Independent Science Panel
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Recommendations for Monitoring Salmonid Recovery in Washington State

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Executive Summary

The Independent Science Panel (ISP) was created by the legislature in 1998 to provide scientific oversight of Washington's salmon, steelhead, and trout recovery efforts. Legislation in 1999 required that the Panel make recommendations on:

- Standardized monitoring indicators and data quality guidelines for use by entities involved in habitat projects and salmon recovery activities across the state,
- Criteria for the systematic and periodic evaluation of monitoring data in order for the state to be able to answer critical questions about the effectiveness of the state's salmon recovery efforts,
- The level of effort needed to sustain monitoring of salmon projects and other recovery efforts, and
- Any other recommendations on monitoring deemed important by the panel.

We consider the development and implementation of a comprehensive statewide monitoring program to be fundamental to salmonid recovery in Washington State. Efforts to recover salmon, trout, and char will not be scientifically credible without comprehensive monitoring focused on recovery objectives.

The principal purpose of monitoring is to help make decisions by reducing uncertainty and tracking progress toward recovery goals. This requires: (1) confirming that management decisions were implemented (implementation monitoring); (2) making accurate status assessments of the resource to determine whether management objectives are being achieved (effectiveness monitoring); (3) and improving understanding of salmonids and their environments so as to determine the extent to which changes in status were the result of management actions (validation monitoring). Many programs already monitor indicators relevant to salmonids, but the efforts are largely uncoordinated or unlinked among programs, have different objectives, use different indicators, and lack support for sharing data. Existing programs lack shared statistical designs to address specific issues raised by listing of species under the Endangered Species Act (ESA).

We recommend that a comprehensive monitoring program be developed with the following eight characteristics, to be scientifically credible:

- Goals, objectives, and questions that need to be addressed must be clearly articulated.
- Statistical designs need to be appropriate to the objectives.
- Indicators and variables need to be defined by objectives and the appropriate geographical, temporal, biological scales. Measuring the same indicators in the same way is essential when data are to be combined from different areas, agencies, or times to provide replicability. Interpretation of indicators, indexes or statistics calculated from monitoring data from different areas, however, cannot be standardized.
- Monitoring protocols need to be standardized to allow comparison among locations, times, or programs (consistent with design needs).
- Procedures need to be developed to ensure quality assurance and quality control of all data used to monitor salmonid recovery and recovery actions.
- Data management systems need to allow easy access, sharing, and coordination among different collectors and users.
- Funding needs to be stable and adequate. Cost of monitoring will depend on the degree to which decision-makers wish to be certain that management actions are having an anticipated response.
- Decision support systems need to help integrate monitoring information into decision-making.

Based on our review, we believe that to provide a scientifically sound adaptive management framework, existing programs either need to be: (1) significantly changed, linked, and coordinated with new program elements to achieve a comprehensive monitoring program, or (2) a new program must be developed that adequately treats recovery as an experiment. Both of these will require increased and stable levels of funding and policy commitments.

Introduction

The goal of Washington's recovery efforts is to recover healthy and harvestable salmonid populations and to improve the habitats on which fish rely. The balance of science, effective use of resources, and policy decisions that will recover salmonids depends on scientifically valid monitoring to measure success and reduce uncertainty. The Washington State legislature found

> *"…it is important to monitor the overall health of the salmon resource to determine if recovery efforts are providing expected returns. It is important to monitor salmon habitat projects and salmon recovery activities to determine their effectiveness in order to secure federal acceptance of the state's approach to salmon recovery."*[a]

The Washington legislature established the Independent Science Panel (ISP) in 1998, with duties further delineated by the legislature in 1999[b]. Governor Locke appointed members in May 1999. The ISP is charged with providing scientific review and oversight, and assurance that science guides the state's salmonid recovery efforts. Products requested by the legislature include a report on monitoring for delivery in December of 2000 to include recommendations on:

- standardized monitoring indicators and data quality guidelines for use by entities involved in habitat projects and salmon recovery activities across the state,
- criteria for the systematic and periodic evaluation of monitoring data in order for the state to be able to answer critical questions about the effectiveness of the state's salmon recovery efforts,
- the level of effort needed to sustain monitoring of salmon projects and other recovery efforts, and
- any other recommendations on monitoring deemed important by the panel.

In an earlier technical memorandum (ISP 2000a) we noted that "*Monitoring is the fulcrum for salmonid recovery*" and "*a key element*" in all aspects of the state's recovery program. We stated that

> "*Monitoring provides accountability and learning. Monitoring is necessary to determine whether projects were implemented, whether they were effective, and whether the scientific relationships upon which the expected benefits were based were appropriate.*"

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[a] Second Engrossed Substitute Senate Bill 5595 (Section 10).
[b]The Independent Science Panel was formed by Engrossed Substitute House bill 2496, with duties further defined in Second Engrossed Substitute Senate Bill 5595 (Section 10).

In ISP (2000a), we identified the scientific and institutional issues that are important in the design and implementation of salmonid monitoring plans and activities. We made similar points in our review (ISP 2000b) of the *"Statewide Strategy to Recover Salmon: Extinction is Not an Option"* (JNRC 1999). We now expand on these points by identifying the elements we believe must be included in scientifically based monitoring programs that can provide information for decision making. We also discuss options available to incorporate such elements into a statewide monitoring program.

Many entities with different jurisdictions, such as the National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), tribes, counties, and cities, are involved in salmonid recovery and monitoring. Although specific elements and approaches used in monitoring salmonid recovery may vary by entity and jurisdiction, the overall goals and objectives must be consistent and complementary. In addition, linkages between such programs must facilitate data sharing and information exchange to maximize what can be learned from these efforts in a scientifically rigorous and efficient manner.

This document provides our recommendations for the foundation of a comprehensive monitoring program in Washington. We did not set out to produce a guidebook on monitoring. Detailed examples of technical frameworks for monitoring exist (e.g., MacDonald et al., 1991; McCullough and Espinoza 1996) and others are in preparation. As we noted in ISP (2000b) the monitoring section of the *"Statewide Strategy to Recover Salmon: Extinction is Not an Option"* outlines many of the important considerations in a monitoring program. Our objective in this report was to identify the necessary elements for a scientifically credible statewide monitoring program directed at tracking the success or failure of efforts to restore healthy and productive salmonid stocks in Washington and to review several options for its development.

This report has four major parts. First, we briefly review the general **scientific issues** involved in monitoring in natural systems; we describe some **existing efforts** (listed in Appendix A); and we discuss how monitoring should **change** in response to threatened and endangered species listings under the ESA. Second, we identify and briefly describe the **necessary elements** for a scientifically credible monitoring program in the context of an adaptive management framework. Third, we briefly discuss three potential **options** for developing a monitoring program and how they may or may not provide these necessary elements. Finally, we **recommend directions** that should be considered in developing a statewide monitoring program. We also include a list of technical references to assist those seeking additional information on monitoring, along with references we cited in this report.

Monitoring for Recovery in Natural Systems

Ecological systems present a number of challenges: they are exceedingly complex; we did not build them; we do not have their plans; and we do not know exactly how they work. Obviously, it is easier to understand engineered systems than natural systems complicated by unknown forces and interactions, as well as by lags in time and space between cause, effect, and recovery. Yet, managers will need to decide how to proceed even though they cannot fully forecast their ultimate impacts on ecological systems. **Adaptive management**[1] based on monitoring is the foundation for reducing uncertainty in managing ecological systems.

Monitoring Provides Accountability

Reducing uncertainty about whether management decisions were implemented, whether management objectives in trend and status of fish and their habitats are being achieved, and whether the management actions that were taken really explain the changes, provides accountability. One role of science is to determine cause and effect relationships. Monitoring, when integrated into a properly designed and statistically valid experimental designs, can be used to define such relationships and weed out inefficient management actions and waste. This can increase public confidence for political and scientific efforts to recover salmonids; failure to provide accountability can undermine these efforts.

The public is interested in implementing on-the-ground actions to benefit salmonids. This interest, if it becomes a priority, can overshadow attention to up-front design and implementation of comprehensive monitoring programs that can give useful information. For example, despite the nearly 20 years of effort and many millions of dollars expended in the Columbia River on salmonid recovery, the development, implementation, and funding of a comprehensive program to evaluate the results of the Columbia River Fish and Wildlife Program is lacking (ISG 2000). Without comprehensive monitoring, it is difficult to show that limited fiscal resources are well spent.

Monitoring Reduces Uncertainty

Natural resource monitoring is the deliberate and systematic counting or measurement of environmental conditions, organisms, and human actions that affect our natural resources. The principal purpose of monitoring is to help make environmental decisions by reducing uncertainty. This involves three different kinds of scientific objectives and three different kinds of monitoring:

- Confirming that management decisions were *implemented (implementation monitoring*);
- Making accurate status assessments of the resource to determine whether the management objectives are being achieved (*effectiveness monito*ring); and
- Confirming that management actions have the desired result through improved understanding of how the populations and ecosystems function (*validation monitoring*).

Four major sources of scientific uncertainty that generally confound evaluations and decisions in natural resource management. A scientifically credible monitoring program of implementation, effectiveness, and validation monitoring will need to address the four major sources of uncertainty. The four sources of uncertainty are: (1) framing uncertainty, (2) stochasticity, (3) measurement uncertainty, and (4) model uncertainty (Schrader–Frechette 1995; Lein 1997). Institutional uncertainty affects how the decisions are implemented. *Framing uncertainty*[2] recognizes that how a question is asked often determines what the answer will look like. *Stochasticity*[3] refers to the unpredictable or random variation that occurs in natural systems over time and space that limits our ability to make precise measurements or assess causality. *Measurement error*,[4] in contrast, arises from our inability to measure or record qualities or conditions of the environment exactly. *Model uncertainty*[5] refers to our inability to use mathematical models to completely represent reality. This is uncertainty that arises from ignorance of how natural systems actually function. *Institutional uncertainty* arises from uncertainty associated with budgets, changes in political leadership, conflicting institutional objectives and mandates, and lack of appropriate training or equipment.

Comprehensive Monitoring Addresses Multiple Objectives Over Different Scales

A major challenge to designing comprehensive monitoring programs is that monitoring often has multiple objectives that encompass different geographical and temporal scales (Ringold et al. 1996). The challenge is both scientific and institutional. Information gathered from monitoring, for example, may be needed for making decisions about activities in individual reaches of a stream, in watersheds, and at larger geographic units, such as regions or ranges of evolutionarily significant units (ESUs). Each of these represents a different geographical scale with different natural characteristics. Consequently, measurements of natural characteristics made at one scale can be difficult to translate to natural characteristics at another scale and may produce misleading results (Weins 1981). To further complicate matters, different resource agencies with different frames of reference may have different responsibilities for measuring the physical, chemical, or biological attributes that characterize what is happening at different scales.

Identifying the correct scale to measure and interpret responses is critical for monitoring. For monitoring to be successful it must measure the correct attributes at the appropriate times in the appropriate places. In addition, monitoring depends on identifying the appropriate aggregations of fish to track, which may range from groups that temporarily share common habitats, to populations or groups of populations, such as subspecies or ESUs.[6] The factors that affect species and their habitats occur over different scales of time, space, and evolutionary diversity. Over large geographical areas and long time periods, for example, climate, geology, vegetation, and species distributions determine watershed characteristics and population structure of a species. At smaller geographical scales and shorter time periods, organic debris, competition and predation, and within-population genetic diversity control stream characteristics and population persistence. Monitoring changes in fish distribution and stream characteristics in a small stream, for example, means that a lot of what is happening will be driven by external phenomena outside the stream, which are unmeasured. In contrast, monitoring at a much broader level will identify the differences in climate, geology, or land cover that affect regional trends in abundance or fish distribution but it may be difficult to adequately document stream-specific effects.

Inferences From Monitoring Rely on Sampling and Modeling

Different objectives and uncertainties often lead to two different approaches to monitoring ecological systems. One approach emphasizes sampling designs focused on testing specific null hypotheses to draw inferences. The other approach is more synthetic and uses formal descriptions of how systems work (models) developed from selected well-studied areas (that are important for attaining the objectives). Each of these approaches has different advantages and disadvantages.[7] The sampling-based approach derives its strength from the sampling design and statistical analysis. The better the design and analysis, the more certain the conclusions are likely to be. In contrast, diagnostic or model-based approaches are descriptions of how organisms respond to changes in their environment that are constructed from detailed studies of ecological processes in a few key areas or selected sites. Because this approach can specifically capture the management decisions as alternatives in the model and uncertainty affecting decisions or outcomes (Ellison 1996), the diagnostic approach can be especially useful when maximizing the certainty associated with management decisions becomes a main objective of monitoring.

The two approaches can be complementary. The model-based approach lets managers ask "What if..." questions that can focus sampling-design based monitoring on estimating probability of an event related to a set of proposed management choices. Management and monitoring can be focused in the areas that are most likely to reduce uncertainty. Sampling design based monitoring, in turn, provides information to update the model and make its results more generally applicable. A combined approach fits well with adaptive management, because it allows scientists to integrate data across disciplines, consider all possible sources of uncertainty, and prioritize sampling designs for large monitoring programs.

Monitoring Under ESA Has A Special Focus

Monitoring programs for detecting trends, ensuring compliance, testing hypotheses, and evaluating project effectiveness have been widely applied. These range from large scale monitoring programs, such as those proposed for the San Francisco Bay and San Joaquin River systems (CALFED 1999), to much smaller, focused monitoring that often accompanies specific actions such as biological monitoring below hydroelectric projects, or compliance monitoring associated with construction activities. Although such programs may include species that are currently listed under the ESA, it is important to recognize that monitoring targeted specifically to address ESA differs in its intent and overall scope.

The purpose of monitoring under ESA is to determine when listed ESUs or distinct population segments (DPSs) have sufficiently recovered to no longer warrant ESA protection ("delisting") and to provide data to assess the status of additional species. The NMFS and the USFWS, which are the federal agencies responsible for administering the ESA, have yet to develop clearly articulated monitoring guidelines for recovery of salmon, trout, and char populations. Two NMFS documents, "*Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units*" (McElhany et al. 2000), and "*Recovery Planning Guidance for Technical Recovery Teams*" (NMFS 2000) and the USFWS's "*Bull Trout Interim Conservation Guidance*" (USFWS 1998) provide some indication, however, of what monitoring for recovery under ESA might mean to those agencies.

Different regions of Washington contain different ESUs and DPSs. Although these are the most important scales for ESA considerations, most monitoring will be focused at the scale of populations. A species can be delisted only when it is no longer threatened or endangered in "all or a significant portion of its range" (McElhany et al. 2000), which implies that when an ESU or DPS consists of different populations, the populations will be an appropriate scale for monitoring. Federal recovery teams will identify these salmonid populations, which may or may not be different from existing population delineations or sampling units used in current monitoring programs. In NMFS's Technical Recovery Team processes, monitoring at the population level will be focused on attributes that describe four characteristics of viable salmonid populations: (1) abundance and productivity; (2) status and trends; (3) spatial distribution; and (4) diversity (McElhany et al. 2000; NMFS 2000).

Currently, monitoring emphasis under the ESA focuses primarily on salmonids and their population characteristics – there is generally no comprehensive habitat monitoring counterpart at this time. Although NMFS recognizes that "restoration of freshwater habitat is expected to be an important factor in the recovery of most ESUs" (NMFS 2000), the agency has described no unifying approach for characterizing habitat that can guide monitoring has been expressed, as it has for viable salmonid populations

Components for Monitoring Exist But Are Not Coordinated

The majority of the monitoring programs in the state of which we are aware exist for reasons other than monitoring salmonid recovery. Based on our cursory review of some of the major monitoring programs in the state for which information was readily accessible however, it is clear that many focus on aspects of natural resource monitoring relevant to salmonids (Appendix A). These programs track certain key indicators for which a specific agency has jurisdiction. For example, the Department of Ecology (DOE) administers monitoring programs that among other things collect monthly water quality data for rivers and streams throughout the state. The focus is to determine if water bodies are in compliance with state water quality standards. The Washington Department of Fish and Wildlife (WDFW) has a number of monitoring programs that directly relate to salmonid abundance in Washington's streams and rivers. In joint effort between WDFW and the tribes, the Salmonid Stock Inventory (SaSI) program has been ongoing for almost 10 years (WDF et al. 1993; WDFW 1998, 2000) and is focused on providing regular assessments of the status of the state's salmon, steelhead, trout, and char species. In another example, the WDFW, the tribes, and other state and federal agencies on the Pacific Coast have developed a comprehensive coded-wire tag program to understand salmon abundance and trends.

We are aware that other entities not under the sole or direct authority of the State of Washington have ongoing monitoring programs. These include, as examples, monitoring under the Forests and Fish Agreement, Timber Fish and Wildlife at the Northwest Indian Fisheries Commission, federal land management agencies under the Northwest Forest Plan, U.S. Geological Survey, fish health monitoring by the tribes, federal, and state pathologists, local governments, and others. Our review was unable to discern, however, the extent to which these monitoring programs or data from them are currently linked or coordinated across institutional, spatial, and temporal boundaries. Such coordination appears pivotal to the development and implementation of an effective, comprehensive statewide monitoring program.

Necessary Elements of a Statewide Monitoring Program for Salmonid Recovery

It is fundamentally important in large scale efforts to recover salmonids to recognize the possibility of surprises caused by uncertainty and to correct avoidable mistakes (Lee 1993). The legislature and state agencies have adopted adaptive management, which we believe is the best available management paradigm to integrate science and policy in salmonid recovery efforts. Adaptive management places fundamental importance on monitoring programs. Thus, each of the elements we describe below should be viewed within an adaptive management framework that address the fundamental sources of uncertainty by integrating the different kinds of monitoring and preserving the ability for changes to be made in the monitoring program. Table 1 shows how these pieces fit together.

Monitoring in the context of adaptive management must include tracking of trends in characteristics of salmonid populations and obtaining information about what caused observed changes. A necessary step in developing a credible statewide program is therefore to specify the distribution, abundance, productivity, and groups of fish needed to exceed the viability threshold of an ESU or DPS and to sustain harvest. A population will comprise several subpopulations[6] in watersheds that are each influenced somewhat differently by factors such as the biotic community, temperature, flow, geomorphology, and geochemistry at that location. The number, distribution, and diversity of fish must be monitored to ensure that the characteristics of healthy, viable populations are protected and restored and to determine that increases are indeed occurring and are the result of program actions. Demonstrating that the viability of salmonid populations has been restored requires information about population structures,[6] abundance, trends in the growth of populations in different habitats, and life history diversity. These data represent the endpoints for ESA recovery and therefore are critical to a statewide monitoring program.

Table 1. Relationship between objectives for monitoring, type of monitoring, uncertainties that monitoring addresses, and the relevant necessary elements of a monitoring program.

Purpose of monitoring	Type of monitoring (type of indicator)	Uncertainties addressed	Relevant necessary elements of monitoring program
Validate that management decisions were implemented	Implementation (Compliance indicators)	Institutional uncertainty	Adequate funding & resources Analysis and integration into decision making
Make status assessments of the resource to determine whether management objectives were achieved	Effectiveness (Status Indicators & Early Warning Indicators)	Framing uncertainty	Clearly articulated goals and objectives
		Measurement error	Appropriate indicators Data quality and assurance Standardized monitoring protocols Analysis and integration into decision making
		Stochasticity	Appropriate statistical design
Improve understanding of how populations and ecosystems function	Validation (Diagnostic indicators)	Model error & Framing Uncertainty	Appropriate model design Analysis and integration into decision making

Necessary Elements

Scientifically credible monitoring programs in an adaptive management context should express the following eight characteristics. Elements 3, 4, and 6 address issues specifically identified by the legislature.

1. Successful monitoring is predicated on a set of clearly articulated goals, objectives, or questions that need to be addressed,
2. The statistical designs are appropriate,
3. Indicators and variables are based on needs defined by objectives and the appropriate geographical, temporal, biological scales,
4. Monitoring protocols are standardized to allow comparison among locations, times, or programs,
5. Programs are in place for quality assurance and quality control of the data (QA/QC),
6. Data are managed to allow easy access and coordination among different collectors and users,
7. Funding is stable and adequate to allow planning and implementation of sustained long-term efforts, and
8. The information is analyzed and integrated into decision-making. We describe these in more detail below.

1. Identify Goals and Objectives

The goal of Washington's recovery efforts is to restore the salmon, steelhead, and trout populations to healthy and harvestable levels and to improve the habitats on which fish rely. These are the fundamental goals toward which the state will have to track progress. Additional goals and objectives for monitoring need to be identified and structured hierarchically, based on evolutionarily similar groups of populations and aquatic communities, geography, and time. Hence, **the most important step in developing a credible salmonid recovery monitoring program is to specify the hierarchy of objectives and related key questions for distribution, abundance, productivity, and diversity of populations needed to ensure the viability of ESUs and to sustain harvest.** To monitor progress, these goals need to be broken down *into performance objectives* and *means objectives*.[8] To describe means objectives, which are the actions in habitat, hatchery reform, and harvest reform that are the means to reach a certain performance objective, it is necessary to know the current conditions relative to the objectives.

2. Choose Appropriate Statistical Designs and Models

A comprehensive salmonid recovery monitoring program should incorporate both sampling-design and modeling-based approaches over appropriate periods of time. Sampling-design based approaches should be used for implementation monitoring and effectiveness monitoring to assess status and trends. Modeling-based approaches are necessary to understand the driving forces (e.g., habitat changes, harvest, hatchery production, and extrinsic influences such as climate variability), link monitoring to decision-making, and prioritize sampling-design based monitoring.

Duration—Adaptive management is a long-term strategy for natural resource policy based on the assumption that policy makers, scientists, and the public want better certainty. As long as this is true, monitoring must continue. Practically, we do not foresee a point in time when monitoring will not be necessary, for two reasons. First, recovery of natural functions in streams and riparian areas that can support viable populations of salmonids may take 50-100 years. Detecting statistically reliable trends in salmonid populations can also take a long time, especially if the management change that is being compared is relatively small. Second, the inherent surprises and uncertainty associated with nature and the need to take corrective action in natural resource management will not disappear when salmonids are no longer listed under the ESA and are being harvested. As policy makers and scientists learn what works in some areas and what does not, priorities for monitoring are likely to shift but not diminish.

Sampling-Design Based Monitoring—Because the recovery program operates at ESU, DPS, regional, metapopulation (a group of interacting subpopulations), basin, watershed, stream, and stream-reach/site scales, it will take a significant amount of planning and continuing analysis to ensure that recovery actions are effective and monitoring information is being used adaptively to learn from mistakes and successes. Hypotheses developed for recovery of populations will show need for action in one or more of the factors for decline of salmonids. Once these actions are identified and implemented, monitoring is needed to determine whether the intended results are produced.

The only way to avoid having to monitor everything, everywhere, is to have strong statistical designs. This applies to all three kinds of monitoring: implementation monitoring, effectiveness monitoring, and validation monitoring. Strong statistical designs require careful planning. Statisticians must be involved early in the formal development of the monitoring program to adequately address statistical issues of sampling, accuracy and precision of the data, replication, and controls. Decisions evolving from monitoring programs must rely on data that are statistically unbiased (or where biases are known and understood in interpretation of analyses), and that reflect results that are representative of biological responses that have occurred due to policy and management actions.

When attempting to determine cause and effect relationships (validation monitoring), monitoring in areas other than where the management action is actually being implemented is essential to the overall success of the program. Replicating experiments and controlling for unwanted sources of variation in ecological systems can be extremely difficult. A variety of designs are possible, such as reference and treatment, before-after and upstream-downstream comparisons, replication of time for space, time for time, and staged implementation of different management actions. Walters et al. (1988), Underwood (1994, 1996), and Conquest and Ralph (1998) provide good discussions of potential statistical designs. Each design, however, involves a commitment to monitor in the reference areas as well as the treatment areas.

Modeling Based Monitoring – Modeling based monitoring focuses on understanding the phenomena that are causing the changes in characteristics of healthy salmonid populations. Monitoring of driving forces is necessary to determine whether observed changes are in response to the recovery program and not just in response to changing climatic or marine conditions.

Assessment and interpretation of monitoring data will require a synthetic, diagnostic approach based on integrating a variety of complementary indicators (and perhaps interpreting conflicting signals from them) into a model. No single approach will apply in all watersheds, although similar watersheds may share similar approaches. Likewise, no single indicator can be used to consistently imply the same things in all watersheds. This kind of diagnostic monitoring program needs to be "place based" and integrated with the sampling-based statistical design, as both the physical habitat and the interface with life history stages of different salmonids will vary geographically.

Monitoring of the driving forces that influence salmonid abundance will require a systematic approach involving several steps. "Watershed assessments" to evaluate what is possible at site, watershed, or regional scales can be achieved through a variety of systematic approaches to identify the factors influencing the structure and dynamics of a watershed and provide a basis for assessing what changes are needed to halt disruption that is deleterious to salmonids. Once the factors shaping the physical environment are identified, the systematic use of models can help to compare the outcomes of alternative scenarios, examine uncertainty and statistical confidence, and provide transparency to the public. Ideally, quantitative models of likely benefits for fish population distribution, abundance, and productivity can project the anticipated results expected from habitat improvements or other measures. Using qualitative predictions, indicators, or indexes can help, as long as they are based on formal models describing their linkage to fish distribution, abundance, and productivity, and incorporate critical expert review of existing information and "best estimates." Monitoring elements needed to assess the success of habitat improvements include an initial survey to determine present (baseline) conditions at locations in the statistical design, and subsequent monitoring to determine whether the program is closing on the objectives.

3. Identify Variables and Indicators

Choice of variables and indicators depends on objectives, related questions and hypotheses, and statistical design needs. Monitoring programs typically involve the collection of data that collectively represent a suite of variables or "indicators" that can be used to evaluate the response(s) of either the target organism or other feature of the system to specific actions. Some indicators are "better" than others for given circumstances. The type of monitoring and the monitoring questions addressed, will influence the type of indicator needed.

Three different kinds of indicators will be important in a comprehensive statewide monitoring program (Table 1). These include: (1) *compliance indicators,* which address compliance and implementation of management decisions, (2*) status and early trend* *indicators*, which can be attributes of population and habitat status and also indicators that can also be used to detect deterioration or improvement before there is substantial impact, and (3) *diagnostic indicators*, which can be used to understand causal relationships and reasons for noncompliance or success.

Characteristics of Good Indicators—For each of these three kinds of indicators, ideal indicators should be: (1) *relevant* to the environmental, institutional or biotic endpoint; (2) *applicable* to the landscape, population, and temporal hierarchy; (3) *responsive* to human activities; and (4) reliably and efficiently *measurable*.

Relevance to an endpoint simply means that the indicator measures an attribute that actually occurs at the right time and place. Specific indicators for salmonid recovery should be selected and measured at the appropriate hierarchical scale (e.g., reach, stream, river, basin) to answer the question being asked.[9] The indicators need to be based on appropriate measurement scale,[10] with an understanding that using a lower scale generally limits the statistical flexibility in analyzing the data. Choice of the appropriate measurement and hierarchical scales allows data to be integrated from diverse sources and different levels. It also allows indicators to retain their predictive power over a wide range of conditions. Responsiveness to human actions means that those indicators that directly influence changes in population or habitat characteristics as a result of management actions are more useful than those that are highly correlated with the factor of interest but that do not cause the change. Indicators that have a fast response time are particularly useful, if they also satisfy the above criteria, because management policy can be informed in the quickest time frame possible. That means that errors can be corrected quickly and that mistakes will be less costly. Reliability means the indicators can be measured precisely and are repeatable.

Standardization of Indicators—Based on our review, we concluded that no single set of indicators is likely to fulfill all the objectives for monitoring the effectiveness of salmonid recovery actions. It is important, however, that **indicators or variables that will be aggregated across different scales of the hierarchy for analysis need to be standardized across the lowest possible hierarchical scales.** Standardized indicators are needed to contribute to replicability and the ability to analyze patterns across different scales, such as among watersheds or over time.

Many monitoring projects implicitly assume that a few characteristics or indicators will be applicable over a wide geographic area, and have minimal spatial or temporal variability. **We concluded that most monitoring requires a suite of indicators, including standardized indicators and scale-specific indicators.** These latter indicators will be needed to address watershed-specific problems.

Standardization of Interpretation—It is important to distinguish between standardized indicators (i.e., measuring the same attribute) and standardized interpretation, where some level, index, or calculated statistic of indicators implies a certain population status, ecological condition, or degree of implementation. **We concluded that the interpretation of monitoring information should not be standardized due to**

inherent differences in ecological, biological, and institution factors in different areas. Any one indicator, or even a set of indicators can mean potentially different things according to the location in the channel network, channel type, population structure and history, and disturbance history. Sorting through and interpreting the different indicators can be complex and difficult. Assessments must begin with an understanding of the dominant processes that are operating in the stream channel, watershed, and aquatic community and consider the likely temporal variability in these processes.

4. Standardize Monitoring/Sampling Protocols

Replicability is essential to the scientific process. Standardized sampling and survey protocols are essential to ensure replicability and reduce measurement error. Sampling and survey protocols describe data collection methods/protocols to be followed when collecting different data types (e.g., redd counts, juvenile trapping, habitat surveys, water quality sampling). Sampling efforts for indicators that are intended to be aggregated across different hierarchical scales for analysis need to be standardized. Use of differing sampling methods and protocols oftentimes severely limits the utility of the data collected, and the ability to generalize from the results. Thus**, for the broadest applicability, sampling protocols should be standardized across the lowest possible hierarchical scales.**

5. Assure Quality of Data

Monitoring programs generate useful information if the data are valid. That is, the data have been collected and compiled in accordance with quality control (QC) protocols that serve to ensure data integrity and validity. Data validation is a process by which data are accepted or rejected based on a set of criteria that are either rigorously defined, as in the example of analytical chemistry, or verification of adherence to established QC procedures. The process of data validation is especially important if the resulting data sets are to be shared and relied upon by multiple users that may represent widely different interests. The data quality control component of the statewide monitoring program should include a number of elements including:

- Program Organization – describes overall reporting relationships and responsibilities regarding data acquisition and management, data flow, and database management;
- Quality Assurance (QA) Objectives for Measurement Data – lists objectives for data collection and defines characteristics for the assessment of generated data, including accuracy, precision, completeness, representativeness, and comparability;
- Data Transfer Protocols – describes procedures for data transfer from the field, laboratory etc. into the office/project files; ensures traceability and control of project information and data from its origin to final use in meeting monitoring objectives;

- Calibration and Preventative Maintenance Procedures and Frequency – to ensure that field and laboratory equipment used in the collection and analysis of data are maintained in accordance with manufacturers specifications;
- Data Reduction, Validation, and Reporting – defines process/steps to be followed that will ultimately render the data collected under the program as valid or invalid;
- Quality Assurance Audits and Corrective Actions – periodic audits of the overall program or portions of the program are important for documenting that data collection has been completed in accordance with specified methodologies.

6. Coordinate and Manage Data to Provide Access

Many organizations are involved with monitoring related to salmonid recovery (e.g., Appendix A). Making data readily available to other agencies, scientists, and the public will help to guarantee the credibility of the adaptive management process in salmonid recovery. Recent advances in information technology should be useful in overcoming the logistical constraints that once made this difficult.

Cooperation and awareness by agencies and organizations involved in monitoring of similar efforts should lead to more complete databases. As each agency or organization has its own monitoring objectives, compatibility of sampling designs, protocols, sampling scales, sampling intervals, and metrics should be examined. Sufficient calibration should be encouraged to standardize data and data quality and reduce redundancy and inefficiencies without compromising each agency's mission.

7. Provide Adequate Funding

Monitoring can be extremely expensive. However, coordination and collaborative partnerships can lead to efficiencies and cost savings. The hesitancy of funding entities to commit large amounts of money over a sustained period of time for often-undefined purposes is understandable. All too often, monitoring programs have been developed and implemented with no clear objectives in mind, leading to an endpoint where a substantial amount of data have been collected but no analysis performed or decisions made based on the data. A key in the development of successful monitoring programs is therefore to clearly identify the overall objectives of the program(s) and to select indicators that will provide the most expedient, direct, and cost-effective feedback relative to attainment of those objectives.

The total annual cost of a scientifically credible program to meet the monitoring needs identified for fish abundance and distribution, harvest management, habitat improvement, and to fulfill the promise of adaptive management can be expected to be greater than past expenditures. We did not try to estimate what this increase might be, but **we did conclude that at any potential level of increase, stable funding is more important to success than the absolute amount.** Cost will depend on a number of factors, including the ability of existing institutions to find efficiencies in coordinating their efforts and the importance that decision-makers place on risks of uncertainty and accountability to the public. If decision-makers desire to be 95 percent confident in evaluating salmonid recovery efforts within 5 years, for example, the annual cost is likely to be greater than a less demanding level, such as 70 percent confidence within 10 years. Reasons for these difficulties result from the highly variable nature of salmonid populations and other environmental attributes from year-to-year, and from place-to-place. Attempting to define expected levels of certainty based on existing data is a necessary step in deciding whether to commit limited resources.

8. Analyze and Integrate Data into Decision Making

For monitoring to work, data need to be analyzed and the results must be incorporated into decision-making. This requires two different kinds of analyses: (1) analyses of data for patterns, trends, and cause and effect, and (2) analyses of decisions. In our review of the Statewide Strategy to Recover Salmon (ISP 2000b), we described the relationship between the *biologically possible* and *socially attainable* as intersecting circles with the area of overlapped being what is *potentially sustainable*. Mathematicians often use this kind of conceptual diagram to illustrate the likelihood or probability of different conditions. A rich body of theory shows how to calculate the probabilities of where different conditions intersect. Conceptually, monitoring describes what is biologically possible. From monitoring, scientists can estimate the probability of different biological conditions, such as changes in fish habitat, abundance and productivity. In contrast, the art of the attainable has usually been relegated to politics. To be able to estimate what is sustainable, however, requires similar quantitative processes for estimating what is socially, economically, and culturally attainable under different conditions. Decision analysis provides a variety of tools for this purpose. To our knowledge, this has not been a regular part of salmonid management. Without such it, it is not possible to provide scientifically credible estimates for what is sustainable.

Design, analysis, and interpretation of monitoring data require a relatively high level of insight and expertise, regardless of the scale. There is no easy way around the conclusion that a monitoring program will require the efforts and supervision of trained scientists. At smaller scales however, measurements can be simpler and use less expertise, such as trained volunteers, as long as it is within the scope of a larger overall program

Options to Provide Necessary Elements for Monitoring

Although it is widely assumed that monitoring will need to be increased and improved for successful salmonid recovery programs (JNRC 1999), the State of Washington and its federal, tribal, and local partners in salmonid recovery have yet to express a comprehensive analysis of what is desirable, available, and needed for monitoring. At least three approaches are possible: (1) **status quo**, (2) a **revised** approach that uses and adds to existing programs but provides much better coordination and integration, or (3) a **new**, comprehensive approach specifically designed to monitor salmonid recovery as a large experiment, or inter-related set of experiments. Briefly, the *status quo* approach would allow agencies and local partners to continue ongoing monitoring of the aspects of salmonid ecosystems for which they are responsible or have an interest, without major changes. Alternatively, existing programs could be used as a basis for a *revised* and integrated, combined approach. This would fill-in the gaps in goals and objectives, design, data collection, and analysis that are missing from existing programs so that they address key salmonid recovery monitoring objectives and questions at appropriate scales. The *new,* comprehensive approach would require a more centralized effort that would identify common monitoring goals, objectives, and questions, and design sampling and data collection efforts to address the key goals at appropriate scales. The new, comprehensive approach would design monitoring efforts as part of a single large experiment with subsets of smaller experiments rigorously nested within the overall framework. Each of these three approaches has advantages and disadvantages. The status quo and new, comprehensive approaches form opposite ends of the spectrum. Advantages and disadvantages are summarized in Table 2.

1. Use Existing Programs (Status Quo)

Based on our review, continuing existing programs without change will not provide a scientifically defensible monitoring program for salmonid recovery. Although many monitoring programs provide specific, useful information to different agencies and groups, existing programs lack the necessary elements (Table 2) for scientifically rigorous adaptive management programs. However, programs are now in development that may do so in the future (e.g., the adaptive management component of the Forests and Fish Agreement).

2. Revise Existing Programs to Achieve Interagency and Regional Coordination

Many programs already measure attributes of salmonid populations and habitats that are related to monitoring for recovery. As noted earlier, however, the objectives and design of these programs do not necessarily address the particular issues that are important to salmonid recovery and viewed collectively, they lack the necessary cohesive structure to form a comprehensive monitoring program. It is possible, however, that existing programs could be modified or supplemented to make progress toward a comprehensive monitoring program.

Compared to initiating anew, comprehensive monitoring program specifically designed for salmonid recovery (see below), this option may create efficiencies by capitalizing on existing sources of funding, reducing or eliminating redundant monitoring programs, and allowing more efficient exchange of information. If successful, it could also produce more reliable information for making policy decisions about salmonid recovery, and provide supporting evidence to federal ESA authorities that programs are addressing ESA needs. This option would be considerably more expensive than status quo, however. Modifying, supplementing, and coordinating existing programs would increase administrative costs associated with developing common goals and objectives, statistical design development, testing or adding new indicators, bolstering analytical capacity, establishing data quality and data control systems, and establishing data management

Table 2. Comparison of the advantages (+) and disadvantages (-) of two approaches for monitoring salmonid recovery.

Key Elements	Approaches			
	Status quo		New, Comprehensive	
	+	-	+	-
Goals, objectives, and key questions	Cost savings, existing info & expertise	Unclear goals in existing programs, different objectives and legal mandates, not well linked to salmonid or ESA objectives	Highly defined; linked to salmonids; maximize critical information relative to cost; goals linked to uncertainties and policy needs; apparent expertise where needed & coordinated	May be redundant with some existing goals.
Indicators & protocols	May have data from existing indicators; easier to attain	Value of existing indicators unknown; some indicators too specific to expand to other analyses; not standardized	Values known, validated; standardized protocols, non-standardized interpretation; generalist and sensitive/stable	May be redundant with some existing programs.
QA/QC	Some programs exist - stability	Data variable; inconsistent validation and error checking; data may not be acceptable to all parties	High quality, valid data collected and managed using standard protocols	Increased cost of checking, standardizing, and sharing the data.
Statistical design	Existing designs may be good/useful (unknown); some highly specialized, but unlinked or integrated (habitat-fish)	Data sampling (time/space) not appropriate	Effort/sampling appropriate to address sources of error and provide statistical power	Increased cost of design, probabilistic data collection.
Data management	System stability/known	Non-compiled; no metadata, access different/difficult	Manipulatable data structure; metadatabases exist and are accessible; access is centralized; completely compiled and geo-referenced	May be expensive to establish, but once established could be less expensive than current system.
Analysis	Specialized analyses for certain problems and mandates	Specialized analyses are limited; level of integrated analysis limited	Independent analysis; oriented at salmonid problem	None
Integration into decision-making	Some decision-making systems; some may relate to salmonids	Mandate-dependent; may not link directly to salmonids; risks/benefit analysis frameworks not clear or clearly documented	Well documented; conflicts understood and controlled; benefits to salmonids maximized given conflicts; and risks reduced	Uncertainty about complexity of needed change (institutional, legal, technical); costs.

systems, at least initially. In addition, new monitoring programs may need to be added to fill key gaps, such as estuaries and near shore habitats, about which we know very little but which are very important for recovery of anadromous salmonids.

3. Develop New, Comprehensive Approach

Scientifically, the most effective option would be to develop a new, comprehensive strategy using large policy/management changes designed as large experiments with subsets of smaller experiments rigorously nested within the overall framework. This approach would not exclude existing monitoring programs and activities if they were consistent with the new approach. It would require policy guidance and the participation of multidisciplinary technical personnel versed in strategic applied research. The approach could generate formal working partnerships between state and federal agencies, academic institutions, and others to support the wide range of monitoring design and analysis needs in watersheds and regions across the state. An alternative implementation concept is the formation of an independent salmonid monitoring science center. The focus and integration these alternatives offer would provide the greatest opportunity for independence and accountability, as well as stability, and standardization necessary for long-term effectiveness and validation monitoringprograms and projects in the state.

Implementation alternatives for this option would require the political commitment to pursue management changes as experiments and to provide new, long term, and stable funding. Although the approach has the potential to be the most independent and consolidated, it is also likely to be expensive. It would require substantial new financial support to complement existing monitoring programs. However, without a detailed cost analysis, it is not clear whether these costs would exceed the administrative costs associated revising existing monitoring programs (option 2).

Recommendations and Conclusions

Washington needs a credible monitoring program to track progress toward its goal to restore salmonid populations to healthy and harvestable levels. The program must help answer the following questions:

1. Were management decisions, guidelines, programs, and restoration projects implemented?

Implementation monitoring should be a priority for both individual habitat restoration projects and for statewide programs. Standards for implementation monitoring should be part of all hatchery, harvest, and habitat projects and programs. Project-level and program-level implementation monitoring could be funded and managed through new and existing processes, including Salmon Recovery Funding Board and Salmon Recovery Scorecard (JNRC 2000) processes. Whether habitat projects were built as designed and how they needed to be modified to accommodate site conditions revealed during construction are important to know for ensuring accountability and facilitating improvements in the future.

2. Are the status and trends of populations and habitat characteristics achieving desired performance objectives?

Effectiveness monitoring addresses this question. Effectiveness monitoring for statewide salmonid recovery efforts should consist of science-based, issue-driven assessments of habitat protection and restoration projects and programs, hatchery management protocols, harvest management plans, and other aspects of statewide salmonid recovery efforts. **Effectiveness monitoring should focus on every group of salmonids having identified recovery goals, and a subset of the habitat projects and programs.** For salmonids, performance standards should be set at the population level, focusing on desired attributes of abundance, productivity, distribution, and diversity. Data to address these are only partially provided for some populations by existing fish monitoring programs. Because different population management actions, such as harvest and hatchery production within a river system, may contribute differently to the overall performance at the population level, it is important for each of these to have their own performance standards that make up the overall standard.

Based on valid statistical designs, all key programs but only a subset of habitat projects need to be included in overall effectiveness monitoring efforts. Different approaches will be needed for programs than will be needed for projects. It would be infeasible to require every individual habitat project to attempt to establish how many fish the project produced, for example. In contrast, some level of effectiveness monitoring is needed for each key program. Performance standards for evaluating the effectiveness of habitat projects and other recovery programs can occur at different scales. Indicators used to monitor for the desired change should be chosen depending on the condition and scales the projects or programs are intended to address. There is no single model for effectiveness monitoring. For projects, an effectiveness monitoring program might consist of well-designed studies of particular project types or restoration techniques, or the evaluation of several different approaches to a similar project, all drawing upon the available pool of projects of each category or type.

3. Did management actions and restoration projects produce the desired change in conditions and status?

Validation monitoring addresses this question. It tests the underlying assumptions behind the specific types of actions undertaken in statewide efforts to recover salmonids. Validation monitoring is needed to relate overall program efforts across all scales to progress toward achieving recovery objectives for individual ESUs and DPSs. Likewise, monitoring data collected in validation monitoring programs tailored to each ESU could be aggregated to evaluate performance of salmonid recovery efforts on a statewide basis.

Validation monitoring should focus on testing specific hypotheses about the causal effects of actions necessary to achieve recovery. A fundamental question here is "Are changes in population characteristics occurring only for salmonids in treatment areas (e.g., project streams or where management changes have been made), or are similar increases occurring in non-treatment areas?" A subset of projects and programs used for effectiveness monitoring can be used for validation monitoring. These should be chosen to maximize the power of opportunities to learn what works, what does not, and how to improve salmonid recovery efforts. **Based on appropriate statistical designs, non-treatment areas (or times) should be identified and maintained during the experiment.** Comparison of these with treatment areas (or times) is essential to infer that the changes were the result of management actions rather than chance, changing climate, or different oceanic conditions. Validation monitoring efforts should integrate information obtained from implementation and effectiveness monitoring programs, as well as long-term trend monitoring of salmonid abundance and habitat characteristics in index and reference reaches in specific areas, such as Water Resource Inventory Areas.

Implementation of Monitoring

We recommend the development and implementation of a comprehensive monitoring program incorporating each of the following eight necessary elements we identified earlier (and summarized below).

- Goals, objectives, or questions that need to be addressed must be clearly articulated.

- Statistical designs need to be appropriate to address the objectives.

- Indicators and variables need to be defined by objectives and experimental design needs at the appropriate geographical, temporal, biological scales. A variety of indicators are needed including standardized indicators and indicators as may be developed for a specific problem or place. Measuring the same indicators in the same way is essential when data are to be combined from different areas, agencies, or times to provide replicability. Interpretation of indicators, indexes, or statistics calculated from monitoring data from different areas, however, cannot be standardized. Programs using indicators that describe the structure and dynamics of groups of populations and subpopulations in an ESU or DPS will need to be expanded, enhanced, and coordinated to obtain the data required for monitoring population viability.

- Monitoring and sampling protocols need to be standardized to allow comparison among locations, times, or programs.

- Procedures need to be developed to ensure quality assurance and quality control of all data used to monitor salmonid recovery and recovery actions. We recommend development of quality assurance plans that would specify how data used to track salmonid recovery and recovery action are to be collected, reviewed, compiled and managed.

- Coordinated data management systems need to be developed and used that allow easy access among different collectors and users.

- Funding needs to be stable and adequate. Implementation, effectiveness, and validation monitoring of programs and projects is likely to require new program elements or new roles for existing programs. Costs of monitoring will also depend on the degree to which decision makers wish to be certain that management actions are having the anticipated response. Recovery planners should identify when monitoring to reduce uncertainty is likely to succeed and when natural variability so great that sampling to detect trends in the near-term may be prohibitively expensive.

- Decision support systems need to help integrate monitoring information into decision-making.

We examined three potential options for a comprehensive monitoring program. We concluded that option 1 (Status Quo) will not provide a scientifically credible comprehensive monitoring program. Option 3, a new, comprehensive program, is most attractive from a strictly scientific perspective, because it approaches salmonid recovery monitoring as a large, consolidated experiment. Even if it draws upon appropriate existing efforts and programs, this approach would likely be expensive, however, and would require substantial political commitment to plan large management changes as experiments and to provide new, long-term and stable funding. Option 2, based on revising, linking, coordinating, and adding new program elements to existing programs, has the potential to create efficiencies while maximizing the use of existing fiscal resources for monitoring. This option would not be easy to implement. Existing programs will need to be reviewed and perhaps modified and new objectives added to address specific issues raised by listing of species under the ESA; indicators will need to added or changed; protocols will need to be changed and standardized while minimizing limitations on use of existing historical data; experimental designs will need to be developed or altered; and agreements and technology for data management and sharing will need to be acquired. This may require considerable expense, at least initially.

Certain aspects of statewide monitoring efforts are well suited for centralized approaches, whereas others are well suited for decentralized approaches. Implementation monitoring and some aspects of validation monitoring could be conducted in a decentralized manner to take advantage of local knowledge and expertise where available and appropriate. But the statewide effort would need to be managed through a centralized program to ensure that local efforts can be scaled up into a coherent program. Likewise, an accessible statewide monitoring database could be managed through centralized or decentralized approaches, using developing information technology. Statewide monitoring data could be analyzed by an independent center or network of sub-units, a state technical team, or an integrated mixture of efforts by different agencies. Whether centralized or decentralized, establishing a scientific forum for the annual or biennial exchange of information and reporting of effectiveness and validation monitoring results would help reduce scientific uncertainties, track overall progress and improve accountability of the comprehensive statewide monitoring program.

Notes

[1] Adaptive management is an approach to natural resource policy based on the assumption that policies can be experiments from which policy makers, scientists, and the public can learn (see Lee 1993). Adaptive management provides a direct feedback loop between science and management so that management and policy decisions can be modified based on new information. Adaptive management focuses on reducing uncertainty by treating human intervention into natural systems as experiments. It works most effectively in the context of policies and management actions occurring over large scales. It requires that information be collected carefully based on explicit descriptions of what is expected (hypotheses) so that expectations can be compared with actuality. It requires policy commitment to learn from the comparisons, to correct errors and change management action, and to continue to reduce uncertainty.

[2] Framing uncertainty arises because managers or scientists have different sets of theoretical assumptions for structuring their data and problem solving. This can happen when scientists are trained in different disciplines or work for institutions that have different objectives.

[3] Stochasticity reflects chance events that affect the birth, growth, and survival of salmonids. These can result in salmonid populations that fluctuate unpredictably in abundance from year to year making it difficult to assess trends or whether a change in status in a response to a change in management. Stochasticity affects the whole range of salmonid persistence from the changes in genetic composition of a population that occur because in any generation only a fraction of the genes can be passed along to the next generation to the chance of large floods or mud slides that can catastrophically affect survival.

[4] Measurement error includes the error that occurs when direct measurement of a variable is not possible and we rely on surrogate variables or indicators. It also includes error introduced by different standards of data quality and data assurance.

[5] Model uncertainty includes the error that arises from modeling itself, such as using too few variables to represent complex phenomena, errors in describing the interaction among variables, or setting inappropriate boundaries for the world that the model is trying to represent. Ignorance or uncertainty about community interactions, for example, may lead scientists to hypothesize (or model) species changes as reflecting only the direct effects of habitat conditions and not incorporate the effects of other species (Rose 2000).

[6] Fish occur individually and as groups. Populations are groups are interbreeding individuals that persist independently of other groups of the same species over multiple generations. They are the reservoirs of the genetic information that allows organisms to grow, reproduce, and respond to changes in their environment and pass that information on to future generations. Genetic variation, especially among populations, is important because it may reflect local adaptation to different habitats across the range of the species and consequently different responses to management actions. Genetic variation can be considered at different scales, ranging from subpopulations, which are semi-independent groups of individuals that make up more persistent populations, to populations to groups of genetically similar populations to the species. Scientists often identify groups of genetically similar populations that are distinctly different from other such groups as subspecies. “Evolutionarily significant units” (ESU) and “distinct population segments” are terms used by NMFS and FWS to identify one or more similar populations that are listed for protection under the ESA.

[7] As an example of these two approaches, consider how to monitor the success of engineered logjams in recovering salmonid streams. The sampling-based approach would be to test a specific null hypothesis about the efficacy of engineered logjams based on some expected response, such as changes in stream morphology or fish distribution. In this approach, the design would be based on sampling a large number of engineered logjams across the state, assuming that every logjam has an equal probability of being sampled in the strata of interest, periodically measuring the attributes of interest, and testing the prediction using statistical tools. In contrast, the modeling-based approach would be to study the ecological and geomorphic processes related to logjams intensively in a small number of sites or watersheds, and thereby

develop a general model. The model could then be used to predict where and how engineered logjams would work or to diagnose why they are not working in other specific project applications.

The two approaches have different advantages and disadvantages. In the sampling design approach, the conclusions are based on data collected from a large number of areas. Consequently, the general conclusions apply to all those areas. The sampling design approach can be very successful at small scales but difficulties can arise when applied to larger spatial scales. Expense of collecting data increases substantially, because powerful inferences may require large sample sizes and probabilistic sampling procedures that can be expensive to implement. Researchers have less control over unexpected events that can disrupt the experimental design. Disruption of the design because of natural catastrophes or human error can significantly weaken conclusions and leave investigators with little learned from a lot of expense. It may take longer to see a biologically and statistically significant results when examining phenomena that occur over large spatial scales. This can be frustrating for the public and management agencies, who desire more immediate certainty about the effects of their management decision.

In contrast, conclusions from modeling-based approaches can provide more immediate guidance for making management decisions. In addition, results are often cheaper to obtain. Investigators can collect information on a large number of variables. Unexpected events do not necessarily weaken the conclusion, because they can be incorporated into the model. The modeling-based approaches also allow scientists to integrate data across different disciplines. A major disadvantage, however, is that it can be difficult to generalize results from sentinel sites to other areas. It may be difficult to find representative index sites that capture the variability among watersheds. Finally, modeling or diagnostic approaches may be uninformative for detecting regional trends (Jassby 1998).

[8] Goals and objectives can be organized into hierarchies, where the higher levels represent general objectives and the lower levels describe the important components of the high levels. Goals are the highest level objectives that express fundamental values about what is important. These are established by policy decisions. They can be broken down into more specific fundamental objectives, performance objectives, and means objectives. Performance objectives are descriptions of a state or condition that can be evaluated by measuring attributes to determine whether the objective is being achieved. In this case, attributes are synonymous with "indicators." Means objectives, in contrast, describe how other objectives will be accomplished. Hierarchical goals and objectives are important because they enable sorting of objectives by other natural hierarchies, such as groupings of populations, geography, and time.

[9] Natural patterns are linked in time and space at different scales. Choosing the appropriate spatio-temporal scale is critical for monitoring programs because it affects the detectability of the response "signal" against the background of environmental "noise" created by highly dynamic environments. The ability to correlate habitat change with fish densities, for example, may depend on choosing the appropriate scale (Walters and Collie 1988; Rose 2000; Ham and Pearsons 2000). Temporal and spatial scales form a sampling grain, or level of resolution. If measurements are taken at natural cycles of renewal (e.g., generation times or intervals of change and succession), signals become clearer and environmental noise is reduced. Lower variance in measurement results because natural processes, such as emigration and immigration on the spatial scale and short-term fluctuations on the temporal scale get smoothed over time (Cooper et al. 1997; White and Walker 1997; Peterson et al. 1997).

Using a hierarchical strategy for monitoring salmon recovery is efficient, because the appropriate sampling grain will match the objectives of each level of management strategy. The speed of response to management actions and the stability of biological patterns are governed by scale. Small-scale patterns react fast to input, but the patterns are highly variable, change quickly and are more ephemeral. Large-scale patterns are slower to develop, but the patterns are less variable and more stable. The decision to base a monitoring program on certain scales should consider objectives. Monitoring for signs of early warning will require measuring at smaller spatio-temporal scales at the risk of a lower signal to noise ratio. However, validation monitoring will require broader spatio-temporal scales because the signal will be clear, less equivocal. Also, as a general rule for validation monitoring, patterns should be monitored at several scales because (1) different ecological processes emerge in importance and (2) patterns at larger scales constrain those at smaller ones. This helps increase understanding, as illustrated by the determination of factors governing habitat requirements for two species at risk of extinction, spring chinook salmon (Torgersen et al. 2000) and the Arkansas darter (Labbe and Fausch 2000). Likewise, understanding selection of spawning sites by salmonids, for example, requires knowing how larger scaled environmental features affect features at a smaller scale (Montgomery et al. 1999; Baxter and Hauer 2000).

[10] There are four kinds of measurement scales (nominal, ordinal, interval, and ratio) (Poole et al. 1997). Nominal measurements assign things to categories but the categories do not describe anything about how they are related (i.e. bigger or smaller, up or down, first or latter, etc.). "Chinook salmon," "rainbow trout," "pool," or "riffle" are examples of nominal measurements. Ordinal measurements are made on a scale or rank or order. These indicate ascending or descending order, but the magnitude of change between the ranks does not have to be constant. "Egg," "fry," "smolt," and "adult" are examples of ordinal measurements of life history stages. The interval scale, in contrast, implies rank or order but with consistent change between ranks. It has no absolute zero, however. The ratio scale is an interval scale that has an absolute zero. Linear measurements are an example of the ratio scale.

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Appendix A

Examination of Monitoring Programs in Washington State

Purpose

The purpose of this appendix is to provide an overview of the range and types of current monitoring activities in Washington State that are strongly related to salmon recovery, with emphasis on those identifiable via an internet-based search. The purpose was not to perform a comprehensive search for all state agency and other programs that collect information directly or indirectly related to salmon and/or watersheds. Such an effort was beyond the scope of this work.

Overview of Methods Used

A web-based search was performed to identify and characterize readily accessible information about existing state programs and databases having a strong relationship to actual (field/data) monitoring of salmon and watershed condition and recovery. A number of tribal and federal monitoring efforts were also identified, all of which were deemed to have fundamental relationships to state activities or interests. The results of this search were compiled into a matrix describing key features of the major programs.

Search emphasis was placed on state agencies most involved in salmon monitoring issues. These agencies included the Departments of Fish and Wildlife, Ecology, Transportation, Natural Resources, and the Puget Sound Action Team. Monitoring programs that appeared to have elements relevant to salmon, even if they were not salmon-specific, were included in the matrix. Often, the data itself were not available online, but a description of the program and contact information was.

There are various sources of information that we did not include in the matrix that have a relationship to salmon, but relationships to monitoring are less clear. For example, the State Conservation Commission (i.e., Limiting Factors Analysis reports) and the Interagency Committee for Outdoor Recreation (PRISM - Salmon Recovery Funding Board restoration project activity database) create and maintain information related to salmon. In addition, a data survey is underway as part of the state's Salmon Recovery Scorecard effort, that may provide a comprehensive picture of salmon-related data needs and resources. These information sources are not referenced in the matrix.

In many cases state web pages were linked to federal and tribal pages. These latter programs were included as appropriate. In some cases academic databases were also included.

Comments o an early draft of this appendix and summary matrix were solicited from the state agencies of the Joint Natural Resources Cabinet, in an effort to avoid omitting key information and to help ensure contents were represented accurately.

Overview of Findings

Clearly, there are additional and substantial monitoring programs and databases important to salmon and watersheds in use in the state that are not found on the web. For the purposes of this report no attempt was made to identify all monitoring programs or databases, whether web-based or not.

Some of the important data resources that were identified but found not to be web accessible included the Department of Fish and Wildlife's Stream and Lake Fish Database, Priority Habitats and Species, Hatchery release (Form4), Wild Salmonid production data, Soft data system (AFCRS-harvest), Fish Ticket system (LIFT-harvest), Catch Record Card System (recreational harvest), Angler Fish Database, Hatchery Returns (Form 5), Spawning ground survey, Wild salmonids return data, biological data (Scales), and Genetic Stock Identification Data (GSI). We expect a wide variety of relevant monitoring data are compiled and used by other agencies as well.

It is understandable that most of the existing monitoring programs and resulting data exist due to mandated agency efforts that were initiated prior to the current emphasis on salmon recovery and related watershed protection and restoration issues. This review was unable to discern the extent to which agency monitoring programs related to salmon are linked or coordinated across traditional agency boundaries. In addition, it is not clear how those programs do/may acquire and deliver monitoring information over temporal and spatial (e.g., site/reach, sub-watershed, watershed, region/ESUDPS) scales relevant to salmon recovery monitoring.

Examples of State Monitoring Activities in Washington Watersheds for Salmon and Water
(some tribal and federal activities are included)

Agency Contacts	Geographic and Spatial Scope	Monitoring Questions or Goals	Use of Data	Indicators	Maps available?	Links to other projects or agencies	Project Status	Reporting Status	Analysis Summaries
FISH									
WDFW Salmonid Stock Inventory (SaSI) www.wa.gov/wdfw/fish/sassi/intro.htm	Washington Sate	Classify stocks as healthy, depressed, critical, unkown, or extinct.	The data is used to track status of wild stocks of salmonids.	No/100m2, No/m2, adult snorkel count, snorkel count, fish caught/hour, fish caught/day, %habitat use, recruits/spawners, age composition, size			Updating and revision of the SaSI documents is underway and will be completed by mid-year 2001. Thereafter the documents will be updated regularly with the addition of new conservation priorities.	1992 Salmon and Steelhead Stock Status Inventory Report. 1998 Bull Trout/Dolly Varden Report 2000 Coastal Cutthroat Report	WDFW releases volumes on the status of different species. These reports take information around the state and from different agencies and sources to determine the health of different stocks of the species.

Agency Contacts	Geographic and Spatial Scope	Monitoring Questions or Goals	Use of Data	Indicators	Maps available?	Links to other projects or agencies	Project Status	Reporting Status	Analysis Summaries
Pacific States Marine Fisheries Commission. Cooperators are the agencies and tribes of Oregon, Washington, Idaho, and Montana, the Columbia River Inter-Tribal Fish Commission, the USFWS, and the BPA, NMFS, USGS, EPA and USFS www.streamnet.org	Washington, Oregon, Idaho, Montana	To create, maintain, and enhance high quality, regionally consistent data on fish and related aquatic resources that are directly applicable to regional policy, planning, management, and research	Effective implementation of the Northwest Power Planning Council's fish and wildlife program, Endangered Species Act activities, other fish and wildlife management activities	Estimates of Spawning Population, Peak/Other Spawning Counts, Redd Counts, Spawner/Recruit Estimates, Age Data (Adult or Juvenile), Distribution Information, Dams, Hatcheries, BPA Fish & Wildlife Projects, Juvenile Abundance, Mitigation/Restoration Project Data, Protected Areas, Reference Catalog, Smolt Density Model, Water Temperature.	Maps - Anadromous Distribution, Resident Distribution, View Pre-built Maps		Funded by the Northwest Power Planning Council.	Provides Baseline data	Not available
PSMFC www.psmfc.org/pittag/ Pacific States Marine Fisheries Commission, 45 SE 82nd Drive, Suite 100, Gladstone, Oregon 97027-2522, or call (503) 650-5400	Columbia River Basin	Operate and maintain the Columbia Basin-wide database for PIT Tagged fish and to operate and maintain the established interrogation systems	A research and management tool for monitoring the movement of juvenile and adult salmonids in the Columbia River Basin	Fish with this tag can be recognized by devices located within collection facilities at hydroelectic dams. Before release PIT tag number, tagging location, organization responsible for the tagging, species, run, weight, length, wild or hatchery type, marks and general health are recorded in a central database.	Data is taken at hydroelectric facilities: BonnevilleDam, The Dalles, John Day Dam, McNary Lock and Dam, Ice Harbor Lock and Dam, Lower Monumental Lock and Dam, Little Goose Lock and Dam, Lower Granite Lock and Dam		Over 2,318,000 fish have been tagged and monitored since 1987	A database is available on the web. It is query based with information available for a specific tag number, Interrogation Site Event Logs, Site Tally Reports, Annual Tagging Summaries, recent and historic adult returns, "Raw" Interrogation Files and "Raw" Tagging Files	Not available

Agency Contacts	Geographic and Spatial Scope	Monitoring Questions or Goals	Use of Data	Indicators	Maps available?	Links to other projects or agencies	Project Status	Reporting Status	Analysis Summaries
NWIFC www.nwifc.wa.gov/fisheriesdata/runreconstruction.asp	Tribal Hatcheries in Western Washington	What is the size and composition of returning runs?		Extreme terminal, extreme terminal run size, terminal area run size, total Puget Sound run size. These categories are broken down into hatchery and wild fish.			Data began in 1965	Online reports available from 1965-1996	Not available
Army Corps of Engineers www.nwp.usace.army.mil/op/fishdata/Adultfishcounts.htm	Columbia River Dams	How many adult fish pass through each dam?	Monitor health of stocks	Daily and YTD counts, Monthly Summaries, Running Sums, Daily Fish Passage Report, 10 year averages	Testing at Bonneville, The Dalles, John Day, McNary, Ice Harbor, Lower Monumental, Little Goose, Lower Granite, Priest Rapids, Rock Island, Rocky Reach, and Wells		Only 1998, 1999, 2000 data online, however, data at least goes back to 1990.	Updated daily	Not available

Agency Contacts	Geographic and Spatial Scope	Monitoring Questions or Goals	Use of Data	Indicators	Maps available?	Links to other projects or agencies	Project Status	Reporting Status	Analysis Summaries
HABITAT									
WDFW: David Johnson (360) 902-2603 johnsdhj@dfw.wa.gov www.wa.gov/wdfw/hab/sshiap NWIFC: www.nwifc.wa.gov/sshiap/map.asp Randy McIntosh (360) 438-1181 (xt. 369) rmcintos@nwifc.wa.gov	Statewide	Cooperative project to document current habitat conditions and to assess the role of habitat degradation and loss in the status of salmon and steelhead stocks.	SSHIAP is designed to support regulatory, conservation, and analysis efforts such as Washington State Watershed Analysis, State Salmon Recovery, Habitat Conservation Planning, Ecosystem Diagnosis and Treatment (EDT), and others	CORE ATTRIBUTES: Stream gradient, valley type (confinement), habitat type, salmonid distribution (SaSI stock), obstructions to migration, channel length, elevation, geology, hydromodifications, riparian condition, estuarine/nearshore condition, land use. SECONDARY ATTRIBUTES: historical habitat conditions, water temperature, channel width, wood debris, water withdrawals, water quality, stream flow.	Limited at the present.	SSHIAP incorporates existing data (where available) from outside sources. Other projects with data links include: SaSI, StreamNet, SSHEAR, WCC Limiting Factors Analysis, HPA database, IAC Restoration Database, among others.	SSHIAP began in August 1995. SSHIAP currently covers WRIAs 1-23; work is partially funded and underway to extend SSHIAP coverage to WRIAs 24-62	Stored within a database, the information can be queried and analyzed according to user-defined criteria. Information can be retrieved by basin, watershed, individual tributary, species or SaSI stock. Linkage of the database to a GIS is in progress, thus enabling users to retrieve information using a map-based interface.	The SSHIAP information system is designed for watershed-, basin-, and regional-scale habitat analyses to focus salmonid protection and restoration efforts. A web-based, query driven interface is being developed that will enable users to generate their own data summaries and GIS coverages of SSHIAP segments

Agency Contacts	Geographic and Spatial Scope	Monitoring Questions or Goals	Use of Data	Indicators	Maps available?	Links to other projects or agencies	Project Status	Reporting Status	Analysis Summaries
WSDOT www.wsdot.wa.gov/eesc/environmental/LegInitatives/fish_passage.html Fish Passage Program Asst: Cliff Hall (360) 705-7499 hallcli@wsdot.wa.gov	Intersections of streams and WSDOT roads in Washington State	1. Determine if culverts constitute a barrier to fish passage 2. Mitigate barrier 3. Evaluate effectiveness of mitigation.	Data is used to prioritize restoration activities at fish passage barriers. Once a barrier has been removed data is collected to determine the utilization of the habitat by salmonids.	Habitat assessments are done by full physical surveys, threshold determinations and expanded threshold determinations. To determine effectiveness adult spawner surveys and juvenile electro-fishing are done above and below the project.		DOT works with WDFW in designing fish passage systems and evaluating their effects.	681 fish barriers have been identified. Of these, 359 need to be repaired and 59 have already been fixed.	WSDOT released the report <u>WSDOT Fish Passage Barrier Removal Program Progress Performance Report for Inventory and Fish Barrier Corrections</u> in April 2000.	Not available
Northwest Indian Fisheries Commission (TFW) www.nwifc.wa.gov/TFW/ Dave Shuett-Hames, TFW Monitoring Program Coordinator, (360)438-1181 Ext. 333, dschuett@nwifc.wa.gov	Washington State	Gather and assemble information on the status of salmonid habitat, stream channels, and watershed input processes, and to document changes in these conditions over time	Data supports Washington's Watershed Analysis in assessing current conditions and the impact of logging practices on those conditions. Also, it provides feedback for TFW and WSA adaptive management.	Stream Segment Identification Method, Reference Point Survey, Habitat Unit Survey, Large Woody Debris Survey, Stream Temperature Survey, Salmonid Spawning Gravel Composition Survey, Salmonid Spawning Habitat Availability Survey, Salmonid Spawning Gravel Scour Survey	Maps of reaches surveyed are archived at NWIFC.		Ongoing.	Maintains a database containing survey information. Many reports are also available on the website. Maps of reaches surveyed can be obtained from WDFW. Use of database is subject to permissions.	Several reports on methodology, but not analysis of the results.

Agency Contacts	Geographic and Spatial Scope	Monitoring Questions or Goals	Use of Data	Indicators	Maps available?	Links to other projects or agencies	Project Status	Reporting Status	Analysis Summaries
WATER									
USGS http://wa.water.usgs.gov/waterdata.html	United States	Water quantity. Monitor streamflows at multiple stations across the state	Immediate decision making and future planning, project design, flood forecasts, legal obligations, research, water quality monitoring	Flow (ft^3/sec), stage (ft), date, time	Available on line (not easily printed, list attached) disproportionately large numbers of stations near Seattle.		Data from 1895 to 1998	Data is updated every 15 minutes, immediate and historical data is available online	Not available
ECOLOGY www.ecy.wa.gov/programs/eap/flow/shu_main.html Brad Hopkins bhop461@ecy.wa.gov (360) 407-6686	Washington streams	Water quantity. Monitor stream flow at multiple sites across state	Water quality monitoring (flow-adjusted trends, etc), TMDLs (loads), salmon habitat recovery monitoring, IFIM support	Flow (cfs), stage (ft), date, time	Maps available on web for flow sites that are part of Ecology's stream water quality monitoring program	Much of the data is collected in support of Ecology's stream water quality monitoring program	Data collection began about 1998	Some data available on web	Some analysis available on web
ECOLOGY *www.wa.gov/ecology/eils/fw_riv/rv_main.html* **Eastern WA**: Dave Hallock daha461@ecy.wa.gov (360) 407-6681 **Northwestern WA**: Bill Ward, bwar461@ecy.wa.gov (360) 407-6621 **Central WA**: Bill Ehinger wehi461@ecy.wa.gov (360) 407-6682 **Southwestern WA**: Rob Plotnikoff, rplo461@ecy.wa.gov (360) 407-6687	Washington streams	Water quality. Monthly water quality monitoring at hundreds of river and stream stations throughout the state. 80 stations each year, some on a one-year basis, some on a five-year rotation, and some are monitored continuously.	Data is used to determine if water bodies exceed state limitations on temperature, oxygen, and pH and fecal coliform for a monthly report. Also, this data allows Ecology to compile a 303(d) list of impaired waterways to submit to EPA under the Clean Water Act.	Attributes include temperature, pH, conductivity, dissolved oxygen, turbidity, total suspended solids, fecal coliform bacteria, ammonia-N, nitrate+nitrite-N, total nitrogen, total phosphorus, soluble reactive phosphorus, and at most stations, discharge. Dissolved metals are monitored bi-monthly at a few stations.	Maps available on website. Shows all test sites in lakes and rivers (attached)		In progress since 1959	Preliminary exceedence reports showing results exceeding water quality standards criteria are posted monthly. These reports come out approximately two months after the sampling month. Summary provisional data from the most recently completed water years (October through September) are available online. Additional information is available by contacting the appropriate agency contact.	Analytical reports on various aspects of the data are available at the website http://www.wa.gov/ecology/biblio/99342.html. This includes data compilations, trends analysis source identifications, environmental impact assessments, and others.

Agency Contacts	Geographic and Spatial Scope	Monitoring Questions or Goals	Use of Data	Indicators	Maps available?	Links to other projects or agencies	Project Status	Reporting Status	Analysis Summaries
ECOLOGY www.wa.gov/ecology/eils/fw_lakes/lk_main.html Maggie Bell-McKinnon, mbel461@ecy.wa.gov (360) 407-6124	Washington lakes	Water quality. Monitor water quality in the state's lakes	Data is used to assess the water quality of lakes for recreational activities as well as compliance with state and federal laws governing water.	Temperature, pH, conductivity, and dissolved oxygen profiles, hardness, chlorophyll, total nitrogen and total phosphorus. At selected lakes: turbidity, total suspended solids, and fecal coliform bacteria	Attached. Same as stream water quality map.		Lake quality monitoring began in 1989	Last water quality report issued in 1998	Lake data analysis is with river analysis at the web address http://www.wa.gov/ecology/biblio/99342.html.
ECOLOGY www.ecy.wa.gov/programs/eap/wrias/index.html Will Kendra wken461@ecy.wa.gov (360) 407-6698	Fresh and marine waters statewide	Water quality. Address known or suspected pollution problems in water, aquatic sediments, and fish/shellfish tissue	Identify the source, effect, and fate of pollutants released into the environment, and recommend appropriate pollution controls	May include conventional parameters like temperature, oxygen, and nutrients, as well as toxic pollutants like metals and pesticides	In monitoring plans and completed study reports. Some available on web.		Initiated 1957	Some data available on web.	1,600 study reports published to date. All can be requested via web, some downloaded directly at www.ecy.wa.gov/biblio/eap.html
NWIFC www.nwifc.wa.gov/ctnrm/2000_water.htm 6730 Martin Way E., Olympia WA., 98516; or call (360) 438-1180	Water Resources that affect the 26 Federally recognized Washington tribes	Water quality. The project has resulted in a tribal water quality database design, a tribal water quality standards template, and a cooperative state/tribal 303(d) strategy	The program is designed to develop watershed management plans, monitor water quality trends, map problem areas, and develop water quality standards.		Not available		Begain in 1990 in conjunction with EPA	Beginning to implement a Coordinated Tribal Water Quality Database	Done at the tribal level, available from individual tribes, no central archive

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MARINE									
DNR www.wa.gov/dnr/htdocs/aqr/nshr/montinfo.html Aquatic Resources Division PO Box 47027 Olympia, WA 98504-7027 (360) 902-1100 (voice) (360) 902-1786 (fax)	Puget Sound	Monitors trends in habitat quantity and quality	Part of a larger effort by PSAMP to assess the status and trends of Puget Sound's biological resources and changes in the physical environment	Submerged Nearshore Vegetation Monitoring, Bulkhead inventory, Kelp Habitat Along the Outer Coast and the Strait, Spatial Patterns of Intertidal Communities in South Sound, Research Into A Probability-Based Method for Monitoring Change, Exotics Survey	Not Available	Part of the Puget Sound Ambient Monitoring Program with The Puget Sound Water Quality Task Force.	There is an update through PSAM every other year.	An inventory of habitat and vegeation was released in 1997 and 1999. There is a 1998 Puget Sound Update.	Analysis of findings can be found in the 1998 Puget Sound Update
ECOLOGY www.wa.gov/ecology/eils/mar_wat/mwm_intr.html Skip Albertson, salb461@ecy.wa.gov, (360) 407-6676	Puget Sound and the Coastal Estuaries (Grays Harbor and Willapa Bay)	What is the quality of the marine waters, particularly estuaries, off Washington State?	Data is used to detect hypoxia and eutrophication which can lead to noxious algae blooms and has severe implications for shelf fish harvesting.	Temperature, light transmission, Secchi disk depth, salinity, density, pH, dissolved oxygen, ammonium-N, nitrate-nitrite-N, orthophosphate-P, chlorophyll a, phaeopigment, and fecal coliform bacteria. Depth of sampling includes: 0.5, 10, and 30 meters. (Fecal coliform bacteria data are from 0.1 meter.)	Yes, available on website. Shows all test sites (attached).		Data collection began in 1973	Washington State Marine Water Quality in 1996-97 is available online.	Many analytical reports based on this data are available at http://www.wa.gov/ecology/biblio/estuary.html

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Puget Sound Water Quality Action Team www.wa.gov/puget_sound/pslibrary/workplan99/actions/support.htm	The Puget Sound Ambient Monitoring Program	Assess the health of Puget Sound and its resources and provide information to measure the success of environmental programs	Data is used to provide decision makers with scientific tools to use in the protection of the environmental quality of puget sound	Monitor marine and fresh waters, sediments, marine biological resources, nearshore habitat, and assess the effects of contaminants on fish.		Coordinated by this program, federal, state and local agencies monitor indicators. This program also uses studies conducted by other government agencies and programs. Ecology provides lab accredidation services, DNR provides inventory of nearshore habitat, tribes and local government provides long-term water quality monitoring and use data.	Began in 1987	Every two years, the Action Team publishes a Puget Sound Update report summarizing the findings of the monitoring program and related studies.	The PSWQAT acts as a clearinghouse for information on the health of Puget Sound. They gather data from all levels of government that monitor in the sound and use the information to determine if mitigation efforts are working and to advise policy makers.
ECOLOGY www.ecy.wa.gov/programs/eap/mar_sed/msm_intr.html Maggie Dutch mdut461@ecy.wa.gov (360) 407-6021	Puget Sound, Hood Canal, and Strait of Georgia	Evaluate spatial and temporal trends in sediment chemistry, toxicity, and benthic macroinvertebrate community structure	To provide a record of the condition of Puget Sound sediments, to aid in the identification of reference sites/values, and to provide data for use by researchers concerned with sediment quality.	Broad suite of toxic chemicals, sediment bioassays, benthic infauna assemblage indicators	Maps available on web.	Part of Puget Sound Ambient Monitoring Program	Program initiated in 1989	Some data available on web	Program analytical reports available on web

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HATCHERIES									
NWIFC / WDFW Future Brood Document www.nwifc.wa.gov/fisheriesdata/fbd.asp	Western Washington	What are the planned releases of hatchery salmonids by species, stock, size, and stream?	Get an estimate of the number and type of hatchery fish released into each stream, by species, timing, stock, and fish size. Track egg take and disposition.	egg take goal, planting goal, transfer in, transfer out				1999 plan available online	Not available
Pacific States Marine Fisheries Commission, Regional Mark Information System www.rmis.org/cwt/cwt_qbe.html	Alaska, British Columbia, Washington, Oregon, Idaho California and Montana	House information relating to the release, sample, and recovery of coded wire tagged salmonids throughout the Pacific region	Coded-wire tag data base. Facilitate exchange of CWT data between release agencies and the sampling/recovery agencies, and other data users. The RMPC also serves as the U.S. site for exchanging U.S. CWT data with Canada for Pacific Salmon Treaty purposes.	Releases of groups of hatchery fish associated with a tag code; tagged fish sampled at fisheries coast wide; tags removed from fish and decoded are linked to the location of catch, date of catch, fishery, and other biological data; and geographic locations of release, sample, and specific recovery of fish	Not available		Data from 1973-2000	All agencies report to RMIS who compile the information into a web query based database available to anyone.	Not available

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NWIFC www.nwifc.wa.gov/fisheriesdata/cras.asp	Alaska, British Columbia, Washington, Oregon, Idaho and California for Chinook and Coho	To facilitate the access and analysis of coastwide salmon release and recovery information	Coded-wire tag retrieval and analysis system (CRAS). A system to facilitate the access and analysis of coastwide salmon release and recovery information available to everyone	The recovery of tag codes.	N/A	The information is gathered by all agencies in the states of the Pacific Northwest.	Includes data from 1958 to 1997. Last updated June of 1998	Online Data base. Available information includes Recovery Distribution - find out where a tag code was recovered. Fishery Recovery - what tag codes were recovered in fisheries during a time period. Freshwater Recovery - information on freshwater recovery locations and fisheries for a tag code.	Not available
NWIFC http://www.nwifc.wa.gov/fisheriesdata/stats.asp	Tribal Hatcheries in Western Washington	Number of fish produced		Fish produced by the hatchery by species and year.				Data online from 1995-1997	Not available
INTERDISCIPLINARY MONITORING AND DATA SYSTEMS									
UW DART www.cqs.washington.edu/dart/dart.html cvh@cbr.washington.edu. Columbia Basin Research, University of Washington	Columbia River Basin	An interactive data resource designed for research and management purposes relating to the Columbia Basin salmon populations and river environment	**Adult Passage** - Daily counts of adult salmon at all major Columbia and Snake River dams. **Endangered Species** - Daily counts of selected PIT-tagged endangered salmonids logged as they pass through Columbia Basin dams. **Hatchery Releases** - Daily counts of hatchery. **Smolt Index** - Detailed salmonid counts at fish passage observation sites. **River Environment** - Daily river environment data including outflow, spill, dissolved gas, dissolved oxygen, barometric pressure, temperature (C), and turbidity at Columbia and Snake River dams. **Headwater Flows** - Daily Columbia River Basin headwater stream flow and water temperature.		Not available. Majority of data taken at the major Columbia River dams and Observation sites include dams and river traps along the Salmon, Snake, Columbia, Imnaha and Grande Ronde rivers		Historic information dating back to 1910 is accessible online	Online database that attempts realtime data. The user queries the database with the perameters of year, species, location, and wild or hatchery.	Not available

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WSDOT Geo Data Distribution Catalog www.wsdot.wa.gov/ gis/geoDataCatalog/	Washington State	To provide a database of information pertaining to transportation issues	A public storehouse of information that can be used in planning, project evaluations, management and other uses.	Includes information on transportation, political and administrative boundries, geographic reference, and environmental issues.	Many maps of the physical locations of DOT managed things.		Most of the data has been entered, however the water quality data is not present	Information is in downloadable form on the web site	Not available
ECOLOGY www.wa.gov/ecolog y/gis/data/data.htm	Washington State	Aids in accomplishing protection of the land, air, and waters	Collection of data used by the agency to meet their needs	Ambient, Baseflow Stations, Counties, Dairy Farms, Dams, Environmental Information Monitoring Stations, Facility Site, Groundwater Management Areas, Lakes, Lake Bathymetry, Rivers, State Tribal Lands	All information is spatially represented in maps		Data is entered when collected by the agency	All data is available for downloading online. It is in metadata or map form.	Not available
ECOLOGY Russ Darr, Environmental Information Management System (EIM) Data Coordinator	Washington State	EIM is Ecology's data repository for surface water, ground water, sediment, and biological data--also contains some information collected by local governments and private entities	Collection of data used by the agency to meet their needs	All types of environmental results are present	All information includes spatial coordinates--maps are available on request	Ecology--the Environmental Information Management System (EIM) contains much of the above referenced Ecology data and results from many intensive studies of the aquatic environment	Data are available when the individual project owner has completed entry	All data are available to Ecology and by request.	Not available