-tagging be determined and developed?*

*6. What new harvest strategies can be employed to increase harvest opportunity while considering harvest mortality impacts on individual populations?*

(Additional research recommendations are presented in Appendix F.)

## Recovery Planning

### Overview

Fish and wildlife species and populations are characterized by life history, ecological, behavioral, phenotypic, and genetic diversity. Such diversity buffers fish and wildlife populations against short- and long-term environmental variation and has become more important as human activities have increased the rate and amplitude of environmental fluctuations over those that occurred historically. Human-caused development has altered the organization of fish and wildlife populations and consequently probably altered metapopulation organization. This has very likely caused losses in adaptive capacity and resulted in a reduction in the regional stability of production. Nevertheless, fish and wildlife populations in the Columbia River today can still form the base for rebuilding population abundance and diversity. It is important to identify strong, weak, and at-risk native populations and determine what actions can be taken to preserve and protect native populations (see ISAB, 2001-7 Review of Salmon Recovery Strategies for the Columbia River Basin).

A growing body of theory and empirical evidence suggests that localized persistence and resilience of species in aquatic ecosystems will be understood only within a broader spatial and temporal context. A better understanding of the dominant processes influencing the distribution, interconnection, and dynamics of populations through time and space will require work at multiple scales, especially at larger scales than typical of past research. Therefore, in order to identify and conserve diversity and integrity, it will be necessary to define the appropriate scales necessary to understand the distribution, resilience, and persistence of native aquatic species (*see* NOAA, 2000; U.S.F.W. 1999; and U.S.F.W. 2002.)

**Diversity -** It is important to recognize the importance of stock diversity in all aspects of the restoration effort. Diversity has been reduced by the extinction of many local populations, as well as a reduction in population size of most remaining populations. Losses of genetic diversity may have decreased the reproductive and ecological fitness, and therefore decreased the

probability of long-term persistence for many stocks. Generally there has been a lack of success in salmonid introductions and re-establishments within the basin. Under unconstrained conditions, metapopulation structure would act to stabilize losses of diversity and reproductive fitness within individual populations. Present restoration efforts have focused primarily on remaining satellite populations, which are smaller and less productive and may have higher probabilities of extinction than core populations. This may have rendered present metapopulation organization more sensitive to the effects of regional variation by reducing metapopulation size, increasing local population extinction rates, and reducing dispersal between populations.

Populations are often the fundamental unit of viability analysis, so effectively evaluating the status of a species may depend on correctly understanding its population structure. For restoration and recovery actions to succeed, there must be understanding of how these distinct populations individually respond to environmental variables that are likely controlled by very different limiting factors. Sub-watershed and site-specific restoration and recovery actions must be tailored to specific populations and to their particular environmental and biological attributes (CENR, 2000).

**Predation -** Degraded habitat conditions can result in increased exposure to predation or decreased ability to avoid predators due to decreased availability of refugia or slower reaction times. For example, in a system where the habitat is poorly managed and large numbers of smolts are directly released into streams become food for the intermediate predators such as bass and sunfish. Conversely, where the larger predators are intact and sufficient refugia exist, the smolts have the cold-water advantage; i.e., they are faster in cold water than their predators, but slower in warmer water.

The cumulative effects of predation must be evaluated including marine mammals, avian species such as terns, cormorants, mergansers, as well as piscivorous fish including northern pike-minnow, walleye, and smallmouth bass. The increase in avian and fish predation in the Columbia and Snake Rivers is in part a result of how the river is managed. Predation-related research should address factors such as low flows and dredging that create avian predator habitat.

## Critical Management Uncertainties

1. *Which approaches to recovery will be most effective in regaining meta-population structure that will increase viability?*

2. *Can the loss of meta-population structure caused by increased mortality rates be determined?*

3. *Is the adoption of an anti-degradation approach to management; i.e., protecting the best remaining water, habitat quality, or natural wild stock production, necessary for avoiding jeopardy and achieving recovery.*

4. *Will the loss of stock diversity reduce the fitness, and hence survival rate, of remaining populations?*

5. *What is the relationship between genetic diversity and ecological performance?*

6. *Can the diversity of anadromous salmonid stocks be sustained over the long term?*

7. *What is the baseline level of genetic diversity necessary to maintain sufficient "canvas" for adaptive behavior?*

8. *Can monitoring and evaluation determine if certain life history types are favored, or selected against, by specific restoration actions?*

(Additional research recommendations are presented in Appendix G.)

**Emerging Issues**

The emerging issues include several topics that warrant attention, but are not currently being addressed by the Fish and Wildlife Program or recovery planning efforts. The emerging issues that affect anadromous fish, resident fish, and wildlife include the implications of climatic effects, toxic contaminants, invasive species, and the impacts of human population expansion. These are issues for which there is leadership at the state and national level, but not at the regional level.

Two of these topics may be scheduled for ISAB reviews during 2006. The others are recommended for consideration because of their potential to undercut the restoration gains of the Program. Consequently, they are raised here because they include important management questions for the Fish and Wildlife Program; and, are generally neglected within the scope of most other regional plans. Because the emerging issues encompass broader federal and state resource management issues, it is recommended that the Regional Research Partnership develop implementation scenarios in which parties other than the Council will have leadership roles and responsibilities, and a substantial cost-share.

## Impacts of Climate Change on Fish and Wildlife Restoration

**Overview**

The potential impacts of global climate change are recognized at national and international levels. In addition, the impacts of short and longer-term climate variation and ocean conditions are now recognized as major contributors to fluctuations and trends in fish and wildlife abundance coast-wide. While a widely recognized phenomenon, the impacts of climate change are rarely incorporated into natural resource planning. The ISAB noted that the Council's program and the NOAA Fisheries recovery strategies do not consider the impacts of climate change and implicitly assume a level base case. However, the changes in regional snowpack and stream flows in the Columbia Basin projected by many climate models could have a profound impact on the success of restoration efforts and the status of fish and wildlife populations. The

cumulative effects of human impact may not become apparent until severe climatic stresses trigger a dramatic response. Such interactions may be particularly severe in the Pacific Northwest where periods of reduced ocean survival of salmon and periods of stressful freshwater conditions, due to reduced precipitation, low stream flow, and increased stream temperatures, tend to be concurrent.

**Critical Management Uncertainties**

The risks of global warming are potentially great for Columbia Basin salmon due to: the sensitivity of southern salmon stocks to climate-related shifts in the position of the sub-arctic boundary; the strength of the California Current; the intensity of coastal upwelling; and, the frequency and intensity of El Niño events. While the potential effects of global warming on ocean circulation patterns are poorly understood, the implications for salmon restoration efforts throughout the Pacific Northwest are significant.

1. *What are the climate trends in the Pacific Northwest that affect species under the Fish and Wildlife Program, parameters such as marine conditions, snow pack, stream flow, temperatures, and species ranges?*

(Research recommendations may be forthcoming, following the completion of the ISAB reports.)

## Toxics

**Overview**

Environmental contaminants such as heavy metals, pesticides, petroleum, and related petrochemical compounds pose a substantial threat to some aquatic ecosystems. Fish are vulnerable in rivers and lakes draining watersheds that support irrigated agriculture, mining, fossil fuel power generation, large municipal and industrial complexes, and other concentrated sources of human activities. Managers require contaminant surveys and bio-monitoring to detect the occurrence and bioaccumulation of suspected contaminants.

It is important to integrate chemical processes into the "habitat" perspective, especially for agricultural and urban watersheds and can be critical determinants of habitat quality. Otherwise, restoration projects could continue to make the landscape appear restored, without addressing the health of the underlying ecosystem. The challenge of urban stream restoration should be viewed as a case study in fish and wildlife habitat restoration. On a larger scale, various studies have shown that anthropogenic contaminants may have deleterious impacts on the health of fish in the Columbia River Basin e.g., the results of the Bio-monitoring of Environmental Status and Trends (BEST) Program have been reported by Hinck, et al., (2004).

The USGS has developed a body of salmon-specific eco-toxicological literature, surface water monitoring reports, and, related documents under the National Water-Quality Assessment Program. Distribution of dissolved pesticides and other water quality constituents in small streams, and their relation to land use, have been examined in the in the Willamette River Basin,

Oregon, by Anderson et al. (1997). The seasonal and spatial variability of nutrients and pesticides in streams of the Willamette Basin, Oregon were reported by Rinella and Janet (1998). Water quality in the Willamette Basin, Oregon has been reported by Wentz et al. (1998). The occurrence and an assessment of factors affecting concentrations and loads of pesticides in the surface waters of the Yakima River Basin, Washington, has been reported by Ebbert and Embrey (2002). Thus, information is available that documents both environmental conditions in the Columbia River Basin in regards to exposure as well as response; i.e., adverse toxicological impacts on salmon and/or their habitats. In addition to the issues of persistent and bio-accumulative legacy pollutants, the current use of pesticides and the various contaminants associated with agricultural and urbanizing watersheds in the present-day Columbia River Basin, should also be examined.

Little information exists on contaminant body burdens in hatchery fish versus wild listed stocks. Wild fish will not have the extra exposure from feed that is seen in hatchery fish, but wild fish also may remain in the estuary longer and accordingly have more potential to take up contaminants from the estuary environment. It is known that off-channel habitats, where wild juvenile salmon tend to be found, are the areas with comparatively higher levels of chemical contaminants in sediment and presumably prey. Juvenile out-migrant Chinook salmon are accumulating appreciable levels of toxic contaminants before they leave the Lower Columbia River estuary, and the levels are among the highest seen in any populations examined to date by the U.S. Environmental Protection Agency along the Oregon and Washington coasts. Part of this contamination comes from hatchery feeds and from bio-accumulative contaminants such as polychlorinated biphenyls and DDT. Salmon are also exposed via contaminated prey items in the Lower Columbia River. Other contaminants, which do not bio-accumulative in fish are still toxic, and salmon collected at the confluence of the Willamette and Columbia Rivers show evidence of such exposure as well.

Although a considerable amount of information has been developed regarding exposure via surface water, sediment, and tissue monitoring, we know much less about toxicological response. While it is known that salmon are exposed to potentially toxic contaminants, it is unknown whether these exposures are causing adverse affects sufficient to undermine conservation and recovery efforts throughout the Columbia River Basin. The region must determine how to develop a research, monitoring and evaluation program for toxics and contaminants. Contaminant monitoring and research should be conducted as part of overall investigations of chemical habitat quality, including studies of organic carbon transport and cycling. A major information gap is the lack of a "relative risk model" to extrapolate potential contaminant risk to fish and wildlife in the many areas where there is little of no data.

**Critical Management Uncertainties**

1. *What is the extent of toxic contaminants in the Columbia River Basin and how do they affect fish and wildlife survival and productivity?*

2. *Several populations of Pacific salmon with different life histories utilize the Columbia River estuary. Does exposure to toxic contaminants in the estuary pose a significant uncertainty for recovery efforts for Columbia River stocks?*

*3. Polychlorinated biphenyls are near levels of concern and fish are exposed to multiple contaminants. What are the biological consequences of the current levels of exposure?*

*4. What is the extent of concentrations of toxic pollutants found in the sediments in reservoirs behind dams in the mainstem?*

*5. What are the effects of air pollution and acid rain on the fish and wildlife resources in the Columbia River Basin?*

(Additional research recommendations are presented in Appendix H.)

## Invasive Species

### Overview

Invasive species comprise one of the most significant alterations of native ecosystems for fish and wildlife, and plants, and are rapidly becoming a dominant component of aquatic ecosystems within the Columbia River Basin (*see* Office of Technology Assessment, 1993). The impacts of non-native fish, mostly from eastern North America and stocked for recreational opportunities, are widely recognized but there are may other non-native plants and animals that could have a large impact on salmonid habitat productivity. They include aquatic plants e.g., Eurasian milfoil; aquatic invertebrates e.g., New Zealand mud snail, zebra mussel; riparian plants e.g. Japanese knotweed, Himalayan blackberry, giant reed; and riparian-associated animals such as livestock.

For the purpose of this plan, invasive and native species are defined as following Section 1. of Executive Order 13112 on invasive species, as follows:

> (f) "Invasive species" means an alien species whose introduction does or is likely to cause economic or environmental harm or harm to human health.
>
> (g) "Native species" means, with respect to a particular ecosystem, a species that, other than as a result of an introduction, historically occurred or currently occurs in that ecosystem.

As invasive and non-native species become more dominant in the ecosystem they will have a greater impact on native fish and wildlife populations. A recent survey of aquatic nonnative species in the lower Columbia River found 81 aquatic nonnative species below Bonneville Dam http://www.clr.pdx.edu/projects/cr_survey/index.htm. Aquatic invasive species issues are not independent of other hydro-system issues, as management has the potential to influence invasions in ways that dramatically influence desirable species or conditions.

From a fisheries perspective, some of the most challenging long-term management problems will involve nonnative, invasive species, such as the widespread rainbow and brook trout. These were introduced to provide angling opportunities, including replacement of opportunities lost through hydro-system influences. Now there is a need for better assessments of the biological

and economic consequences of these invasions. This would include research to identify patterns and consequences of invasions on species and ecosystems, monitoring protocols, and decision support tools. A key issue in the control of nonnative trout invasions is the conflict between fish passage restoration for native species, and the chance that such passage may open the door for invasive species likely to be introduced to the Columbia River Basin, such as New Zealand mudsnails, crayfish, other nonnative fishes such as northern pike, Atlantic salmon, and new diseases.

A proactive approach to anticipating invasions and identifying areas at-risk, could potentially save millions of dollars in future efforts to control species once they become established and threaten native fisheries. The Columbia River Basin should heed the lessons learned from highly invaded areas like the Great Lakes. An extensive study of nonnative species in the United States (OTA 1993) found that intentional introductions of several taxa, including fish, have proven just as likely to cause harm as have unintentional introductions.

A number of studies of walleye, smallmouth bass, and channel catfish have been conducted. One of those studies by Zimmerman determined that these three species account for over 20 percent of juvenile salmon predation, and that smallmouth and walleye prey proportionally more on salmonids than do native pike minnows. It is likely that shad, yellow perch, bluegill and other sunfish, crappies, Eurasian milfoil, Asiatic clams (*Corbicula manilensis*), and other species effect juvenile salmonids and other aquatic biota, either directly as predators, competition, or indirectly by altering the food base, water chemistry, physical habitat attributes, etc.

Habitat restoration may be ineffective at restoring native species where nonnative species are well established. Further, some types of habitat restoration activities may actually promote establishment of nonnative species by providing short-term disturbance regimes. Available science suggests that some nonnatives can be effectively suppressed where habitats maintain relatively natural stream flows, thermal regimes, habitat diversity, and intact native fish assemblages. However, these actions are usually only partially effective and only for the duration of the action. In the preceding section on toxics it was noted that sub-lethal effects on juvenile and Chinook may result from the application of herbicides, 2,4-D, fluridone, diquat, and triclopyr, which are herbicides commonly, used to treat invasive milfoil in Washington.

**Prevention -** Projects outside of the Columbia River Basin, particularly lake rehabilitation, have been successful in removing hybridized fish populations, creating genetic reserves for native fish, drastically improving fisheries, and eliminating source populations for further illegal introductions. However, there have been relatively few examples of success in eradicating established aquatic invasive species at an ecosystem level. Further, significant ecological and economic trade-offs occur when control is attempted. Past experience demonstrates relatively low levels of success in eliminating the impacts of well-established invasive species. While there are many important research questions regarding impacts and control of invasive species currently in the Basin, answering questions that will aid prevention and detection of new species may be more urgent. Therefore, research should be conducted to support a risk analysis of significant potential invaders, e.g., zebra mussels, and related preventive actions that can reduce those risks.

Attempts to control or mitigate for the effects of invasive species will only be effective if measures are in place that will curtail the introductions of new species. To date, methods to mitigate introductions via major pathways e.g., from ballast water or hull fouling, are in the process of being developed, thus, the efficacy of these measures is largely untested.

To determine whether species are, or are becoming, dominant in the ecosystem, initial baseline and monitoring information suitable to detecting trends in abundance is necessary. There are a number of nonnative species in the Columbia Basin that lack sufficient data to determine if they are invasive from a population growth, dispersal, or impact standpoint. In the absence of basic information on the distribution and abundance of these species, and how these species interact with other components of the Columbia River ecosystem, the magnitude of the effect is unknown. In the absence of this basic information, focusing control and management efforts on species that likely have a large effect may not be possible. Even for species identified to be invasive, willingness to remove that species may be influenced by positive economic impacts for some interest groups.

**Critical Management Uncertainties**

1. *What is the current distribution and abundance of invasive and nonnative species; i.e., the baseline condition?*

2. *To what extent do invasive and nonnative species affect native fish and wildlife species in the Columbia River Basin?*

3. *What is the relation of the current distribution and abundance of invasive and nonnative species to existing habitat conditions including flow and temperature regimes?*

4. *What areas harbor high nonnative predator abundance and what is their effect through entrainment and connected waterways?*

5. *What are the primary invasive and nonnative species introduction pathways, and can new protocols and methodologies be developed to limit new introductions?*

6. *Determine how to build capacity for prevention, early detection, and rapid response to new invasive species.*

7. *What mechanisms might reduce the likelihood of establishment, or inhibit the growth and dispersal of invasive population?*

8. *What are the economic consequences of invasions throughout the system, on native species, recreation, lakefront property values, and power generation, e.g., the effect of Eurasian water milfoil (*Myriophyllum spicatum*) or curly-leaf pondweed (*Potamogeton crispus*)?*

(Additional research recommendations are presented in Appendix H.)

## Impact of Human Development Patterns on Fish and Wildlife Restoration

### Overview

Like climate change, the impact of an increasing human population in the Columbia Basin is a widely recognized issue that is rarely incorporated into fish and wildlife planning. The human population of the Columbia Basin is increasing rapidly, a trend that is expected to continue. This increase is not occurring uniformly across the basin, but is largely concentrated in and around urban areas and generates human impacts such as the deployment of toxics into the environment. Urbanization and land use associated with an expanding human population is a contributing factor in salmonid declines and may be a significant barrier to recovery. These issues are being addressed by an initiative titled "Salmon 2100."

The growing population will potentially impact non-urban areas as well through increased recreation and housing in riparian and rural areas. At the same time, the economy of the region is shifting with the potential for both positive and negative impacts on fish and wildlife habitats. The ISAB has pointed out that the Council's program and the NOAA Fisheries restoration plans do not include consideration of human population trends but, as with climate change, assume a level base case. Because the Council's Fish and Wildlife Program mitigates human impacts on fish and wildlife, and their habitats, it is important to consider human demographic trends and their potential impact on efforts under the Program to restore and recover fish and wildlife resources.

### Critical Management Uncertainties

How might human population changes affect fish and wildlife habitats, and how might projected changes in economic patterns moderate or exacerbate these impacts? How can human demographic changes be effectively incorporated into fish and wildlife planning, e.g., setting restoration priorities under subbasin plans?

(Additional research recommendations are presented in Appendix H.)

## III. Critical Management Uncertainties: Monitoring and Evaluation

### Overview

The 2000 Fish and Wildlife Program, Basinwide Provision D.9, states that:

> "The Council will initiate a process involving all interested parties in the region to establish guidelines appropriate for the collection and reporting of data in the Columbia River Basin."

Consequently, an important objective of the research plan is to encourage the development of an effective and economical long term monitoring program to provide a basis for future programmatic evaluations. (Definitions of research and monitoring are presented in Appendix I.) The Columbia Basin has already developed some of the components of an effective and economical long term monitoring program, e.g., counts of returning anadromous adults at dams, estimates of number of out-migrating juveniles, harvest estimates, hatchery production, etc. Yet the Program needs to facilitate the development of additional components that are important to a long term monitoring program, including long term PIT tagging of important populations of anadromous populations, coordinated estimation of spawners or escapement into tributaries by standardized sampling and estimation methods, and standardized habitat and water quality sampling and estimation methods.

In order to effectively implement subbasin, recovery, and conservation plans, it is necessary to follow a logical process and paradigm of *Assess, Design, Implement, Monitor, Evaluate and Adaptively Adjust* plans and their implementation processes (Figure 1).

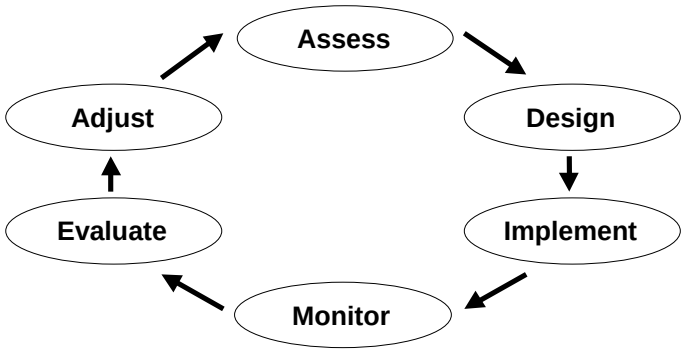



Figure 1. A framework for adaptive management, from Nyberg, 1999.

The axiom "all plans fail at implementation" can be avoided here by following the steps in Figure 1: 1) *assessing* limiting factors and critical uncertainties; 2) *designing* projects, programs and monitoring to maximize both on-the-ground effectiveness and learning; 3) coordinated and documented *implementation* of projects; 4) consistent *monitoring* through standardized methods, protocols, and training; 5) timely and thorough *evaluation* of effectiveness, and 6) overall guidance to the region to *adjust* plans and programs at the Province and subbasin level. Monitoring and evaluation is at the heart of the construct because it will provide the information,

data and analysis for identification of need and subsequent tracking the progress of plans and populations—or their lack of progress—to decision-makers and resource managers. The success of current plans and programs depends on the consistent application of well-designed research, monitoring and evaluation at multiple scales. These scales range across tributaries with major projects, populations, major population groups, sub-basins, Evolutionarily Significant Units (ESUs) or Distinct Population Segments (DPSs), and the entire Columbia Basin. To be useful to decision makers, such RME must identify the information required for different types of decisions at each scale e.g. management of harvests, the hydrosystem, and hatcheries; decisions on the protection and restoration of habitat.

Evaluating the occurrence and magnitude of trends requires a commitment to long-term monitoring (multiple years), and consistent data collection through networks of sites that represent the target population(s) of interest. Although substantial research has been conducted on trend detection e.g., form of trend, best tools to detect trend (Esterby 1993), there has been little discussion in the ecological literature of what constitutes a ‘‘policy-relevant’’ trend and how well we can measure or detect it (Urquhart, Paulsen and Larsen, 1998).

**Current Monitoring Activity**

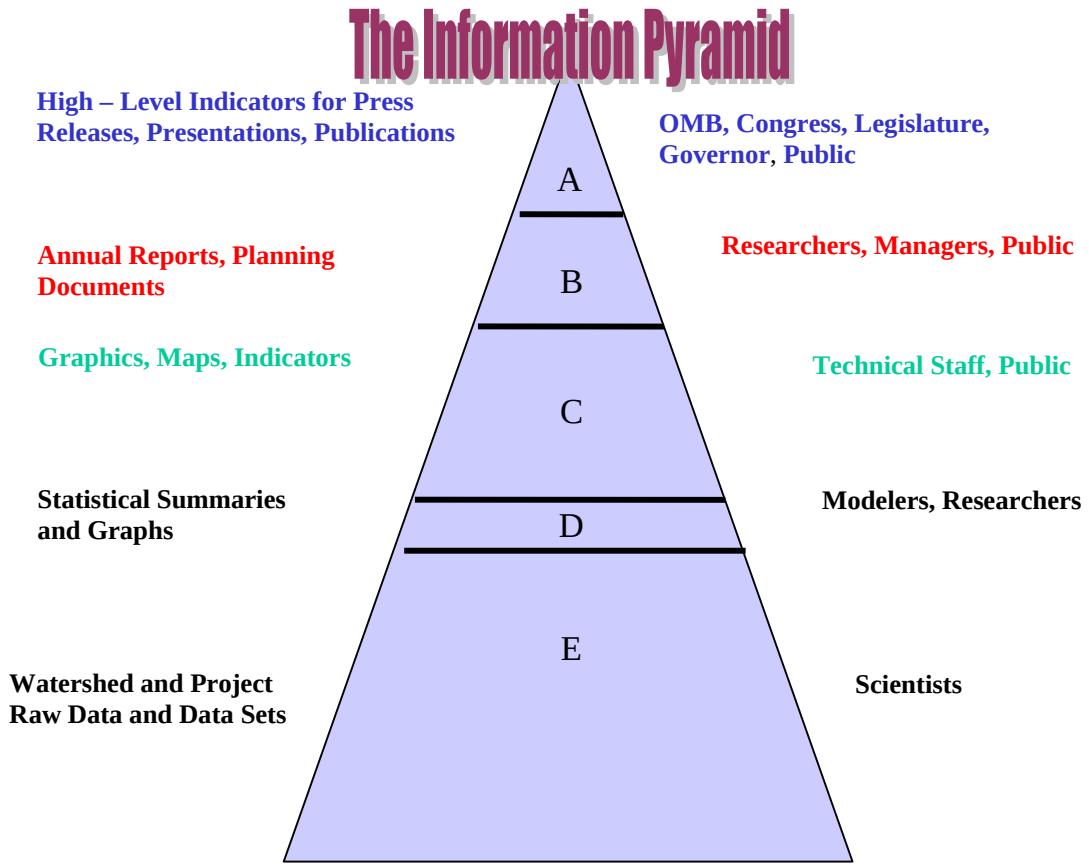
Monitoring in the Fish and Wildlife Program has primarily been conducted to evaluate work at the project scale, across all subject areas. This approach yields information derived from monitoring individual or opportunistic protection and restoration efforts and the effects of isolated or tactical actions and activities. Monitoring must focus its limited resources in a more programmatic approach, an approach that is designed to identify the need for and detect the sum total effect of actions at the population, subbasin and/or Province level. This will in turn support future analyses of more strategic actions and Plans and allow decisions to be made at a scale that is ecosystem and population based. Finally, performance metrics and high level indicators are derived from the programmatic approach and can be reported to Congress, Council, State, Federal, and Tribal resource managers (*see F*igure 1.)

While work at the project scale has intrinsic value, and we will continue to do so in select cases, it cannot substitute for the lack of a monitoring program of sufficient scope to provide a basis upon which the program as a whole can be evaluated, and re-directed. Monitoring is required at a number of different scales to assess the performance of the program relative to biological and programmatic objectives, to identify where and why there are performance problems, and to identify the most effective actions needed to correct problems so that program objectives can be achieved. This type of monitoring and evaluation across multiple geographic and temporal scales requires standardized approaches and programmatic, long-term commitments and interconnections for effectively combining information and answering program management questions. The absence of a regionally coordinated approach to monitoring and evaluation in the Columbia River Basin has constrained restoration and planning efforts for decades.

For this reason, it is important that a more hierarchical approach be utilized with increased emphasis on achieving useful outcomes from monitoring. Specifically, methods need to be developed and implemented so that monitoring results can be “rolled up” to provide

scientifically defensible evaluations of whether the aquatic ecological condition of a subbasin, an ESU, or the Columbia River Basin as a whole is improving or declining over time. This

Figure 1. In the monitoring information pyramid, examples of types of information are on the left and related users or generators of that information are represented on the right.




capability would be very useful to policy and decision makers as they deliberate on future actions that affect the long-term, ecological health of the basin.

Moving monitoring from project to larger spatial scales has both benefits and challenges. One benefit of focusing on the population scale is that it's a scale with direct relevance to fish managers, who want to know if actions upstream of the monitoring location actually improved a fish population's production e.g. smolts/spawner, in addition to improving habitat conditions in the restored reaches. The population scale is also of great interest to agencies like NOAA Fisheries charged with evaluating the status of listed populations.

There are also some significant challenges at larger spatial scales. Reliably attributing observed changes in fish survival or production to particular sets of management actions requires careful monitoring design. Otherwise, one might erroneously infer that observed changes were due to management actions when in fact they were the result of natural variation in freshwater climate or ocean conditions. Ideally, one would monitor both 'treated' areas (those with habitat restoration actions) and nearby 'reference' areas (those without restoration actions), for several

generations of fish populations, both before and after implementation of actions, and measure other explanatory variables simultaneously. One significant challenge in shifting monitoring to larger spatial scales; i.e. populations, subbasins, provinces, is that at larger scales it becomes increasingly difficult to establish the strong contrasts required to evaluate effectiveness; i.e. areas and times with and without certain classes of restoration actions. For example, adjacent subbasins will each have a variety of implemented restoration actions, so that comparing fish production across these subbasins and over time will not lead to any clear inferences on which actions (if any) were responsible for the observed differences in trends over time. It will therefore still be necessary to conduct effectiveness evaluations at finer spatial scales (project to population), for a carefully selected subset of restoration actions and locations that yields valuable information for the overall Council Program.

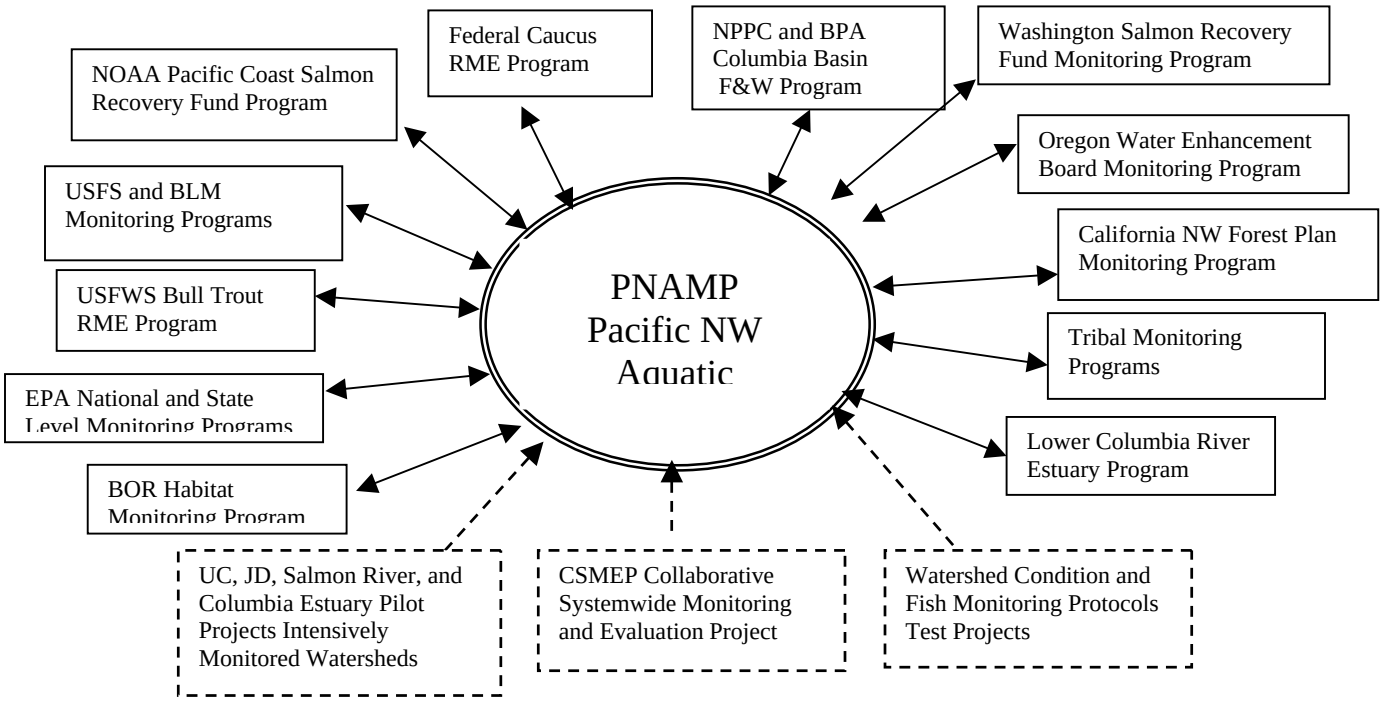
**A Programmatic, Regional Approach to Monitoring and Evaluation**

> *We again call for immediate development and implementation of a system-wide monitoring and evaluation program that is also responsive to critical uncertainties.*
>
> -- Critical Uncertainties in the Fish and Wildlife Program (SRG 93-2)

The objectives and management questions of the Fish and Wildlife Program overlap with those of other regional entities and, local state, federal and tribal governments. The costs of the monitoring and research needed to adequately address these common management questions are more than one program can adequately support or fund alone. Only through the combined efforts of multiple entities can a sufficient level of information be developed to guide these regionally shared resource management decisions through coordinated, standardized and programmatic approaches to monitoring. There are a number of existing efforts in the region to coordinate and collaborate around monitoring and evaluation but until recently there has been a lack of an organizing principle or central forum to facilitate these efforts. In 2005, the Pacific Northwest Aquatic Monitoring Partnership (PNAMP) was chartered to provide such a forum. As members of PNAMP, the Council, Bonneville, and the fish and wildlife managers are working to implement the Fish and Wildlife Program within the context of a regional network of monitoring effort so that the shared monitoring needs and objectives of the program can be achieved (*see* Figure 2.). The Council has directly supported this work through the Collaborative Systemwide Monitoring and Evaluation Program (CSMEP) to assure and facilitate implementation within the Columbia Basin. In close coordination with PNAMP, the CSMEP has been working since October 2003 to develop rigorous approaches to monitoring and evaluation that directly serve the needs of specific decisions, and build on the strengths of existing monitoring infrastructure. PNAMP and CSMEP have been, and will continue to, work closely together.

The components of the Research Plan that provide support for the development of regional monitoring framework are its long-term vision and its organization around biological concepts and management questions. Several other large-scale planning documents support this approach by identifying similar objectives and priorities. Source documents that have contributed to the conceptual foundation of the regional approach include:

Figure 2. Regional Partnership of Monitoring Efforts.




- Monitoring Section of ISRP's Retrospective Report – *NPCC 2005*
- Draft Research Plan for the Columbia River Basin – *NPCC 2005*
- Strategy for Coordinating Monitoring of Aquatic Environments in the Pacific Northwest – *PNAMP 2005*
- Considerations for Monitoring in Subbasin Plans 2004 – *PNAMP 2004*
- Conservation of Columbia Basin Fish; Final Basinwide Salmon Recovery Strategy - *Federal Caucus 2000*
- Research, Monitoring, and Evaluation (RME) Plan for the NOAA Fisheries 2000 Federal Columbia River Power System (FCRPS) Biological Opinion - *Action Agencies and NOAA 2003*
- ISAB and ISRP Review of the Action Agencies and NOAA Fisheries' Draft Research, Monitoring & Evaluation Plan for the NOAA-Fisheries 2000 Federal Columbia River Power System Biological Opinion (RME Plan) - *ISAB and ISRP, 2004-1*
- Updated Proposed Action for the FCRPS Biological Opinion Remand - *Action Agencies 2004*
- Proposed Design and Evaluation of Preliminary Design Templates – *CSMEP 2004*
- Data Quality Objectives for Decisions Relating to Status and Trend of Fish Populations, as well as Action Effectiveness of Habitat, Hatchery, Harvest and Hydrosystem Actions - *CSMEP*
- Scope of Work for Implementation of the Northwest Environmental Data Network Project - *Northwest Environmental Data Network 2005.*

## Components of a Regional Framework For Research, Monitoring and Evaluation

Through this Research Plan, the Fish and Wildlife Program will contribute to the design and implementation of a coordinated and integrated regional monitoring network of programs. This network of regional programs is being built on a common monitoring framework that includes 1) common management questions and information needs supporting the management questions, 2) common research, monitoring, and evaluation categories, monitoring designs and protocols that allow the communication and networking of regional programs, and 3) common understanding on responsibilities and cost sharing of the monitoring needs. The management questions and RM&E project category components of this framework are well developed through ongoing regional coordination efforts and are identified in the following sections. The development of standard monitoring protocols and identification of regional responsibilities and cost-sharing agreements is continuing to be advanced and is discussed further under monitoring priorities.

### Key Management Questions and Information Needs

Research and monitoring should be designed to generate the information needed to answer key management questions that are essential to quantifiably assessing program objectives. The broad biological objectives of the Council's Fish and Wildlife Program were introduced at the beginning of this plan. More detailed and quantifiable program objectives will be developed as part of the Council's initiative to develop provincial scale objectives. The following management questions provide a focus for identifying the priority of research and monitoring that should be addressed by the Fish and Wildlife Program.

1. Are we meeting biological and programmatic performance objectives established within the Columbia Basin Fish and Wildlife Program; e.g., subbasin plans and mainstem amendments; FCRPS BiOp; and ESA Recovery Plans? If not, how should we change our current management?
   - Status and Trend Monitoring of adult fish abundance, adult and juvenile survival through the hydrosystem (Tier 1 and 2 monitoring), and changes in survival or productivity, distribution and diversity associated with offsite mitigation actions (Tier 3 monitoring), as appropriate.
   - Implementation and Compliance Monitoring to assess project outcomes relative to project objectives and programmatic level standards e.g., provincial scale objectives.

2. What factors are limiting our ability to achieve performance standards or objectives?
   - Fish Population and Habitat Status and Trend Monitoring for limiting factors at each life stage (Tier 1 and 2 monitoring).
   - Uncertainty Research to better understand the underlying relationships between fish population performance and habitat conditions.

3. What mitigation actions are most effective at addressing the limiting factors?
   - Action Effectiveness Research (Tier 3 monitoring) targeting specific limiting factors and associated mitigation actions.

The regional framework for monitoring is depicted in a matrix that identifies the types of monitoring activity on going or needed in support of the management questions. These high-level management questions have several subordinate questions and supporting information needs that fit within the regional monitoring framework, depicted in Table A. Draft Regional Monitoring Framework, in Appendix A. The framework provides an organizing structure for identifying the types of monitoring activity needed in support of management questions.

### Common Categories of RM&E Within the Framework

A regional monitoring framework needs common terminologies for the different categories of RM&E to clarify the discussion of coordination efforts and the identification of current or needed RM&E projects. The following definitions of key categories of research, monitoring and evaluation are consistent with coordination activities between regional federal, state and tribal agencies under PNAMP, the Federal BiOps/Recovery Planning efforts, and the Fish and Wildlife Program:

1. Fish/Wildlife Population and Environmental Status and Trend Monitoring – census or statistically designed monitoring of fish or wildlife population and/or environmental conditions (i.e. watershed conditions) to assess the current status or change (trend) over time. This monitoring data may also be used to correlate fish performance with environmental conditions.
    - Ecosystem/Landscape level, broad-scale, periodic monitoring (referred to as Tier 1 Monitoring)
    - Geographically localized, frequent monitoring (referred to as Tier 2 Monitoring)

2. Action Effectiveness Research – research to determine the effects of an action or suite of actions on fish survival, productivity and/or habitat conditions (referred to as Tier 3 monitoring). This is experimental research that statistically assesses the effect of a treatment (action) condition relative to a control or reference condition. Action effectiveness research can be performed for a localized effect (project or stream reach level effect) or for a watershed level effect (intensively monitored effect). Localized (project level) effects most commonly identify changes in habitat conditions associated with the action, while fish or biological responses may require a watershed level (intensively monitored approach) to capture a broader area in which a biological response is expressed.

3. Uncertainties Research – research to resolve scientific uncertainties regarding the relationships between fish or wildlife health, population performance (abundance, survival, productivity, distribution, diversity), habitat conditions, life history and/or genetic conditions (e.g., the existence and causes of delayed mortality, hatchery spawner reproductive success relative to wild populations, etc.). This is experimental research that involves the manipulation of variables to demonstrate cause and effect relationships using statistical designed hypothesis testing. Uncertainties research does not include experimental research and monitoring specifically targeting the effect of a mitigation or restoration action (this is Action Effectiveness Research). It also does not include

monitoring of fish or habitat conditions with statistical correlation assessments (this is Status and Trend Monitoring).

4. Project Implementation/Compliance Monitoring – monitoring the execution and outcomes of projects. Project *implementation* monitoring determines whether projects were carried out as planned. This is generally carried out as an administrative review and does not require any parameter measurements beyond those specified by the project design requirements. Project implementation monitoring documents the type of management action, the location, and whether the action was implemented properly or complies with established standards. This type of monitoring does not require environmental response data directly linking restoration actions to physical, chemical, or biological responses. It is usually a low-cost monitoring activity that should be included for all mitigation or restoration projects. Project *compliance* monitoring determines whether specified project criteria are being met. Project compliance monitoring of restoration projects will be used to provide a form of post project auditing of project performance. This type of monitoring would typically not be carried out by the project sponsor and may require the development of independent, compliance-monitoring projects with one contractor tasked to monitor and assess multiple completed projects. A limited, statistical sample of projects would be monitored annually for compliance.

5. Data Management – support system(s) for data sharing and analysis.

6. Regional Coordination – coordinating processes and agreements across the various Federal, State and Tribal agencies and regional monitoring programs. These processes, agreements and the projects that support them are the glue that connects the network of monitoring efforts that together make up a regional comprehensive monitoring framework.

**Steps for the Solicitation and Selection of RM&E Projects**

A logic sequence of steps should be followed in the solicitation of research and monitoring projects under the Fish and Wildlife Program, to ensure that projects funded are most effective at achieving program objectives and contribute to advancing a regional monitoring framework. The completion of the following key steps is recommended for the effective allocation of limited Fish and Wildlife Program funding in concert with other regional RM&E programs with common objectives.

1. Identify the suite of management questions that need answers to effectively meet the objectives of the Fish and Wildlife Program.
2. Identify RM&E needed to address these management questions.
3. Solicit project proposals to meet these RM&E needs.
4. Obtain ISRP review of project proposals.
5. Complete an inventory of what, where, when, and who, for existing regional RM&E projects and programs to assess current coverage, areas of needed coordination, and cost sharing opportunities across existing federal, state, and tribal agency programs.
6. Add Fish and Wildlife Program proposed projects to the inventory of RM&E.
7. Develop a set of project selection criteria.

8. Use the selection criteria and the regional inventory of existing and proposed RM&E projects to perform a gap and prioritization assessment.
9. Identify cost sharing opportunities and responsibilities of other regional entities.
10. Allocate funding to high priority projects and gaps within allocated funding levels.
11. Develop targeted requests for proposals to fill remaining high priority gaps.

**Critical Management Uncertainties for Monitoring and Action Effectiveness Research**

This section identifies priorities for 1) Fish/Wildlife Population and Environmental Status and Trend Monitoring and 2) Action Effectiveness Research. These two components of RM&E are discussed together because monitoring for action effectiveness research projects is often coordinated with regional status and trend monitoring that may be occurring within the study area. The development of a coordinated regional approach to monitoring will continue to require planning, assessment, and research with other regional entities into the future. The ISRP, in their Retrospective Report, provided recommendations for monitoring priorities to the Council that will be helpful in the development of a regional approach to monitoring. They pointed out that an extensive long-term status-monitoring program can identify important and unexplained trends and changes. The ISRP suggested that the approach embodied in the four priorities they recommend is the most likely to accomplish successful large-scale, long-term research, monitoring, and evaluation programs for the following reasons. These are incorporated into the rest of this section.

Concurrently, PNAMP, the RME Workgroup of the Federal Caucus, NOAA Fisheries, The ESA Technical Recovery Teams, The Oregon Plan and the Washington State Forum have identified priorities for monitoring and action effectiveness evaluations. Subbasin and recovery plans outline these priorities incompletely but are instrumental in matching them up with population limiting factors. However, the Fiscal Year 2007-2009 project selection process provides an immediate vehicle for the Council and Bonneville to support projects that can develop the structures of, and give form to, a coordinated network of regional monitoring programs. Consequently, this section sets forth monitoring and action effectiveness research priorities. (Additional H-specific monitoring recommendations identified by the fish and wildlife managers and other entities during the public review of the draft Research Plan are presented in Appendix I.)

**Develop Common Protocols for Fish/Wildlife Population and Environmental Status and Trend Monitoring**

Fish or wildlife population and/or environmental conditions monitoring is defined as census or statistically designed monitoring to assess the current status or change (trend) over time and includes ecosystem/landscape level, broad-scale, periodic monitoring (Tier 1 Monitoring) and geographically localized, frequent monitoring (Tier 2 Monitoring). Biological monitoring programs e.g., coordinated and standard methods for estimation of spawners/escapement, coordinated and standard methods for monitoring of habitat, etc.

A primary need for monitoring is the development of data collection methods that will result in a common currency for statistically valid analyses. The region needs a coordinated approach to

monitoring at different scales to ensure consistency in data collection and to provide a basis for "rolling-up" data to higher scales in order to answer evaluation questions at a programmatic scale. This will require development of common monitoring approaches, including quality control/quality assurance programs; shared evaluation tools; integrated status and trend monitoring efforts; land use, land cover, and riparian vegetation categorization; core data for subset of watersheds in all represented states. (Although, such stratification cannot be applied universally, it will be applied where appropriate.) The objectives are to develop: standardized protocols; the ability to cross walk between protocols; and, connections between protocols designed for different purposes such as habitat assessment protocols for watershed management and habitat assessment for fish population management.

The ISRP recommended developing a sound Tier 1 trend monitoring procedure based on remote sensing, photography, and data layers in a GIS format. They recommended that landscape changes in terrestrial and aquatic habitat and land use should be monitored for the smallest units; i.e., pixels or sites, possible. Future technology may allow low cost remote sensing of important parameters such as water temperature. Accuracy and precision of data layers in the GIS should be evaluated using "blind" classification of randomly selected units by on-the-ground verification during field visits. Large-scale Tier 1 trend monitoring of fish populations might include fish counts and condition in by-pass systems at dams, adult counts at dams, and adult counts at weirs.

### Population Status, Trends and Distribution

Fish population status and trend data (abundance, distribution, and productivity of all Columbia basin populations) requires further development. This requires regional cooperation and joint funding of standard monitoring designs and monitoring programs to obtain more expanded, robust, and accessible information on adult escapement and smolt production. Furthermore, monitoring is needed to determine the indirect, delayed, or direct mortality levels associated with harvest. This information needs to be combined with more advanced harvest management assessment techniques.

Therefore a standardized set of metrics and compatible protocols for sampling designs and data collection must be identified and developed and implemented. Methods manuals for training and project level consistency must be developed and deployed. An annual symposium that brings decision-makers, monitoring designers, developers, practitioners, and implementers must continue and possibly be expanded.

### Develop Common Site Selection Procedures

The implementation and refinement of subbasin plans provides the opportunity to promote the collection of research and monitoring data with common methods throughout the entire Columbia Basin. The ISRP recommended that entities within the Columbia Basin cooperate in the development of a common Tier 2 probabilistic (statistical) site selection procedures for population and habitat status and trend monitoring. Use of probabilistically selected sites should be made as soon as possible to avoid inherent biases in subjectively selected and non-co-located study sites. The measurement of indicator variables should be co-located on the

same sites to the extent possible. The Program should cooperate with status and trend monitoring plans being developed by the Action Agencies for implementation of the EPA's Environmental Monitoring and Assessment Program (EMAP) probabilistic selection of aquatic sites in pilot projects in the Wenatchee, John Day, and Salmon Subbasins, (*see* BPA Draft Report "Research, Monitoring & Evaluation For the NMFS 2000 FCRPS Biological Opinion." EMAP can provide the basis for sampling, but some individual population needs, higher levels of uncertainty, or lack of data will require a Generalized Random Tessellation Stratified (GRTS) plus design (Stevens and Olsen, 2004).

PNAMP has pointed out that using a common probabilistic sample design, or Universal Sampling Design, as the basis for status monitoring would support data summaries or "report cards" on the condition (based on key indicators) of riverine/riparian/watershed resources and the tracking of changes and trends over time at broad regional scales. Such a sampling proposal would allow the aggregation of data at multiple landscape levels, while simultaneously meeting the needs of individual entities within the region. Objectives include:

- Coordinate state, federal, and tribal watershed status and trend monitoring efforts into an integrated sampling strategy. This may lead to changes in locations or watersheds selected for sampling for both state, federal, and tribal monitoring program sample sites, but would allow for improved efficiencies for use of data across a variety of scales.

Develop and recommend a regional aquatic monitoring design covering the states of Washington, Oregon, Idaho, and Northern California, using the EMAP probabilistic GRTS + design developed by the EPA to ensure random, spatially balanced placement of sampling sites (Peck, et al. 2001).

### Develop Models for Predicting of Abundance

The ISRP recommended proceeding on the development of empirical e.g., regression, models for prediction of current abundance or presence-absence of focal species concurrent with the collection of data on status and trends of wildlife and fish populations and habitat. Potential predictor variables include not only physical habitat variables such as flow, temperature, but also measures of habitat recovery actions that are currently in place or are implemented in the future. The empirical models can be used to evaluate the relative importance of physical factors and habitat improvements and to predict abundance or presence-absence throughout major sections of the basin. (It will be important to adequately cover the geographical breadth and biological depth of the region.) If adequate coverage exists with current study sites, it may be advisable to conduct initial analyses on current data.

### Habitat Monitoring

Some restoration projects will generate data that is relevant to regional monitoring objectives at scales beyond the project; i.e., watershed, subbasin, province, ESU, or basinwide. The data generated by such restoration projects presents an opportunity to help populate a regional database that can be manipulated for analytical purposes; i.e., the assessment of program elements. One example is the need for collection of data on the high level indicators that the region agrees should provide the basis for evaluation at the basin scale. A dialogue on this topic

is being hosted by the PNAMP Subcommittee on High Level Indicators. This would follow the approach of Washington State in their application of a modest number of key high-level indicators that collectively cover the range of watershed conditions. It will be important to regularly assess the effectiveness of these parameters for programmatic scale evaluation.

More specifically, data relevant to the assessment of progress towards or away from provincial scale objectives provides an example of use for program assessment of data collected at projects. In order to develop data that constitutes a common currency, it is essential that projects generating data for higher scale monitoring purposes utilize data collection protocols endorsed by PNAMP for regional use, and must be selected as a representative subset of all the projects being implemented within the basin. Rolling up the results of a subsample of projects that were not representative of the Program's efforts to date would yield an inaccurate inference of the Program's effectiveness at the basin-scale. Therefore, it will be important to continue supporting the Upper Columbia, John Day, and Salmon Pilot Studies as testing areas for comparing protocols and sampling methods.

### Action Effectiveness Research

Action Effectiveness Research is defined as research to determine the effects of an action or suite of actions on fish survival, productivity and/or habitat conditions (supported by Tier 3 monitoring). Monitoring for action effectiveness research projects is often coordinated with regional fish/wildlife population and environmental status and trend monitoring that may be occurring within the study area. This is experimental research that statistically assesses the effect of a treatment (action) condition relative to a control or reference condition. Action effectiveness research can be performed for a localized effect (project or stream reach level effect) or for a watershed level effect (intensively monitored effect). Localized (project level) effects are most commonly identifying changes in habitat conditions associated with the action, while fish or biological responses may require a watershed level (intensively monitored approach) to capture a broader area in which a biological response is expressed.

### Habitat Project Effectiveness

Monitoring of stream and watershed restoration to ascertain the effectiveness of restoration efforts were recently reported in Roni, 2005, and Crawford, 2005. Yet little remains known about how habitat improvements will affect target populations. Quantifying the results of restoration activities by having research projects that compare the effects of restoration projects to control or reference conditions will be fundamental to success. For many restoration actions, the relative recovery time frames are not well quantified. Thus, it will be important to assess not only the projected benefits of a restorative action, but the length of time needed to achieve those benefits and the rate of habitat improvement over time. Detecting change based on a discrete action, or a suite of actions, will be difficult without proper design and even more challenging to ascribe the effect to the biological constituents.

Research should be conducted to assess how fish production changes as actions are implemented or as habitat changes. Currently, such information is lacking for most habitats, though elaborate systems exist to approximate such information e.g., EDT. However, simply monitoring change will not be sufficient, a treatment and control experiment is required. It is important to determine

what sort of improvements we would expect in habitat and target populations as a result of specific restoration activities.

In their report, Review of Strategies for Recovering Tributary Habitat (ISAB 2003-2), the ISAB recommended that intensive watershed monitoring at selected locations be included in overall strategies for evaluating habitat improvement projects. Understanding the effect of habitat conditions on salmonid population performance requires carefully designed Before-After-Control-Impact (BACI) or other designs over several generations at the population scale. Few evaluations of tributary habitat in the Columbia River Basin have successfully implemented this level of intensive monitoring (Marmorek et al. 2004).

The expense and effort needed for research experiments evaluating the response of fish and wildlife to habitat restoration and to adaptively manage programs is considerable. It is likely to require several generations of a population to get statistically supported answers to questions about the effectiveness of habitat restoration. This supports an approach of focusing intensive monitoring efforts on a relatively few locations and to involve multiple parties in a collaboratively conducted and funded research effort (see Washington Salmon Recovery Funding Board. 2003a). This type of research has already begun in the context of the Federal RME pilot studies (Jordan et al. 2003, Hillman et al. 2004; WA SRFBa; and WAIMW 2004). By implementing these evaluations with clear objectives, careful employment of experimental and statistical design, disciplined adherence to the experimental constraints in treatment and reference sites, and patience, results can be obtained that will greatly improve the ability to ensure viable fish and wildlife populations.

Therefore, Washington State has invested heavily in the Intensively Monitored Watershed approach, which holds promise for qualitatively evaluating effectiveness of restoration and generalized action categories. The Program can help complement this effort by:

- Identifying the need for and funding sources for, intensively monitored restoration work in large river systems, which are not currently emphasized by Washington State. The John Day River, for example, might be a good candidate for such a study. However, inferences drawn from these subsamples must be carefully scrutinized for their applicability across a variety of eco-types and unique populations life histories.

- Providing supplemental funding for aspects of the Washington IMW research studies that are receiving inadequate attention and possibly expanding the network of IMW's to cover a broader variety of environmental conditions present in the Northwest.

- Providing a venue for stakeholders to participate in the IMW effort in Oregon and Idaho as well. This means bringing these two States into collaboration with what Washington is doing, and encouraging the tribes, federal agencies, and States, to engaged in or lead the work.

Members of PNAMP and other entities working with support from the Pacific Coastal Salmon Recovery Fund have already identified some watersheds for the intensive monitoring of restoration project results. The PNAMP Effectiveness Monitoring Workgroup has developed a

document to help guide this parallel activity, "Establishing a Network of Intensively Monitored Watersheds in the Pacific Northwest." The Fish and Wildlife Program is supporting this work via Project #200301700 "Develop and Implement a Pilot Status and Trend Monitoring Program for Salmonids and their Habitat in the Wenatchee and Grande Ronde River Basins." This project is an example of the current development of Tier 2 statistical monitoring for status and trend of salmonids and aquatic habitat over three large subbasins in the Columbia Basin. Concurrently, the Bonneville Environmental Foundation is also supporting similar work in the Chinook River in the lower Columbia and Kootenai. The Program should concentrate on supporting these current efforts, expanding the scope to other eco-types, and carefully managing and balancing technical investments in other watersheds.

Entities interested in conducting effectiveness evaluations of restoration projects should first carefully review work being done by the Washington Salmon Recovery Funding Board, and the IMWs, to determine what types of categories of restoration actions have not yet been evaluated in their ecoregion at the scales of interest. Secondly, these entities should meet with other groups (within their subbasin and/or within other subbasins in the same ecoregion) to develop integrated proposals that encompass a larger sample of this category of restoration action, as well as appropriate reference reaches or populations. This can maximize the opportunity for contrasts in actions, required for reliable inferences on action effectiveness.

### Estuary

Habitat restoration, research, and monitoring in the lower Columbia River, estuary and ocean are important aspects of the Council's Fish and Wildlife Program. There is a need to continue building a coordinated, integrated "estuary" program among the various funding entities and project sponsors. This program is being designed to address the estuary/ocean management questions and associated metrics, evaluation methods, experimental designs, etc. are contained in Table A., Appendix A. This material is based on PNAMP Level 1 (highest) type of management question, NOAA Fisheries' *2000 and 2004 FCRPS Biological Opinions*, Action Agencies' *Implementation Plan for the Updated Proposed Action*, Fresh et al. 2005 *Role of the Estuary in Recovery of Columbia Basin Salmon and Steelhead*, Bottom et al. 2005 *Salmon at River's End*, the Lower Columbia River Estuary Partnership's *Comprehensive Conservation and Management Plan*, the NOAA Fisheries/Action Agencies' *Plan for Research, Monitoring, and Evaluation of Salmon in the Columbia River Estuary*, and the Northwest Power and Conservation Council's *2000 Fish and Wildlife Program*. In summary, the key management questions for the lower river/estuary/ocean are:

- Is there a functioning adaptive management process in place to design, collect, analyze, disseminate, and evaluate data to inform decision-makers?
- What is the ecological importance of the Columbia River estuary and oceanic plume to the viability and recovery of salmonid populations in the Columbia Basin?
- Quantitatively, to what extent are we avoiding further loss to existing shallow water wetland habitat and restoring degraded habitats, in particular for listed salmonids?
- Is the off-site mitigation program of habitat restoration in the Columbia River Estuary improving habitat conditions for listed salmonids?
- What are the status/trends in ecosystem structure and function of the Columbia River Estuary?

- What are the annual ocean conditions and how are they affecting salmon survival?

### Artificial Production Effectiveness

Monitoring the effects of artificial production on population health is an issue that has long lacked a regional forum, but has recently been addressed by CSMEP. Such work is currently conducted project-by-project, yet constitutes a significant component of the current monitoring budget. Some ongoing artificial production projects have monitoring planning or research elements embedded in them and are coordinating their development with programmatic RME activities, e.g., Northeast Oregon Hatchery (NEOH), ISS, Umatillia, Yakima Fishery Project, and the Nez Perce Tribal Hatchery. When these elements address monitoring questions or needs relevant to the region such projects should no longer be viewed solely as hatchery projects, but should be identified as dedicated monitoring or research projects warranting long-term funding commitments. The Council acknowledges that the continuation, or addition, of work elements relevant to monitoring at the regional scale may significantly increase the annual funding requirements of the project, and that not all project sponsors will be interested in expanding this aspect of their work.

In their report Monitoring and Evaluation of Supplementation Projects, the ISAB and ISRP concluded that monitoring and evaluation of supplementation projects is critically important, and that:

1. For the monitoring to be effective, a very rigorous design is needed, and the scale and logistics of implementation will carry costs that are significant. The scientific issues underlying the definitions of performance metrics and the necessary controls in the design are genuinely complicated. Some of the scientific tools for measuring performance are new, and involve a level of knowledge of population and molecular genetics which until recently has not been part of the standard fisheries curriculum.

2. The consequences of not conducting these studies and continuing to assume no deleterious impacts from supplementation, and being wrong, are much greater than short-term changes in salmon abundance. The natural populations that may be lost if supplementation actually decreases their fitness are irreplaceable. On the other hand, if supplementation proves an aid to natural population during distress, further application may be warranted. Both outcomes remain uncertain without adequate monitoring and evaluation, which will likewise guide best management practice and cost effectiveness.

### Hydro Related Research, Monitoring and Evaluation

Hydro related research, monitoring and evaluation (RME) in the Snake-Columbia River System, are important elements contained in the Council's F&W Program. There is a need to coordinate these FWP activities with those funded under the USACE AFEP. In combination these two programs direct and fund Hydro-related RME activities many of which are described in this portion of the program. These RME activities are designed to address the Hydro-related management questions and associated metrics, evaluation methods, experimental designs, etc. as described and summarized in the accompanying table. This organization of this material is

meant to be consistent with PNAMP Level 1 (highest) type of management questions as distilled from the NOAA Fisheries' *2000 and 2004 FCRPS Biological Opinions*, Action Agencies' *Implementation Plan for the Updated Proposed Action*, the NOAA Fisheries/Action Agencies' *Plan for Research, Monitoring, and Evaluation for the FCRPS*, and the Northwest Power and Conservation Council's *2000 Fish and Wildlife Program*. Material in this table focuses specifically on RME objectives and activities associated with the FWP, not many actions funded under the AFEP Program. Nevertheless, to avoid redundancy in RME and ensure critical information gaps do not emerge it is incumbent on managers to closely coordinate activities between the programs.

### Uncertainties Research

Uncertainties Research is empirical research; i.e., experimental research that requires hypothesis testing using statistical designs for before and after conditions or parallel treatment and controls or reference conditions. Uncertainties Research is a long-term strategy, intended to resolve scientific uncertainties regarding the relationships between: fish or wildlife health, population performance (abundance, survival, productivity, distribution, diversity); habitat conditions; life history and/or genetic conditions (existence and causes of delayed mortality); and, hatchery spawner reproductive success relative to wild populations.

### Project Implementation/Compliance Monitoring

These types of monitoring address the execution and outcomes of projects. Project implementation monitoring determines whether projects were carried out as planned and constitutes a lesser level of effort and resource allocation. This is generally carried out as an administrative review and does not require any parameter measurements beyond those specified by the project design requirements. Project implementation monitoring documents the type of management action, the location, and whether the action was implemented properly or complies with established standards. This type of monitoring does not directly link restoration actions to physical, chemical, or biological responses, as none of these response parameters are measured. It does not require environmental response data and is usually a low-cost monitoring activity that should be included for all mitigation or restoration projects. This category can be used to track compliance with existing regulatory mechanisms and laws however such as state Growth Management, Critical Areas Ordinances, permitting processes and variance-granting procedures by local governments. This is key to ensure that "threats" to future viability are being addressed in land use and development processes as they represent significant impediments to mitigation, conservation and recovery of basin fish and wildlife species and populations.

Project compliance monitoring determines whether specified project criteria are being met. Project compliance monitoring of restoration projects will be used to assess the status of contract compliance and to provide a form of post project auditing of project performance. Only a percentage of program projects will have annual or periodic compliance monitoring after a project is completed.

### Long-term Priorities for Developing A Regional Monitoring Framework

#### High Level Indicators

It will be important for the provincial level objectives of the Program to encompass a core set of objectives common to the four states, while respecting additional reporting needs of the individual states. The process of developing, negotiating, and gaining regional acceptance of provincial level objectives will be highly analogous to the on-going efforts of Washington and Oregon. These efforts have been driven either by statutory requirements or by pressure from Congress and Legislatures for accountability. Once established, provincial level objectives will provide targets for our effort to develop a regional approach to monitoring in order to evaluate the effectiveness of the overall Fish and Wildlife Program. Figure 2. shows the relationship between types of information and how they how support decision-making. For example, the status of high-level indicators compels the activities at the bottom of the pyramid e.g., on the ground methods, protocols, and logistical implementation requirements. They also can help direct decisions, and recommendations about the analytical processes and statistical designs in the middle of the pyramid.

In order to implement adaptive management, resource management agencies need high-level indicators that are easy to understand in terms of every day definitions and experiences, and yet flow explicitly from on-the-ground monitoring programs providing information on progress towards biological objectives. A subcommittee of PNAMP is currently working to develop a pool of high-level indicators that can be used as the basis for developing provincial scale objectives that the agencies and tribes of the Pacific Northwest region can endorse and implement. Through the coordinated use of high-level indicators, a uniform message about watershed health can be provided with all participating agencies speaking the same language, using the same terms, and coming to similar conclusions.

### Inventory

It would be valuable for long-term planning and evaluation to assemble a comprehensive and detailed inventory of all monitoring activity in the Pacific Northwest region. The inventory should be structured to provide a web-based, searchable database. The benefit here is clear: knowing who is doing what, where, why and how, will enable cost savings through elimination of duplicate work, and enable a higher level of collaboration and communication. This inventory will also identify critical gaps and areas where strong and weak data sets currently exist. CSMEP has conducted detailed inventories, and assessments of the strengths and weaknesses, of data within a dozen subbasins of the Columbia Basin. These very detailed data inventories, which are available on an internet-accessible website, need to be complemented by a broader, less detailed inventory. Additional inventory work, on the scale of the entire Pacific region, is being conducted by the State of Salmon project, a joint effort of Ecotrust and the Wild Salmon Center.

### Data Management

A regional approach to monitoring cannot be achieved without the support of a data management system that can serve as a repository for the data and provide public access, on a timely basis, for analytical manipulation. To be successful a data management system must be able to assist scientists in the identification and development of data standards as it relates to the monitoring of

fish and aquatic habitat. This objective helps to identify solutions that improve access, sharing, and coordination among different collectors and users of fish and aquatic habitat monitoring data. It also provides a data reporting foundation that would lead towards coordinated agency reporting, uniform monitoring protocols, and improved data quality and quantity. Objectives include:

- Develop a consistent data management methodology within and across each of the types of monitoring.
- Establish a close working relationship for data consistency across the data sources.
- Identify and document the specific data needs of the region for watershed condition monitoring, fish population monitoring, and effectiveness monitoring.
- Develop and recommend data collection standards and information to be shared across the various monitoring programs.
- Share requirements and results with regional data networking entities to ensure sharing of monitoring data
- Test the collection protocols, sampling methods and data sharing mechanisms.
- Implement coordinated solutions within regional programs.
- Embed common analysis capabilities and reporting capacity.
- Provide public access sections or linked web sites for informational and collaborative processes

## IV. Implementing Research Recommendations

The ISRP also recommended that the Research Plan address overarching questions and assist in making decisions about the relative importance among projects by providing a prioritization for future research. In this plan, the critical management uncertainties are presented in order of priority as determined by Council staff. However, before the Research Plan is finalized, it is expected that the prioritization of the critical management uncertainties may be revised, based on the recommendations of the ISAB, the ISRP, and the fish and wildlife managers. From time to time, the Council may also need to respond to rapidly emerging management uncertainties by identifying additional research priorities.

**Summary of Research Priorities for the Fish and Wildlife Program**

1. *What are the range, magnitude, and rates of deterioration of natural spawning fitness of integrated (supplemented) populations and the relationship of the deterioration with management rules, including the proportion of hatchery fish permitted on the spawning grounds, the broodstock mining rate, and the proportion of natural origin adults in the hatchery broodstock is undetermined?*

2. *What is the relationship between levels of flow and juvenile and adult salmon survival through the Columbia hydrosystem?*

3. *What is the efficacy of the current operational measures designed to protect out-migrating juvenile fall Chinook?*

4. *What pattern and amount of habitat protection is needed to insure long-term survival of fish and wildlife populations in the face of variable environmental regimes?*

5. *Can the benefits of on-the-ground habitat restoration and protection measures be quantified?*

6. *Which estuarine habitat types should have the highest priority for restoration?*

7. *Determine if hatchery production should be scaled back during periods of low ocean productivity in order to minimize competition in the estuary or marine environments.*

8. *Uncertainties exist regarding stock-composition and stock-specific abundance, escapement, catch, and age distribution of resident and anadromous fish. Can harvest be managed in mixed-stock areas like the ocean and mainstem Columbia by ESU or even individual populations?*

9. *What is the extent of toxic contaminants in he Columbia River Basin and how do they affect fish and wildlife survival and productivity?*

10. *Identify primary invasive and nonnative species introduction pathways and develop protocols and methodologies to limit new introductions.*

12. *Develop, cooperatively, a common Tier 2 probabilistic (statistical) site selection procedures for population and habitat status and trend monitoring.*

13. *Develop a sound Tier 1 trend monitoring procedure based on remote sensing, photography, and data layers in a GIS format.*

14. *Develop empirical e.g., regression, models for prediction of current abundance or presence-absence of focal species concurrent with the collection of data on status and trends of wildlife and fish populations and habitat*

**Identification of Knowledge Gaps**

The Committee on the Environment and Natural Resources in their 2000 report explained why knowledge gaps exist.

> *Science is subject to the common tendency to add knowledge about already well-defined topics instead of seeking entirely new approaches and concepts. While incremental gains in understanding recognized problems are certainly necessary and it is appropriate to use science to support and refine existing management options, its value as a means to identify and test new options should not be overlooked. Research directed at further incremental gains in familiar subject areas must be balanced by research to close the many knowledge gaps.* (Emphasis added.)
>
> -- Committee on the Environment and Natural Resources, 2000

At their 2002 retreat, the Council's independent science groups identified the need to close key gaps in knowledge as a goal for the Research Plan. ISRP reviews have also highlighted the need for a Research Plan that would help close these knowledge gaps by evaluating the relevance of on-going research, identifying needed shifts in emphasis, and identifying emerging research topics. In this Research Plan a "gap in knowledge" is considered to exist whenever a critical management uncertainty set forth in Chapters II and III is not being addressed by:

- A research project(s) under the Fish and Wildlife Program proposed for continuation;
- A research project proposed for the Fiscal Year 2007-2009 Project Selection Process;
- A research project(s) funded by member(s) of the Regional Research Partnership; or, another entity who will make results publicly available.

A gap in knowledge can only be closed when sufficient results are accumulated and supportable conclusions are drawn from those results. Closing a knowledge gap may require a single project, several projects, or a long-term program. A research gap analysis for the Program will be conducted by comparing the critical management uncertainties identified in the Research Plan with the work proposed by project sponsors in the Fiscal Year 2007-2009 Project Selection Process. Although this exercise will be conducted after the draft Research Plan is submitted to

the ISAB and ISRP for final review, it will be completed ahead of the formulation of staff recommendations for funding for Fiscal Year 07-09.

**Getting Underway**

The Research Plan sets forth a comprehensive set of critical management uncertainties and research priorities that will require several funding cycles to address and is therefore is designed to be durable over a six to nine year period. The priority critical management uncertainties presented at the start of this section identified a variety of work that can be categorized as:

- Within the purview of the Fish and Wildlife Program;
- Shared by the Program with other entities; or,
- Under the mandates of other entities, but affecting the Council's Program.

These may be funded by the Council; the Council in collaboration with other members of the Regional Research Partnership; or solely by other members of the Regional Research Partnership; or other entities. Consequently, staff proposes implementing work under these categories via two different, but complementary implementation scenarios, the Project Selection Process for Fiscal Year 2007-2009 and a Regional Research Partnership.

**Project Selection Process for Fiscal Year 2007-2009**

The Project Selection Process for Fiscal Year 2007-2009 can provide a vehicle for implementing research that is central to the Fish and Wildlife Program; i.e., supports the mitigation and restoration of wildlife, resident fish, unlisted anadromous fish, and listed anadromous fish. In contrast to the Fiscal Year 2004-2006 funding cycle, the Fiscal Year 2007-2009 process will have benefit of the priorities set forth in the draft Research Plan, subbasin plans, the PNAMP Aquatic Monitoring Strategy, and NOAA Recovery Planning documents. These sets of priorities provide project sponsors clear targets for their proposals and will be used to help the guide the review of on-going work. The competing demands on available Fish and Wildlife Program funding underscores the need for an assessment of proposed research activity in relation to priorities for future research. It is important to make as much progress as possible on implementing these research priorities in the Fiscal Year 2007-2009 project selection process, and to recognize that implementing new research may require a reallocation of research dollars during the Fiscal Year 2007-2009 and subsequent funding cycles.

Existing projects can provide a strong start for a new research focus; i.e., on-going projects with strong links to regional research priorities will be considered as vehicles for addressing those priorities. The fact that there may be multiple on-going projects addressing a research topic does not preclude an enterprising sponsor from proposing a new or novel approach to the same problem. In the past, the Council has received project proposals submitted in response to solicitations that were geographic in scope, and did not actively seek proposals to address specific critical management uncertainties. The open solicitation approach has proved costly in terms of failing to address the knowledge gaps, frustrating project sponsors, and expending ISRP review time on proposals that neither the Council nor Bonneville would consider funding. In the past the ISAB and ISRP have suggested directing the available research and monitoring resources to a smaller number of projects that are well designed and have the intellectual and

financial resources to generate useful information. Many restoration projects are conducted that contribute to resolving critical uncertainties because they have a research component, but the overall project is not a dedicated research project.

### ISRP Review

The Northwest Power Act affords the Council broad discretion to develop the procedures for conducting project review and selection. The Act requires all projects to undergo an independent scientific review by the ISRP to ascertain their scientific and technical merits. In addition to the ISRP's scientific review, proposals are evaluated within a policy context to determine their potential contribution to management decision-making. The regional fish and wildlife managers provide recommendations to the Council on these matters and it is essential that they continue their key role in determining which projects are most likely to benefit fish and wildlife, including research projects that may provide the basis for eventual management actions. In summary, the Council's recommendations for Bonneville funding rest on a mix of priorities, legal considerations, technical adequacy, management urgency, regional opportunities, and available funding.

### Prioritization Criteria for Research Projects

The following criteria are proposed for use in identifying priority research in the Fiscal Year 2007-2009 Project Selection Process.

Critical Management Uncertainties - Projects that address critical management uncertainties identified in this plan will be considered priority projects. The results of such work must have broad application; i.e., provide a basis for extrapolation across ecologically similar subbasins, or provinces.

Time Required, Statistical Power - If the activity is likely to produce useful results within the five- to ten-year timeframe for the Biological Opinion, it will be ranked higher than one where more time will be required to yield information relevant to management decisions. Activities that yield statistically reliable results given the design of the experiment (duration, type, and intensity of monitoring) will be ranked higher than those that do not. If survival rates are being monitored, the change should be large enough to be important in reducing extinction risks, or increasing the likelihood of recovery.

ESU Significance - Monitoring directed at ESA-listed ESUs will be ranked higher than activities directed at other stocks. For those directed elsewhere, there should be another justification for conducting the activity e.g., smolt-to-adult returns (SARs) for Middle Columbia Chinook, to compare the Snake and Upper Columbia stocks. Populations with higher extinction risk or greater requisite increases in survival rates will generally receive higher priorities for both management and research actions.

Cost Feasibility - In prioritizing competing research activities intended to produce roughly the same information, cost of the different activities will be one criterion in selecting projects for funding. Feasibility will also be important. For example, a project may be powerful and well designed, but may be impractical due to logistical constraints e.g., take permits cannot be issued quickly, customized equipment may take too long to build.

Relationship to Other Research - To what extent does the proposed activity depend on other projects, and to what degree does it build on ongoing, related work? Some projects may conflict with other research. For example, a "control" stock for habitat enhancement cannot simultaneously be a "treatment" stock for nutrient supplementation. These conflicts require resolution before research activities are undertaken.

Innovation is a critical element of any large management or research program and should be encouraged. The Innovative Project category was suggested by the ISRP in past annual program reviews and was designed to improve knowledge, encourage creative thinking, and provide an opportunity for project sponsors to test new methods and technologies. Innovative projects were funded in Fiscal Years 1998, 2000, 2001, and 2002. Although, innovative project solicitations were not pursued in Fiscal Years 2003-2005, Council members have expressed continued support for an innovative project category. Although the innovative category is not being used in the Fiscal Year 2007-2009 funding cycle, the cycle still provides an immediate opportunity to support the funding of projects that are innovative in nature. Given the intractability of some research challenges it is important to keep the spark of innovation alive.

By providing research priorities for consideration during project solicitations, the Fish and Wildlife Program can shift from a reactive mode to a proactive mode. Future RFPs should be fully supported by fish and wildlife managers and include specific criteria for project sponsors to address. The opportunity also exists to use Request for Proposals (RFPs), with designated budgets agreed to by Bonneville, to address critical management uncertainties not addressed by Fiscal Years 2007-2009.

**Developing New Institutional Arrangements**

> *Historically, science has played two different roles in salmon management. The first, a technical leadership role, has involved establishing the fundamental relationship between salmon and their environment that collectively forms the basis for management decisions. The second, a "sustaining," has involved selectively seeking data and analyses to support regulatory actions or policy decisions by agencies, tribes, or other organizations. Ideally, science focuses on the more objective first role, but in fact, salmon management has been dominated by the second.*
>
> -- Committee on the Environment and Natural Resources, 2000

Acknowledgement of the dominance of the "sustaining" role of science in the Columbia River Basin is essential to a realistic assessment of where restoration and recovery efforts stand today. This recognition does not impugn the quality of the science conducted in the basin, but it does help explain why in some cases work of apparently low relevance is continued, while in other cases the application of results of high relevance remains a promise unfulfilled. Further, it explains disparities in the availability of data to support various management alternatives. A common manifestation of this phenomenon is that insufficient information will be available on politically controversial management alternatives. In the selection of new research projects, agencies understandably tend not to fund studies that seem to have limited usefulness for supporting current management practices, or that might produce results that actually contradict

current practice. Thus, the scientific basis for making management decisions is skewed by the propensity of institutional funding sources to support non-controversial research on an almost indefinite basis, resulting in repetitive research that generates data of diminishing value.

The National Research Council (NRC) stated that current institutional arrangements in the Pacific Northwest have contributed to the salmon problem and probably will need modification if an understanding of how to include "good science" as part of the institutional arrangement is important (NRC, 1996). The NRC recommended that the adoption of a coordinated, interagency approach to new scientific efforts could help reduce the tendency to fund research in areas of past agency investment.

Further, the NRC found that cooperative management implies an institutional change or shift in the structure of decision-making that acknowledges the role of various interests, such as consumers, representatives of different industries, and environmentalists, in the areas of policy, planning, implementation, and evaluation. Although the Northwest Power Act process falls short of the ideal of "power-sharing in the exercise of resource management" (Pinkerton, 1992), it did merge the inherent conflicts of fish and wildlife mitigation and hydropower production in a way that forced conflicts into the open and fostered joint action.

> *A great deal is known about the requirements of salmon, yet much remains unknown, and some gaps in knowledge are crucial to a long-term, stable solution to the salmon problem. Enough is known in the short term to improve the prospects of salmon if knowledge is applied wisely and quickly, but not enough information is known to warrant confidence in a long-term regional plan for salmon….the components of the salmon problem are so diverse that no one person can know all that needs to be known for a comprehensive solution. Thus, the salmon problem is in a sense a cognitive problem whose solution will depend on <u>close cooperation and collaboration of people with many kinds of experience and expertise</u>.* (Emphasis added.)
>
> -- National Research Council, 1996

## Regional Research Partnership: A Forum for Collaboration

### Context

The draft Columbia River Basin Research recognizes other research plans as important components of a coordinated regional research program, and provides a framework for establishing linkages between the Program and existing research programs and initiatives. The plan recommends research to be funded through the Fish and Wildlife program. It also proposes creation of a forum for development of recommendations for research that will require collaborative, multi-party funding commitments by the regional entities with research mandates.

Staff proposes using the Columbia River Basin Research Plan as a starting point for the development of a regional research agenda, by providing a rough framework on which discussion of coordination amongst potential partners can focus. While the draft plan does not constitute a complete research agenda for the region, it does provide a framework for developing

one, through the identification of potential partners, programs, and funding sources for working on research questions held in common. The disagreement, which exists about priorities for research, stems from the various different, yet sometimes overlapping management authorities within the Columbia River Basin and the broad geographic scope of the region. The Research Plan can help diminish this disagreement by:

- Fostering agreement upon a tractable number of well-chosen priorities;
- Stating the priorities in ways that promote effective research solutions;
- Providing a means for resolving disagreements on priorities;
- Taking advantage of unforeseen research opportunities that arise from advancements in technology and scientific knowledge or are simply facilitated by immediate environmental or social opportunities; and,
- Fostering collaborative research with other entities.

**Convening a Regional Research Partnership**

The 2000 Fish and Wildlife Program states that a meeting of fish and wildlife agencies, tribes and hydrosystem operating agencies should be convened regularly to identify key uncertainties about the operation of the hydrosystem and associated mainstem mitigation activities. In the past, executive level multi-agency groups and fora have been convened for the purpose of coordinating resource management decision-making across the Columbia River Basin. Yet no similar effort has been mandated to coordinate the research agendas of the various management entities. Therefore, this plan proposes the convocation of Regional Research Partnership as a vehicle for meeting the directives set forth above and making a major step towards meeting the recommendation of the NRC.

The Research Plan could help the Regional Research Partnership by bringing focus to initial discussions of how best to address research topics that are shared by the Council and other entities, or belong completely to other entities but affect Program resources. Under this implementation scenario, the Regional Research Partnership would provide a forum for implementing research that is important to the Fish and Wildlife Program, but is not the responsibility of the Program alone; i.e., it shared with other natural resource science management entities. The Regional Research Partnership will also provide a forum for Council involvement in discussion of how best to coordinate research that belongs to others, e.g., federal programs that interface with states represented by the Council.

All of the resource management entities contacted during the development of this Research Plan expressed support for this concept. Several initial meetings have been held with potential partners to discuss the Regional Research Partnership, with CBFWA in Portland, and with NOAA, USGS, and EPA in Seattle. These exchanges indicated strong support for a document that facilitates a regional approach to research, and also could inaugurate a process for coordinating existing research initiatives. The effort to launch the Regional Research Partnership could be staffed by Council until such time that it becomes sufficiently organized to have the members provide support on a rotating basis. The CBFWA, USGS, NOAA, and Bonneville have all offered to work with Council staff to help sponsor the Regional Research Partnership.

## Implementing Regional Research Priorities

The role of the Regional Research Partnership would be to update and prioritize currently identified research needs and facilitate coordination of the research efforts of the various State, Federal, and Tribal agencies to ensure that limited funds are allocated for the highest research priorities. The Council is strongly positioned to convene the Regional Research Partnership as the framework established by the Northwest Power Act has been characterized as the largest attempt to cooperatively manage power and fish and wildlife (Lee et al. 1980). A Regional Research Partnership could help the region move beyond the institutional impediments to coordinating research and provide a forum where researchers could transcend disciplinary and institutional boundaries, cross-pollinate ideas, and find peer support for potentially controversial recommendations. A major challenge for the Partnership would be to develop a programmatic approach for managing research within the region. For example, moving beyond the piece-meal solutions that have undercut the success of past restoration efforts, e.g., design a comprehensive effort to reduce sources of mortality across the life cycle of the salmon. The Regional Research Partnership could foster integration of the currently compartmentalized research agendas and budgets of entities that share common objectives. The fish and wildlife scientists and managers in the region could accomplish this by cooperatively developing the forum and a process for identifying research priorities that address shared critical management uncertainties.

A Regional Research Partnership could provide a venue for the identification of ways to share resources, experience, and expertise; fostering teamwork; and leveraging investments from multiple sources. For example, the Regional Research Partnership could be an appropriate forum for organizing the type of multi-party experiments have often been proposed in ISAB and ISRP reports, or by the Council itself, such as studies of the flow/survival relationship of juvenile salmonids. Uncertainties related to supplementation, tributary restoration actions, mainstem passage and survival, and other issues have been discussed in many ISAB and ISRP reports. These reports provide suggestions as to how these uncertainties might be addressed. In most cases, it is suggested that answers can best be obtained by coordinated experiments e.g., the recent ISAB suggestion for the load-following experiment.

### Identifying Regional Research Priorities

There will always be more research questions to answer than there are resources to provide answers. Therefore, research should be focused first on those questions that have the greatest relevance to the region. For example, does a critical management uncertainty apply to single or multiple subbasins, or the status of a single population or will it help multiple populations?

Scientists who work with “systems theory” often warn that trying to optimize one component of a complex system like the Columbia River Basin, such as the mainstem, may not necessarily increase the system’s overall performance. Furthermore, the current emphasis on mainstem research may not provide the certainty that is sought in relation to the recovery of ESA-listed salmonids. In order to achieve an ecological approach it will be important to maintain a diversity of research activities across the basin and among anadromous fish, resident fish, and wildlife. The research priorities should guide the selection of projects so that the funded projects move us forward in a defined and consistent way that provides synergy across the projects.

The federal, state, and tribal members of the Regional Research Partnership would work together to identify shared critical management uncertainties. The diverse membership of the Regional Research Partnership should provide an opportunity for open debate amongst peers and a sense of equity in the outcomes. An initial task will be to develop a set of decision criteria to guide the identification of research priorities. It is anticipated that these decision criteria will be drawn from the prior experience with the internal prioritization processes of the respective members. Four key questions need to be addressed by the Regional Research Partnership:

- Who should decide the priority of the research agenda?
- How should collaborative experiments be designed and implemented e.g., cost sharing and other means?
- Why and how should data be collected, stored, and analyzed?
- Who should be responsible for synthesis and dissemination of the results and identifying management implications?

The Partnership should meet as necessary to identify priorities and develop funding estimates that the members can use to inform their respective budget requests.

**Recommendation:** The Council proposes convening a Regional Research Partnership to provide a forum for the identification of shared regional research priorities and development of collaborative implementation strategies.

### Monitoring and Data Management in Support of Research

In order to succeed, a Regional Research Partnership would require administrative support in two key areas: monitoring and evaluation, and data management. It is recommended that the Regional Research Partnership draw support on monitoring issues from the Pacific Northwest Aquatic Monitoring Partnership (PNAMP). The mission of PNAMP is to coordinate existing individual monitoring programs into a regional approach in order to provide a basis for evaluation at the programmatic scale. The Northwest Environmental Data Network (NED) is concurrently working to develop regional data standards program to support regional data networking. The development of a regional data management partnership is a concept for which Council sponsored projects and support have already provided significant substance. It is recommended that the Regional Research Partnership draw support on data management issues from the Northwest Environmental Data Network (*see* Appendix K. Data Management).

If these three partnerships could coordinate their respective efforts, the research partnership could increase the ability of the region to reduce scientific uncertainty; the monitoring partnership could support the programmatic evaluation of the Fish and Wildlife Program; and the data partnership could develop a data repository for analytical manipulation of data at different scales. Even if these partnerships are only semi-formal in an administrative sense, and only loosely coupled in a decision-making sense, the synergy that would result from linking research, monitoring and evaluation, and data management would significantly increase the ability of the region to re-direct its efforts based on the cumulative results of project scale work.

### Facilitating Programmatic Coordination

Currently, a myriad of entities such as universities, private consultants, tribes, state and federal agencies conduct research within the region, yet the lack of a forum for coordination often results in poor communication between project sponsors. This increases the risks of: duplication of effort and inefficient use of funds; conflict among research project objectives; damage to long term monitoring sites; and, increased intrusive sampling of ESA listed and sensitive native species. The Regional Research Partnership could facilitate communication between all researchers working within a specific watershed, so that they are aware of and coordinate with each other's plans and projects in advance. The Regional Research Partnership could also facilitate communication between individuals conducting similar research in different locales; i.e., within the Pacific Northwest, or nationally. It will be important to identify research projects that complement one another, e.g., multiple treatments of the same question in different locations to increase sample size. Additionally, multiple studies of different issues within a single watershed can share monitoring to provide a more holistic view of the outcomes. Another issue is the coordination of research, and restoration activities, so as not to interfere with on-going research. Finally, the Partnership could coordinate the compilation and dissemination of technical information on the best tools for research and monitoring to its members.

### Collaborative Funding

In 2000, the Council shifted from an annual project funding cycle to a three-year cycle. Because state and federal agencies remain on an annual funding cycle, it is difficult for them to make long-term funding agreements. Consequently, formal arrangements such as memoranda of agreements may be necessary to secure long-term funding commitments for selected large-scale field experiments e.g., MOA between Bonneville and U.S. Forest Service. In regards to the Fish and Wildlife Program, it is important to acknowledge the difficulty inherent in reprogramming existing funds to support additional research initiatives, within the available direct program budget.

Yet the important question is not how much investment in additional research the Program might afford, but rather how to develop a comprehensive regional research agenda that can be funded from multiple sources, sustained, and managed to mutually endorsed outcomes. A more systematic and strategic approach to leveraging investment by many parties is warranted. The Research Plan identifies critical management uncertainties that need to be addressed by multi-agency initiatives, cooperative funding agreements, and the sharing of responsibility for implementation.

New large-scale field experiments should be conducted collaboratively via shared funding arrangements with other entities. It might be argued that there are already de-facto large-scale field experiments underway, but they were not designed to resolve specific uncertainties or establish cause and effect relationships. It may be possible to link project-scale efforts together in order to achieve large-scale field experiments, such as by sharing controls for hatchery and habitat projects. However, the current funding structure does not facilitate development of controls, for example much of the research on hatchery effectiveness has been done without paired study of natural production. Similarly, much of the research on habitat treatments has

been conducted without paired control sites. For these reasons, current research activity that resembles large-scale field experiments does so by default, not by design.

Some identified research and monitoring needs are currently, or should be more appropriately, the requirement or shared responsibility of federal or state agencies other than Bonneville, under mandates other than the Northwest Power Act. This point is particularly relevant to ESA recovery planning and implementation research needs that are a proposed for the Columbia River Basin but have application coast-wide. Discrete elements of the identified research and monitoring present differing degrees of opportunities for regional coordination and funding opportunities. In order to succeed, it will be incumbent upon the Regional Research Partnership to develop and implement incentive strategies. Incentives may include funding, regulatory flexibility, or recognition, all of which can work in combination. Thus, there is a need to work cooperatively with entities that represent alternative funding sources, and have responsibilities that overlap those of the Council e.g., Trust for Public Lands, and others. The regional entities should recognize that all programs are limited by what they can afford to sustain, but that by working together, all the programs could benefit from focused, coordinated expenditures.

## Integrating Research Results into Council Policy and Decision-making

### Evaluating Research Results

Research results must be reviewed and evaluated in order to direct new research and inform on-going work to protect and restore fish and wildlife. The effectiveness of new research results must be evaluated objectively before the results are widely applied, e.g. the removal of log jams, which "impeded" the return of adult salmon to spawn. The review of research results must be conducted across projects and subject areas to determine the contribution of particular results to overall improvements in management. Some tools and metrics for evaluating research contributions across the “H” topic areas and across all life stages of a species were developed and used during subbasin planning. Others are currently being developed under the auspices of PNAMP, and through various ESA related processes such as PATH. Additional tools and metrics may need to be developed.

Annual workshops sponsored by the Regional Research Partnership could provide a forum for evaluating and disseminating the results of research. The results of individual research projects can provide a basis for larger-scale reviews of the effectiveness of the research program and discussion of additional complementary approaches, including:

- Broader scale analysis that applies information from several projects to address a particular question;

- Synthesis reports of work completed in a particular area, such as the Giorgi report, “Mainstem Passage Strategies in the Columbia River System: Transportation, Spill, and Flow Augmentation” (Council Document 2002-3); and,

- Expanded provincial review presentations.

- Workshops structured around single topics driven by critical questions, such as transportation effects, and projects synthesized to address that topic.

- Workshops and symposia on emerging topics, such as toxics.

These workshops could help assess future research priorities through oral presentations, reporting of results of relevant studies, and the development of scenarios for applying research results in support of management actions. The workshops could promote the free flow of scientific results and provide the Council with information to better inform future funding decisions.

**Dissemination of Research Results**

The Council will work with the other members of the Regional Research Partnership to develop a strategy for the transfer of research results to other researchers and interested parties. The public nature of Bonneville funding implies that research results are the property of the general public. Bonneville should post all final research reports on its website to facilitate access. Research reports and data should be made available to scientific collaborators, administrators, and the public for additional analyses. The final reports, and any other products derived from them, should be submitted to the StreamNet Library. This library includes materials relating to the resources of the Pacific Northwest and maintains a regional depository of all research projects funded under the Fish and Wildlife Program. The StreamNet Library provides regional services that include reference, referral, database searching, inter-library lending, and document delivery.

The ISRP has recommended that all project proposals reference past achievements and that annual and final reports be issued on time and made available to the region. The ISRP also recommended that "…CBFWA … include in its Annual Implementation Work Plan a report of past accomplishments at the watershed and subregional/subbasin levels or topical level…." Further, the ISRP has supported publication of evaluations of work conducted under the Fish and Wildlife Program in a "Columbia River Basin Journal," as a way to disseminate results and provide a forum for advancing regional knowledge on Program actions (FY00 Council AIWP Vol. I., p. 21). Council staff is currently discussing this recommendation and support the idea of Council sponsorship of a journal that could:

- Provide short turn around on the presentation of program results to a regional audience that includes managers;

- Provide a common information base to support decision-making by the middle management groups; and,

- Help focus discussion on future directions.

**Recommendation:** The Council should support publication of a Columbia River Basin Journal as a vehicle for disseminating results of Program actions and as a forum for advancing regional knowledge.

### Adaptive Management

The integration of scientific knowledge into management decision-making is a challenging task for public officials, planners, and environmental lawmakers. This integration is central to adaptive management, a concept that provides a framework for managers to launch the implementation of policies despite uncertainty, variability, and potential risks. At the core of this approach is a deliberate plan to learn from decisions and progressively fill knowledge gaps. This way management actions, whether successful or not, provide valuable information to improve our understanding of program effectiveness and influence future management decisions.

In practice, adaptive management is a method for taking action in the absence of information, or when only limited information is available. This may occur when the information is so unique that it does not exist; there is no basis in prior experience from which to extrapolate; or, when prior experience occurred at such a different scale as to be irrelevant. Adaptive management provides a valuable tool for ensuring that timely feedback from such diverse activities informs the re-direction of future research to increase effectiveness. In their seminal work applying adaptive management in a hydropower context, Professor Kai Lee and Jody Lawrence wrote:

> *Adaptive management is learning by doing... Adaptive management is both a conceptual approach and a strategy for implementation. As a conceptual approach, it sets a scientifically sound course that does not make action dependent on extensive studies. As a strategy for implementation, adaptive management provides a framework within which measures can be evaluated systematically as they are carried out… Information from these evaluations should enable planners to estimate the effectiveness of protection and enhancement measures on a system wide basis. Measures should be formulated as hypotheses. Measures should make an observable difference. Monitoring must be designed at the outset. Biological confirmation is the fundamental measure of effectiveness*. (Emphasis added.)

(From "Adaptive Management: Learning from the Columbia River Basin Fish and Wildlife Program," Environmental Law Vol.16:431-460, 1986.)

The National Research Council (NRC) related several lessons learned about the practicability of adaptive management and the institutional conditions that affect how experiments on the scale of an ecosystem can be conducted (NRC, 1996). These lessons are:

- Learning takes from decades to as long as a century. Patience is both necessary and difficult, particularly in institutional settings such as governments that work in faster cycles.

- Systematic record keeping and monitoring are essential if learning is to be possible. But collecting information is expensive and often hard to justify at the outset and during times of budget stringency because the benefits of learning are hard to estimate quantitatively.

- Cooperative management in the design and execution of experiments is indispensable. Experimentation within the context of resource use depends on the collaboration of resource users.

- Adaptive management does not eliminate political conflict but can affect its character in important, if indirect, ways.

Although "adaptive management" has been the foundation underlying numerous conservation plans and strategies for restoring aquatic habitat conditions and native species, our knowledge remains very limited in this area. Long-term commitments to science-based evaluations of management actions will move us towards adaptive management. Future research in the Columbia River Basin should include interdisciplinary work along the lines of projects supported by the NSF bio-complexity program, e.g., integrating physical, biological, economic, and social sciences, as appropriate.

One challenge to an adaptive management experiment is providing a large enough perturbation to a system so a detectable change in a response variable can be measured. For example, by measuring responses to a limited range of spill and flow levels in the Columbia River hydrosystem, it will be difficult to assess detectable changes over the salmon and steelhead life-cycle and to contrast those changes in life-cycle survivals to those for transported juvenile fish. This is a key question that needs to be addressed in order to evaluate the future of transportation, spill, and flow measures in restoring salmon, steelhead, and other aquatic populations that use the mainstem Columbia River.

**Recommendation:** Large-scale adaptive management experiments, e.g., at the scale of river subbasins or basins, should be included as viable options for addressing management needs.

### Balancing Curative and Preventative Approaches to Restoration

Today the Fish and Wildlife Program is in a transitional state. After 25 years of implementing a broad-based program for restoring anadromous fish, resident fish, and wildlife, the Council is now reconfiguring the program to address new responsibilities under the ESA. In order to successfully address these new and more specific responsibilities under the ESA, this draft Research Plan provides specific guidance for research in support of recovery planning.

The Council emphasizes a balanced approach to implementing the Fish and Wildlife Program, despite strong external pressures to shift the entire program into an ESA implementation mode. Shifting program emphasis too far in the direction of the ESA could become self-defeating, as the curative approach embodied in the ESA is expensive and the outcomes are uncertain. In contrast, the Fish and Wildlife Program embodies the preventative approach of protecting the viability of all affected species to preclude additional listings under the ESA. The preventative

approach is less expensive and more likely to protect existing fish and wildlife. The Council must strike a balance between these two approaches, even while moving beyond the status quo.

# V. Appendixes

## Appendix A. Sources of Critical Management Uncertainties

### Independent Science Groups

The Council has relied on committees of scientists for their expert advice on fish and wildlife issues ever since the Council was formed. In the early 1990s, the Council asked its Scientific Review Group (SRG) to identify critical scientific uncertainties for the purpose of focusing implementation of the Fish and Wildlife Program. In January 1993, the SRG issued its report, entitled *Critical Uncertainties in the Fish and Wildlife Program* (Council Document SRG 93-2).

The SRG concluded that a major shortcoming of the Fish and Wildlife Program was that it lacked an explicit conceptual foundation "that couples life histories and production with appropriate ecosystem components." The SRG described the critical ecological uncertainties that identify important gaps in knowledge of the resources and functional relationships that determine fish and wildlife productivity in the Columbia River ecosystem. The SRG also identified six "ecological uncertainties that encompass the Fish and Wildlife Program as a whole, as opposed to a long list of uncertainties associated with each of the program elements." The six uncertainties were programmatic in scale, and were rephrased as appropriate and included in Chapter III under the most appropriate research topic. They are included here in their original form, but phrased as questions.

1. What are the key assumptions in the fish and wildlife program, and are they scientifically valid?

2. Can salmonid populations in the Columbia River be increased and sustained over the long term, given the multitude of biological, physical, and cultural constraints?

3. Can the diversity of anadromous salmonid stocks be sustained over the long term?

4. What are the relative contributions of habitat loss, harvest, predation, and mainstem passage to reduced riverine survival and production of anadromous salmonids and other fishes targeted in the program?

5. To what extent are hatchery production and supplementation programs detrimental to wild salmonid productivity and stock diversity?

6. To what extent are assumptions in the wildlife part of the Fish and Wildlife Program ecologically sound?

Subsequently, the Council revised the Fish and Wildlife Program and included actions to address the uncertainties, including creation of the Independent Scientific Group (ISG) to provide an ongoing evaluation of the program on its scientific merits. Importantly, the Council made clear that uncertainties should be used to guide the prioritization and funding of research efforts conducted under the program. To provide for this guidance the Council created the Independent

Scientific Review Panel (ISRP) for the purpose of reviewing projects proposed for funding under the program. The Council and NOAA Fisheries also jointly created the Independent Scientific Advisory Board (ISAB) to provide advice to both agencies, and now also the Columbia River Indian Tribes.

Unlike the ISRP, which is solely under the Council's purview, the ISAB is jointly sponsored by the Council, NOAA Fisheries, and the Columbia River Basin Indian Tribes. The ISAB provides general scientific advice on recovery efforts whereas the ISRP provides scientific review of specific project proposals. (Further background on the science review groups can be found at http://www.nwcouncil.org/fw/science.htm.) The Council also created a separate panel of economists to offer independent economic advice and analysis regarding fish and wildlife issues, the Independent Economic Advisory Board (IEAB).

The ISRP recommended in its review of the previous draft Research Plan (April, 2002), that development of a long-term Research Plan would be facilitated by a workshop with members of the ISRP, ISAB and IEAB organized to identify critical uncertainties and research recommendations. During February 2003, the ISAB, ISRP, and the IEAB met for a workshop and discussed the elements of the Research Plan.

The challenge of determining and compiling a definitive list of critical uncertainties and research recommendations was managed in the following way. An initial listing of critical uncertainties and research recommendations was drawn from the prior publications and recent reports of the Council's science review groups. Members were then polled for what they considered the primary key uncertainties facing the basin. These were then discussed at the workshop, which provided a forum for the cross-pollination of ideas regarding critical uncertainties and research recommendations. One conclusion of the workshop was that many research areas outlined in the Independent Scientific Group's *Return to the River* (1996) and Williams, 2005, were still not being addressed in the basin. Consequently, it was recommended that the list of research items identified at the meeting and in *Return to the River* might provide adequate guidance for an initial research agenda. The recommendations in this Research Plan were developed from prior efforts and updated with the current thinking of the three independent science groups.

**State of the Science Documents**

The Fish and Wildlife Program calls for the initiation of projects to review the current state of the science in key research areas. This effort may include the use of reports, surveys, conferences, and journals. The program identifies the ISAB as the body charged with developing a series of reports to survey past research and summarize the state of the science in key areas. In recent years the ISAB and the ISRP have completed several reviews that evaluate the state of the science underpinning specific topics. In light of the timeliness of these reports, and the research recommendations they contain, their findings collectively shaped the profile of research needs addressed in this plan. These reviews are cited throughout the plan.

**Fish and Wildlife Managers**

A formal public comment period on the draft Columbia River Basin Research Plan was held from October 1 to November 30, 2004.. A total of 28 comments were received from the tribes (three), state agencies (eight), federal agencies (eight), local governments (one), academic institutions (two), consulting firms (four), and private individuals (two). A list of all the entities that provided comments is presented at the end of this section.

Many valuable recommendations were received from the fish and wildlife managers and other resource management entities and incorporated in the plan. The fish and wildlife managers are uniquely qualified to help identify research priorities, and determine when and where to implement projects, an important part of the coordination of large-scale planning. The types of comments received ranged from very general points affecting the organization of the document, to very specific comments on a particular research topic. Where appropriate, the more specific comments were incorporated into the draft by either making the suggested revisions and/or including new text and recommendations.

**National Scientific Reviews**

The Committee on Protection and Management of Pacific Northwest Anadromous Salmon was formed in 1992 under the auspices of the National Research Council's Board on Environmental Studies and Toxicology. The Committee was charged with assessing the state of the stocks, analyzing the causes of decline, and analyzing options for management, taking into consideration socioeconomic costs and benefits. The NRC Committee's efforts culminated in the 1996 publication of *Upstream: Salmon and Society in the Pacific Northwest*. Although, this initiative did not focus on research needs per se, it addressed gaps in knowledge, information needs, and scientific uncertainty. Key points from these topics, as well as insights on institutional arrangements, have been included in the plan.

In November 2000, the National Science and Technology Council, Committee on Environment and Natural Resources (CENR), released *From the Edge: Science to Support Restoration of Pacific Salmon*. The report was prepared to support President Clinton's Pacific Coastal Salmon Recovery Initiative, initiated in 1999 to help reverse the decline of Pacific salmon. It is important to note that key authors of this report included members of the ISAB. A major element of the initiative was to accelerate the use of Federal science and technology to assist in the conservation of Pacific salmon. The CENR was requested to develop an assessment that identified knowledge gaps and research priorities based on the considerable amount of scientific information already in existence. The report discusses the science needs for remediation, reviews the findings of several management-oriented science summaries for the Columbia River Basin, discusses the role of science in a restoration program, and underscores the importance of monitoring the status of salmon stocks and the magnitude of risk factors. The report also identified six broad categories of relevant and important research that have been under-emphasized in the past, are included in Chapter II. These include:

1. Definition of critical ecosystem features for the full life cycle of salmonid species and stocks.

2. Quantitative definition and assessment of risks (natural and human caused) during upstream, downstream, and estuary/ocean life stages.

3. Clarification of fundamentals of biological diversity in salmon species, races, and stocks.

4. Development of remedial technologies that work with nature rather than replacing it.

5. Clarification of the regional variation in the physical, biological, social, cultural, and economic environments of salmon.

6. Development of quantitative indicators and analytical methods to assess the status of salmon, characterize risk factors, and evaluate out-comes of remediation efforts to improve environmental conditions or reduce risks.

**List of Reviewers of the Columbia River Basin Research Plan**

Alaska Resource and Economic Development, Inc. (consulting firm, Wrangell, Alaska)
Columbia Basin Fish and Wildlife Authority
Columbia River Inter-Tribal Fish Commission
Confederated Tribes of the Umatilla Indian Reservation
Oregon State University, Institute for Natural Resources
Economic Development Council, Clatsop County
ESSA Technologies Limited (consulting firm Vancouver, British Columbia, Canada)
Federal Caucus
Lathim, Mr. Del (citizen, Pasco Washington)
Lower Columbia River Estuary Partnership
Montana Department of Fish, Wildlife, and Parks
Natural Solutions (consulting firm, Helena MT.)
Northwest Fisheries Science Center, NOAA
Oregon Department of Environmental Quality
Oregon Department of Fish and Wildlife
Pacific States Marine Fisheries Commission
Taylor, Mr. Bernie (citizen, Newberg, Oregon)
Tinsley, Mr. Thomas (citizen, Springfield, Oregon)
University of Notre Dame, Department of Biological Sciences
US Bureau of Reclamation
US Department of Energy, Bonneville Power Administration
US Fish and Wildlife Service
US Forest Service
US Environmental Protection Agency
US Geological Survey
Washington Department of Fish and Wildlife
Washington Department of Ecology
Wyoming Game and Fish Department

## Appendix B. Prior Efforts to Identify Research Priorities

Since its inception, the Council has made significant efforts to identify research priorities including the following. Section 206 of the Council's 1987 Fish and Wildlife Program contained what could be called a research plan for salmon and steelhead. Section 206 called on Bonneville to fund research in specified areas of emphasis over the ensuing five years. It also directed Bonneville to fund the Technical Working Groups whose responsibilities included developing five-year work plans in those areas of emphasis. The work plans were to be approved by the Council, thus becoming Council plans. Thus, section 206 provided the basis for the appointment of Technical Working Groups and their development of five-year Research Plans that included assessments of past research and identification of research needs.

In *Return to the River*, the ISG (1996) developed a conceptual foundation for restoration of salmonid fishes in the Columbia River Basin. In 1998 the Council published the *Development of a Regional Framework* (Document 98-16) that introduced a set of broad scientific principles (Part I) and applied these principles to a description of the Columbia River as an ecosystem (Part II). This document also states that "A third part of the scientific foundation, a set of analytical tools based on Parts I and II, remain to be developed."

The Council continued to develop an explicit scientific foundation by articulating a set of eight scientific principles and discussing their implications for salmon restoration (*see* page 15, 2000 Fish and Wildlife Program, Council Document 2000-19). These principles were derived from a number of other reviews and recovery strategies for Columbia River salmon including *Return to the River*. Other science review groups (President's Committee on the Environment and Natural Resources, 2000; and the National Research Council, 1996) have also emphasized the need for an ecosystem perspective as a basis for designing a recovery program for salmon in the Pacific Northwest. The science foundation developed by the Council represents an important step in the development of a recovery program founded on ecological principles.

In January 2002, Council staff produced a draft Research Plan and requested an ISRP review. On April 15, 2002 the ISRP released its review (Council Document ISRP 2002-4), which recommended a substantial reorganization of the staff's draft plan. The draft plan was not finalized or released but provided a profile of on-going research and helpful information regarding the funding process that was useful in drafting this Research Plan.

Thus in 2003, despite a history of coordination and prioritization efforts, the Council still did not have a Research Plan that identified critical uncertainties and prioritized research recommendations. This is not to diminish the earlier efforts to develop a research plan or identify uncertainties, nor to diminish the excellent research that has been completed in the past at the project scale. Development of this Research Plan should be viewed as an evolutionary progression, as it is now possible to separate some of the broader, vexing uncertainties into more discrete research questions or recommendations. While derivative of the prior efforts, this draft Research Plan is also a continuance of them. In order to succeed, the research program must institutionalize accountability at the programmatic scale, and will therefore be closely coordinated with the initiative of Pacific Northwest Aquatic Monitoring Partnership to develop a regional approach to monitoring.

### Development of Scientific Review

The Northwest Power Act instructs the Council to prepare a fish and wildlife recovery program for the Columbia River Basin that includes measures "...based on, and supported by, the best available scientific knowledge." The Council has sought "the best available scientific knowledge" in different ways as the Fish and Wildlife Program evolved. The Power Act directs the Council to review the program at least every five years, and the Council has done so. With each revision, the Council paid attention to the mandate regarding best available scientific knowledge. In preparing the first version of the program, the Council formed the Scientific and Statistical Advisory Committee to assist in evaluating recommendations for measures to include in the program. In the 1984 Program, the Council created a Fish and Wildlife Committee comprising four Council members and gave the committee duties that included assessing past and present research projects. In the 1987 program revision, the Council created Technical Working Groups consisting of the representatives of agencies, tribes and some other parties. The Technical Working Groups were charged with summarizing existing information and identifying Fish and Wildlife Program research needs in areas such as hatcheries, fish disease and habitat. In 1989, Bonneville and the Columbia Basin Fish and Wildlife Authority (CBFWA) established the Implementation Planning Process for the fish and wildlife program and formed the Scientific Review Group (SRG) as its independent scientific advisory body. The Independent Science Group (ISG) was created by the Council in the 1992 Program, replacing the SRG, to provide advice and to conduct a review of the program that became *Return to the River* (1996). The ISG later evolved into the ISAB and the ISRP.

The Council later addressed the need to satisfy the "best available scientific information" provisions of the Act by utilizing the recommendations of the Basin's fish and wildlife managers and incorporating independent scientific review into the decision-making process. In most years, the fish and wildlife managers, through the Columbia Basin Fish and Wildlife Authority (CBFWA), develop a draft annual program implementation work plan for the projects proposed for funding. This draft annual work plan is the culmination of a technical and management review of the feasibility of all proposed projects, and it establishes a proposed annual budget and project priorities. The ISRP and the Council review the projects proposed for funding in the context of the fish and wildlife managers' draft work plan. The project reviews and advice of the fish and wildlife managers are valuable to the Council as it deliberates on its funding recommendations. In sum, the Council has an established process to create and implement a program based on the best available scientific knowledge.

The Council recognizes that the quality of the information collected through research is important to the credibility of its decision-making. Every year the Council implements its mandate to base program measures on the best available science by recommending the funding of numerous research projects to gather necessary scientific knowledge.

### Independent Scientific Review Panel

The ISRP consists of eleven members assisted by a number of Peer Review Group members. The ISRP was created by amendment to the Northwest Power Act in 1996 and charged with providing scientific review of projects funded by Bonneville under the Council's program.

Congressional report language subsequently expanded the role of the Panel to include scientific review of projects sponsored by the Corps and other federal agencies that are funded by Bonneville through reimbursement. The ISRP and the Council's review process have served to appreciably increase the level of scientific rigor in Bonneville projects and hopefully have increased the effectiveness of projects to meet the Program's vision. In addition to the ISRP, the Columbia River Basin is served by the Independent Scientific Advisory Board (ISAB). Unlike the ISRP that is solely under the Council's purview, the ISAB is jointly sponsored by the Council, NOAA Fisheries, and the Columbia River Basin Indian Tribes. The ISAB provides general scientific advice on recovery efforts whereas the ISRP provides scientific review of specific project proposals. (Further background on the science review groups can be found at http://www.nwcouncil.org/fw/science.htm.)

The 1996 amendment to the Northwest Power Act requires the ISRP to determine whether projects proposed for funding:

- Are based on sound science principles.
- Benefit fish and wildlife.
- Have clearly defined objectives and outcomes.
- Have provisions for monitoring and evaluation of results.
- Are consistent with the program.

Thus, current decision criteria for ranking projects as "fundable or not fundable" are based primarily on technical merit and do not include any specific reference to research priorities. The consideration of research priorities is left to the ISRP to reference the Fish and Wildlife Program, which does not contain research priorities at this time. Consequently, this Research Plan, by providing priorities, should allow the ISRP to better compare and evaluate projects for relevance to research priorities.

## Appendix C. Hatcheries

### Regional Research Recommendations

#### Wild-Hatchery Fish Interactions

1.1 Develop an experimental design to estimate the impact of hatchery releases on the abundance and productivity of naturally spawning salmon and steelhead populations.

- What are the competitive impacts of hatchery and wild fish in a system? Is competition between hatchery and wild fish a source of mortality for wild stocks in the Columbia Basin e.g., are early releases on fall Chinook competing with upriver transitory fall Chinook?
- What are the predation impacts of hatchery on wild fish in a system e.g., are hatchery releases predators on wild salmon and steelhead stocks?
- Does maintaining wild characteristics in the hatchery population reduce the deleterious interactions?
- What are the effects of supplementation on resident fish?
- At what level does non-local origin straying, and interbreeding become a problem for natural spawning local stocks?

#### Genetics

1.2 What is the relative reproductive success of hatchery and natural adults in nature?

- How do culture practices influence reproductive success?
- What are the genetic effects of hatchery programs where a small number of parents produce a majority of the offspring?
- If hatchery fish quality and health are improved to achieve increased survival and reproductive success after release, is the reproductive success (fitness) of naturally spawning integrated individuals improved in contrast to integration with hatchery salmon of lesser quality?

#### Supplementation

1.3

- Determine the rate of domestication and re-naturalization of hatchery salmon populations.
- What are the long-term effects of domestication, what culture practices cause it and how can we minimize it?
- Determine the exact timing of imprinting in juvenile resident salmonids, including native west slope cutthroat trout and bull trout. (Montana)
- Do differing hatchery-rearing methods lead to different physiology, behavior, and life history patterns of hatchery products when contrasted to natural populations? Can any of these methods be used to maintain life history types in hatchery, natural and composite hatchery/natural populations?
- What broodstock collection protocols are most appropriate for supplementation programs?
- What spawning protocols are most appropriate for supplementation programs e.g., how should jacks be used in hatchery spawning to mimic their contributions in nature?
- How should we adjust the ratio of wild and hatchery fish and different age classes spawning in nature above a weir?

- What release strategies will best distribute hatchery adults on the spawning grounds?
- How can we better prevent and treat bacterial kidney disease (BKD) and predict the likelihood of vertical transmission of BKD from a specific female?

**Programs and Partners for Implementation**

**Who:** NWPPC - APRE and ISAB findings, NOAA, USFWS

**Definition of Hatchery Terms**

The following definitions are derived from the *Review of Artificial Production of Anadromous and Resident Fish in the Columbia River Basin* (Council document 99-4), or from the Viability of ESUs Containing Multiple Types of Populations (2005-2).

**Anadromous Fish.** Individuals produced from eggs that are incubated in freshwater and that subsequently undergo a downstream migration and enter marine waters, before returning as adults from a marine migration to reproduce in freshwater. The parents could have been either resident or anadromous.

**Resident Fish.** Individuals that remain in freshwater and do not inhabit marine waters for a portion of their life-cycle. The parents could have been either resident or anadromous.

**Natural Fish.** Individuals produced from eggs that were fertilized by natural spawning and incubated instream in gravel and subsequently from fry reared in natural habitats before migration to the ocean, regardless of the culture history of the parents.

**Wild populations**. Fish that have maintained successful natural reproduction with little or no supplementation from hatcheries.

**Hatchery Fish.** Individuals produced from eggs/fry that were incubated/reared in a fish hatchery before release to complete their life-cycle under natural conditions, regardless of the culture history of the parents.

**Hatchery Program**. The APRE defines a *hatchery program* as production of a "like" group of fish that spends some portion of its life cycle in a hatchery environment and is released at a location within a subbasin or along the mainstem Columbia River. A hatchery program was identified by species, stock, and release location. A hatchery facility may contribute to several hatchery programs and a hatchery program may involve more than one hatchery for different rearing phases. A group of fish delineated by the fishery managers on the basis of management purpose is termed a *stock*. Because of the management implications in this definition, fish are often divided into hatchery and natural stocks.

**Population.** A *population* is a group of fish delineated on the basis of genetic affinity. A population may include both hatchery and natural components if the fish are believed to represent a common evolutionary legacy and have a close genetic relationship. A group of

related populations is termed an Evolutionarily Significant Unit (ESU) under Endangered Species Act (Waples 1995). An ESU is a legal and management notion that draw on the scientific concept of a *metapopulation*, which is a group of local breeding populations which are genetically connected by patterns of migration and straying and which occupy distinct habitat patches.

**ISAB Recommendations and Findings**

Recommendations from the ISAB's Review of Salmon and Steelhead Supplementation (ISAB 2003-3) include:

1. The purpose and use of artificial production must be considered in the context of the environment in which it is used.

2. Artificial production remains experimental. Adaptive management practices that evaluate benefits and address scientific uncertainties are critical.

3. Artificial production programs must recognize the regional and global environmental factors that constrain fish survival.

4. Species diversity must be maintained to sustain populations in the face of environmental variation.

5. Naturally spawning populations should be the model for artificially reared populations.

6. Fish managers must specify the purpose of each artificial production program in the basin.

7. Decisions about artificial production must be based on fish and wildlife goals, objectives and strategies at the subbasin and basin levels.

8. Because artificial production poses risks, risk management strategies must be implemented.

9. Production for harvest is a legitimate management objective of artificial production. But to minimize adverse impacts on naturally spawning populations, harvest rates and practices must be dictated by the need to sustain naturally spawning populations.

10. Federal and other legal mandates and obligations for fish protection, mitigation, and enhancement must be fully addressed.

An important criticism from the report is that inadequate replication and widespread failure to include un-supplemented reference streams, coupled with a lack of coordination among projects, make it uncertain whether such projects will be able to provide convincing quantification of the benefits or harm attributable to supplementation. However, the published literature includes examples of theoretical and empirical studies in the area of hatchery program risks and benefits, which have advanced our understanding of hatchery programs and conservation. Some of the key findings include:

1. Artificial production must be used in a manner consistent with ecologically based scientific principles for fish recovery.

2. Fish raised in hatcheries should have a minimal impact on fish that spawn naturally.

3. Fish reared in hatcheries or by other artificial means for the purpose of supplementing the recovery of a wild population should clearly benefit that population.

4. Improperly run, artificial production programs can damage wild fish runs. However, when fish runs fall to extremely low levels, artificial production may be the only way to keep enough of that population alive in the short-term to ensure a chance of recovering in the long term.

5. Hatcheries have been successful at preserving some of the genetic legacy, which would otherwise have been lost, from salmon populations formerly occupying severely degraded habitats.

6. The decision about when and where to deploy supplementation programs should make use of the metapopulation concept.

What is not clear is the extent to which artificially produced fish can be mixed with a wild population in a way that would sustain and rebuild the wild population. The Council has weighed these uncertainties and recognized that inaction also holds a large risk. In the past, hatchery operations including some instances of broodstock selection, inter-basin transfers, and release practices have contributed to the decline of natural production and loss of locally adapted stocks in the basin. Hatchery practices are one of the factors that have altered the genetic structure of stocks in the basin.

## Appendix D. Hydrosystem

### Regional Research Recommendations

| | |
|---|---|
| | Fish Passage and Migration |
| 2.1 | Evaluate spillway passage at each mainstem project. Determine an optimal passage strategy at each dam and for each passage route that maximizes improvements in survival.<br>• Examine the efficacy of current operational measures designed to increase survival of juvenile fal1 Chinook.<br>• Conduct research necessary to design, test, and implement new surface passage systems, e.g. flow velocity enhancement using directed turbulent currents, removable spillway weirs.<br>• Evaluate new fish guidance technology to concentrate fish at fish passage structures.<br>• Evaluate turbine passage to determine the optimum fish survival through turbines. Continue the research and design work on improved turbines and the relationship between survivals and overall turbine operating efficiencies.<br>• Evaluate alternative turbine designs to improve juvenile salmon passage survival.<br>• Evaluate passage conditions for white sturgeon at mainstem projects and develop recommendations for modifications in conjunction with similar work for Pacific lamprey.<br>• Determine the biological and physiological effects on wild and hatchery juvenile salmonids migrating through the mainstem dams that are exposed to stress from bypass, collection, and transportation at the mainstem dams. |
| 2.2 | Conduct the necessary feasibility studies to restore anadromous and resident fish to blocked areas, not including areas blocked by natural barriers. |
| 2.3 | Determine the life history patterns of fall Chinook out migrants.<br>• Identify ocean versus reservoir type life history traits for fall Chinook and the effect of these different migration strategies on juvenile hydrosystem survival. |
| | Spill and Flow |
| 2.4 | Design and implement a comprehensive, system-wide research program that will integrate biological and physical responses of various flow operational strategies at each dam in the Columbia Basin Power and Flood Control System with overall system survival and critical habitat evaluations.<br>• Measure the physical features of flow important to fish migration and survival e.g., water velocity or within-day variations due to load following (power peaking).<br>• Implement summer spill tests to examine the benefits of the current summer spill program for out migrating juvenile fall Chinook.<br>• Re-evaluate the use of flow augmentation to speed migration in light of the reservoir life history pattern.<br>• Document the amount and timing of flows required to stabilize and improve Kootenai white sturgeon and burbot populations in the Kootenai River.<br>• Determine whether free-flowing reaches downstream of hydroelectric dams can be regulated to achieve normative flow and temperature regimes thereby allowing the river to naturally restore instream and floodplain habitats and food webs. |

| | |
|---|---|
| | • Determine the effects of flow and water temperature on survival, growth, migration timing, and smolt to adult return ratios of juvenile salmonids in the Columbia and Snake River basins.<br>• Determine how specific operations, flow, and spill conditions affect fish and wildlife species downstream of dams. |
| | Reservoir Operations |
| 2.5 | Determine the impacts of water releases and reservoir levels on resident fish and their prey species.<br>• Determine the best pattern of lake level changes for Lake Pend Oreille and the Pend Oreille River above Albeni Falls Dam to improve shoreline spawning habitat for kokanee, over-winter habitat for warm water fish, enhance near-shore productivity, and prevent shoreline erosion.<br>• Evaluate the benefits for listed bull trout and Kootenai white sturgeon of the Council's proposed reservoir drafting strategy and summer flow augmentation.<br>• Determine the impacts of water releases and reservoir levels on resident fish and their prey species. |
| 2.6 | Determine the effects of altered temperatures on salmon and their relationship to flow.<br>Determine how to provide storage reservoirs with selective withdrawal systems to create a more normal annual temperature cycle in the rivers. |
| | Transportation |
| 2.7 | Determine the optimal transport strategy and determine the best estuary release dates.<br>• Evaluate survival benefits of transport from McNary Dam to determine whether the benefits are sufficiently greater, at least under certain circumstances, than inriver passage to justify continuing (or increasing) the transportation.<br>• Evaluate relative success of transporting various groups of fall Chinook throughout the Snake River through the current transportation study.<br>• Determine the relationship between ratios of transport and inriver return rates and measurements of juvenile survival (D values). |

**Programs and Partners for Implementation**

**Who:** NWPCC, Bonneville Power Administration, U.S. Army Corps of Engineers

**Anadromous Fish Evaluation Program**

The U. S. Army Corps of Engineers, Northwestern Division, has sponsored biological studies continuously since 1952 in an integrated, applied research program to better understand and improve anadromous fish passage conditions at its multi-purpose projects on the Columbia and lower Snake Rivers, in Oregon and Washington. These research, monitoring, and evaluation studies are managed under the Anadromous Fish Evaluation Program (AFEP). The AFEP is the process that coordinates the Corps' fish program with federal, state, and tribal fish and wildlife agencies that provide both technical and policy level input to the Corps on study objectives,

experimental design, and methodologies. (A few AFEP studies are funded from project operations and maintenance accounts as well.)

The main purpose of the AFEP is to produce scientific information to assist the Corps in making engineering, design, and operations decisions for the eight main-stem Columbia and Snake river projects to provide fish with safe, efficient passage through the mainstem migration corridor. Each project (dam) has multiple authorized purposes and uses and are affected by several environmental and project operating statutes. These include the ESA, Clean Water Act, National Environmental Policy Act, Northwest Power Act, and the Fish and Wildlife Coordination Act. At the current time, ESA guidelines for protection of listed salmon, steelhead, bull trout, and white sturgeon species are contained in biological opinions prepared by NOAA Fisheries and U.S. Fish and Wildlife Service (USFWS), and strongly influence the Corps' fish program, including the AFEP. These biological opinions include measures to evaluate and make decisions on new and existing passage technologies and system configurations. The resulting biological studies have a high priority in the AFEP program. Most are conducted to facilitate system configuration decisions by answering key questions about behavior, survival, and condition of fish as they migrate through the mainstem corridor.

**Current Allocation of Expenditures by Research Topic Under the Anadromous Fish Evaluation Program**

Army Corps of Engineers expenditures for FY04 under the Anadromous Fish Evaluation Program (AFEP) are presented in Table B.

Table B. FY 04 Corps of Engineers funding levels for anadromous fish research under the Anadromous Fish Evaluation Program. (Data source: the SCT Spreadsheet and the Fish and Wildlife Operations and Maintenance spreadsheet.)

| Topic | CRFM | O&M | Totals |
|---|---|---|---|
| Adult Passage (Salmonids, Kelts, Lamprey, etc.) | 2,871,000 | 1,146,000 | 4,017,000 |
| Juvenile Passage (Spill, Turbines, etc.) | 23,987,000 | 0 | 23,987,000 |
| Transportation/Delayed Mortality (D) | 2,624,000 | 2,216,000 | 4,840,000 |
| Other | 50,000 | 0 | 50,000 |
| Estuary | 4,100,000 | 0 | 4,100,000 |
| Predation (Avian primarily) | 1,717,000 | 282,000 | 1,999,000 |
| | 35,349,000 | 3,644,000 | 38,993,000 |

Most studies are integral components of elements of the Columbia River Fish Mitigation project, a large Corps construction account that funds numerous fish passage improvements at Columbia and Snake river mainstem dams. Research schedules are closely linked to those elements so that biological questions can be answered in a timely manner. Historically, Corps funded studies have focused primarily on project-specific adult and juvenile salmonid passage issues. However recently, estuarine, mechanism oriented, sturgeon and studies of juvenile and adult lamprey have been conducted as well. Most of the passage facilities and operations on the river have been developed and refined based on results of these studies. Passage issues include adult fish ladders and collection channels, juvenile bypasses with turbine intake screens, turbine passage, the

juvenile fish transportation program, spill for juvenile fish passage, and a comprehensive set of project/hydrosystem operating criteria. Consequently, research studies evaluate passage success, survival, and fish condition for these technologies. Many research projects are related to new passage technologies, while some evaluate existing project features.

Based in part on the recommendations by the ISRP, the Corps is also working to develop a long-term strategic plan for its fish research program. A long-term plan currently exists for Bonneville Dam and is being developed for John Day and The Dalles dams. A document is also being developed to examine the major system improvements at McNary and the Lower Snake River Dams. This plan will be incorporated or referenced in more detail in this plan at a later date.

The AFEP lacks, but would benefit from, a strategic, multi-year Research Plan or framework. Strategic multi-year Research Plans with contingencies and alternative tests built in would make the program stronger by reducing time and resources spent annually. The Corps should conduct strategic planning to identify where a more mechanism-oriented strategy e.g., behavioral or mortality mechanisms, could yield benefits in research productivity, efficiency and economy of time and funds and thus faster implementation of fish-protective features.

## Appendix E. Habitat

### Tributary and Mainstem Habitat

**Regional Research Recommendations**

Biological and Physical Processes

3.1 Identify the extent, diversity, complexity and productivity of fish and wildlife habitat that supports existing populations that are healthy.

- Evaluate the amount, location, and quality of spawning habitat for resident and anadromous fish e.g., fall Chinook and Chum core populations in the lower and mid-Columbia area, and fall Chinook in the lower Snake area and conduct new evaluations for steelhead, white sturgeon, mountain whitefish, and Pacific lamprey.
- Determine the importance of protecting mainstem habitat for recovery of bull trout.
- Determine whether spawning success or survival of juveniles is the limiting factor on recruitment and production in each of the mainstem spawning areas.

3.2 Determine how fish and wildlife habitat and productivity is affected by:

- Changes in terrestrial communities can affect key ecological functions e.g., loss.
- Changes in plant communities, including riparian and upland vegetation.
- Temperature changes in tributaries, and other coldwater refugia, such as ground water upwelling and hyporheic exchange, are part of the environmental change that has fragmented salmonid habitat, and support existing programs to improve tributary temperatures for salmonids e.g., TMDLs and watershed planning.
- Supplementation.

3.3 Identify critical habitat conditions for bull trout, west slope cutthroat trout, burbot, redband trout and Kootenai white sturgeon, and assess potential to improve existing habitat conditions where deemed necessary.

- Identify habitat elements necessary for bull trout and develop an inventory of streams that provide the cold-water habitat conditions necessary for bull trout, west slope cutthroat trout, native redband trout, and burbot, such as coldwater refugia and migration corridors in larger rivers.
- Develop patch-based models of suitable habitat with bull trout on the west side of the Cascades and Columbia Gorge and identify key site and landscape characteristics that define habitat capable of supporting persistent populations.
- Determine the importance mainstem habitat for recovery of bull trout and other native salmonids throughout the Columbia River system.
- Map the distribution of potentially suitable habitat for large migratory bull trout throughout the species range.

3.4 Test and compare the effectiveness of “Best Management Practices” in use by different agencies for new timber harvest prescriptions, sustainable agriculture practices, and other land use practices for upland and riparian areas. Determine the most effective techniques for:

- Improving connectivity of streams with the floodplain;
- Increasing inter-gravel survival of incubating fry;
- Increasing food supplies in the mainstem during out migration; and,

Reducing sedimentation due to land clearing practices.

3.5 Integrate analysis of upland and aquatic habitat characteristics and spawner surveys with models to assess trends in population dynamics.

3.6 Identify a well-distributed network of reserve watersheds and riverine habitat patches to establish experimental natural baselines for evaluation of effectiveness of management practices.

3.7 Identify the role of habitat condition on the invasion of nonnative fish species; i.e., can habitat restoration activities be designed to reduce the likelihood that nonnative species will invade and replace native species?

3.8 Determine how water quality (DO, toxics, pH) and flow in tributaries are part of the environmental change that has fragmented salmonid habitat, and develop programs to improve tributary water quality and flow for salmonids.

### Hydosystem Management Effects on Habitat

3.9 Evaluate the relationship between physical conditions associated with both steady state and fluctuating flow scenarios and spawning activity and success by white sturgeon.

- Develop spring flow recommendations for white sturgeon spawning habitat targets in all mainstem spawning areas in conjunction with development of flow targets for salmonid downstream migrants.
- Investigate the effect of conditions recommended for mainstem fall Chinook production on spawning and rearing conditions for white sturgeon.

3.10 Identify the impacts of hydrosystem induced lake level changes on shoreline spawning habitat on natural lakes that have been impounded.

- Determine whether restoration of substantial mainstem habitat can be achieved by drawdown of selected reservoirs to expose and restore alluvial reaches, for example in the upper ends of John Day and McNary pools.

3.11 Determine the best pattern of lake level changes for Lake Pend Oreille and the Pend Oreille River above Albeni Falls Dam to improve shoreline spawning habitat for kokanee, over-winter habitat for warm water fish, enhance near-shore productivity, and prevent shoreline erosion.

3.12 Determine the geographic distribution of suitable or potentially suitable fall Chinook spawning habitat in the tailraces and upper pool areas of the four lower Snake River projects and the mainstem Columbia River projects downstream from Grand Coulee Dam.

3.13 Conduct a comparison of the physical attributes of alluvial mainstem rearing habitats and floodplain areas created under the various drawdown scenarios, with the physical attributes of the adjacent downstream reservoir areas. Determine distribution, abundance, food habits, and growth of rearing subyearling fall Chinook for both types of areas.

### Food Webs

3.14 Conduct an integrated assessment of the role of primary and secondary production in regards to action options for restoration of riverine food chains such as induced flooding, hydro operations, and riparian habitat restoration to promote ecologically based food webs. For example:

- Determine the value of macrophytes for producing food for mid-Columbia river fish.
- Compare and contrast native versus invasive macrophytes for habitat and food

production.

- Determine insect colonization and growth during flooding and spatial analyses of floodplains.
- Determine the quantity of salmonid food potentially produced by flooded riparian lands in the lower Columbia-Snake basins and lost by river regulation, and relate quantitatively to the food requirements of migrating juvenile salmonids.
- Determine the stability and productivity of food production in near shore rearing areas.

3.15 Determine the availability of food, food habits, and the nutritional state of:

- Juvenile salmonids during transportation from upper river dams to below Bonneville Dam;
- Migrating Snake River salmonids in relation to that of mid-Columbia stocks; and, Juvenile fall Chinook in the Hanford Reach.

3.16 Determine the impacts of declining wild salmonid populations on ecosystem processes, such as the transport of marine derived nutrients from ocean to upland settings, and consequent changes in species and key ecological functions.

- Identify the effects of nutrient imbalances and their relationships to changes in the key ecological functions of the historical suite of native species.
- Determine an independent measure of the appropriate nutrient level in streams e.g., criteria based upon the abundance or composition of communities of benthic macro-invertebrates or epilthic communities.
- Determine the value of salmon pellets/carcasses, as well as inorganic nutrients, to increase habitat productivity.
- Evaluate nutrient cycling, carcass increases, and productivity of macro-invertebrates.

**Programs and Partners for Implementation:**

NOAA Fisheries' 2000 Biological Opinion calls on the federal Action Agencies, in conjunction with the Environmental Protection Agency and the U.S. Geological Survey, to develop a program to 1) identify mainstem habitat sampling reaches, survey conditions, describe cause-and-effect relationships and identify research needs; 2) develop improvement plans for all mainstem reaches; and 3) initiate improvements in three mainstem reaches. The USFWS 2000 Biological Opinion also contains similar measures for Kootenai white sturgeon and bull trout. (CBFWA)

**Bull Trout Habitat Requirements**

Regarding mainstem habitat, an overview of current conditions needs to be developed and integrated into a coordinated plan for improving specific aspects of mainstem habitat. The mainstem habitat initiative is not focused on the mainstem habitat needs of the salmon and steelhead populations currently listed. Rather, it is a multispecies approach that recognizes that mitigation, enhancement, and rebuilding opportunities in the mainstem may have greater benefit for non-listed populations than to listed populations.

For example, the 2000 FCRPS Biological Opinion called for continued research into the distribution of bull trout within the mainstem Columbia and Snake rivers. Bull trout migrate seasonally from some local populations to the mainstem Columbia and/or Snake Rivers, using mainstem habitats during a portion of their life history. Research is needed on the movement, seasonality, and importance of use of different habitat types in the Columbia and Snake Rivers by adult and subadult bull trout. For fluvial bull trout using mainstem habitats, the timing of use (arrival and departure), the habitat conditions in the mainstem associated with these movements, the manner in which fish use the mainstem, the frequency with which fish enter or leave the mainstem, and the fidelity that fish have to a particular tributary all need to be determined.

Bull trout, ranging in size from about 150-250 mm, often adopt migratory lifestyles and use a surprising array of habitats. The typical model for bull trout; migrating to larger main-stem, laucustrine, or marine habitats, does not seem to apply for these small fish. Although small bull trout utilize these habitats, they also move up into very small tributaries on a seasonal basis. Thus, a much larger portion of the stream network may be more important for bull trout than previously understood. (This same issue has been highlighted by recent work on seasonal habitat use by migratory coastal cutthroat trout. The logistics of working on any salmonids of this size are considerably more difficult, since telemetry is more difficult, and monitoring fish movements with PIT tags or other marking methods is extremely labor intensive.)

Most of the focus on bull trout habitat requirements has been on spawning and rearing areas. However bull trout do use a large portion of the basin. Over 60 telemetry studies involving more than 3,000 fish have been conducted throughout the species range. (Data from bull trout telemetry synthesis project can be accessed from this website www.northwestbulltrout.com.) Although the vast majority of this data has not been published, Forest Service scientists are currently working to develop approaches to analyzing patterns of habitat use, and have drafted a list of key site and landscape variables.

For many years, Forest Service research scientists have advocated a “patch-based” view of bull trout habitat refugia on the landscape. (Refugia are relatively pristine areas containing native species assemblages and managed as wilderness or roadless areas that provide a living laboratory for future research actions.) However, there is still only one example where this approach has been implemented e.g. the Boise River basin. Several studies in the Boise basin have demonstrated the value of this approach for understanding long-term persistence, monitoring, and interpretation of genetic population structuring. The Western Division AFS Bull Trout Sampling Protocol suggests that patches could also serve as the building blocks of a monitoring strategy, habitat protection and restoration programs, and the planning for bull trout reintroductions currently underway in the Willamette, McKenzie, and Clackamas River basins.

The lack of understanding of how the nutrients and calories flow through the food web in freshwater to juvenile salmon (and how it varies between the different species and lifestyles of salmon and different stream systems) has led to the adoption of a simplistic model. Specifically, if there are estimated to be fewer spawning salmon than before we have records, then add carcasses, or equivalent nutrients to replace the presumably missing carcasses. Yet in many instances, anthropogenic impacts have resulted in significant increases in the flux of nutrients into streams. It has also resulted in a loss of rearing habitat for salmon that is fewer juvenile can

be supported and the system may need fewer returning salmon to support the maximum sustainable salmon population. The ecology of naturally functioning streams which support healthy salmon runs need to be better understood, otherwise it will be difficult to determine whether a stream has been culturally oligotrophicated; i.e., the loss of nutrient inputs due to the reduction in spawning salmon, or whether other cultural activities have replaced the nutrients once provided by spawning salmon. Recent studies indicate that these nutrients have also affected the distribution and abundance of other plant an animal species in adjacent upland communities.

### Estuary

**Regional Research Recommendations**

#### Biological

4.1 Determine the linkages between salmonid life history diversity, population fitness, and survival in the estuary and estuarine habitat conditions.

- Conduct research on food web dynamics and the key ecological functions of the estuary.
- Conduct research to understand juvenile and adult migration patterns and residence times.
- Determine the downstream migration timing of juveniles to optimize food availability in the estuary.

4.2 Determine the effectiveness of ongoing PIT tagging and other tagging and marking studies and data to determine origin and estuarine habitat use patterns of different stocks.

4.3 Conduct research on the effects of invasive species and the feasibility to eradicate or control them and reinstitute research and monitoring of invasive species in the estuary.

4.4 Determine how to manage sources of salmonid predation in the estuary through restoration of natural habitats, removal of habitats artificially created due to channel construction and/or maintenance, or controlling predator populations.

- Determine the optimal timing to release salmon juveniles in the estuary to avoid avian predators.

4.5 Conduct research on the linkages between physical and biological processes, such as: evaluate flow effects, river operations, and estuary-area habitat changes on the relationship between estuary and near-shore plume characteristics and the productivity.

#### Physical

4.6 Develop a metric of habitat connectivity in order to track changes in reconnection restoration efforts. Evaluate removal of dikes in the lower river and upper estuary to restore connections between peripheral floodplains and the river or fluvial zone of the estuary.

4.7 Determine an allocation of water within the annual water budget for the Basin, that would simulate peak seasonal discharge, increase the variability of flows during periods of salmonid emigration, and restore tidal channel complexity in the estuary, aided by removing pile dykes where feasible.

4.8 Conduct research on sediment transport and deposition processes in the estuary.

4.9 Conduct research on the role between micro- and macro-detrital inputs, transport, and end-

points.

4.10 Determine additional shallow water bathymetry data needs for refining the hydrodynamic modeling, and identifying/evaluating potential opportunities for specific restoration projects.

### Chemical

4.11 Develop a comprehensive, long-term water quality-monitoring program for the estuary that includes pollutant fate and transport.

4.12 Improve understanding of the biological meaning and significance of the estuarine turbidity maximum relative to fish restoration actions.

4.13 Conduct research on the effect of toxic contaminants on salmonid fitness and survival in the Columbia River Estuary and ocean.

**Programs and Partners for Implementation**

**Who:** Lower Columbia River and Estuary Partnership, Army Corps of Engineers, Bonneville Power Administration, NOAA, U.S. Fish and Wildlife Service, Oregon State University.

**Supplemental Information**

The Columbia River estuary has undergone tremendous changes as a result of settlement and development, and these changes have affected its physical character and biological resources. Physical characteristics such as depth, velocity, salinity, temperature, and turbidity vary dynamically within the Columbia River estuary, presenting a highly variable environment. The environmental changes that have occurred have substantially affected habitat availability, habitat quality, species composition, and other biological attributes of the estuarine ecosystem. The complexity of the physical and biological processes and interactions within the Columbia River estuary system contribute to the challenges and opportunities faced by aquatic organisms. While less is known about the potential for improvement in the estuary compared to other parts of the Columbia River Basin, there are indications that substantial improvements are possible, and that these improvements may benefit anadromous fish populations.

Characterization of the estuary's physical and biological attributes that support salmon is underway, but is in its infancy. The draft NMFS report, *Salmon at River's End: The Role of the Estuary in the Decline and Recovery of Columbia River Salmon*, assessed the potential impact of flow regulation on juvenile salmon utilization of the estuary. The report found that hydrologic and climate factors likely have consequences for the estuarine physical environment. However with the existing data it is not possible to separate these effects from compounding factors or to rank these factors' effects on salmon. Nevertheless, it is clear that reductions in tidal wetland habitats, such as marshes and swamps, have occurred that affect the estuary's capacity to support juvenile salmon and that have reduced habitat complexity. The Bonneville sponsored report, *An Ecosystem-Based Approach To Habitat Restoration Projects with Emphasis on Salmonids in the Columbia River Estuary*, provided a scientific basis and implementation guidelines for a habitat restoration program designed to improve ecosystem functions and enhance juvenile salmonid survival in the Columbia River estuary.

### Natural Variation and Ocean Productivity

**Regional Research Recommendations**

5.1 Integrate research on the effects of ocean conditions on productivity of salmon with estuarine and riverine research.

5.2 Determine whether hatchery practices affect the migratory patterns and potential marine survival of salmon.

5.3 Determine if components of estuarine and marine mortality relate to predation versus competition, and whether the large-scale oceanographic and climatological shifts impact these relationships.

5.4 Determine the relative effects of the ocean on different fish stocks compared to the effects of inland actions.

5.5 Determine how different species migrate and utilize the ocean environment.

**Programs and Partners for Implementation**

**Who:** NOAA, Oregon State University, University of Washington

**How:** Shifts in oceanic regime involve substantial changes in the distribution of species, the structure of marine food chains, and the physical processes of biological production. Anticipating such change and understanding its effects on salmon production in the Columbia Basin will require evaluation of ecological indicators other than the abundance of salmon. Decadal cycles of ocean productivity have the potential to mask changes in the survival of salmon during freshwater phases of their life cycle, leading to erroneous interpretation of the performance of restoration efforts and increased losses of some stocks (CENR, 2000). Therefore, remediation for poor ocean conditions should entail taking an ecosystem approach to management of anadromous fish which variability and diversity on the freshwater side are considered normal attributes to be safeguarded.

## Appendix F. Harvest

### Regional Research Recommendations

6.1 Determine how to base sustained-yield management of a fish populations on numerical spawning escapement goals at the watershed level, which represent the productive capacities of the habitats for fish populations.

6.2 Evaluate innovative techniques to improve access to harvestable stocks and reduce undesirable direct and indirect impacts to wild populations.

6.3 Evaluate appropriateness of stocks used in weak stock management.

6.4 Determine the origin and the temporal and spatial distribution of wild fish.

6.5 Evaluate selective harvest technology.

### Programs and Partners for Implementation

Harvest remains the primary reason for hatchery programs in the Columbia River Basin. This is especially true in the lower river, whereas the purpose of upper river programs appear more evenly divided between harvest and conservation. Upriver bright fall Chinook salmon and sockeye salmon populations are not largely supported by hatcheries.

Yet the management of fisheries on mixed hatchery and wild stocks is believed to have contributed to the decline of natural production in the Columbia Basin. Because of declining natural production, those fisheries that still harvest Columbia River salmon are largely supported by hatcheries.

Whether hatcheries are intended solely to produce fish for harvest may be used to create a replacement for the lost or diminished stocks is a significant policy. How hydropower-caused losses or reductions in numbers of naturally producing stocks should be mitigated into the future?

Hatcheries must be located and operated in a manner that does not lead to adverse effects on other stocks through excessive straying or excessive take of weak stocks in a mixed-stock fishery. The risks of detrimental effects of straying are a de-facto supplementation to naturally spawning populations are real, and likely far more serious than the risks involved in a well-designed supplementation program.

## Appendix G. Recovery Planning

### Regional Research Recommendations

#### Viability of ESUs

7.1 Determine how to relate measures of diversity to integrated demographic metrics that directly relate to persistence of one or many populations.

7.2 Conduct research and monitoring to improve the reliability of viability assessment methods for salmonids.

#### Salmonids

Determine the genetic basis of various life history strategies in salmonids**.**

7.3 Determine whether fisheries management practices such as harvest, dam operations, hatchery operations, and transportation have reduced genetic variation in fish stocks.

7.4 Determine the extent that the use of hatchery stocks may have reduced the between-population component of genetic variation in some species, such as Lower Columbia River and Upper Columbia River Chinook.

7.5 Determine whether re-establishment of metapopulation structure between Columbia Basin salmonid populations would slow or stabilize the loss of diversity in isolated local populations.

7.6 Identify and characterize interactions among basin populations, metapopulations, ocean survival rates, life history stage (survival) trends, and population viability.

7.8 Increase the number of genetic markers to enable researchers to determine the genetic integrity of individual fish to help select appropriate donor parents for replicating unique genetic strains of fish that are threatened by extirpation.

Evaluate and document the impact of hydro operations in terms of numbers of ESA-listed fish taken, and estimated impact on smolt-to-adult return ratios.

#### White Sturgeon

7.9 Continue research and monitoring programs on life history, habitat requirements for all life-stages, population status, and trends of the Kootenai River white sturgeon. (USFWS)

7.10 Identify white sturgeon habitats necessary to sustain white sturgeon reproduction (spawning and early age recruitment) and rearing in Kootenai River basin waters. (USFWS)

7.11 Evaluate how changes in biological productivity in the Kootenai River basin affect white sturgeon and their habitats. (USFWS)

7.12 Continue to research and develop a conservation aquaculture program to prevent the extinction of Kootenai River white sturgeon that includes protocols on brood-stock collection, propagation, juvenile rearing, fish health, genetics, and stocking. (USFWS)

7.13 Continue to monitor water temperature profiles in the south end of Lake Koocanusa during May and June to provide information necessary for timing to sturgeon spawning/rearing flow augmentation. (USFWS)

7.14 Design and conduct those studies necessary to determine the effects of Libby Dam operations and other threats on sturgeon life history, and the cause(s) of sturgeon mortality. (USFWS)

7.15 Evaluate the effects of contaminants and possible additional biological threats, e.g.

predation and species composition, on Kootenai River white sturgeon and their habitats. (USFWS)

### Lamprey

7.16 Determine the status, limiting factors, and management alternatives for anadromous and resident lamprey.

- Develop methods to differentiate among species at all life stages.
- Develop standardized sampling protocols and conduct systematic basin-wide surveys to assess adult and juvenile abundance and distribution.
- Define, improve, and continue historic distribution and abundance indices (e.g., dam counts, tribal harvest records, smolt trap collections, etc.).

7.17 Determine limiting factors for anadromous and resident lamprey.

- Document habitat preferences and habitat availability for all life stages of anadromous lamprey.
- Evaluate the physiological and behavioral responses of lamprey to a variety of environmental stressors e.g., capture and handling, elevated temperatures, contaminant exposure, and sedimentation.
- Assess trophic relationships e.g., predation by exotics, reduced host availability.

7.18 Determine passage requirements for anadromous and resident lamprey.

- Identify potential obstacles to passage e.g., loss of recruitment upstream from a potential obstacle, observation of lamprey aggregations or mortalities at potential obstacles during migration periods.
- Assess passage efficiency, direct mortality, and/or other metrics that relate to loss of fitness; i.e., stresses or injuries that reduce ability to reproduce.
- Determine the specific structures or operations that delay, obstruct, or kill migrating lamprey.
- Develop aids to passage e.g., modify structures or operations, provide lamprey-specific fishways, or bypasses.

7.19 Identify the biological and ecological processes important to anadromous and resident lamprey.

- Understand the ecological function of anadromous lamprey e.g., predator/prey relationships, linkages to other aquatic and terrestrial organisms.
- Understand the biology of anadromous lamprey e.g., reproduction, feeding.
- Develop methodology for gender identification in the field and laboratory e.g., identify spawning sex ratios, and sex related behavioral characteristics.
- Develop aging techniques.
- Assess life history characteristics of freshwater and ocean-phase anadromous lamprey e.g., age, growth, timing of metamorphosis, movement, basin-specific comparisons.

### Bull Trout

7.20 Characterize, conserve, and monitor genetic diversity and gene flow among local populations of bull trout that use the mainstem Columbia and Snake rivers. (USFWS)

7.21 Conduct research and monitoring to implement and evaluate bull trout recovery activities, consistent with an adaptive management approach using feedback from implemented, site-

specific recovery tasks. (USFWS)

7.22 Determine the current, and future, role of the mainstem Columbia and Snake rivers in the recovery of bull trout. (USFWS)

7.23 Determine the effectiveness and feasibility of using artificial propagation to aid bull trout recovery in the Columbia and Snake rivers. (USFWS)

7.24 Determine the current extent of bull trout distribution and seasonal use areas. (USFWS)

7.25 Determine the movement and seasonality of use of different habitat types in the Columbia and Snake rivers by adult and sub-adult bull trout. (USFWS)

7.26 Determine the impacts of hydropower facilities on bull trout and their habitat should be evaluated, e.g., fish ladder use, entrainment, spill, flow attraction, and water quality. (USFWS)

7.27 Determine juvenile dynamics and capacity for each sub-population of bull trout and the dynamics for emigrants and Lake residents. (Montana)

Predation

7.28 Determine the effects of predation on salmonid recovery and how predation is affected by other environmental factors.

- Evaluate and document the impact of predation in the mainstem in terms of numbers of ESA- listed fish taken, and estimated impact on smolt-to-adult return ratios.
- Improve the estimates of the impact of pinniped predation on salmonid stocks and on the recovery of depressed stocks.

7.29 Evaluate the impact of predation on fish survival and smolt-to-adult return rates.

7.30 Determine the factors influencing predation rates on salmonid smolts in the Columbia River estuary.

7.31 Continue to improve estimates of the impacts of seabird predators on wild salmonids.

**Programs and Partners for Implementation**

**Who:** NOAA, U.S. Fish and Wildlife Service, Bonneville Power Administration, U.S. Army Corps of Engineers, U,S, Bureau of Reclamation

The ESA requires that recovery plans contain objective, measurable goals for delisting; a comprehensive list of the actions necessary to achieve the delisting goals; and an estimate of the cost and time required to carry out those actions.

**NOAA -** In addition, NOAA Recovery Planning Guidelines suggest that recovery plans include an assessment of the factors that led to population declines or that are impeding recovery, hence the need for related research. Finally, it is important that the plans include a comprehensive monitoring and evaluation program for gauging the effectiveness of recovery measures and overall progress toward recovery.

The list of research recommendations include a number of tasks that are, or will be, addressed in processes such as by the Technical Review Teams and other processes which are contributing more appropriately to development of Recovery Plans. To implement these elements of

recovery, NOAA Fisheries has formed geographically based Technical Recovery Teams (TRTs), in coordination with existing science teams and ongoing conservation planning efforts. The TRTs are technical workgroups convened and chaired by NOAA Fisheries to determine the preliminary biological criteria necessary to ensure the viability of Evolutionarily Significant Units, or ESUs, listed under the ESA.

The TRTs will provide technical support and analysis to these efforts and have been convened for the Puget Sound and Willamette/Lower Columbia/Southwest Washington regions, and the Interior Columbia River Basin. The TRTs will develop products that:

1. Identify population and ESU de-listing goals;

2. Characterize habitat/fish abundance relationships;

3. Identify the factors for decline and limiting factors for each ESU; identify the early actions that are important for recovery;

4. Identify research, evaluation, and monitoring needs; and,

5. Serve as science advisors to groups charged with developing measures to achieve recovery.

After population identification, the next step in the technical recovery planning process is to develop biological criteria for population and ESU viability. In determining biological viability criteria, the NOAA Technical Recovery Teams, or TRTs, generally follow the guidelines discussed in the *Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units* (NOAA Technical Memorandum NMFS-NFWSC-42, June 2000). According to NOAA Fisheries, recovery goals must, at a minimum, restore listed ESUs to levels at which they are no longer threatened and can therefore be de-listed under the ESA.

NOAA Fisheries is also working with state, local, regional, tribal, and private entities to develop a collaborative recovery planning process for each planning area. The collaborative recovery plans will focus on identifying the measures and actions necessary to achieve the recovery goals identified by the TRTs. NOAA Fisheries believes it is critically important to ground the recovery planning process in the many state, regional, tribal, local, and private conservation efforts already underway throughout the region, such as subbasin planning. NOAA has also published a guidance outlining an integrated watershed approach to recovery planning. (see NOAA Ecosystem Recovery Planning for Listed Salmon: An Integrative Assessment Approach for Habitat. NOAA Technical Memorandum NMFS-NWFSC-58

http://www.nwfsc.noaa.gov/publications/techmemos/tm58/tm58.pdf).

**USFWS -** On December 21, 2000, the USFWS released its final biological opinion on the effects of power system operations on the endangered Kootenai River white sturgeon and threatened bull trout. This strategy was based on the best available science, extensive public input, and broad discussions and consultations with tribal, state, and local authorities. It placed the highest priority on actions with the best chance of providing solid, predictable benefits for the broadest range of species. It also established mechanisms to gauge success, factor in new science as it became available, and adjust the recovery actions at major midterm reviews as needed. Federal agencies are using this strategy as a blueprint to guide their recovery efforts and interactions with state and local governments and tribes.

**Bull Trout -** Recent work on regional patterns of genetic variability and evolutionary relationships has been helpful in identifying major population groupings. Yet gaps in our understanding of the phylo-geography of bull trout remain. Additional research in this area would be useful for understanding patterns at a finer scale. This finer-grained genetic information would enhance understanding of the distribution of diversity within bull trout, and inform planning for reintroductions. A more concerted effort to standardize marker sets, e.g., micro-satellite primers, among labs would also be useful.

In addition, the impact of hydropower facilities on bull trout and their habitat must be evaluated. These studies should be done in conjunction with studies on bull trout from adjacent recovery units, e.g., Imnaha-Snake, Clearwater, Tucannon, Hood River, to determine areas of overlapping use and possible interactions. Research is also needed to determine the migration timing and pathways in and between tributaries.

As bull trout recovery actions are implemented such as fish passage at Condit Dam, bull trout will likely increase their use of the mainstem Columbia and Snake rivers. As a result, the need for research to investigate problems associated with fish ladder use, entrainment, spill, flow attraction, and water quality will become more important as recovery proceeds.

## Appendix H. Emerging Issues

### Toxics

**Regional Research Recommendations**

8.1 Determine how to identify and quantify sources of toxic contaminants in the Lower Columbia River.

8.2 Determine the biological consequences of contaminant exposure in anadromous and resident fish and wildlife.

- Determine the biological consequences of contaminant exposure for impacts on aquatic habitats and/or community structure e.g., prey species and higher trophic levels, such as piscivorous birds.
- Determine the exposure patterns of wild versus hatchery fish, in populations with different life histories and patterns of estuary use, in various listed ESUs.

8.3 Determine whether contaminant transport in suspended particulates contributes to contaminant uptake in fish.

8.4 Determine the pollutants and toxicity in the reservoirs behind dams in the mainstem, including water column, fish tissue, and sediment.

8.5 Identify and implement actions to reduce toxic contaminants from entering the Snake and Columbia rivers.

8.6 Identify alternative pesticides and non-pesticide management activities that can be used for the eradication of specific aquatic invasive species?

8.7 Determine potential nontarget impacts of management techniques, such as sub-lethal impacts of herbicides on juvenile and Chinook e.g. 2,4-D, fluridone, diquat, and triclopyr, relative to other chemical stressors that may be limiting salmon productivity.

**Programs and Partners for Implementation**

**Who**

**Environmental Protection Agency -** The Environmental Protection Agency's (EPA) "Watershed Protection Approach" is a strategy for effectively protecting and restoring aquatic ecosystems and protecting human health. This strategy has as its premise that many water quality and ecosystem problems are best solved at the watershed level rather than at the individual water body or discharger level. Major features of the Watershed Protection Approach are: targeting priority problems, promoting a high level of stakeholder involvement, integrated solutions that make use of the expertise and authority of multiple agencies, and measuring success through monitoring and other data gathering.

**U.S. Geological Survey -** The U.S. Geological Survey (USGS) is comprised of four Divisions of Water, Biology, Geography, and Geology. Thus, the USGS has a strong interdisciplinary approach, and brings diverse and highly specialized scientific expertise to bear on research problems. The scientific mission of the Western Fisheries Research Center (WFRC) is part of the Division of Biology.

**NOAA -**The core mission of the NOAA Ecotoxicology and Environmental Fish Health Program is to determine the impacts of human activities on the health of wild fish, especially Pacific salmon and marine fish. To do this, the program has five research teams, four of which focus on different aspects of fish physiology and biology, and one of which focuses on assessing risks posed to fish health by human activities, especially the releases of chemical contaminants into freshwater, estuarine, and marine waters.

**How**

**EPA -** EPA also implements water quality standards that are the foundation of the water quality-based control program mandated by the Clean Water Act. Water Quality Standards define the goals for a water-body by designating its uses, setting criteria to protect those uses, and establishing provisions to protect water quality from pollutants. A Total Maximum Daily Load or TMDL, is a tool for implementing water quality standards and is based on the relationship between pollution sources and in-stream water quality conditions. The TMDL establishes the allowable loadings or other quantifiable parameters for a water-body and thereby provides the basis to establish water quality-based controls. These controls should provide the pollution reduction necessary for a water-body to meet water quality standards. However, that EPA has not developed Alternate Concentration Limits for the vast majority of chemicals of concern for aquatic species, which decreases the applicability of TMDLs.

The EPA Office of Water has various programs that store data in associated databases. These databases are separately managed with little coordination among them. Under Watershed Assessment, Tracking & Environmental Results (WATERS), an integrated information system for the nation's surface waters, these program databases are being connected to a larger framework. This framework is a digital network of surface water features known as the National Hydrography Dataset which can link one program database to another, so that information can be shared across programs.

Although the Office of Pesticide Programs has included endangered species considerations in its risk assessments for many years, the Endangered Species Protection Program (ESPP), was started in 1988. It is largely voluntary at the present time and relies on cooperation between the U.S. Fish and Wildlife Service, EPA regions, states, and pesticide users.

**U.S. Geological Survey -** WFRC conducts research on how ecosystem dynamics affect critical living aquatic resources in large river systems. The WFRC is active in the Columbia River Basin and maintains the Columbia River Research Laboratory near White Salmon, Washington. WFRC scientists have identified aquatic invasive species, effects of multiple stressors on Pacific salmon and other species, and a suite of habitat-species issues in the lower Columbia River/estuary as issues of great concern. WFRC is supporting the research needs of the U.S. Bureau of Reclamation, Army Corps of Engineers, and the Bonneville Power Administration. The WFRC is working with multiple collaborators in several large ecosystems, including the Columbia, Klamath, and Sacramento-Bay/Delta systems. WFRC is also working on contaminant projects with multiple partners, such as USFWS, U.S. Bureau of Reclamation, NOAA Fisheries, and the Water Resources Division of the USGS.

**NOAA -**While NOAA has expertise in ecotoxicology, there is substantial effort made to assess the normal physiology of wild fish, and natural variations in response to non-anthropogenic factors, as a backdrop against which human activities, such as the release of toxic chemicals, can be assessed. In addition to determining the effects of toxic contaminants on fish health, an important part of our research also examines the recovery of fish health after remedial activities are undertaken to clean up contaminated sites. This important line of research allows us to determine the efficacy of cleanup operations, and better determine the accuracy of our models, which predict risk to our living aquatic resources.

### Invasive Species

**Regional Research Recommendations**

Ecological Impacts

9.1 Determine the current distribution and abundance of invasive species to provide a baseline condition.

- Determine the relation of the current distribution and abundance of invasive species in relation to existing habitat conditions including flow and temperature regimes.
- Determine the environmental constraints on abundance and distribution of currently established or eminently threatening invasive species.

9.2 Identify the interactions between native and invasive species, including:

- Predators, prey, food chain organisms, pathogens, and those that alter habitat structure;
- How competitors respond to altered systems and to restoration and recovery actions; and,
- How food supplies have been altered and how they can be restored.

9.3 Determine the ecological and economic consequences of invasions on native fish fauna and aquatic organisms e.g. competition, predation, and cascading trophic effects on native species, nutrient cycling, effect of management activities.

- Determine the impact of nonnative aquatic and terrestrial species that are invasive on salmonid recovery.
- Determine the impacts of nonnative species invasions i.e., rainbow and eastern brook trout, on abundance, distribution, life history and genetic diversity on bull trout, redband trout, and west slope cutthroat trout populations.

9.4 Determine the impact trophic impacts of nonnative species.

- Determine whether the economic and ecological effects invasive species have greater impacts at some trophic levels or in specific guilds than others.
- Determine the current extent of the colonization of reservoirs by non-native estuarine and mountain stream species and their role in reservoir food webs and headwater storage projects.

9.5 Determine the ecological impacts of “naturalized” non-indigenous species.

9.6 Determine whether regionally accepted non-indigenous species, such as warm-water fish, can be managed to minimize ecological effects.

9.7 Identify the number and importance of introduced disease organisms, parasites (plant and animal) and aquatic insects in the lower Columbia.

### Detection and Prevention

9.8 Determine primary nonnative species introduction pathways and develop protocols and methodologies to limit new introductions.

- Determine how low-density populations of invasive species can be detected i.e., new monitoring techniques and optimized search protocols.
- Determine what factors limit invasive species in their native range, such as viruses, bacteria, fungi, parasites, predators.

9.9 Develop risk analyses regarding species that have not yet established widely in the Columbia Basin, and the associated need for management strategies to reduce the risks of introducing invasive species of concern.

9.10 Develop rapid response methodologies to eliminate new nonnative species at the source of introduction before they spread and become unmanageable in the environment.

### Suppression and Eradication

9.11 Evaluate effectiveness of actions to control established species and to limit the introduction of new species by evaluating long-term trends in monitoring data.

- Assess the effectiveness of nonnative fish suppression programs on native salmonid populations; i.e., abundance, distribution, life history structure, and genetic composition and diversity.
- Determine the potential nontarget impacts of management techniques, specifically the sub-lethal impacts of herbicides on salmonids. Evaluate alternative pesticides for use in eradicating specific aquatic invasive species.
- Determine how to reduce the impact of invasive species by environmental manipulations e.g., reductions in water temperature can reduce impacts from nonnative predators through physiological means although not necessarily reducing the predators numbers or dispersal.
- Determine how presently established nonnative species e.g., shad, walleye, *Corbicula*, Eurasian watermilfoil, can be managed to minimize ecological and economic effects, including use of effective biological control agents.

**Programs and Partners for Implementation**

**Who: 100th Meridian Initiative -** The 100th Meridian Initiative is a cooperative effort between state, provincial, and federal agencies to prevent the westward spread of zebra mussels and other aquatic nuisance species in North America. The goals of this Initiative are to: prevent the spread of zebra mussels and other aquatic nuisance species west of the 100th meridian; and, to monitor and control zebra mussels and other aquatic nuisance species if detected in these areas.

**How:** Establish research program for identification of other pathways and risk evaluation that could cause introductions of Zebra mussels and other related aquatic nuisance species west of the 100th meridian. Evaluation of these pathways and development of specific plans of action to address these identified potential risk.
http://100thmeridian.org/

## Impact of Human Development Patterns on Fish and Wildlife Restoration

### Regional Research Recommendations

10.1 Determine whether salmonid populations in the Columbia River can be increased and sustained over the long term, given the multitude of biological, physical, and cultural constraints. (Council Document SRG 93-2).

10.2 Identify regional variation in the physical, biological, social, cultural, and economic environments of salmon (CENR, 2000).

### Programs and Partners for Implementation

**Who: Pacific Northwest Regional Collaboratory -** Pacific Northwest National Laboratory (PNNL) and the Institute for Natural Resources of Oregon State University are working to develop a regional sustainability decision support system to address these types of basin-wide information needs, through the Pacific Northwest Collaboratory (www.pnwrc.org). The Northwest Sustainability Atlas Project being conducted by Battelle and the Institute of Natural Resources addresses both geospatial research and applications, and is a potential vehicle for this work.

## Appendix I. Monitoring and Evaluation

### Defining Research

Research is necessary to provide scientifically credible answers to questions pertinent to management that are complicated by uncertainty. Research is most literally focused on dealing with uncertainty and not on monitoring population status, trend or the effectiveness of plans or actions. Monitoring and evaluation are necessary to assure that the effects of actions taken under the program are measured and analyzed to provide better understanding of the results and then use this knowledge to direct future actions. The differences between research and monitoring and evaluation are often difficult to differentiate, especially for large-scale questions, e.g., hydrosystem and habitat actions. In cases where actions are based on the extrapolation of results from small-scale research projects, they constitute research on a larger scale and may require long-term monitoring. Understanding the effect of habitat conditions on the performance of fish and wildlife populations requires replicated observational studies or intensive research level experiments to be conducted across spatial and temporal contrasts in habitat actions and conditions, at multiple spatial scales (Marmorek et al. 2004). Few evaluations of tributary habitat in the Columbia Basin meet these criteria, nor in other regions of the United States (Bernhardt et al. 2005).

Research can also be thought of as work that seeks knowledge that would have future and broad benefit. Thus, projects conducting monitoring for the sole purpose of evaluating work at the project scale were not deemed research, while project scale work that could have broad implications was considered research. Another example is that work by the Army Corps of Engineers on improving fish passage was defined as research, whereas work under the Fish and Wildlife Program testing the effectiveness of passage strategies was considered monitoring.

The CENR (2000) report recommended that research efforts in the area of monitoring and evaluation would greatly enhance the scientific precision and accuracy in monitoring fish and wildlife restoration efforts and recovery planning by providing timely feedback to managers and policy makers. If properly designed, monitoring can help identify limiting factors to salmon recovery and provide feedback to managers and to the public about how management plans and activities are affecting species and the environment. Thus, monitoring can facilitate the prediction and subsequent validation of the effects of specific restoration actions, which can help direct management of the Program and provide a basis for evaluating the relative effectiveness of how restoration dollars are spent. Monitoring can also provide the basis for ensuring accountability for program expenditures and for establishing future program priorities. Thus, monitoring and evaluation provides the mechanism for reducing the uncertainties that challenge the effective implementation of the Program.

Finally, many policy questions concern trends, not of individual systems, but across collections or populations of systems. Early decisions on policy often are based on status estimates, with concerns about trends emerging later as decision makers seek evidence of the effectiveness of their decisions. Adaptive management is the process by which monitoring data and information is incorporated into periodic amendments of plans and actions. These actions are then intended to make future actions increasingly effective from many standpoints such as cost, biology, legal

obligations and societal values. The adaptive management cycle (Figure 1.) requires careful design of the implementation of actions, as well as of monitoring and evaluation, so that the collected information will provide reliable insights on which actions are most effective.

### Defining Monitoring

In the Columbia River Basin several large-scale planning documents have categorized three types of monitoring in a hierarchical sequence e.g., the All-H Paper, the 2000 Biological Opinion, and the Retrospective Report of the Independent Scientific Review Panel (ISRP). The three types of monitoring differ in terms of their application, and along spatial and temporal scales. The ISRP and ISAB recognized the "inconsistent terminology concerning research, monitoring, and evaluation among the various fields of science e.g., fisheries, hydrology, wildlife, genetics" and in particular with the scientific basis for "effectiveness monitoring" of management actions (ISRP 2005-14). The ISRP and ISAB have used the words "Tier 1, Tier 2, and Tier 3" in a slightly different manner in past reports referring more to the way data are collected i.e., census versus sample, than to the scale of the study. To eliminate potential confusion in the future, they have dropped the use of the word "Tier" when referring to the way data are collected. The relationship of the ISRP's definitions of census and statistical monitoring to Action Agency (2002) Tier 1, 2 and 3 monitoring is set forth in the ISRP's Retrospective Report 1997-2005. In addition to monitoring for biological, environmental and physical data, there is compliance and implementation monitoring associated with monitoring of restoration projects.

**Regional Research Recommendations**

#### Hatchery Monitoring

8.1 Determine the reproductive success of hatchery fish spawning in the wild relative to wild fish.

8.2 Determine the effects that hatchery reforms have in reducing extinction risk of listed species and contributing to recovery.

#### Watershed Condition Monitoring

8.3 Develop a sound Tier I trend-monitoring procedure based on remotely sensed data obtained from sources such as aerial photography or satellite imagery for monitoring riparian vegetation, channel change, etc.

8.4 Develop and implement a long-term statistical monitoring program (Tier 2) to evaluate the status of fish and wildlife populations and habitat. This action would entail development of probabilistic (statistical) site selection procedures and establishment of common protocols for cost-effective "on the ground" or remotely sensed data collection of a limited number of indicator variables.

8.5 Implement a research monitoring (Tier 3) effort at selected locations in the Columbia Basin to establish the underlying causes for the changes in population and habitat status identified in Tiers 1 and 2 monitoring.

8.6 Develop a spatially balanced survey design and integrated sampling strategy that allows the aggregation of data at multiple landscape levels.

8.7 Identify a core set of attributes and protocols that state, federal, private and tribal monitoring programs will use for assessing status and trends in watershed condition both within and outside of the Councils Program.

### Effectiveness Monitoring

8.8 Develop a regionally acceptable standard for obtaining statistically valid samples of habitat restoration projects to determine with certainty that the projects sampled represent the effectiveness of the project category as a whole.

8.9 Develop a list of habitat restoration project categories that if designed and constructed using documented BMP criteria are considered effective.

8.10 Identify the attributes and protocols that state, federal, and tribal monitoring programs will use for assessing project effectiveness.

8.11 Strategically place intensively monitored watersheds throughout the Pacific Northwest to monitor and evaluate cause and affect relationships between habitat changes and fish abundance.

8.12 Develop a core set of high-level indicators of watershed health and salmon recovery at a third field level that can be aggregated to state and regional levels.

### Fish Population Monitoring

8.13 Identify field sampling attributes and protocols that state, federal, and tribal monitoring programs will use for assessing status and trends in fish abundance, other biological indicators, and harvest to ensure compatibility throughout the Pacific Northwest.

8.14 Develop or improve existing empirical models for prediction of abundance or presence-absence of focal species as data are obtained in a Tier 2 status-monitoring program.

8.15 Improve monitoring of smolt to adult return ratios of some stocks, e.g., sub-yearling Snake River fall Chinook evaluations need to be improved.

8.16 Develop prediction models for bull trout and west slope cutthroat trout populations in the Flathead and Kootenai River drainages e.g., age-structure and environmental covariates.

### Hydrosystem Monitoring

8.17 Determine juvenile hydro survival (priority total system/secondary in-river) in relation to performance standards. Determine the relative proportion and survival of migrating juvenile salmonids passing through the various passage routes, including spillways, located at the mainstem dams.

8.18 Determine the effectiveness of transportation versus in-river migration.
Determine the differences in migration timing and relative survival for transported and in river juvenile salmon and steelhead.

8.19 Develop and implement a monitoring plan to evaluate the effectiveness of management actions implemented as a result of the Total Dissolved Gas and temperature TMDLs established by EPA on the Columbia River.

### Harvest Monitoring

8.20 Determine the extent of harvest incidental mortality imparted on non-targeted, listed species.

8.21 Determine the extent of harvest incidental mortality in terms of impact on pre-spawning survival and spawning success for listed species.

## Programs and Partners for Implementation

> *A regional science based monitoring and evaluation program is necessary to assess the status of populations and habitat, as well as the adequacy of management and restoration actions in achieving restoration goals. Research needs include monitoring technologies, indicators of stock success and environmental health, databases for information storage and retrieval, straightforward evaluation procedures, and mechanisms to ensure communication to those who implement adaptive management.* (Emphasis added.)
>
> -- Committee on the Environment and Natural Resources, 2000

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 types of monitoring are needed, and can be afforded, for managing an effective fish and wildlife restoration program. All opportunities to conduct collaborative research on monitoring should be fully exercised. Regional coordination and cost sharing on tributary monitoring and research of habitat conditions, fish, habitat action effectiveness, and critical uncertainties should be addressed up-front in the overall vision of the plan and its longer-term implementation.
For example, the effectiveness research being conducted in pilot watersheds under the Fish and Wildlife Program is highly analogous to work in Puget Sound under the Pacific Coastal Salmon Recovery Fund. Further, the Bonneville Environmental Foundation has recently inaugurated similar work. These three corollary efforts, being conducted by separate entities indicate the need for coordination at a broad scale. The issues of scientific leadership, institutional innovation, and governance are being addressed by the Pacific Northwest Aquatic Monitoring Partnership in regards to the prioritization, design, and coordination issues for large-scale monitoring linked to management experiments.

### Pacific Northwest Aquatic Monitoring Partnership

Several years ago, Federal Executives asked staff of the U.S. Forest Service's Aquatic and Riparian Effectiveness Monitoring Program to develop a monitoring partnership with Washington, Oregon, and California agencies in support of the President's Forest Plan. This resulted in an ad hoc group of state and federal natural resource and watershed specialists meeting since November 2001 to coordinate and integrate their different watershed condition monitoring efforts. This group is now operating as the Pacific Northwest Aquatic Monitoring Partnership or PNAMP. In recognition of the common objectives and overlap among participants in existing monitoring programs, the initial group decided to expand their partnership group to include the federal research, monitoring and evaluation planning and coordination effort, and to bolster the effort by inviting participation from tribal organizations. Participants to date have included a wide range of organizations – state, federal, and tribal.

The PNAMP has developed a regional coordination plan for monitoring and evaluation, separate from this Research Plan. Nevertheless, many of the research needs essential for the development of the monitoring plan are identified in this Research Plan. The relationship between these two

planning documents should be viewed as complementary. However, the scope of the PNAMP plan differs from that of the Research Plan in two ways. First, although the Partnership's plan includes research efforts, it is focused on a single subject area, monitoring and evaluation. In contrast, the Council's plan spans many topic areas, including monitoring and evaluation. Second, the Partnership's plan encompasses the region within which the President's Forest Plan is being implemented, from the Canadian border south to northern California, whereas the Council's plan only encompasses the Columbia River Basin.

This Research Plan includes research recommendations from the Monitoring Strategy developed by PNAMP, because the Council, and the majority of parties to the Regional Research Partnership have signed the PNAMP Charter. PNAMP's coordination strategy takes into account the major funding sources, including the two major federal sources – the Pacific Coast Salmon Recovery Fund, and the Bonneville Power Administration's funding to the Council for its Fish and Wildlife Program. The Council's Research Plan recommends that the coordination of state research, monitoring, and evaluation activities under these two programs take place through PNAMP.

The Chair and the Coordinator of the Federal Caucus recently asked PNAMP for assistance in developing an approach to monitoring that can support eventual de-listing decisions. PNAMP responded affirmatively, and asked that the Caucus make the request formally via a letter that would detail the needed elements of the approach. This is an example of how PNAMP can contribute significantly as a forum for recommending strategies for sharing and networking research and monitoring efforts and multi-agency funding agreements. The effectiveness of PNAMP coordination will rely on agency level commitments to support a strong top-down, programmatic framework; existing bottom-up approaches that can contribute will need to be modified to fit within this framework. For these reasons, the Council supports a top-down approach to regional monitoring that meets the bottoms-up approach (typified by the existing portfolio of ongoing projects) halfway by the time of the next implementation funding decision process.

### Collaborative Systemwide Monitoring and Evaluation Project

The Collaborative Systemwide Monitoring and Evaluation Project, or CSMEP, is an example of an ongoing "on the ground" project to build collaborative partnerships between state, tribal and federal agencies across the Columbia River Basin in order to develop and implement improved and coordinated monitoring and evaluation programs and protocols. This project is a collaborative effort, led by the Columbia Basin Fish and Wildlife Authority (CBFWA). It is co-sponsored by the National Marine Fisheries Service (NMFS), the U.S. Fish and Wildlife Service (USFWS), four state fish agencies (WDFW, ODFW, IDFG, and MFWP), the Fish Passage Center (FPC), and the Columbia River Inter-Tribal Fish Commission (CRITFC). It also involves members of PNAMP, WA SRFB, Federal RME, and the Action Agencies.

CSMEP has a strong technical focus on fish monitoring, and is actively coordinating with PNAMP to define their respective roles in improving monitoring and evaluation in the Columbia River Basin. CSMEP and PNAMP are currently coordinating on how best to allocate effort

between their respective levels of expertise to address this question. Eventually the project may function as PNAMP's technical group for fish monitoring and evaluation.
The project focuses on the issue of systemwide monitoring and evaluation of fish status, addressing requirements of NMFS and USFWS Biological Opinions and Recovery Plans as well as the NWPPC Fish and Wildlife Program. It proposes an integrated effort by fisheries scientists and biometricians to:

1) Document, integrate and make available existing monitoring data that bear on the problem of evaluating the status of salmon, steelhead, bull trout and other species of regional importance across the Columbia River Basin;
2) Work collaboratively to critically assess the strengths and weaknesses of existing monitoring and evaluation methods for answering key questions regarding both stock status and responses to management actions; and,
3) Work collaboratively to design improved monitoring and evaluation methods that will fill information gaps and provide better answers to these questions in the future.

(Additional information on CSMEP and its products CSMEP can be found at: http://www.cbfwa.org/committees/csmep/default.cfm.)

### Federal Research, Monitoring, and Evaluation Plan

In NOAA's 2000 biological opinion, monitoring and evaluation was a strong and central theme. Over a two year period, Bonneville, the Corps, and the Bureau of Reclamation work with NOAA Fisheries to develop a *Research, Monitoring, and Evaluation (RME) Program for the NOAA Fisheries 2000 Federal Columbia River Power System (FCPRS) Biological Opinion and a Columbia River Federal Salmon Recovery Strategy MOU*. Recommendations for research relevant to monitoring and evaluation and the hydrosystem identified in the RME plan are reported in this Research Plan. The ISRP reviewed the plan and issued Review of Draft Action Agency and NOAA Fisheries RME Plan (2004-1), which made several recommendations for revisions to the plan.

The federal RME plan focused on stocks of anadromous fish listed under the ESA and called for programmatic monitoring and expanded coordination with other federal and state monitoring programs. In contrast, the Monitoring Strategy of the PNAMP embraces monitoring for watershed conditions, status and trends, and project effectiveness. Although the federal monitoring plan addresses a narrower range of resources, it was developed over a two-year period and will make a significant contribution to the regional monitoring efforts.

### Pacific Coastal Salmon Recovery Fund

The Pacific Coastal Salmon Recovery Fund (PCSRF) was established in fiscal year 2000 to provide grants to the states and tribes to assist state, tribal and local salmon conservation and recovery efforts. The goal of the PCSRF is to make significant contributions to the conservation, restoration, and sustainability of Pacific salmon and their habitat. The PCSRF was requested by the governors of the states of Washington, Oregon, California and Alaska in response to ESA listings of West Coast salmon and steelhead populations. The PCSRF supplements existing state,

tribal and federal programs to foster development of federal-state-tribal-local partnerships in salmon recovery and conservation. It also promotes efficiencies and effectiveness in recovery efforts through the enhanced sharing and pooling of capabilities, expertise and information.

The recovery of sustainable salmon populations will likely take decades, and require a substantial investment. Nonetheless, it is important to track the work accomplished by current investments and measure activities and changes on a regular basis. NOAA Fisheries has developed a comprehensive performance measurement system for the PCSRF in conjunction with the states and tribes in response to requests by Office of Management and Budget and Congress for program accountability. The MOUs between NOAA Fisheries and the states and tribes, which previously established criteria and goals for prioritizing PCSRF project funds have been amended to include these program-wide performance goals and reporting metrics. It is anticipated that the use of these project level reporting metrics, combined with larger scale watershed and subbasin assessments, and results from monitoring and evaluation efforts, will facilitate long term assessments of program effectiveness in terms of increased numbers of salmon. (Bonneville is currently adopting these metrics into its project tracking system.)

### Bonneville Environmental Foundation

The Bonneville Environmental Foundation (BEF) initiated its Model Watershed Program in October 2003. BEF signed two 10-year agreements supporting long-term, monitoring-intensive watershed restoration efforts in Idaho's lower Kootenai River and the Chinook River in southwest Washington. In agreements with the Kootenai Tribe of Idaho and Sea Resources (a community-based watershed restoration organization located in Chinook, WA.), BEF has committed to provide scientific oversight, an independent peer review panel, and at least $500,000 in support of restoration and quantitative monitoring efforts over a 10-year period.

With its model watershed approach, BEF is hoping that long-term investments in scientifically accountable restoration programs will prove more effective than short-term and piecemeal project grants scattered among Pacific Northwest watersheds. Over time, BEF plans to seek additional resources and apply its own funds to support 10 to 12 long-term Model Watershed programs across the Pacific Northwest.

There is a clear opportunity to link the three sets of pilot intensively watersheds (the BEF projects, the PSCRF projects, and the pilot watershed work under the FCRPS Biological Opinion) to increase the pool of experimental sites, which would save funds and time.

## TABLE A. DRAFT REGIONAL MONITORING FRAMEWORK

| RM&E Framework Component | Management Questions | Subordinate Questions | Regional Information Needs | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Metrics | Data Required | Survey or Experimental Design | Spatial Scale | Temporal Scale | Responsible Agencies[2] for Cost Sharing |
| | | | | | | | | |
| **Tributary Habitat Status and Trend Monitoring** | Are Columbia Basin fish populations meeting population level objectives (abundance, productivity, and diversity)? | | | | | | | |
| | | What is size of adult salmon, steelhead, and bull trout populations? | Numbers of adult fish | Numbers of adults, spawners, or redds | Census or spatially balanced survey[3] | Columbia Basin, ESU, Population, Core Area, or Sub-population | Annual sampling | 1st: FR 2nd: AA, LU, S, T |
| | | What is the distribution of adult salmon, steelhead, and bull trout populations? | Presence/absence of adult fishes | Presence of adults, spawners, or redds | Census | Columbia Basin, ESU, Population, Core Area, or Sub-population | Sampling every 3 to 5 years | 1st: FR 2nd: AA, LU, S, T |
| | | What is the growth rate of adult salmon, steelhead, and bull trout populations? | Returns/Spawner, Lambda, Temporal Trends | Numbers of adults, spawners, or redds | Census or spatially balanced survey | Columbia Basin, ESU, Population, Core Area, or Sub-population | Annual for at least 3 generations | 1st: FR 2nd: AA, LU, S, T |
| | | What is the freshwater productivity of | Smolts, fry or parr produced per adult, spawner, | Number of smolts, fry or parr | Census or spatially balanced survey | Columbia Basin, ESU, Population, | Annual sampling | 1st: FR 2nd: AA, LU, S, T |

[2] FR= Fish Regulatory Agencies (NOAA and/or USFWS); AA= Action Agencies (BPA, COE, BOR); LU= Land Use Agencies (USFS, BLM); EPA= Environmental Protection Agency; S = State Agency; T= Tribe

[3] Spatially-Balanced Survey Design (e.g., EMAP-GRTS design; see Stevens and Olsen 2004)

| RM&E Framework Component | Management Questions | Subordinate Questions | Regional Information Needs | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Metrics | Data Required | Survey or Experimental Design | Spatial Scale | Temporal Scale | Responsible Agencies[2] for Cost Sharing |
| | | these populations? | or redd | | | Core Area, or Sub-population | | |
| | | What is the age structure of these populations? | Age of returning adults or spawners | Otolith, scale, or length of adults or spawners | Census or spatially balanced survey | Columbia Basin, ESU, Population, Core Area, or Sub-population | Annual sampling | 1st: FR<br>2nd: AA, LU, S, T |
| | | What fraction of the spawners of these populations is of hatchery origin? | Ratio of hatchery to total fish abundances | Number of hatchery produced adults or spawners | Census or spatially-balanced survey | | | 1st: FR<br>2nd: AA, LU, S, T |
| | Are aquatic, riparian, and upland ecosystems of the Columbia Basin being degraded, restored or maintained relative to desired conditions or objectives? | | | | | | | |
| | | What is the biological condition of spawning and rearing habitat for Columbia Basin fish populations? | Macro-invertebrate and fish assemblages | | Spatially-Balanced survey | Stream, watershed, subbasin | Annual sampling | 1st: FR, EPA, LU<br>2nd: AA, S, T |
| | | What is the physical condition of spawning and rearing habitat for | Valley characteristics (valley bottom types, valley | | Spatially-balanced survey [1] | Stream, watershed, subbasin | Annual sampling | 1st: FR, LU<br>2nd: AA, S, T |

| RM&E Framework Component | Management Questions | Subordinate Questions | Regional Information Needs | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Metrics | Data Required | Survey or Experimental Design | Spatial Scale | Temporal Scale | Responsible Agencies[2] for Cost Sharing |
| | | Columbia Basin fish populations? | widths and gradients, valley containment, road density, land ownership, land use); Channel characteristics (bed-form types, channel types, gradient, width/depth ratio, stability); Riparian vegetation (structure, disturbance, canopy cover); Habitat access (dams and diversions); Stream flows; Habitat quality (substrate, embeddedness, large woody debris, pools, off-channel habitat, fish cover) | | | | | |
| | | What is the water quality in spawning and rearing habitats for Columbia Basin fish populations? | Temperature, Turbidity, Conductivity, pH, Dissolved Oxygen, Nutrients, Toxic | | Spatially-balanced survey | Stream, watershed, subbasin | Annual sampling | 1st: EPA, S, LU<br>2nd: FR, AA, T |

| RM&E Framework Component | Management Questions | Subordinate Questions | Regional Information Needs | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | **Metrics** | **Data Required** | **Survey or Experimental Design** | **Spatial Scale** | **Temporal Scale** | **Responsible Agencies[2] for Cost Sharing** |
| | | | Pollutants and Heavy Metals | | | | | |
| **Tributary Habitat Action Effectiveness Research** | What actions are most effective at addressing the limiting factors preventing achievement of habitat, fish or wildlife performance objectives? | | | | | | | |
| | | Did all tributary habitat actions in aggregate for a sub-population increase juvenile survival or adult abundance, compared to a similar sub-population with few or no habitat actions? | Type, location, timing and intensity of habitat actions, and juvenile survival or adult abundances | Depends on management actions | Large-scale Before-After (BA) Studies[4] | Watershed, Subbasin | Depends on management action(s) | 1st: AA, LU<br>2nd: FR S, T |
| | | What contribution did all tributary habitat actions for an ESU make toward increasing the ESU-level population growth rate? | Type, location, timing and intensity of habitat actions, and ESU population growth rates | Depends on management actions | Large-scale Before-After (BA) Studies | ESU scale | Depends on management action(s) | 1st: AA, LU<br>2nd: FR S, T |
| | | Did a single | Type, location, | Depends on | Project-scale | Stream, | Depends on | 1st: AA, LU |

[4] Intensive BA, BACI, or Staircase designs; see Roni et al. 2005

| RM&E Framework Component | Management Questions | Subordinate Questions | Regional Information Needs | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | **Metrics** | **Data Required** | **Survey or Experimental Design** | **Spatial Scale** | **Temporal Scale** | **Responsible Agencies[2] for Cost Sharing** |
| | | tributary habitat action increase local fish abundance or distribution, or improve local environmental conditions, compared to a similar control or reference site? | timing and intensity of habitat action, local fish abundance or distribution, and/or habitat conditions | management actions | Before-After Studies[5] | Watershed | management action(s) | 2nd: FR S, T |
| | | Did some classes of actions (e.g., riparian restoration actions) perform better than other classes (e.g., passage improvement actions) in improving localized conditions or sub-population juvenile survival rates? | Type, location, timing and intensity of habitat actions, and local habitat conditions and/or juvenile fish survivals | Depends on management actions | Project-scale Before-After Studies | Stream, Watershed | Depends on management action(s) | 1st: AA, LU<br>2nd: FR S, T |
| **Tributary Habitat Uncertainty Research** | What are the limiting factors or threats preventing the achievement of | | | | | | | |

[5] Intensive BA, Extensive BA, or replicated BACI; see Roni et al. 2005

| RM&E Framework Component | Management Questions | Subordinate Questions | Regional Information Needs | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | **Metrics** | **Data Required** | **Survey or Experimental Design** | **Spatial Scale** | **Temporal Scale** | **Responsible Agencies[2] for Cost Sharing** |
| | desired habitat, fish or wildlife performance objectives? | | | | | | | |
| | | What is the relationship of habitat processes and functions of upslope, riparian, and aquatic systems to biological and environmental habitat attributes? | Watershed condition metrics identified above. | Watershed condition data identified above. | Depends on correlation or experimental approach | Stream, watershed, subbasin | Depends on correlation or experimental approach | 1st: LU<br>2nd: FR, EPA AA, S, T |
| | | What is the relationship of habitat attributes, processes, and/or functions to fish and wildlife abundance, productivity, and diversity? | Watershed condition and fish population metrics identified above. | Watershed condition and fish population data identified above. | Depends on correlation or experimental approach | Stream, watershed, subbasin | Depends on correlation or experimental approach | 1st: FR, LU<br>2nd: AA, EPA S, T |
| | | | | | | | | |
| **Hydro Status and Trend Monitoring** | Are salmon and steelhead meeting juvenile and adult hydro passage objectives? | Are smolts achieving survival standards prescribed in the NOAA BOs? | Smolt survival estimates through impounded reaches of the Snake and lower Columbia<br><br>System survival estimates reflecting | PIT tag detection histories through the FCRPS<br><br>Tagging ample # of fish at hatcheries as | Cormack-Jolly-Seber single release model | LGR to BON tailrace, when possible | Annual | 1st: AA<br>2nd: FR |

| RM&E Framework Component | Management Questions | Subordinate Questions | Regional Information Needs | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | **Metrics** | **Data Required** | **Survey or Experimental Design** | **Spatial Scale** | **Temporal Scale** | **Responsible Agencies[2] for Cost Sharing** |
| | | | delayed effects of transported smolts | surrogates for wild ones.<br><br>Annual estimates of D | | | | |
| | | Are adults achieving survival standards prescribed in the NOAA BOs? | Survival indices of adult salmon and steelhead through the FCRPS.<br><br>*NOTE- AFEP funds some, but not all, data elements required under this objective. Close coordination with* | PIT detection histories at ladder-based detectors, for known source fish.<br><br>Estimates of stray rates<br><br>Estimates of harvest removals of | Accounting of fates for returning PIT tagged fish. | BON to uppermost dam as applicable to an ESU | Annual | 1st: AA<br>2nd: FR |

| RM&E Framework Component | Management Questions | Subordinate Questions | Regional Information Needs | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | **Metrics** | **Data Required** | **Survey or Experimental Design** | **Spatial Scale** | **Temporal Scale** | **Responsible Agencies[2] for Cost Sharing** |
| | | | *AFEP required* | PIT tagged fish in the Mainstem.<br><br>Estimates of incidental harvest mortality, e.g., net drop out rates, catch and release related mortality, etc. | | | | |
| **Hydro Action Effectiveness Research** | *NOTE- AFEP funds elements required under this objective. Close coordination with AFEP is required.* | | | | | | | |
| **Hydro Uncertainty Research** | What is the magnitude of delayed effects associated with transporting smolts? | Under what conditions does inriver passage yield higher SARs that transport | Estimates of D for wild and hatchery fish | PIT tag detections juveniles and returning adults<br><br>SAR for transport and inriver groups, i.e. TIR | Empirical estimates & model derived estimates for populations of some inriver migrants | Individual transport sites to designated return site. | Annual | 1st: AA<br>2nd: FR |

| RM&E Framework Component | Management Questions | Subordinate Questions | Regional Information Needs | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Metrics | Data Required | Survey or Experimental Design | Spatial Scale | Temporal Scale | Responsible Agencies[2] for Cost Sharing |
| | | | | estimates<br><br>Inriver survival estimates<br><br>Direct transport survival estimates | | | | |
| | | Is transport appropriate for some locations and not others? | TIR estimates for wild and hatchery fish | | | | | 1st: AA<br>2nd: FR |
| | Do smolts migrating through the FCRPS incur delayed effects? | What is the magnitude of such effects? | SARs linked to different smolt passage fates or experiences | PIT tag detections as juveniles to describe migratory experience<br><br>PIT detections of returning adults | Compare SAR among treatment groups | Variable | One to several years | 1st: AA<br>2nd: FR |
| | | What are the causes and can they be rectified? | Localized smolt survival rates (Identify zones of particularly intense mortality that could depress SAR) | Variety, e.g. PIT, acoustic tag or radio telemetry data from smolts. | Compare survival with reference areas. | Geographically localized, e.g. bird predation centered at islands | One to several years | 1st: AA<br>2nd: FR |
| | | | | | | | | |

| RM&E Framework Component | Management Questions | Subordinate Questions | Regional Information Needs | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | **Metrics** | **Data Required** | **Survey or Experimental Design** | **Spatial Scale** | **Temporal Scale** | **Responsible Agencies[2] for Cost Sharing** |
| **Estuary Habitat Environmental Status and Trend Monitoring** | Are aquatic, riparian, and upland ecosystems of the estuary (from Bonneville Dam to the mouth of the Col. R.) being degraded, restored or maintained relative to desired conditions or objectives? | Using a hierarchical habitat classification system based on existing hydro-geomorphology, to what quantitative extent are we avoiding further loss to existing shallow water wetland habitat and restoring degraded habitats, in particular for listed salmonids? | Characterization of Vegetation cover, Geology/ soils, Floodplain topography, Bathymetry | Habitat classification | Census (mensurative) or spatially balanced survey | BON to mouth | Depends on metric | 1st: FR<br>2nd: AA, S |
| | | What is the amount of habitat in absolute acreage, by habitat type, that was restored annually and by proportion of the total lost historically for each habitat type for each reach of the CRE? | Measurements of Area affected | Habitat classification Habitat condition | Census (mensurative)<br>or spatially balanced survey | BON to mouth | Annually | 1st: FR<br>2nd: AA, S |
| | | What is the index of habitat connectivity by reach and its status/trend? | Connectivity -- Inventory of Passage barriers and Total edge, density and | Habitat connectivity | Census (mensurative)<br>or spatially balanced survey | BON to mouth | Annually | 1st: FR<br>2nd: AA, S |

| RM&E Framework Component | Management Questions | Subordinate Questions | Regional Information Needs | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | **Metrics** | **Data Required** | **Survey or Experimental Design** | **Spatial Scale** | **Temporal Scale** | **Responsible Agencies[2] for Cost Sharing** |
| | | | sinuosity of floodplain and tidal channels. | | | | | |
| | What are the status/trends in attributes of the CRE, plume, and ocean ecosystems? | What are estuary habitat physical properties? | Habitat -- Characterization of Vegetation cover, Geology/ soils, Floodplain topography, Measurements of Bathymetry | Habitat condition and classification | Statistical (mensurative) or Spatially balanced survey | BON to mouth | Depends on metric | 1st: FR<br>2nd: AA, S |
| | | What are estuary fish population properties, especially with respect to listed salmonids? | Fish – Estimates of Species composition, Age/size-structure, Stock identity, Temporal distribution, Spatial distribution, Migration pathways, Growth rate, Residence time, Prey availability, Foraging success, Survival rate, Predation index | Life history diversity, spatial distribution, growth, survival | Statistical (mensurative)<br>or spatially balanced survey | BON to mouth | Depends on metric | 1st: FR<br>2nd: AA, S |
| | | What are estuary hydrograph and water quality properties? | Water -- Measurements of Hydrograph, Temperature, Salinity, | River discharge, water quality | Statistical (mensurative)<br>or spatially balanced survey | BON to mouth | Depends on metric | 1st: FR<br>2nd: AA, S |

| RM&E Framework Component | Management Questions | Subordinate Questions | Regional Information Needs | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | **Metrics** | **Data Required** | **Survey or Experimental Design** | **Spatial Scale** | **Temporal Scale** | **Responsible Agencies[2] for Cost Sharing** |
| | | | Dissolved oxygen, pH, Turbidity, Nutrients, Toxics | | | | | |
| | | What are invasive species properties? | Invasives -- Invasive species list, Invasive spatial distribution, Invasive abundance | Invasive species assessment | Statistical (mensurative) or spatially balanced survey | BON to mouth | 3 yrs | 1st: FR<br>2nd: AA, S |
| | | What are the environmental conditions and salmon ecology in the Col. R. plume and ocean relative to salmon production and survival? | Plume and Ocean -- Estimates of Juvenile salmon usage, Growth, Survival, Zooplankton prey base, and Anchovy/ herring index in the plume and Measurements of Sea surface temperature, Northern oscillation index, Upwelling index, chlorophyll | Ocean and plume conditions, Growth, residence time, survival, | Statistical (mensurative) or spatially balanced survey | Plume and N. Pacific Ocean | Depends on metric | 1st: FR<br>2nd: AA, S |
| **Estuary Action Effectiveness Research** | What actions are most effective at addressing the limiting factors preventing achievement of | What is the cumulative effect of multiple habitat restoration projects on the CRE | See "Connectivity", "Habitat" and "Fish" above | Habitat cond's, habitat connectivity, fauna, life history | Effectiveness (mensurative) or Large-scale Before-After (BA) Studies | BON to mouth | Depends on metric | 1st: FR<br>2nd: AA, S |

| RM&E Framework Component | Management Questions | Subordinate Questions | Regional Information Needs | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Metrics | Data Required | Survey or Experimental Design | Spatial Scale | Temporal Scale | Responsible Agencies[2] for Cost Sharing |
| | habitat, fish or wildlife performance objectives? | ecosystem? | | diversity, spatial dist., growth, survival, predation, water quality physical cond., | | | | |
| | | What are the effects of hydrologic reconnection projects (e.g., dike breaches, new tide gates and culverts) and revegetation projects? | See "Connectivity", "Habitat", "Fish" and "Invasives" above | Habitat connectivity, life history diversity, spatial dist., growth, survival, invasive species | Effectiveness (mensurative) or Project-scale Before-After Studies | BON to mouth | Annually | 1st: FR, AA<br>2nd: S |
| | | What possible changes to FCRPS operations might improve habitat conditions in the CRE for Columbia basin salmonids? | Ibid. | Ibid. | Effectiveness (mensurative) or Large-scale Before-After (BA) Studies | BON to plume | Depends on metric | 1st: FR, AA<br>2nd: S |
| **Estuary Uncertainties Research** | What are the limiting factors or threats in the estuary preventing the achievement of desired habitat, fish or wildlife performance objectives in the Col. | What is the ecological importance of the Columbia River estuary and oceanic plume to the viability and recovery of salmonid | See "Connectivity", "Habitat", "Fish", "Invasives" and "Plume and Ocean" above | Habitat cond's, habitat connectivity, fauna, life history diversity, spatial dist., growth, | Effectiveness (mensurative) or Large-scale Before-After (BA) Studies | BON to plume | Depends on the metric | 1st: AA<br>2nd: FR, S |

| RM&E Framework Component | Management Questions | Subordinate Questions | Regional Information Needs | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Metrics | Data Required | Survey or Experimental Design | Spatial Scale | Temporal Scale | Responsible Agencies[2] for Cost Sharing |
| | Basin? | populations in the Columbia Basin? | | survival, predation, water quality physical cond., river discharge, plume conditions | | | | |
| | | What are the effects of toxics on salmonids? | See "Fish" above, plus estimates of concentrations and distributions of Toxics | Water quality, life history diversity, spatial distribution, growth | Depends on correlation or experimental approach | BON to mouth | Depends on metric | 1st: FR<br>2nd: AA, S |
| | | What are the causal mechanisms affecting survival of juvenile salmon during their first months in the ocean? | See "Fish" and "Plume and Ocean" above | life history diversity, spatial dist., growth, survival, predation plume conditions | Depends on correlation or experimental approach | BON to plume | Depends on metric | 1st: FR<br>2nd: AA, S |
| | | What is the survival rate by species of juvenile salmonids migrating downstream from Bonneville Dam to the mouth of the Columbia River? | Estimates of smolt survival rates, predation indices | Survival | Cormack-Jolly-Seber single release model | BON to mouth | Seasonally | 1st: FR<br>2nd: AA, S |

| RM&E Framework Component | Management Questions | Subordinate Questions | Regional Information Needs | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Metrics | Data Required | Survey or Experimental Design | Spatial Scale | Temporal Scale | Responsible Agencies[2] for Cost Sharing |
| | | | | | | | | |
| **Hatchery Status and Trend Monitoring** | | What is the relative proportion of hatchery spawning salmon and steelhead compared to wild fish populations? | · | | Develop requisite marking guidelines and proceed with the marking of remaining groups of unmarked fish released from hatcheries to facilitate monitoring of hatchery-origin fish in natural spawning areas | | | 1st: AA<br>2nd: FR |
| **Hatchery Action Effectiveness Research** | | Can hatchery reforms reduce the deleterious effects of artificial production on listed populations, thereby contributing to a reduction in extinction risk for affected natural populations? | | | Studies of modifiied hatchery practices (“reforms”) that involve controlled experiments designed and replicated sufficiently to provide statistically and biologically meaningful results pertinent to multiple programs. | | | 1st: AA<br>2nd: FR |

| RM&E Framework Component | Management Questions | Subordinate Questions | Regional Information Needs | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Metrics | Data Required | Survey or Experimental Design | Spatial Scale | Temporal Scale | Responsible Agencies[2] for Cost Sharing |
| | | Can properly designed intervention programs using artificial production make a net positive contribution to recovery of listed populations? | | | Treatment and control studies using existing safety-net programs intended to reduce extinction risk of targeted populations. | | | 1st: AA<br>2nd: FR |
| **Hatchery Uncertainties Research** | | What is the reproductive success of hatchery fish spawning in the wild relative to the reproductive success of wild fish? | | | hatchery/wild reproductive success studies | | | 1st: AA<br>2nd: FR |
| | | | | | | | | |
| **Harvest Status and Trend Monitoring** | What are the boundaries of uncertainty around harvest point estimates? | What are the harvest rates on listed wild fish? | Numbers of adult fish harvested and numbers of adult fish escaping | Dam Counts; harvest estimates; PIT tag detections at dams | Census at Dams; sub-sample in fisheries | Columbia Basin; ESU | Continual during fishery | 1st: FR<br>2nd: AA |
| **Harvest Action Effectiveness Research** | Are new selective gear types effective at harvesting? | | Catch Per Unit of Effort; Catch related to capital and operating expense | Standardized measures of catch and effort | | Columbia Basin, ESU | Continual during fishery | 1st: FR<br>2nd: AA |

| RM&E Framework Component | Management Questions | Subordinate Questions | Regional Information Needs | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | **Metrics** | **Data Required** | **Survey or Experimental Design** | **Spatial Scale** | **Temporal Scale** | **Responsible Agencies[2] for Cost Sharing** |
| **Harvest Action Effectiveness Research** | What is the post-release survival of salmon caught in a mark-selective fishery compared to fish that were not harvested? | | Survival rates | Tagging for fish that are caught compared to those not caught | Treatment/control | Columbia Basin, ESU | Continual during fishery | 1st: FR<br>2nd: AA |
| | | | | | | | | |
| **Predator Status and Trend Monitoring** | What is the impact of predators on juvenile salmonids within the Columbia River Basin? | | | | | | | |
| | | What are the nesting distribution, colony size, and colony productivity for the major avian predators within the Columbia River Basin? | Presence/absence of avian predator colonies, colony size, number of nesting pairs, reproductive chronology, reproductive success rates | Colony location, colony size, number of nesting pairs, timing of reproductive events, reproductive success | Census; statistical sample | Columbia Basin or colony | Annual sampling | 1st: AA<br>2nd: FR |
| | | What are the juvenile salmonid consumption rates of major avian predators within the Columbia River Basin? | Diet composition, consumption rates | On-colony PIT tag deposition rates and detection efficiency, diet samples, bill load | Statistical sampling of targeted populations | Columbia Basin or colony | Annual sampling | 1st: AA<br>2nd: FR |

| RM&E Framework Component | Management Questions | Subordinate Questions | Regional Information Needs | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Metrics | Data Required | Survey or Experimental Design | Spatial Scale | Temporal Scale | Responsible Agencies[2] for Cost Sharing |
| | | | | observation | | | | |
| | | What are the consumption rates of major pisciverous predators in the Columbia River Basin? | Abundance, distribution, diet composition, fecundity consumption rates | Abundance, distribution, diet composition, consumption rates | Statistical sampling of targeted populations | Columbia Basin | Annual sampling | 1st: AA<br>2nd: S |
| | What is the impact of predators on adult salmonids within the Columbia River Basin? | | | | | | | |
| | | What are the consumption rates of mammalian predators (marine) in the Columbia River Basin? | Abundance, distribution, consumption rates, diet composition | Abundance, distribution, consumption rates, diet composition | Census or statistical sampling | Columbia Basin (BON to estuary) | Annual | 1st: FR<br>2nd: AA, S |
| **Predator Action Effectiveness Research** | What are the most effective management alternatives/actions that could be used to reduce the impact of predators? | | | | | | | |
| | | What is the effect of alternative management alternatives/actions used to reduce the | % Change in Juvenile Salmonid Survival, % Change in Avian | Colony location, colony size, number of nesting | Large-scale Before-After (BA) Studies[6] | Columbia River, alternate habitat location, or colony | Depends on management action(s) | 1st: AA<br>2nd: FR |

[6] Intensive BA, BACI, or Staircase designs; see Roni et al. 2005

| RM&E Framework Component | Management Questions | Subordinate Questions | Regional Information Needs | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | **Metrics** | **Data Required** | **Survey or Experimental Design** | **Spatial Scale** | **Temporal Scale** | **Responsible Agencies[2] for Cost Sharing** |
| | | impact of avian predators? | Predation Rate | pairs, timing of reproductive events, reproductive success, On-colony PIT tag deposition rates and detection efficiency, diet samples, bill load observation | | | | |
| | | What is the effect of management alternatives/actions used to reduce the impact of pisciverous predators? | % Change in Juvenile Salmonid Survival, % Change in pisciverous Predation Rate | Abundance, distribution, diet composition, fecundity consumption rates | Large-scale Before-After (BA) Studies | Systemwide Columbia Basin | Depends on management action(s) | 1st: AA<br>2nd: S |
| **Predator Uncertainty Research** | | | | | | | | |
| | | | | | | | | |
| **Wildlife Status and Trend Monitoring** | | | | | | | | |

| RM&E Framework Component | Management Questions | Subordinate Questions | Regional Information Needs | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | **Metrics** | **Data Required** | **Survey or Experimental Design** | **Spatial Scale** | **Temporal Scale** | **Responsible Agencies[2] for Cost Sharing** |
| **Wildlife Action Effectiveness Research** | What are the species response to the various protection/restoration efforts? | How has the mitigation target species responded to fee title versus conservation easements? | Target species abundance for pre/post protection measure | Numbers of adults by target species | Large-scale Before-After (BA) Studies[7] or Project-scale Before-After Studies[8] | Columbia basin | Depends on management action(s) | 1st : S,T<br>2nd : LU |
| | | How has the mitigation target species responded to various habitat enhancement efforts? | Target species abundance for pre/post enhancement measure | Numbers of adults by target species | Large-scale Before-After (BA) Studies or Project-scale Before-After Studies | Columbia basin | Depends on management action(s) | 1st : S,T<br>2nd : LU |
| **Wildlife Action Effectiveness Research** | | | | | | | | |
| | | | | | | | | |

[7] Intensive BA, BACI, or Staircase designs; see Roni et al. 2005
[8] Intensive BA, Extensive BA, or replicated BACI; see Roni et al. 2005

## Appendix J. Methods of Project Selection

This appendix describes how projects have been reviewed and selected in the past, and might be in the future.

**Rolling Provincial Reviews -** For planning purposes within the Columbia River Basin, the Council has delineated 11 ecological provinces comprising groups of adjoining subbasins that have similar ecological attributes. These provinces constitute the geographic scale at which the recent project selection and funding process was implemented on a three-year cycle. Provincial project solicitations were initiated at different times throughout the year and involved large-scale mailings of general announcements and calls for proposals to broad distribution lists that included federal, state, tribal, and local agencies, universities, private industry, and the general public. The announcements of proposal solicitations were also posted on the Council's web site (*www.nwcouncil.org*), Bonneville's web site (*www.efw.bpa.gov*), and CBFWA's site (*www.cbfwf.org*).

Each province has its own uncertainties concerning environmental issues and fish and wildlife populations, some of which might be resolved by research projects. Subbasin plans should help identify the most appropriate geographic locations for siting research projects. In cases where multiple provinces share similar uncertainties, solutions in one province may inform efforts in others. Project sponsors would remain free to propose research projects unique to their geographic location but could be encouraged to propose research that provides a basis for extrapolation outside of the province in which the project is located.

At this time, the future project selection process is under development. The sequence of when to solicit RFPs, in conjunction with solicitations to meet other needs identified in subbasin plans, will need to be resolved. An effort should be made to allow those research projects with basinwide implications to compete with each other in the same solicitation, instead of being proposed in multiple provincial reviews.

Recommendation: Where feasible, research projects in one province should have broad application to other provinces, or to the basin as a whole.

**Requests for Proposals -** In the past, the Council identified questions of particular importance and initiated requests for proposals in coordination with Bonneville as needed.

Recommendation: Request for Proposals should be used independent of, or in concert with, broader solicitations to ensure the efficient effort of project sponsors, the ISRP, the managers, and the Council.

The future form of the project selection process has yet to be determined. Future project solicitations that occur after completion of the Research Plan may attract research proposals consistent with recommendations in the plan. However, for research recommendations for which no proposals are forthcoming, and/or for recommendations the Council decides to implement in the interim, requests for proposals could be initiated.

## Appendix K. Data Management

There are many different interests and initiatives concerned with improving data collection or management in the Columbia Basin and the Pacific Northwest. These efforts involve many different constituencies, mandates, and obligations. At present, there is no common regional data management network that links these interests and initiatives. To address this situation, the Council has initiated a process for identifying data needs in the basin, surveying available data, and filling any data gaps. The Council, NOAA Fisheries, and other regional entities supporting this effort consider it imperative to develop a regional data network. This network would utilize existing databases, facilitate data management and sharing, help subbasin planners, and underpin salmonid recovery efforts under the FCRPS Biological Opinion.

A memorandum of agreement between the Council and NOAA Fisheries guides this initiative, which is currently developing an administrative arrangement, a cost sharing agreement, and a draft memorandum of understanding for potential partners in regional information system development. This initiative has been supported within the region by the ISRP (2000-3), from independent analysis by Science Applications International Corporation (SAIC, 2003), and in comments received from the public. The data management strategy is also intended to increase the public accountability of this program by making the results accessible not only to specialists, but also to the public at large. The Council is collaborating on a process for establishing an Internet-based system for the efficient dissemination of data for the Columbia Basin. This system will be based on a network of data sites, such as Streamnet, Northwest Habitat Institute, Fish Passage Center, Columbia River Data Access in Real Time (DART), and others, linked by Internet technology.

The methods and protocols used in data collection must be consistent with guidelines approved by the Council and adopted by the region. It is important to note that while the ISRP checks these criteria, it is Bonneville who must enforce the guidelines. Guidelines appropriate for the collection and reporting of data at the project scale include:

- The project must have measurable, quantitative biological objectives.
- The project must either collect or identify data that are appropriate for measuring the biological outcomes identified in the objectives.
- Projects that collect their own data for evaluation must make this data and accompanying metadata available to the region in electronic form.
- Data and reports developed with Bonneville funds should be considered to be in the public domain.
- Data and metadata must be submitted within six months of their collection.

It is important that all projects reach completion in a timely manner. At the present time, many researchers do not end their projects at the completion of the performance period but add new objectives that extend the performance period. This gives rise to projects with multiple and

sometimes unrelated objectives that more closely resemble small programs than discrete projects. ("Infrastructure" projects may warrant an exception to the requirement for an end date.)

**Recommendation:** Specific ending dates should be required for project objectives and tasks to help sponsors meet their intended deadlines.

In order to satisfy their contractual obligation, sponsors should be required to submit to Bonneville a final report at the conclusion of every research project. Bonneville should enforce its contracts to withhold payment for projects that have not completed the reporting requirement. The final report should be in a form that facilitates review of the results.

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