Comprehensive Strategy

The Washington Comprehensive Monitoring Strategy For Watershed Health and Salmon Recovery

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Table of Contents

Table of Contents

Table of Contents

Table of Contents

Introduction

Part I

The overall vision for salmon recovery is captured in the Statewide Strategy to Recover Salmon: Extinction is Not an Option. Washington State will:

"Restore salmon, steelhead, and trout populations to healthy and harvestable levels and improve habitats on which fish rely."

In April 2001, the Governor signed into law Substitute Senate Bill (SSB) 5637 to monitor watershed health and restore salmon. SSB 5637 requires the Monitoring Oversight Committee (MOC) to:

"Develop a comprehensive statewide strategy for monitoring watershed health, with a focus on salmon recovery."

SSB 5637 incorporates monitoring recommendations provided by the state's Independent Science Panel (ISP) to the Governor and Legislature in December 2000[1]. The law also requires the development of a state agency action plan that will phase in a full implementation of the strategy by June 30, 2007.

The intent of the law is to better coordinate existing monitoring activities and improve data exchange most relevant to local, state, and federal watershed health.

Monitoring involves the deliberate and systematic observation, detection, and documentation of conditions, resources, and environmental effects of management and other activities. Monitoring provides the ability to:

- Determine trends in fish populations and habitat conditions;
- Determine the effectiveness of the current state's salmon recovery efforts;
- Evaluate and account for the state's investments in salmon recovery actions; and
- Resolve important scientific and policy questions.

Monitoring is also a required element of salmon recovery plans submitted to the federal government for approval under the federal Endangered Species Act (ESA).

SSB 5637 directs the MOC to complete the following tasks:

(1) Define the monitoring goals, objectives, and questions that must be addressed as part of a comprehensive statewide salmon recovery monitoring and adaptive management framework;

(2) Identify and evaluate monitoring activities for inclusion in the framework, while ensuring data consistency and coordination and the filling of monitoring gaps;

(3) Recommend statistical designs appropriate to the objectives;

(4) Recommend performance measures appropriate to the objectives and targeted to the appropriate geographical, temporal, and biological scales;

(5) Recommend standardized monitoring protocols for salmon recovery and watershed health;

(6) Recommend procedures to ensure quality assurance and quality control of all relevant data;

(7) Recommend data transfer protocols and necessary infrastructure to support easy access, sharing, and coordination among different collectors and users;

1 Independent Science Panel Report 2000-2: "Recommendations for Monitoring Salmonid Recovery in Washington State"

(8) Recommend ways to integrate monitoring information into decision-making;

(9) Recommend organizational and governance structures for oversight and implementation of the coordinated monitoring framework;

(10) Recommend stable sources of funding that will ensure the continued operation and maintenance of the state's salmon recovery and watershed health monitoring program, once established; and

(11) Identify actions that will be taken by state agencies to implement elements of the coordinated monitoring program.

Elements of a Successful Monitoring Strategy

A successful monitoring strategy:

- Produces a cost effective approach to monitoring;
- Determines the effectiveness of the Statewide Strategy to Recovery Salmon (SSRS) recovery strategies; and
- Supports short and long-term management decision options.

Comprehensive Monitoring Strategy Defined

The Comprehensive Monitoring Strategy (CMS) is how the state and its partners will achieve the monitoring goals defined by the MOC, and in the process, address key management issues or policy decisions. The CMS provides specifics on how to monitor watershed health and salmon recovery. The strategy develops a framework for data collection and interpretation that incorporates all aspects of salmon recovery and watershed health. "Comprehensive" is not defined by the measurement all things, at all times, but rather is aimed at determining the most important things that need to be done to address key questions or objectives. To the extent possible, the strategy incorporates existing federal, tribal, and other monitoring efforts.

Action Plan Defined

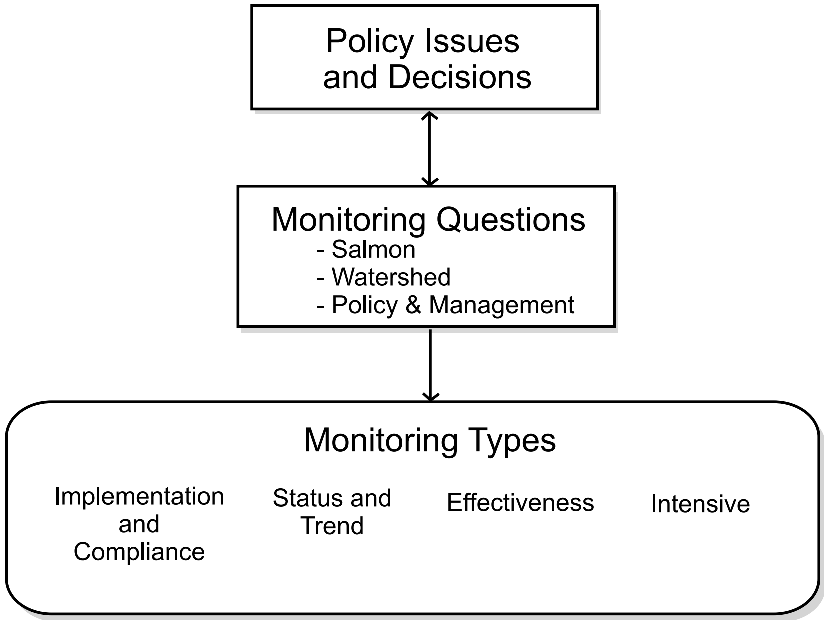
The Action Plan identifies all of the actions needed to fully implement the CMS and adaptive management framework by June 30, 2007. This includes administrative actions that state agencies will take once funding and/or statutory changes have been obtained. The plan includes recommended governance structures and identifies additional resources needed. It also includes timelines, recommended phases for implementation, and strategic planning. The Action Plan provides a cost-effectiveness analysis, and delineates funding options to ensure greater certainty from monitoring programs. Federal and tribal monitoring components may be affected by Congressional and other actions that are not under the state's control.

Organization of the CMS

The CMS provides recommendations to address monitoring questions that are linked to important management issues or policy decisions that need to be addressed by the state's resource managers (Figure 1). It then groups key monitoring questions designed to assist in providing information on the issues into four areas of monitoring inquiry:

- Adaptive management and governance
- Accessibility of monitoring information
- Accountability for effectiveness of state and federal investment
- Recommendations for monitoring habitat, fish, and water

Figure 1. Relationships between issues/decisions, monitoring questions, and monitoring types.



Federal, Tribal, and Local Government Part of the CMS

The ability of the state and its associated partners to finance a comprehensive monitoring program will be constantly challenged by competing interests. Therefore, it is critical that the CMS include federal, local, and tribal government agencies in order to maximize data collection and distribute costs.

The CMS and MAP are based on previous salmon recovery efforts.

Volunteers a Part of the CMS

Volunteers are a vital part of monitoring. Because it is important to build on efforts of watershed groups, interested citizens, and service organizations, we are promoting and supporting a network of volunteers to assist in ongoing state watershed health monitoring efforts. This includes identifying data needs that can be collected by all partners; providing training and guidance to watershed and regional groups and other volunteer organizations; and creating a mechanism by which local groups can access data.

The CMS and the Action Plan Incorporate Existing Monitoring Activities

The Joint Natural Resources Cabinet developed a statewide strategy for recovering threatened and endangered salmon and for measuring recovery success. In extending their efforts, the CMS goals and objectives have incorporated many of the elements of the *Salmon Recovery Scorecard*, Chapter VI of the *Statewide Strategy to Recover Salmon*, the *State Agencies' Action Plan* and *The State of the Salmon Report*.

Introduction

For years, federal, state, tribal, and local governments have been measuring environmental and biological parameters as mandated by laws, and program policies. Although designed for other purposes, many of these measurements relate directly to watershed health and salmon recovery. The CMS capitalizes upon existing monitoring efforts to the extent possible. In addition, the CMS:

(1) Reviews existing monitoring activities that fall within its scope and the legal mandates that created existing monitoring efforts;

(2) Evaluates those activities in the context of the monitoring required to implement the CMS;

(3) Suggests new monitoring activities;

(4) Recommends adjustments to existing monitoring activities where appropriate; and

(5) Makes funding recommendations as needed.

What Should Be Monitored?

The issues and decisions about watershed health and salmon recovery that are faced by policy-makers and resource managers are complex and overlap in many areas. Teams of scientists and agency specialists evaluated existing information to determine what needed to be tracked to produce a scientifically credible monitoring program for watershed health and salmon recovery. Although each watershed is unique in its needs, there are some scientifically based principles that all healthy watersheds share (adapted from Statewide Strategy to Recover Salmon). These principles helped guide the decisions about what needed to be monitored:

- The freedom of rivers and streams to move and change, especially during floods, must be maintained.
- Natural regenerative processes need time to occur to provide recovery of river and stream integrity.
- The natural diversity of species should be protected and the natural diversity of habitats restored within river channels and riparian zones.
- The interaction and connections between the diverse parts of the aquatic ecosystem, including estuaries, rivers, streams, and uplands, should be supported and fostered
- Actions need to be tailored locally and to the whole watershed in the proper sequence of time and place. The system's potential and long-term human commitments need to match the stewardship of the system.
- The needs of human communities must be integrated with the long-term dynamics of rivers and streams.

Monitored Salmon Species

The following species will be monitored in the CMS:

(1) Chinook salmon – *Oncorhynchus tshawytscha*

(2) Coho salmon – *O. kisutch*

(3) Chum salmon – *O. keta*

(4) Sockeye salmon – *O. nerka*

(5) Pink salmon – *O. gorbuscha*

(6) Bull trout/Dolly Varden trout – S*alvelinus confluentus/S. malma*

(7) Steelhead (rainbow) trout – *O. mykiss*

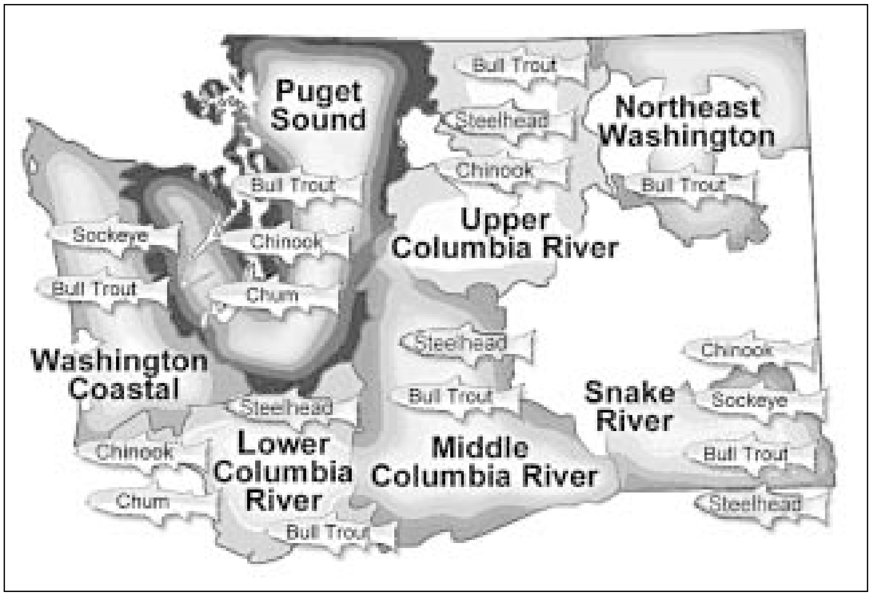
(8) Coastal cutthroat trout – *O. clarki clarki*

(9) West slope cutthroat – *O. clarki lewisi*

CMS Addresses Statewide, Regional, and Watershed Scales

The essential unit for recovery and de-listing of salmon is the Evolutionarily Significant Unit (ESU) for salmon and Distinct Population Segment (DPS) for Bull trout and cutthroat trout.

Figure 2. Salmon Recovery Regions.



ESUs and DPSs are usually distinguished in terms of genetics, behavior and isolation. Salmon Recovery Regions (SRRs) are administrative units that roughly correspond to the identified ESUs/DPSs in Washington for steelhead and chinook salmon. They are the administrative units and entities around which recovery plans will be built.

Given the broad spatial context of monitoring areas (e.g., stream reach, watershed, region, statewide) the CMS must address regional scale monitoring for salmon recovery. Regional scale monitoring draws upon watershed/population monitoring and other statewide information as appropriate to the regional design. Information on statewide population trends is taken from information derived from the regional-scale (ESU/DPS) components. Effectiveness monitoring is also built at the regional scale due to the wide variety of habitat types and broad ecological provinces across the state. However, the state has also provided answers at the watershed and statewide scale for some indicators.

The emphasis of status and trend monitoring is generally at the regional scale, but it is recognized that counties, watershed groups, tribal governments, and municipalities usually seek monitoring information at the watershed scale. The Technical Recovery Teams created by the National Marine Fisheries Service (NMFS) have asked that the CMS include salmon monitoring at the stock or population level scale.

Introduction

Implementation and Administrative Monitoring is Included

It is important to know that activities aimed at salmon recovery and watershed health improvement have been implemented as part of a planned and comprehensive monitoring approach. Some levels of implementation and administrative monitoring are included in the CMS (Figure 1). The *Salmon Recovery Scorecard*, other ongoing agency activities, and the efforts underway to address ESHB 1785 are expected to address most implementation and administrative monitoring issues and needs beyond the scope of the CMS.

An Adaptive Management Model is Included

The CMS includes a model for the organization, analysis, and communication of monitoring information for decision-making purposes. The CMS uses the definition of adaptive management in the *Statewide Strategy to Recover Salmon*. The model enables watershed, regional, and agency salmon recovery and watershed health monitoring or management actions to be changed as appropriate based on the results and analysis of monitoring information.

Committees

Monitoring Oversight Committee

The MOC was created by state statute SSB 6537. The MOC worked collaboratively to develop a monitoring strategy and action plan that enhances the cooperation and data sharing necessary for maximum public service and good government between state, federal, tribal, and local government.

The MOC was required to:

(1) Complete the tasks described in the CMS report;

(2) Address the monitoring recommendations of the Independent Science Panel established under RCW 77.85.040(7), and of the Joint Legislative Audit and Review Committee in its report number 01-1 on *Investing in the Environment* (Section 3(2) of SSB 5637); and

(3) Make recommendations to individual agencies to improve coordination of monitoring activities (Section 3(5) of SSB 5637).

Table 1. MOC members and affiliations

Name of Committee Member	Affiliation
William Ruckelshaus, Co-Chair	Chair, Salmon Recovery Funding Board
Curt Smitch, Co-Chair (through 6/02)	Governor's Salmon Recovery Office
Steve Meyer, Co-Chair (as of 9/02)	Governor's Salmon Recovery Office
Tom Fitzsimmons	Washington Department of Ecology
Laura Eckert Johnson	Interagency Committee for Outdoor Recreation
Jeff Koenings	Washington Department of Fish and Wildlife
Doug McDonald	Washington Department of Transportation
Scott Redman	Puget Sound Action Team
Ed Manary	Washington Conservation Commission
Doug Sutherland, Commissioner of Public Lands	Washington Department of Natural Resources
Bob Whitener	Northwest Indian Fisheries Commission
Elizabeth Babcock	National Marine Fisheries Service
Bob Wunderlich	U.S. Fish and Wildlife Service
Bruce Roll	Nooksack Watershed Planning Unit
Ron Kreizenbeck	U.S. Environmental Protection Agency

Legislative Steering Committee

The LSC was created by SSB 5637 and was required to be briefed quarterly by the MOC on the following issues:

(1) Coordination of monitoring efforts;

(2) Expected benefits and efficiencies from such coordination;

(3) Recommended funding sources and funding levels necessary to provide secure and steady funding for monitoring; and

(4) Whether state agencies are improving coordination of monitoring activities (Section 3(4) of SSB 5637).

The LSC was comprised of the following members:

- Senator Karen Fraser
- Senator Bob Oke
- Representative Bruce Chandler
- Representative Ed Murray

The project management team briefed legislative staff in October 2001 because the LSC had not yet been appointed. As soon as the LSC was appointed, coordination meetings were held in January, May, and September of 2002.

Independent Science Panel

The Independent Science Panel (ISP, established in RCW 77.85.040) was required by SSB 5637 to review work products and to act as an advisor to the MOC. The ISP reviewed all work products developed by the committee, and made recommendations to committee co-chairs. The ISP presented formal comments at MOC meetings. A summary of written responses of the ISP can be found in Appendix 2. In addition, project staff met with the ISP on a regular basis throughout the life of the project to discuss project issues.

Acknowledgements

The strategy and action plan were developed over a period of one year and included 24 different agencies and over 100 participants. The coordination has included input from lead entities, watershed lead agencies, counties, conservation districts, and other interested groups and individuals. Public comment was invited by posting drafts of the CMS on the IAC and GSRO websites and by hosting a workshop for watershed health and salmon recovery partners.

The MOC would like to thank the following agencies and individuals for assisting in developing the Strategy and Action Plan: U.S. Fish and Wildlife Service; National Marine Fisheries Service and Northwest Fisheries Science Center; U.S. Forest Service; U.S. Environmental Protection Agency; U.S. Geological Survey; National Park Service; Washington State Departments of Agriculture, Natural Resources, Ecology, Transportation, and Fish and Wildlife; Conservation Commission; Office of Financial Management; Governor’s Salmon Recovery Office; Puget Sound Action Team, and the Interagency Committee for Outdoor Recreation. We would also like to thank Kelly Moore of the Oregon Watershed Enhancement Board; the Oregon Department of Fish and Wildlife; and the Oregon Department of Environmental Quality for their ideas and lessons learned in producing Oregon’s monitoring plan for the coast. Thanks are also due to the Northwest Power Planning Council, Northwest Indian Fisheries Commission, City of Bellevue, Pierce County, and the Hood Canal Coordinating Council.

Introduction

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Key Monitoring Questions and Goals

Part II

Effective watershed health and salmon recovery monitoring should provide guidance for specific management decisions facing Washington State. Most of the specific management and policy decisions are derived from the SSRS.

The CMS has two major goals:

GOAL 1 *Measure changes, in terms of scientific certainty, in wild salmon populations in terms of abundance, diversity, and geographic distribution and their causes due to trends in effects of harvest, hatcheries, ocean conditions, ecological interactions, and large hydropower.*

GOAL 2 *Measure changes, in terms of scientific certainty, in water quality, water quantity, watershed health, salmon habitat, and their effects on salmon.*

To accomplish these two goals, the following key questions will need to be answered. The objectives listed under each of the key questions detail how the strategy will monitor the environment in order to provide the necessary answers:

Question 1: How are the annual abundance and productivity of salmon by species, ESU, and life stage changing over time?

Objective 1A: Measure status and track trends of the numbers of spawning salmon by stock in each Salmon Recovery Region. Evaluate whether numbers are improving.

Objective 1B: Measure status and track trends of the numbers of juvenile migrant salmon for selected index watersheds. Evaluate whether the numbers are improving.

Objective 1C: Measure status and track trends of the number of resident juvenile cutthroat and bull trout for each stock. Evaluate whether numbers are improving.

Objective 1D: Measure status and track trends of salmon productivity for selected index watersheds.

Question 2: What improvements are occurring in restoring the geographic distribution of salmon by ESU, species, and life stage to their historic range?

Objective 2A: Measure the geographic distribution and evaluate trends of salmon in each Salmon Recovery Region. Determine whether their geographic distributions are improving.

Question 3: Are the unique life history characteristics of salmon within a Salmon Recovery Region changing over time because of human activities?

Objective 3A: Determine the status and trends of genetic and other diversity characteristics of salmon in each Salmon Recovery Region. Evaluate whether they are improving.

Question 4: What are the trends in the climate of the Pacific Northwest that will allow the State to anticipate and account for such conditions in initiating and monitoring management actions for watershed health and salmon recovery What trends in climate may mask or expose the status of freshwater habitat and its role in salmon recovery?

Objective 4A: Determine the status and trends of climate and ocean conditions affecting Washington salmon production.

Question 5: In the context of other sources of natural and human-caused mortality, is predation by avian, marine mammals, or other aquatic species inhibiting the recovery of salmon within each ESU?

Objective 5A: Measure status and trends in the rate of consumption of Threatened and Endangered salmonids by seals and sea lions

Objective 5B: Measure status and trends in seal and sea lion populations in Washington State.

Objective 5C: Determine status and trends of Caspian tern populations at the mouth of the Columbia River and elsewhere in Washington. Determine whether predation rates previously identified are valid.

Objective 5D: Measure status and trends in squawfish populations in Columbia River reservoirs.

Objective 5E: Determine whether squawfish control measures have been effective in reducing predation on juvenile salmon to target levels.

Question 6: What are the trends in effects of hatchery production on the survival and productivity of wild salmon populations within each ESU?

Objective 6A: Determine whether hatchery Best Management Practices (BMP) have been implemented as required under the Wild Salmonid Policy and ESA 4(d) rules.

Objective 6B: Determine whether hatchery BMP have been effective in reducing or eliminating the adverse effects of hatchery fish upon wild salmon productivity and production within each ESU.

Question 7: What is the impact of harvest upon the recovery of wild salmon populations?

Objective 7A: Measure salmon harvest rates and total numbers of harvested salmon for stocks in each Salmon Recovery Region; and determine trends.

Objective 7B: Determine whether harvest restrictions have been implemented as required under the ESA 4(d) rules.

Objective 7C: Determine whether harvest restrictions have been effective in allowing adequate spawner escapement.

Objective 7D: Determine if age-, size-, or sex-selective harvest has been detrimental to natural populations.

Objective 7E: Measure status and trends of illegally harvested salmon.

Question 8: What hydroelectric facilities in each ESU are being operated and/or modified in a manner that is compatible with salmon survival and recovery?

Objective 8A: Measure current status of major hydropower projects upon salmon survival and recovery. Evaluate whether projects are improving.

Objective 8B: Determine how many major hydropower projects have fully implemented fish recovery measures into their operations as required in their license. Determine their status and trends.

Objective 8C: Measure whether mitigation actions at hydro projects have been effective in restoring fish passage and meeting salmon recovery goals.

Question 9: What is the quality of surface waters?

Objective 9A: Measure status of identified water quality indicators.

Objective 9B: Measure status of identified water quality indicators in agricultural, forest, and urban lands.

Question 10: How are surface water quality conditions changing over time?

Objective 10A: Measure the trend of identified water quality indicators at stations representing the cumulative effects of human caused impacts and natural conditions.

Objective 10B: Assess the change in the area-wide conditions of identified water quality indicators estimated under question 9.

Question 11: Where do the water quality conditions not support aquatic life and recreational uses?

Objective 11A: Identify waters where aquatic life and recreational uses are impaired due to surface water quality conditions.

Question 12: How effective are clean water programs at meeting water quality criteria?

Objective 12A: Measure effectiveness of clean water programs in meeting water quality goals.

Question 13: Where have standards for water quantity been established?

Objective 13A: Measure quantity of instream flow necessary to sustain salmonids.

Question 14: Where do water quantity and flow characteristics limit salmon productivity?

Objective 14A: Derive indicators of flow characteristics related to salmon productivity.

Question 15: What are the trends in water quantity and flow characteristics?

Objective 15A: Measure change in identified water quantity and flow characteristics.

Question 16: How effective are the State's water resource management programs for protecting and restoring instream flows?

Objective 16A: Measure identified indicators related to the performance of managing water resources.

Question 17: What are the overall impacts of human related activities on freshwater habitat and landscape processes as they relate to watershed health and salmon recovery?

Objective 17A: Measure status and trends of identified freshwater habitat indicators in agricultural, forest, and urban lands. Evaluate whether they are improving.

Objective 17B: Measure implementation of agricultural conservation practices identified in the Strategy that affect habitat. Evaluate their status, and trends.

Objective 17C: Determine how effective agricultural conservation practices are in improving status of habitat as shown by their indicators.

Objective 17D: Confirm that the Washington Department of Natural Resources (DNR) continues to implement the habitat conservation strategies identified in the agency's 1997 Habitat Conservation Plan (HCP) relative to compliance with the ESA.

Objective 17E:Measure how effectively DNR's HCP management actions contribute to restoring and enhancing salmon habitat as measured by indicators. Evaluate the status and trends.

Objective 17F:Measure success of implementation of habitat conservation practices on forest lands identified in modifications to the Forest Practices Act (FPA) established under ESHB 2091 (also known as the Forest and Fish Agreement).

Objective 17G: Measure how effective modifications to the FPA, (also known as the Forest and Fish Agreement) are in improving status of identified forest habitat.

Objective 17H: Determine status and trends of the identified freshwater habitat and landscape forming indicators identified in the Aquatic/Riparian Effectiveness Monitoring Plan (AREMP) and PACFISH/INFISH (PIBO) in federal lands in Washington. Evaluate whether the indicators are improving.

Objective 17I: Determine how successful the U.S. Forest Service is in implementing identified forest conservation practices identified in the Northwest Forest Plan (NFP) and PACFISH/INFISH. Evaluate status and trends.

Objective 17J: Determine effectiveness of treatments prescribed in the NFP and PACFISH/INFISH in improving the status of identified habitat and landscape forming indicators.

Objective 17K: Determine the success of state and local governments in implementing riparian buffers, water quality treatment Best Management Practices, and storm water control measures identified in the CMS. Evaluate status and trends.

Objective 17L: Determine how effective urban resource conservation measures have been in improving status of identified freshwater habitat and landscape forming indicators.

Question 18: What are the status and trends in habitat-forming landscape processes in riverine tidal, estuarine, and nearshore ecosystems as they relate to watershed health and salmon recovery?

Objective 18A: Measure the current status and trends of the identified habitat indicators in near shore marine areas. Evaluate whether indicators are improving.

Objective 18B: Determine how effective conservation practices are in improving status of identified near shore marine habitat as determined by key indicators.

Question 19: What is the progress of the State in restoring fish passage at barriers?

Objective 19A: Determine the number of human-caused fish passage barriers statewide. Determine and evaluate trends in fish passage barriers.

Objective 19B: Measure the status of fish passage at human-caused passage barriers statewide. Evaluate their status and the trends.

Objective 19C: Determine how effective restoring fish passage at human-caused barriers has been in increasing the geographic distribution of salmon as measured by the identified indicators.

Objective 19D: Measure the state's rate of compliance with fish screening requirements at human-caused barriers.

Question 20: What is the progress of the State in restoring connectivity of freshwater habitat?

Objective 20A: Determine the current amount of fish habitat that has been disconnected by human caused activities. Determine and evaluate trends in freshwater habitat connectivity.

Objective 20B: Measure how successful the state has been in implementing freshwater habitat connectivity restoration projects statewide.

Objective 20C: Determine how effective restoring freshwater fish habitat connectivity has been in increasing the production of salmon as measured by identified indicators.

Objective 20D: Determine whether measures taken at specific sites to restore freshwater habitat connectivity have been effective over time.

Question 21: Are habitat improvement projects effective?

Objective 21A: Provide guidance to the Salmon Recovery Funding Board (SRFB) and other funding entities for best monitoring protocols for habitat projects.

Objective 21B: Determine whether habitat improvement projects are effective in increasing the number of salmon produced.

Objective 21C: Determine what kinds of salmon recovery projects are the most cost effective.

Objective 21D: Determine whether habitat improvement projects were properly implemented.

Question 22: How can monitoring information be effectively shared and coordinated with the public and all levels of government?

Objective 22A: Establish a web portal that will provide monitoring information to all levels of government and to the public.

Objective 22B: Develop a consensus approach among monitoring participants for statewide data sharing protocols.

Objective 22C: Identify crucial data repositories.

Question 23: Are watershed lead agencies developing monitoring strategies complimentary with the Comprehensive Monitoring Strategy?

Objective 23A: Provide guidance to the watershed lead agencies for monitoring types and protocols that would be complimentary to the Comprehensive Monitoring Strategy.

Management Decisions

Environmental monitoring is of little value unless it provides useful information that will assist in making important management decisions affecting salmon recovery and watershed health. Following is a prioritized list of management questions that Washington State is likely to encounter regarding watershed health and salmon recovery. The table also shows linkages between these management decisions and the monitoring questions addressed in the CMS. The management questions have been prioritized in their general order of importance as:

H=High, M=Medium, L=Low

Table 2. Management Decision Matrix.

	Priority	Management questions	Monitoring questions
A	H	Are salmon populations healthy?	1-23
B	H	Is the State meeting requirements of the Endangered Species Act and Clean Water Act?	3, 6, 7, 9, 10, 11, 12, 21
C	H	Are human related activities consistent with salmon recovery?	1, 4, 8, 9, 14, 15, 16
D	H	Are harvest activities consistent with salmon recovery?	2, 3, 11, 21
E	H	Is the state's approach to cleaning polluted waters adequate to ensure clean water for watershed health and salmon recovery?	6, 7, 9, 12
F	H	Are hatchery operations consistent with salmon recovery?	3, 10, 14, 21
G	H	Are state and federally-funded habitat protection and restoration projects resulting in improvements in watershed health and salmon recovery?	1, 3, 7, 9, 11, 14, 15, 16, 18
H	M	Are current stream and wetland buffer widths protecting habitat to ensure watershed health and salmon recovery?	1, 3, 6, 7, 9, 15, 16

Key Monitoring Questions and Goals

	Priority	Management questions	Monitoring questions
I	M	Are efforts to improve instream flows adequate for protecting watershed health and recovering salmon?	3, 5, 17, 18, 19, 20, 23
J	M	Is watershed health and salmon information understandable, accessible, and useable by the general public and other entities?	2, 3, 13, 17
K	M	Are current management infrastructures adequate in supporting watershed health and salmon recovery?	2, 5, 6, 7, 9, 10, 12, 13, 17, 19, 20, 23
L	M	If estuarine and nearshore marine area habitat conditions are not improving, what further restrictions on bulkheads and other shoreline development constraints are necessary?	3, 4, 15
M	M	Are dams operating in a manner that protects watershed health and is consistent with salmon recovery?	3, 5, 8, 11, 14, 19
N	M	Are we adequately enforcing our timber harvest, land use, and water supply regulations?	2, 4, 5, 7, 9, 12, 20, 23
O	L	Does the public support salmon recovery and watershed health improvements?	3, 5, 13
P	L	Is climate and ocean condition information sufficient in anticipating and/or modifying our habitat and harvest activities?	3, 18
Q	L	Are habitat protection measures on state lands improving watershed health and achieving salmon recovery?	1, 3, 7, 9, 15, 16
R	L	Should the state ask the federal government to take additional management actions to reduce natural predation of salmon?	3, 22
S	L	Are efforts to improve fish passage effective and timely enough to recover salmon?	3, 5, 11, 14, 15
T	L	Are salmon protection measures in the Forests and Fish Agreement improving salmon recovery and watershed health on private forestlands?	1, 3, 7, 9, 15
U	L	Are habitat protection measures on federal lands improving watershed health and salmon recovery?	1, 3, 7, 9, 15
V	L	Should the state petition federal agencies to list or de-list salmon, steelhead, or trout?	1, 3, 11, 21

Part III

As stated in SSB 5637, numerous agencies and organizations are currently engaged in monitoring salmon recovery and watershed health indicators. The intent of the legislation is to "encourage the refocusing of existing agency monitoring activities necessary to implement a comprehensive watershed health monitoring program, with a focus on salmon recovery." It also states the CMS will:

- Be based on a framework of greater coordination of existing activities,
- Require monitoring activities most relevant to adopted local, state and federal watershed health objectives; and
- Facilitate the exchange of monitoring information.

Problem Assessment

The starting place to initiate an adaptive management approach as outlined in Part IV (Adaptive Management Approach) for watershed health and salmon recovery is to compile what we know and do not know about the species of interest and their environments. For watershed health and salmon recovery, this includes watershed or other technical assessments, resource inventories, and other diagnostic analyses. These assessments provide initial information to policy-makers as they develop responsive conservation goals, objectives, strategies and action plans for habitats and species at multiple scales (site, watershed, and region). The Limiting Factors Analysis completed by the Conservation Commission as required under state law (Chapter 77.85.070 RCW) provides an initial statewide assessment of problems and provides baselines for habitat assessment. Table 3 provides a summary of watersheds (with completed reports as of May 2002), and associated limiting factors.

Table 3. Watershed limiting factors and percent affected

LIMITING FACTOR	PERCENT OF APPLICABLE WATERSHEDS AFFECTED
Fish Access	88%
Floodplain Connectivity	94%
Large Wood	97%
Pool Habitat	96%
Bank Stability	72%
Substrate/Sediment	97%
Riparian Condition	100%
Water Quality	85%
Peak Flow	56%
Low Flow	78%
Altered Hydrology	42%
Estuarine Function	88%
Marine/Nearshore	60%

Watersheds across the state have multiple limiting factors and detection of improvements in watershed condition through monitoring should measure changes associated with these identified factors.

Monitoring Types

The goals listed in Part II encompass a broad array of monitoring needs across a range of spatial and temporal scales. An approach using several types of monitoring is presented below which can accommodate the broad spatial and temporal scales of monitoring needs and facilitate the integration of results across monitoring scales. The three environmental monitoring types presented below and shown in Figure 3 differ in spatial scale and intensity of effort:

(1) Extensive (status and trends) monitoring – The basic objective is to estimate fish populations, generally at the ESU scale, and to track indicators of habitat, water quality, water quantity, and other factors that impact wild fish. The spatial scale is large and varies from ESU (for fish population estimates) to statewide. This design will not demonstrate cause-effect relationships between actions and outcomes, but is an effective means of assessing the actual condition of variables. For example, the current frequency distribution of large woody debris or pool depth within an ESU could be assessed and tracked over time to determine the net impact of natural events and management actions. These estimates of fish abundance and distribution are the ultimate measure of the effectiveness of salmon recovery efforts as they account for the net effect of natural events and management actions.

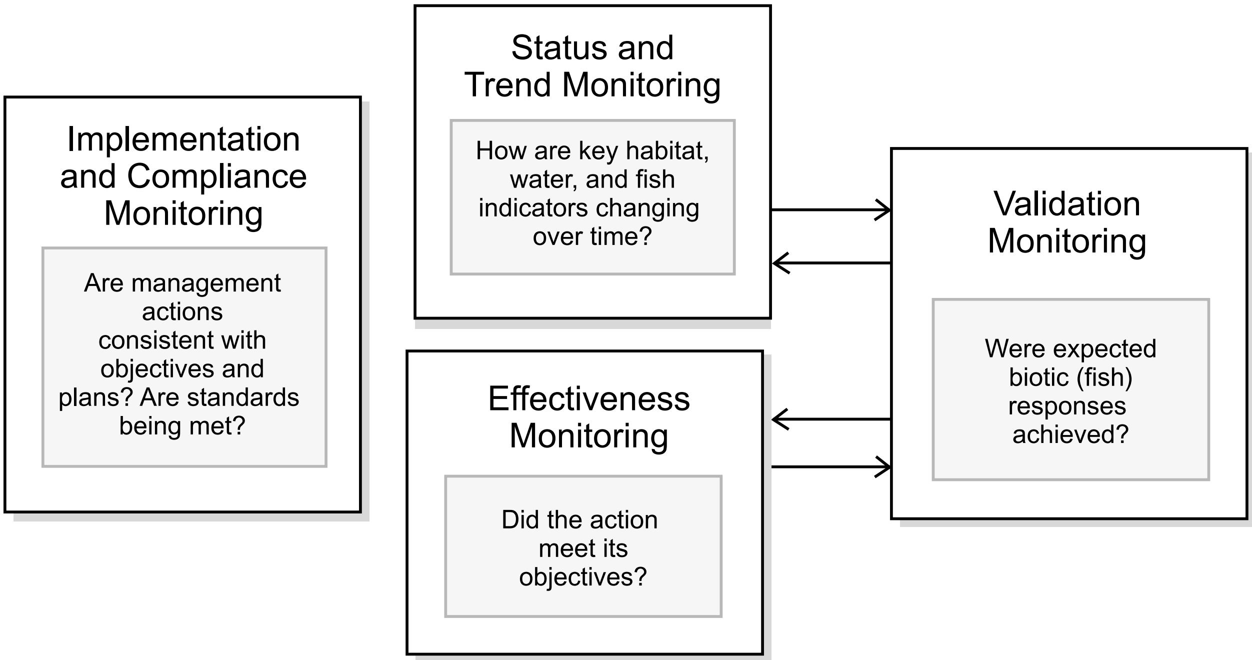
(2) Project effectiveness monitoring – Projects are defined at a small scale, with defined sets of actions meant to protect or enhance specific habitat features or habitat-forming process. Implementation monitoring and effectiveness monitoring are equally important in meeting the objectives of project effectiveness monitoring. An enhancement technique may be difficult to implement properly, but very effective or, conversely easy to implement but rarely effective. Both implementation and effectiveness monitoring are necessary to evaluate specific projects or classes of projects. Because these are small-scale projects, their impacts will generally be local and the indicators monitored should be selected accordingly.

(3) Intensive (validation) monitoring – This category is more research oriented than the other two types of monitoring and is tailored to establish “cause and effect” relationships between fish, habitat, water quality, water quantity, and management actions. It pertains to evaluation of programs that conduct, promote, or regulate, activities meant to protect or enhance habitat, water quality, or fish production. One example of intensive monitoring might be a case study of a watershed that examines the cumulative impacts of forest practices on the freshwater life-stages of a species of salmon. Another example might study of the impacts of a particular hatchery on a specific salmon run. The common theme of these studies is to develop an understanding of the linkage between management actions and the resource. These studies often require measuring many parameters to detect the variable affecting change.

Individually or in combination, these three types of monitoring address nearly all of the objectives in Part II.

Answers to these questions within each monitoring category are needed for the efficient allocation of resources. Answers to some questions are relatively easy to obtain. The effectiveness of individual habitat enhancement projects may be assessed by measuring the characteristics that will be enhanced by the project before it is implemented and again after implementation at an appropriate temporal scale. For example, a riparian planting project could be monitored for seedling survival any time. Increases in shade could be expected in five or more years (depending upon stream size). Decades later, the planting project might be a source of large woody debris.

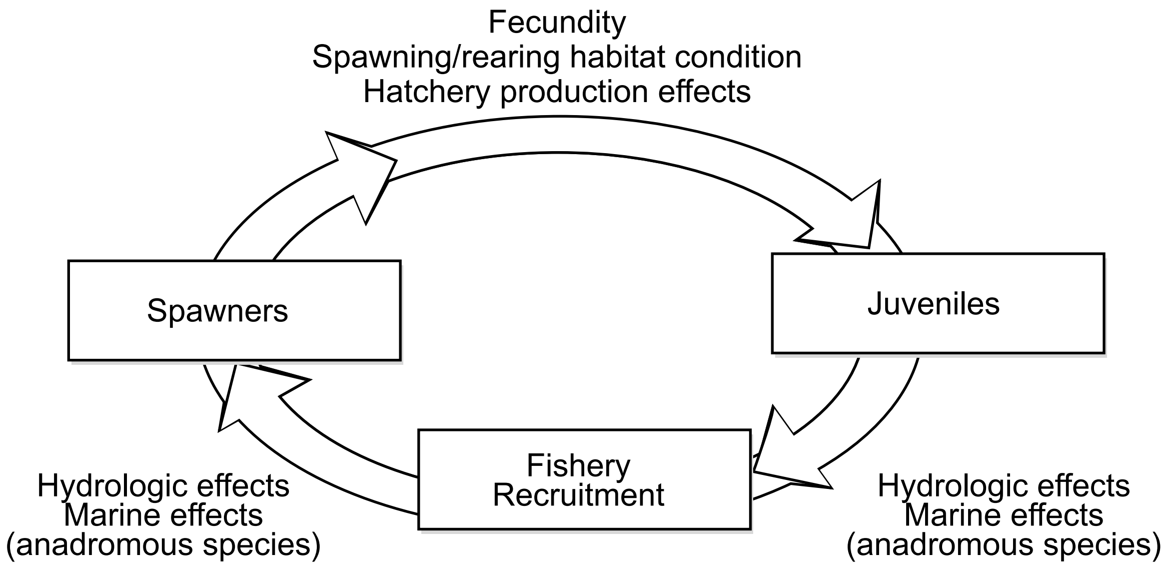
Figure 3. Relationships among monitoring types.



Similarly, many status and trends questions are conceptually straightforward: identify the population and geographic area of interest; then, within logistical constraints, design a plan to obtain an unbiased estimate of that population.

Monitoring plans differ in the type of information needed and the scale of the monitoring. Figure 4 shows a conceptual flowchart that illustrates the general life-cycle of salmonids and the connections between the types of monitoring and indicators of fish and watershed health. The boxes represent information on the status of the resource, and the trends in that status. Indicators include: numbers of spawning adults, and numbers of rearing and migrating juveniles. The number of juveniles per spawning adult would provide a measure of the relationship between the events in the life history. The connections between the boxes represent the factors that affect these relationships: habitat indicators that impact the spawning success or production of juveniles in freshwater, the effects of hatcheries on natural production, the impact of harvest on the number of spawning adults, and other similar factors. Cause and effect monitoring provides information on the factors that impact the productivity of the freshwater and marine habitats. Effectiveness monitoring provides information about how the efforts of management and restoration projects affect the status of the resource.

Figure 4. Life history cycle of salmonids. Boxes indicate stages in the life history where status and trend monitoring occur. Arrows indicate factors that affect the relationship between the life stages, where validation and effectiveness monitoring occur.



Implementation Monitoring

Implementation monitoring is a necessary component of any monitoring program (Figure 3). However, it differs from environmental monitoring in that its answer is always “yes” or “no.” Although implementation monitoring is addressed in the CMS, the nature of implementation monitoring changes as projects or agency actions are implemented and new actions or projects are developed. For both environmental and implementation monitoring, quality of data and program design are critical to achieve successful results.

Strategy Implementation

To implement the Statewide Strategy to Recover Salmon (SSRS) the natural resource agencies formed a Joint Natural Resources Cabinet (JNRC) to cooperatively coordinate their efforts toward salmon recovery and watershed health. Under the leadership of the Governor’s Salmon Recovery Office (GSRO), the JNRC developed a Balanced Scorecard to report progress to the public and to the Governor. It also provided a State Agencies Action Plan, detailing the actions that each agency had pledged to undertake to move the SSRS forward.

In addition to the Scorecard and the Action Plan created administratively, the Legislature created statutorily the Salmon Recovery Funding Board (SRFB) as a mechanism for dispersing state and federal funds for habitat recovery projects. It also created the ability and incentives for local governments to implement salmon recovery and watershed health measures through the forming of Lead Entities and Watershed Planning Units. These entities could identify habitat restoration projects and water needs at the local level and present these needs to the SRFB for funding. The Legislature also implemented the concept of Salmon Recovery Regions (shown in Figure 2) as a means of compiling and organizing watershed information and restoration activities to address the appropriate scale for ESA listings.

The GSRO produced a series of publications designed to guide and assist local watershed entities in assessing watersheds and implementing appropriate habitat improvement projects. The publications include:

- Reference Guide to Salmon Recovery
- Guidance on Watershed Assessment for Salmon
- Roadmap For Salmon Habitat Conservation at the Watershed Level.

Statistical Considerations

Scientific Certainty

Management of water quality, habitat, stream flow, and fisheries requires the input of data. Effective management depends on the quality of the data collected.

For the purposes of a policy decision, data quality depends on the following conditions:

(1) Asking the right questions;

(2) Defining performance measures that provide the answers to those questions;

(3) Creating a project sample design that delivers the indicator defined in the performance measure;

(4) Achieving the level of certainty needed by policy makers; and

(5) Controlling quality in the collection of data.

In management of fish populations, stream flow, or habitat management, policy decisions are made using the information gained from data collection. If all fish are counted or all habitat is measured, there is no uncertainty because a complete sample has been obtained. However, this is seldom possible or cost effective. Therefore, sampling is the accepted approach to determining the answer to a desired question. Sampling provides an estimate of the true value sought.

While the policy agenda may focus on quantification of parameters such as abundance, effective decision-making will be dependent on an appreciation of the uncertainty associated with these parameters. The goal of any project is to provide an accurate and precise estimate of the indicators needed by decision makers. Questions and concerns with sampling estimates include:

- How reliable are the estimates?
- Is the decision correct, based on estimates?
- What is the chance that the decision is wrong?

Current projects need to be evaluated and recommendations made for future monitoring. Uncertainty introduced in decision-making will depend on the accuracy (or bias) of the estimator and the reliability (or precision) of the estimates. An accurate or unbiased estimate is an estimate that does not have systematic error. For example, systematic error could be introduced if only sites with high densities of large woody debris are used to estimate the average amount of large woody debris per mile for all habitat types, high or low density. Bias is not generally a quantity that can be measured, so typically bias can only be minimized by careful consideration of assumptions and methods of data collection in the project sample design.

On the other hand, precision or reliability is measured by variance. A reliable estimate is an estimate with small variance, which measures the precision of the estimator. Imprecision is introduced when sampling is used instead of conducting a census. The precision of an estimate depends on many factors including the underlying population variability, the method of estimation used and on the numbers of samples or sampling effort used. Precision can also be optimized by careful attention to the sample design.

When considering a current project or planning a new monitoring or research project the questions of bias and precision are fundamental. Evaluating a current project requires knowledge of the sample design used to achieve the estimate, because bias and precision are a function of the sample design. Planning a monitoring project requires consideration of bias and precision, because both are criteria driving the development of a sample design (along with the resources available to carry out the project).

Deciding on the acceptable level of uncertainty is not an objective process, but a subjective one driven by policy or management needs and budget constraints. In general, an unbiased estimate is one criterion, and another is a predefined level of precision needed for management or policy decisions. These criteria must take into account the question being asked, the risk involved, and the available project resources.

It cannot be stressed enough that definition of these criteria, particularly of the needed precision, requires communication between the decision makers and the personnel planning or evaluating the project. It is almost always an iterative process, and input that informs this process includes not only the policy issue and the question being answered, but also the logistics of the sampling environment, the costs of the sampling design alternatives and the available resources. This process is very important, because without it the data collection may not provide the information needed by decision makers.

Sample Design

Choices made in sampling design have many consequences. Performing a complete census of all salmon in Washington State is impractical. But collecting a sample that is not statistically valid may result in incorrect inferences about the complete population, and lead to inappropriate management decisions. If you want to know something about a statistical population (in this usage, different than a demographic or genetic population), you must either conduct a full census of the population, or sample it in a statistically valid manner.

The sample design is used to achieve the goals set by the performance measure. It includes:

(1) A statement of the objective of the sample design, including the indicator to be measured, the scale at which the indicator will be measured, and the statistical criteria set by the performance measure;

(2) The method of estimation (analysis of data collected) of the indicator;

(3) Definition, organization and number of the sample units; and

(4) The method of data collection required by the method of estimation.

Statement of Objective and Statistical Criteria

The project objective and statistical criteria are required to develop a statistically valid sample design. As an example, consider the following management question:
Are chinook salmon in stream X meeting their spawning goal objective?

An obvious performance measure would be whether the number of spawning chinook in stream X meets a target spawning goal. And one indicator defined for this measure would be the total number of spawning adults in stream X. Uncertainty statements define statistical criteria, which are then used to evaluate or design sampling projects and experiments. In most cases the first criterion is that an estimate is unbiased. The second criterion sets a precision requirement.

A statement of the objective of the sample design could be:
Estimate the abundance of spawning adult chinook salmon in stream X, such that the estimate is unbiased and has a coefficient of variation of 20%.

The scale of the study in this case is stream X. Statistical criteria require an unbiased estimate and define the precision needed for the estimate: the maximum level of uncertainty (or possible error) that policy makers have defined as acceptable for their purposes of decision making.

Although the quantification of precision depends on the variance estimated, other measures derived from the variance and its relationship to the point estimate or the trend in point estimates are generally used to describe the uncertainty, to evaluate current project design and to plan future projects. These measures include coefficients of variation (CV, defined here as the percent standard error) and confidence intervals (CI) for point estimation and signal to noise ratios (S/N) for detection of trends or differences.

The CV and the CI both provide information about the precision around a point estimate. They both start with the standard error of the estimate, which is simply the square root of the variance of the estimate. The coefficient of variation is a ratio of the standard error over the point estimate. It quantifies uncertainty relative to the point estimate or as a percentage of the point estimate. The CI defines a range around the point estimate defined by the standard error and provides a probability statement about the chance that the true estimate is included in this interval, an upper and lower limit of uncertainty.

As an example, consider an estimate of abundance of spawning salmon of 500 fish with a variance of 10,000. The square root of the variance, or the standard error (SE), is 100. The coefficient of variation (CV) would be:

$$CV = \frac{\text{Standard Error}}{\text{Number of Spawners}} \times 100 = \frac{100}{500} \times 100 = 20\%$$

The CI is estimated as a range using the standard error and a constant multiplier that defines the probability statement. Generally a CI is described as follows: "The confidence interval around the estimate will contain the true value 95% of the time," i.e. 5% of the time the true value could lie outside this interval. The CI could be calculated as:

95% CI = Estimate of spawners ± Standard Error x 1.96

= 500 ± 100 x 1.96

= 500 ± 196.

This results in the interval from 304 to 696. The relative size of this range above and below the point estimate represents 39.2% (196/500) of the estimate. There is a 5% chance of being wrong when concluding that the number of spawners lies between 304 and 696. Making a decision based on this conclusion provides a measure of the risk.

Which of these measures is used depends on why the uncertainty is being described. Both measures can be useful for setting or evaluating project uncertainty goals, and both can be described as relative measures, as a percentage of the point estimate. Relative measures alone do not include information about the point estimate. Often the choice of a relative measure as a goal should be evaluated given the expected point estimate. For example, a CV of 40% on an estimate of 500 represents 200 fish, while a CV on an estimate of 500,000 represents 200,000 fish. Whether these uncertainties are acceptable in a current or a new project depends on the decision being made, or the project goal.

In other cases, the project goals may not lend themselves to a relative measure of precision. When evaluating a harvest management policy, for example, where a target escapement has been set and the project needs to provide an abundance estimate to evaluate whether or not a harvest policy is meeting this goal, the decision depends on the relationship of the target to the confidence interval. If the target was 250, and the estimate is 500 with a confidence interval ranging from 304 to 696, the decision maker will feel more comfortable about stating that the goal was met and the harvest policy is working. However if the goal was 450 fish, and the estimate is 500 with the same confidence interval, determining whether the harvest policy is adequate is more difficult. Although the point estimate is 500, deciding whether or not to change the harvest policy must depend on the risk involved in being wrong.

A third measure of uncertainty can be used to evaluate or design monitoring projects when the question involves evaluating a trend over years. Data associated with watershed health and salmon populations are innately highly variable. With highly variable measures, it is often difficult to discern the “signal” (e.g., trend over time) amidst a high level of variation or “noise.” Describing such a trend involves making point estimates over time, and each point estimate has a measure of uncertainty. The ability to detect a trend depends on the steepness of the trend relative to the uncertainty in the point estimates: the signal to noise ratio. The size of the trend can be expressed as variance over time, and the noise can be expressed as the variance within each point estimate. So the signal to noise ratio is:

$$S / N = \frac{\text{Variance between units (e.g., years)}}{\text{Variance within each unit}}$$

If the noise (denominator) is large, a larger number of units must be measured. This means more years. Decreasing the noise allows the detection of a difference with a higher level of confidence and fewer point estimates, years, or streams. Decreasing the noise is equivalent to improving the precision of the point estimate, and can be accomplished with a different sample design: using a different method of estimation or increasing the sample size used for the estimation, for example.

Estimation Method

A well-designed monitoring project meets the objectives of the monitoring project not only by providing the data needed to make estimates or test hypothesis, but also by meeting the statistical criteria required for policy decisions. The method chosen for estimation depends on the level of precision required, as some methods are more precise than others. A general rule is that the more precision required, the more expensive the monitoring needed to meet that precision requirement. For the example of spawning salmon, several methods of estimation are possible: counting fish as they enter the stream at a weir; redd counts (an estimate based on periodical stream surveys of constructed spawning nests); or a mark-recapture experiment.

Weir monitoring is the most precise, and is the most difficult and expensive to conduct. An estimate based on periodic counts of redds is the easiest to implement, but the least precise and subject to bias depending on the assumptions made for the estimate. A mark-recapture program is also subject to bias, depending on the assumptions of the method used.

Definition, Organization and Number the Sample Units

The definition of the sample units depends on the scale required for the policy or management decision. For a habitat indicator, such as proportion of spawning gravel that is optimal for chinook salmon, the scale might be one watershed, an ESU, or the entire state. How sample units are chosen and organized depends on the scale, the definition of all possible sample units and the method of estimation. The number of sample units chosen is one of the major deciding factors in determining the level of precision. The larger the sample size the more precise the estimate, and, of course, the more costly the project. All of these factors must be considered as part of the sample design.

Data Collection Method

The method of data collection during field sampling depends on the method of estimation of the indicator. Uncertainty in the estimation depends on correct data collection, the quality of the measurement techniques, and the methods of recording and summarizing the data. Data quality is critical for achieving the project objective of an unbiased estimate and precision. The sample design must include clear definitions of the data items needed, and the frequency and methods of data collection and summarizing.

Document Organization

Part VII of the CMS constitutes a detailed evaluation of current ongoing monitoring and evaluation actions taken by the various state, federal, and local agencies. Also included is the recommended overall strategy developed by the technical teams. The proposed monitoring indicators, protocols, quality control measures, certainty criteria, and action agencies are identified. Each section is organized around a major component of the CMS. The elements that address watershed health, such as habitat and water, are listed first. The habitat and water chapters are followed by chapters that discuss salmon abundance and components that directly affect salmon abundance such as harvest, predation, etc.

For specific governance recommendations and timeframes, consult the Action Plan (Volume 3). The following headings can be found under each monitoring question in Part VII. Sub-headings include brief descriptions of:

Objectives

Lists each objective as identified in Part II.

Monitoring indicators

Indicators are the actual parameters or groups of parameters that are to be measured in order to meet the objective. For environmental monitoring, these are usually physical, chemical, or biological properties.

Current monitoring activity

Lists and describes current monitoring activities and agencies responsible for monitoring.

Essential tools

Many of the objectives cannot be realized without specific supporting equipment, programs, or facilities. These have been identified as key components for success in meeting the described objective and answering the specific monitoring question.

Monitoring design

Specific recommended actions are included under this heading for each objective. Certainty levels, sampling strategies and approaches are described. New actions are delineated from ongoing actions.

Identified agencies

The action agencies that are now or should be performing the monitoring are identified.

Recommended sampling protocols

Protocols are the officially recognized methods employed to measure and evaluate the indicators. Commonly accepted and used protocols are important for sharing information and comparing results between locations.

Performance benchmarks

Performance benchmarks are milestones or known measurements of the indicators that can be used to track progress in meeting the objective. Without a benchmark to compare results, monitoring information can be meaningless. Many water quality indicators have benchmarks or targets set by federal or state statute. For salmon populations and habitats, there are few clearly defined performance targets. Historic information or current conditions may be the only benchmark available for some areas or populations.

Identified monitoring gaps/overlaps

Identifies areas where data is lacking or overlaps with exiting monitoring activities.

Quality assurance/quality control

Measures that should be taken to ensure results are accurate and applicable. These are often random, statistically regular checks to ensure the products (data) are accurate and applicable.

Risks

Identifies specific areas of concern or recommended actions.

References

References are listed at the end of each chapter.

Adaptive Management and Governance Recommendations

Part IV

Introduction

The purpose of this chapter is to describe ways of integrating information into decision-making, as required by SSB 5637. This chapter provides a range of initial recommendations intended to align the usual organizational incentives (budgets, mandates, public opinion) with desired conservation outcomes. Specifically, this chapter addresses ways to institutionalize monitoring and "adaptive management," so that they are used routinely to manage watershed restoration and salmon recovery.

Managers frequently look into ways to improve performance, but they often focus on outputs rather than outcomes, or on outcomes that are poorly linked to program activities or inconsistent with those of other agencies. Furthermore, program evaluation may not be systematic or disciplined enough to create desired change. Adaptive management is a process that provides managers with the flexibility to adapt and change in response to new information. It has been defined in state law as "reliance on scientific methods to test the results of actions taken so that the management and related policy can be changed promptly and appropriately" (RCW 79.09.020).

Where large-scale adaptive management programs have been launched in the past, the results have usually been disappointing (Stankey 2001). Too often, such programs have been seen as add-ons to, rather than as integral parts of, management. According to Ralph and Poole (2002), this accounts for many of the failures of applied adaptive management. Nonetheless, there is now more need than ever for conservation management that is guided by its ultimate effects on ecosystems and by economic efficiency. Citizens are waiting for results, and policy makers are demanding greater agency accountability for the millions of dollars that continue to be spent on watershed restoration and salmon recovery.

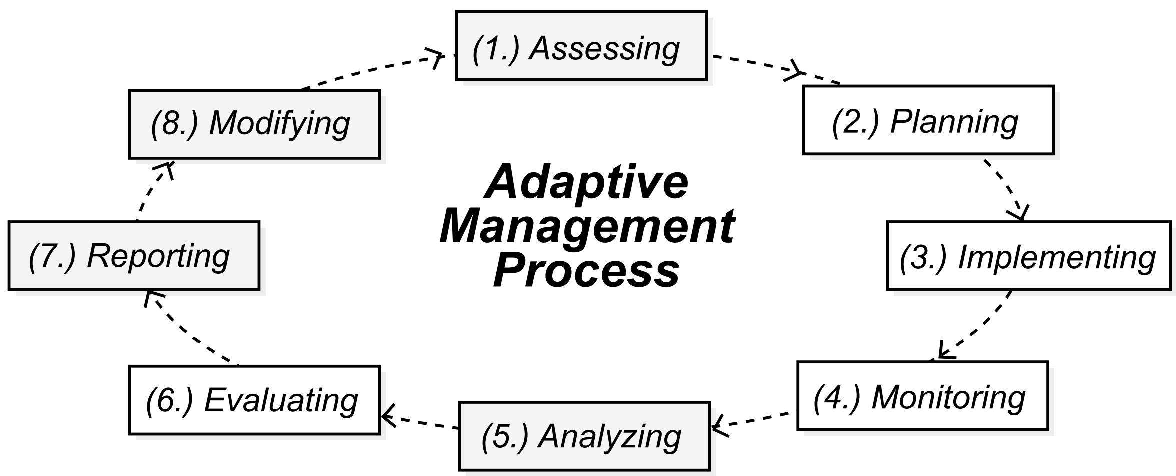
The problem in practice has been lack of systematic implementation of the adaptive management process shown in Figure 5. By adopting a system of adaptive management, agencies can increase their confidence in their ability to reach identified goals and objectives. In addition to recommending that state agencies improve their own internal adaptive management processes, we also recommend that state natural resource and environmental agencies join together in a common adaptive management process focused on attaining the goals and objectives identified in the *Statewide Strategy to Recover Salmon: Extinction is not an Option*, as well as other overarching environmental goals and objectives. By tying agency actions and evaluations together in a larger adaptive management context, there is greater likelihood that efficiencies will occur in monitoring, and that decisions will be made with the greatest access to comprehensive information.

This section recommends changes in fundamental management practices to ensure that environmental information informs decision-making. Monitoring must shift from "a 'follow-up' activity that responds to management actions to an organizational framework that provides guidance in designing management or restoration activities" (Ralph and Poole 2002). We address this issue, first by recommending ways of promoting and enhancing the role of ecological information in management, and second, by proposing new institutional arrangements that flow from, and respond to, the need for information from multiple jurisdictions. Finally, we outline program management options that should provide the ability to assure long-range results.

The Adaptive Management Process

The most significant way to ensure that management activities support salmon recovery and watershed restoration is to adopt the adaptive management process identified in Figure 5. In this figure, the four major adaptive management steps – planning, implementing, monitoring, and evaluating – are arranged in clockwise order. Additional steps (assessing, analyzing, reporting, and modifying) are included to provide greater clarity and specificity.

Figure 5. Adaptive management process



This model should be adopted by state agencies involved in watershed restoration and salmon recovery, as well as by watershed and regional planning groups. If followed diligently, these steps will integrate information into decision-making. Management goals, objectives, performance measures and monitoring indicators should all fit together. If the various management steps do not align properly when first developed, they should continue to be refined in an iterative process until they do so. Proper alignment and linkage of management steps is crucial to successful adaptive management.

Ecological information should be introduced into this management process at the earliest opportunity; i.e., the *assessment* step. In addition to characterizing environmental resources and identifying problems, assessments provide a baseline for monitoring. Ecological assessments are particularly important at the watershed level, although any entity engaged in planning should begin its work with a compilation of existing information and a problem statement or issue description. The *planning* step should identify the management questions that will be answered by monitoring information, as well as the performance measures that will be used to evaluate success. Performance measures are discussed in more detail below.

As Ralph and Poole (2002) suggest, planning for monitoring should be considered at the beginning of a management process, rather than at the end. Planning for monitoring should address the following questions:

- What information is needed?

- How will the information be used?

- How much change is significant (that is, how should "change" be interpreted)?
- How confident do conclusions need to be?

Answers to these questions will assist planners in selecting the appropriate sample design. In addition, this element should describe all of the components that are necessary for conducting monitoring activities; that is, sampling designs, identification of spatial and temporal scales, indicators, metrics, protocols, and analytical methods. The end result should be a "blueprint" for carrying out monitoring activities.

Implementation is the carrying out or realization of the plan. *Monitoring* involves data collection as specified in the management plan. *Analysis* concerns the conclusions that can be drawn from the monitoring data. *Evaluation* allows managers to compare the monitoring results to the planned-for or desired results. *Reporting* ensures that monitoring information is provided to decision makers and/or to the public. If the manager is the decision maker, then the reporting step may not be necessary. The information needs of particular audiences should dictate the content, format and frequency of reporting. Finally, *modifying* or adjusting of management activities takes place before or in the next planning iteration.

Performance Measures

The relationship between performance measures and monitoring can be confusing, so a brief discussion of performance measures and their relationship to planning and monitoring is in order. Performance measures are used to evaluate performance and are the lynch pin for successful adaptive management and effectiveness monitoring. They should be adopted in the planning step described more fully below.

Performance measures are used increasingly to manage administrative divisions in business and government. The focus on government performance measures over the past 10 years stems from repeated calls for more accountability and results from existing programs. The federal government enacted several bills designed to improve accountability for results, including the Government Performance and Results Act of 1993. States have also adopted performance measurement. One of the most sophisticated systems of program evaluation is found in Oregon, which adopted "benchmark-based planning" in 1993. Since then, Oregon has been developing performance measures to link to adopted indicators.

In Washington State, the Office of Financial Management (OFM) has issued budget instructions that call for agencies to adopt strategic plans and performance measures to define success and track progress (OFM 2001). The OFM defines performance measures as: "quantitative indicators of how an agency's programs or services are contributing to the attainment of strategic plan elements. These include outcome, output, and efficiency measures." The OFM considers outcome measures to be the most important because they "indicate the impact on the problem or issue the program was designed to achieve." Because many agency performance measures have been based on "outputs" in the past (e.g., number of grants processed or number of cases closed), the Legislature adopted HB 1785 in 2001, requiring the development of "outcome-focused" performance measures for a dozen capital grant programs, including salmon recovery grants and the centennial clean water fund.

Outcome measures are focused on real world changes, rather than on agency outputs. While outcome measures can reflect different kinds of outcomes, such as environmental, social, and economic, the report that prompted passage of HB 1785 clearly intended to focus on environmental outcomes. With a new program, however, it is often necessary to dedicate a portion of total funding to building "capacity" before money can be spent directly on outcomes. This has been the case with salmon recovery grants, a portion of which is provided for lead entity support.

Outcome-based performance measures can be expressed in terms of desired change (upward or downward trend), targets, or benchmarks. Benchmarks are standards set either by another organization's performance, or expressed as desired results or conditions; e.g., "habitat benchmarks." For example, the same habitat restoration indicator (habitat area) could be expressed as:

- An increase in habitat area *(change)*;
- A specified area (number of acres or stream miles or other metric), or specified percent increase in area protected or restored by a certain date *(target)*; or
- A relational amount or percentage of habitat that is protected or restored by a certain date (e.g., 25 percent of *historic range* is protected or restored by 2025), or an amount or percentage of habitat that achieves a *desired condition* or state by a certain date (e.g., 50 percent of streams meet particular water quality standards by a certain date, *benchmark*).

It is important to recognize that agency programs in themselves do not generally lead to final outcomes. Rather, agencies can expect to influence the conditions that lead to final outcomes. A case in point is Salmon Recovery Grants. These grants are intended to lead to environmental improvements, which in turn are intended to increase salmon abundance and productivity (provided that non-habitat limiting factors are addressed as well). Projects funded by the grants will not, by themselves, lead to final outcomes (e.g., salmon recovery), but they can lead to interim outcomes, such as habitat restoration. To achieve an overarching goal such as salmon recovery requires a sustained and multi-faceted effort between governments and the private sector. Therefore, performance measures should focus on what is attainable by an agency.

➢ *Recommend that every state natural resource and environmental agency make full use of the adaptive management steps shown in Figure 5.*

➢ *Recommend that legislation be adopted requiring state agencies to use this process and requiring the adoption of performance measures for activities included in the State Agency Action Plan.*

Assessing

Assessments should drive the management process. Assessments are both a characterization of current conditions and a problem statement. In watersheds, they provide a diagnosis of the factors limiting watershed health and salmon recovery and their causes. Assessments can be made at various scales and can include varying amounts of ecological information. The Statewide Strategy to Recover Salmon (SSRS) developed an assessment of issues and problems at the statewide level. Ecological assessments relating to salmon called "Limiting Factors Analyses" have been developed at the watershed (WRIA) level, but may not represent a complete ecological assessment in every case.

The Salmon and Steelhead Habitat Inventory and Assessment Program (SSHIAP) describes a number of key hydro-geomorphological features for around two dozen WRIAs in Western Washington. Assessments can also be built at the "sub-watershed level" to provide a higher level of resolution perhaps more useful for project management and local governments, watershed planning groups, and others. Assessments should anchor watershed-scale restoration plans that, in turn, should provide the building blocks for watershed health and salmon recovery.

Unlike planning documents, which serve more transient purposes, assessments should act as repositories of relatively permanent information for a range of potential users. Assessments should include essential information about habitat quality, water quality, the hydrologic system, biological integrity, ecological processes, and disturbance regimes (Table 4), and may include additional information such as land use/land cover, land ownership, road networks, and fish passage barriers. In monitoring terms, assessments provide a baseline for trend monitoring.

Table 4. Essential ecosystem characteristics (adapted for Watershed Health with a focus on Salmon Recovery)

1. Habitat Quality	Instream area, and structure, riparian area and condition, riparian and channel connectivity, channel complexity, spawning area
2. Water Quality	Conventional indicators, nutrients, metals
3. Hydrologic System	Hydroperiod, surface and groundwater flow, water storage, water supply, tidal flushing, wetlands, recharge areas, sediment and materials transport
4. Integrity of Biotic Community	Salmon abundance, productivity, geographic distribution, and genetic diversity; benthic index of biological integrity or equivalent
5. Ecological Processes	Slope stability, succession, ocean conditions, predation
6. Disturbance Regime	Fire frequency and intensity; flooding frequency and intensity; drought frequency and intensity; anthropogenic disturbances (e.g., habitat conversion); disease or pest outbreaks; other outside factors (e.g., sea-level rise, climate change, loss of migratory species' habitat)

Source: Harwell et al. 1999.

Assessments should attempt to integrate a variety of environmental information into a coherent whole by standardizing scales and data sets. They should compile all relevant ecological information into a single map-based data system that can be built over time. If various entities share responsibility for building a single environmental baseline, more useful information can be generated than if planning entities work separately. Local planning entities, with assistance from state and federal agencies, should develop and support ecologically based watershed assessments. The result of such an effort would be to build information management capacity at the local level, as well as provide a focal point for watershed constituencies.

➢ *Recommend completion of watershed assessments for each watershed to serve as a repository of ecological information for use by regional, watershed, and sub-watershed planning entities.*

Planning

The State requires environmental planning under a number of laws, including:

(1) The Shoreline Management Act,

(2) The Growth Management Act,

(3) The Watershed Planning Act, and

(4) The Salmon Recovery Act.

The primary purpose of the Watershed Planning Act is to provide for adequate water supplies for existing and future water uses, including instream flows. Other planning elements may be addressed, including water quality and aquatic habitat.

For historical, legal, and institutional reasons, the state has not managed water, salmon and habitat as a single component. This has resulted in what has been called "stovepipe" management with separate administrative programs (often in separate agencies) managing related resources. One way to reduce historical fragmentation of natural resources management is to encourage an integrated or ecosystem approach at the watershed level, where such a system would be easier to build.

Three principal types of plans are being developed at the watershed level:

(1) Strategies for habitat project identification and prioritization under ESHB 2496 (chapter 77.85 RCW);

(2) Watershed planning by watershed planning groups under ESHB 2514 (chapter 90.82 RCW); and

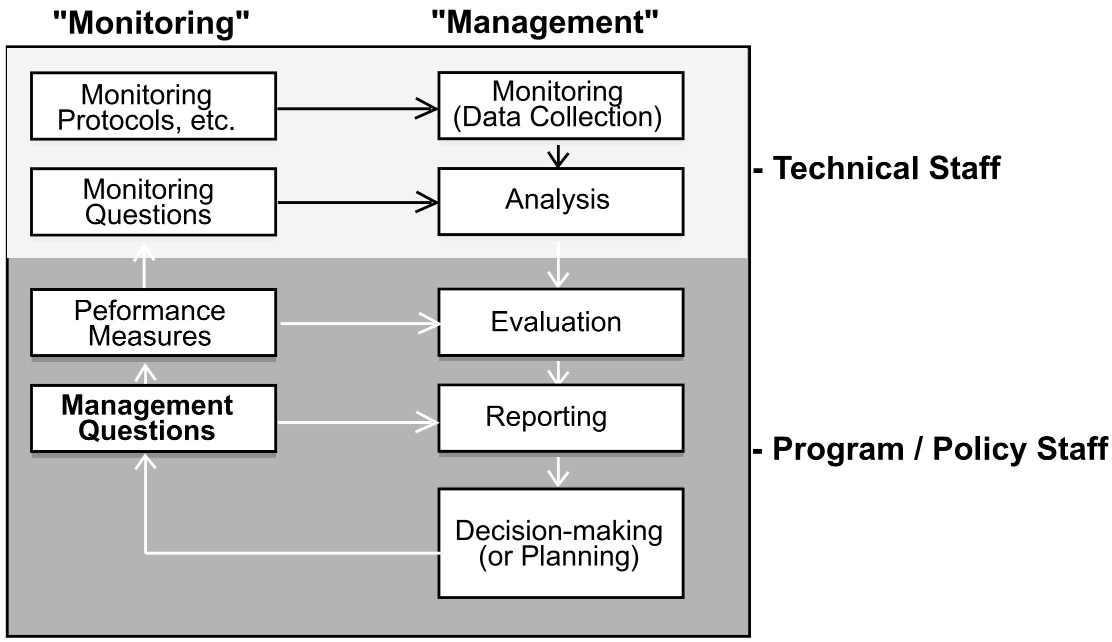
(3) Sub-basin planning by various local entities in the Columbia River Basin under sponsorship of the Northwest Power Planning Council, also for habitat project identification and prioritization.

"Sub-basin" is a term used by federal agencies to describe geographic areas that drain tributaries of the Columbia River. Sub-basins are roughly equivalent to WRIAs. Like lead entity strategies and watershed plans, sub-basin plans are voluntary. Both sub-basin plans and lead entity strategies are intended to be rolled up into salmon recovery plans at the Evolutionarily Significant Unit (ESU) or Salmon Recovery Region level.

Although many lead entities have developed strategic planning information to guide project work, most do not have comprehensive management plans in place. Lead entities and other watershed planners should consider how habitat protection and restoration strategies fit into an overall management framework that allows them to track progress and evaluate success. As in the case of state agencies, comprehensive management plans would enable lead entities to align their management questions, performance measures, and monitoring plans (Figure 6). Such alignment is necessary in order for any entity to actively and purposefully manage watershed restoration and salmon recovery over time.

In addition to creating more thorough and complete plans, there is the potential to combine watershed planning processes (but not necessarily organizations) in order to facilitate coordination and implementation of related goals. Guidance developed for the watershed planning program under ESHB 2514 (now chapter 90.82 RCW) recognizes the linkages between watershed planning and salmon conservation. It notes: "The Watershed Management Act and the Salmon Recovery Act can be viewed as addressing different aspects of the problem. The Salmon Recovery Act primarily addresses identification and funding of specific projects designed to improve salmon habitat. In contrast, the habitat element of the Watershed Management Act can be used to place habitat restoration and salmon recovery in the context of broader priorities for water resources use in the management area" (Ecology 1999). Moreover, habitat-forming processes are largely a function of hydrology and underlying geomorphology. Because hydrological issues are being addressed in watershed planning, the basic parameters of watershed restoration are also being addressed. Salmon and habitat issues should therefore be considered along with water resource issues.

Figure 6. Integration of Monitoring and Management Elements



Because an explicit planning process has been required under chapter 90.82 RCW, such plans could serve as the planning platform for habitat restoration project planning. Watershed plans usually cover the range of relevant environmental resources and require a systematic management approach based on technical assessment. Some regional planning entities (e.g., the Lower Columbia River Salmon Recovery Board) have already embraced a comprehensive approach and are in the process of creating an integrated plan that meets relevant planning requirements.

➢ *Recommend the development of comprehensive plans for aquatic habitat restoration at the watershed or stream scale, including performance measures and monitoring designs. These plans should be consistent with SSRS and the CMS.*

State Level Planning

There have been past strategic planning efforts by the former departments of Fisheries and Wildlife, but since the merger of the agencies, no overall strategic plan for fish and wildlife conservation and management has been developed. In 1993, the Legislature required the Department of Fish and Wildlife to develop a Wild Salmonid Policy in cooperation with the tribes. The policy adopted in 1997 specifically detailed the needs of wild salmon and identified management actions that should be taken to address harvest, hatcheries, habitat, and genetic and other biological considerations. This policy had no binding effect on other agencies, however.

When listing of Washington salmon species under the ESA occurred, legislation incorporated into chapter 77.85 RCW established a Governor's Salmon Recovery Office, an Independent Science Panel, and required a statewide recovery plan. As a result, a comprehensive strategy called the *Statewide Strategy to Recover Salmon: Extinction is not an Option* (SSRS) was developed by the Governor's Salmon Recovery Office (GSRO) on behalf of the Governor's

Joint Natural Resources Cabinet (JNRC) to establish a framework for recovery efforts.

The SSRS (GSRO 1999) describes the salmon recovery framework as comprised of state agency actions, regional salmon recovery plans, local and watershed plans, and individual plans and programs, such as the Conservation Reserve Enhancement Program. The SSRS describes salmon recovery needs organized around the four "Hs" (habitat, hydropower, harvest, and hatcheries) and recommends how state agencies should respond to those needs using their existing authorities. The SSRS has been the state's principal planning document for salmon recovery and watershed health. It has been three years since the strategy was developed, however, and numerous changes have since occurred in the arena of salmon recovery and watershed restoration.

➢ ***Recommend the SSRS, CMS, and other strategies be updated and republished every five years to reflect progress and changes.***

To implement the SSRS, the JNRC also adopted a *State Agency Action Plan* to record specific salmon recovery activities that state agencies committed to undertake in the 1999-2001 biennium. The first Action Plan includes goals, objectives, and intended outcomes, and is followed by proposed action items and outputs. The Action Plan was intended for use in biennial salmon recovery budget development and for tracking of salmon recovery expenditures. This report has proven to be very useful for legislative staff and others interested in state agency performance. It is a product of the present governor, however, and may not be continued by future administrations.

Progress in implementing actions identified in the SSRS and the Action Plan have been monitored and reported to the public and the Legislature through the legislatively required *State of the Salmon Report* and the Governor's *Salmon Recovery Scorecard*. The Action Plan and Scorecard include a range of indicators affecting salmon, water resources, water quality, and aquatic habitat. Many of these indicators have been incorporated into the CMS. Although the linkages between the SSRS, Action Plan and Scorecard are not always as apparent as they could be, the JNRC and the Governor's Salmon Recovery Office have created many of the basic elements of a state adaptive management process and should be recognized for the important contribution they have made in developing state-level strategic planning for salmon recovery.

➢ ***Recommend state agencies continue to develop and report their planned actions and identify performance measures in the State Agency Action Plan and that such plan be required by state law.***

Regional Planning

Salmon Recovery Regions (SRR) are generally comprised of several WRIAs and governed by a "regional recovery board." Their boundary descriptions follow closely salmon ESUs for chinook and steelhead. JNRC identified Salmon Recovery Regions as the level where recovery plans should be coordinated and created. The regional boards have created their own cross-agency technical work groups and have attempted to work closely with the National Marine Fisheries Service (NMFS), which has identified criteria for the recovery of listed salmon populations. Together, the regional boards and NMFS will identify salmon population recovery goals.

Salmon recovery plans will identify conservation strategies for habitat protection and restoration based on salmon population goals developed for de-listing. Recovery plans will meld habitat and conservation strategies related to hatcheries, harvest, and hydropower. Affected interests all agree that a "nested hierarchy" of planning scales is appropriate for managing watershed restoration and salmon recovery; however, critical questions remain about roles and responsibilities.

Monitoring

After projects have been implemented, their effects on the environment can be monitored. When an activity is planned, the assumption, rationale or hypothesis supporting the decision to act is that a particular desired result will occur. The purpose of monitoring in this context is to determine whether the expected results occurred. Data collected to determine the effectiveness of an activity is called "effectiveness" monitoring.

Analyzing and Evaluating

A great deal could be said about analysis, decision-support systems, and predictive models. Unfortunately, the timeline for this project did not allow for sufficient exploration of this topic. This is an area that should be examined by the Independent Science Panel or the State Monitoring Council recommended below.

Evaluation of monitoring results is achieved by comparing monitoring results to performance measures or evaluation criteria. Numerous benchmarks and targets have been proposed in the CMS. Many issues remain to be resolved, however, as part of an ongoing process of refining and improving this Strategy.

Reporting

Reporting serves two purposes. It allows people both inside and outside of government to find out about the status of natural resources and how management activities are affecting those resources. It also allows government agencies and elected officials to be held accountable for outcomes. While it is critical for monitoring information to be available to decision makers, it is equally important that it be available to the public. Often, it is the public that will make use of the information and challenge agency actions.

Reporting requirements are catalysts for ensuring that monitoring data are periodically analyzed, evaluated and communicated to the appropriate parties. For example, a biennial reporting requirement would mean analyzing and evaluating monitoring data at least once in every two-year reporting period. Reporting requirements should be based in statute or covered by contractual agreements. Two of the four major environmental areas covered by the Comprehensive Monitoring Strategy – salmon recovery and water quality - are covered by such requirements. Statewide water resource (quantity) and aquatic habitat conditions are currently not required to be reported.

Key Reports

Water Quality Reports

From the early 1980s through 1995, the State of Washington and EPA Region 10 participated in a State-EPA Agreement (SEA). In 1995, state environmental agencies and EPA agreed to move to a National Environmental Performance Partnership System (NEPPS), with an Environmental Performance Partnership Agreement taking the place of the SEA. The purpose of the change was to put greater focus on environmental results of the activities that address concerns shared by both the State and EPA and to provide Washington with more flexibility in managing environmental programs. The Performance Partnership Agreement for 2002-2003 requires reporting on the following four environmental programs:

- Air quality;
- Hazardous waste and toxics reduction;
- Nuclear waste; and
- Water quality.

Reporting on the following water quality priorities is required by the Agreement:

- Water clean-up plans (Total Maximum Daily Loads or TMDLs);
- Development of consistent water quality standards under the Clean Water Act and Endangered Species Act;

- Implementation of storm water requirements; and

- Status of non-point source pollution prevention and cleanup.

This information should be provided not only to the EPA, but to the Governor, Legislature and the public in an easily accessible format.

Puget Sound Update/Puget Sound's Health

The Puget Sound Ambient Monitoring Program (PSAMP) is a long-term effort to investigate environmental trends, improve decision-making and prevent overlaps and duplication of monitoring efforts (a charge similar to the one for the Comprehensive Monitoring Strategy) in the inland marine waters of Washington State. The PSAMP conducts its own monitoring through existing staff in the departments of Ecology, Fish and Wildlife, Health, and Natural Resources; the U.S. Fish and Wildlife Service; NOAA Fisheries; and the King County Department of Natural Resources.

The PSAMP organizes its analysis and reporting by topics that relate to specific ecosystem characteristics or human-influenced stresses on the environment, including: the physical environment, pathogens and nutrients, toxic contamination, human health, and biological resources. The program was established in 1988 and has published seven reports (the Puget Sound *Update*) on the conditions and health of Puget Sound since 1990. *Puget Sound's Health* is a tabloid document released concurrently with the *Update* that provides a brief overview of the conditions of Puget Sound and its public resources.

State of the Salmon Report

The State of the Salmon (SOS) Report (RCW 77.85.020) is required to be provided to the legislature by the Governor in December of every even-numbered year. The first report was required in 2000. The report may describe a number of outputs and outcomes, including the results of habitat restoration projects. Some key information is not included in the list of possible report subjects, including an accounting of salmon population numbers or of salmon habitat productivity. Also absent is any reference to salmon mortality caused by hydropower. Other reports are available to address some of this information, including, for example, the Salmonid Stock Inventory (SaSI), and various reports addressing Columbia River issues. These are not readily accessible or available to the public, however, and are not provided on a regular basis.

Because of the flexibility provided under RCW 77.85.020, an existing mechanism exists for reporting many of the results of "status and trend" monitoring related to the Comprehensive Monitoring Strategy. In addition to the information already suggested in state law, a more comprehensive report, or set of reports, could provide the following information:

- A summary of the state of knowledge concerning salmon abundance, productivity, geographic distribution and genetic diversity;

- A summary of water quality information from the EPA-Ecology Performance Program Agreement, including biological indicator and toxic contamination information;

- Water quantity and flow conditions for each of the state's watersheds, including hydrographs and relevant adopted performance measures;

- Minimum instream flow requirements established and implemented;

- Water resource project information, such as diversions and storage;

- Land use and land cover data, including impervious surface area;

- Population data;

- Road and road decommissioning data;

- Riparian condition;

- Riparian protection; and
- Aquatic habitat connectivity information.

The issue is to determine the scope of the information that should be reported. If information is not significant enough to be reported, one should question why the information is being developed. Within the next few years, a series of regional salmon recovery plans should become available that will also include monitoring information. When these plans are available, the state report or reports could be refocused to summarize or complement those efforts.

➢ ***Recommend that key watershed health and salmon recovery information be combined into a single report, or into a set of coordinated reports (for example, water, salmon and Puget Sound health), and that watershed health and salmon recovery content not only be suggested, but required by statute.***

Salmon Recovery Scorecard

The Salmon Recovery Scorecard was developed by Governor Locke's Office in May 2000 to establish agency performance measures and track implementation of management actions proposed in the SSRS. The Scorecard is based on the "balanced scorecard" concept developed by researchers at Harvard College, which seeks to integrate various output and outcome measures to align the separate divisions within a corporation toward the same goals and objectives. This model was adopted in Washington State to align (within the sideboards provided in current law) the activities of state natural resource and environmental agencies toward achievement of the state's salmon recovery goals. The Salmon Recovery Scorecard contains 35 indicators[2] intended to report on both environmental status and trends, and agency performance. The Scorecard is not mandatory and has not yet been fully embraced by agencies as a way of measuring agency performance.

In addition to its potential for tracking agency performance, the Scorecard could be a useful way of sharing information with the public. Although Scorecard indicators (without corresponding data) are currently available on the internet, we do not know if they are of interest to the public. In the future, it would be useful to link Scorecard indicators or their successors to the proposed data portal and to provide map-based links to information. The Scorecard could be refined into a watershed health "report card" for the public and could have a similar format to that developed by the Chesapeake Bay Program or the State of Maryland's Environmental Indicators report. The report card should present key indicators from the detailed reports discussed above. Eventually, a broader scope of environmental information could also be added to the report card.

➢ ***Recommend that the state action agencies and the Legislature develop a web-based monitoring reporting system accessible to all citizens of the state.***

Governance

The previous discussion has recommended that individual state agencies adopt a functional adaptive management process that integrates assessment, planning, performance measures, implementation, monitoring, evaluation and reporting. These individual agency activities should be developed within a broader multi-agency context, such as the SSRS. In order to provide coordination across state resource and environmental agencies and support for such agencies, establishment of a coordinating body or organization is recommended. The Monitoring Oversight Committee, established to develop the Comprehensive Monitoring Strategy under SSB5637, provides a model for such an organization. Because MOC duties will be discharged with delivery of the CMS and Action Plan on December 1, 2002, a permanent Monitoring Council should be created by statute.

2 Agencies received funding for 18 of these.

The MOC has addressed this task in broad terms. There is general agreement that a standing oversight group could provide a central point to sustain the development, coordination and dissemination of scientifically-sound, water, habitat, and salmon related data and information. The focusing of monitoring activities and reporting will have a significantly reduced chance of implementation if an oversight body or process is not established to carry on the duties of the Monitoring Oversight Committee. Below we describe a model structure and duties for a permanent Watershed Monitoring Council (WMC). Recognizing that short-term constraints of budget and role definition are not fully resolved at this time, as a stop-gap measure, the MOC could be continued in the interim to complete the remaining tasks needing immediate attention. We nevertheless encourage policymakers to pursue this type of approach over the longer term.

➢ ***It is recommended that a watershed monitoring council be established by statute.***

Roles and Functions

A permanent Watershed Monitoring Council (WMC) would:

- Be a forum for addressing continuing policy and technical issues related to monitoring.

- Encourage and ensure completion of missing elements of the Comprehensive Monitoring Strategy. The CMS has attempted to provide a comprehensive approach to monitoring in the time provided by statute. Due to the short timeframe, some elements have not been completed[3].

- Ensure the implementation of the proposed common framework for data and information management so that there is transparency of data for other agencies and the public.

- Assist the progress of agencies' work to implement their monitoring work plans, performance measures and an adaptive management framework. Assist with coordinating related budget requests. Promote inter- and intra- state coordination and communications.

- Provide a forum to coordinate and incorporate local watershed monitoring efforts with statewide efforts. A process would be developed that would permit watershed and region staff to enter data directly into certain state databases. This option would most clearly have the capability of implementing the Comprehensive Monitoring Strategy and appropriate elements of the adaptive management framework.

- Provide synthesized statewide reporting of environmental monitoring. The Council would publish a biennial Washington State Watershed Health and Salmon report card. The report card's format could be similar to those developed by the Chesapeake Bay Program and by the State of Maryland's Environmental Indicators report.

Structure

A Council should:

- Be established by law,

- Be supported by at least one professional-level staff;

- Report to policy and funding entities as requested, as well as to the public,

- Convene quarterly, bi-monthly, or on some other schedule.

3 *These include reaching agreement on sampling protocols for habitat and salmon indicators, data sharing protocols, establishing benchmarks, etc. for some areas of monitoring, and meeting areas of concern expressed by the Independent Science Panel*

- Be funded by state appropriations, but could apply for monitoring funding from the state and federal funding entities for its activities and for the monitoring activities of others.

- Be chaired by a citizen at large with no vested interest in monitoring activities of any state agency.

- Be housed in a neutral organization that has no direct ties or interest in the outcomes of any specific monitoring report or analysis, and has a reputation for accuracy and integrity. This could be an organization such as the Office of the State Auditor, Washington State Office of the Forecast Council, Office of Financial Management, Interagency Committee for Outdoor Recreation, or the Governor's Salmon Recovery Office.

- Consist of nine voting members and other non voting advisors. Voting members could include representatives of the: Department of Ecology, Department of Fish and Wildlife, Department of Natural Resources, Interagency Committee for Outdoor Recreation, and Puget Sound Action Team. The Governor should appoint the Chair of the WMC, two citizens at large, and a representative from the Washington treaty tribes. The USEPA, US Fish and Wildlife Service, US Forest Service and the National Marine Fisheries Service could advise the WMC as needed. The Independent Science Panel or a similar entity could provide independent periodic review of WMC products.

Funding

While progress toward watershed restoration and salmon recovery can likely be detected in a period of one or two decades, achieving the goals of watershed restoration and wild salmon recovery may take much longer. Monitoring is needed to measure progress toward goals and objectives. Monitoring also provides information about the general status and trends associated with natural resources and environmental conditions and, thus, should be seen as a routine part of management. As the Independent Science Panel (ISP) observed "...we do not foresee a point in time when monitoring will not be necessary" *(ISP 2000)*. If monitoring is to continue indefinitely, then so must the funding for monitoring.

The ISP identified stable long-term funding as critical to the implementation of a monitoring strategy. In particular, stability of funding was deemed more important than the absolute amount of funding available because, for a given monitoring question, an uninterrupted record of long-term data collection and analysis yields better information than a series of disconnected data sets. With changing legislative priorities, however, it is difficult to secure long-term stable funding through the appropriations process. In addition, decreases in government revenues may mean that, even with the best of intentions, funding may simply be unavailable. Other environmental programs or operations and maintenance programs, requiring long-term sustained support, face similar concerns.[4]

Two funding options are considered:

- Creation and endowment of an environmental trust fund, including a management account; and

- Creation of a management account only.

Environmental Trust Funds

An option that is frequently considered when there is a need to address funding for long-term issues requiring a sustained response over a number of years is the creation of "environmental trust funds." These are typically created in and managed by private organizations, and are capitalized by grants from governments and donor agencies, and from taxes and fees specifically designated for conservation. However, these funds can also be set

4 Several task forces have been directed to review and recommend funding options for operations and maintenance of state and local parks, including the 2001 Local Parks Legislative Task Force and the 2002 Task Force on Funding State Parks and Recreation. The recommendations made by those bodies are similar to the ones herein, with a few exceptions.

up by legislative authorities and may use either public or private funds as their source of capital. For example, in 1999, a bill was introduced that would have created a Salmon Foundation for the Puget Sound Region. This foundation would have been created by the state and endowed with private funds. This mechanism would have combined the advantages of security, openness, and accountability, with the efficiency of private fund-raising and transactions. This bill did not pass, but the concept remains viable.

Environmental funds have been set up in many countries in recent years as a way to provide long-term financing for biodiversity conservation and other environmental activities. These funds can be structured in three ways (Norris 2000):

- *Endowment funds:* Funds that spend only income from the principal, preserving the principal itself as a permanent asset;

- *Sinking funds:* Funds that disburse their entire principal and investment incomes over a fixed period of time, usually a relatively long period; and

- *Revolving funds:* Funds that receive new income on a regular basis, such as the proceeds from special taxes, user fees, etc., to replenish or augment the original capital.

Environmental trust funds have central importance among potential state funding options because they can be capitalized by a range of fund sources and can be structured in different ways. Creation of an environmental trust fund is recommended to fund state and state-mandated monitoring activities.

An environmental trust fund could be created to fund monitoring and related activities either in perpetuity or for a defined period of time. Because monitoring is viewed as a permanent activity, a permanent endowment supplemented by additional sources of funding is recommended. Several activities are required to create such a fund. First, legislation is needed to create a public trust fund and a separate management account, specify fund purposes and sources, and clearly identify management responsibilities. Once the trust fund has been established, the principal could be invested by the State Investment Board. The interest from the principal could then be deposited in a management account managed by the SRFB or by the new State Monitoring Council.

To determine the size of the required endowment, a determination of income needs should first be made. If $5 million per year is needed, then – assuming a five percent return – $100 million should be deposited in the trust fund. This income stream could fund a new monitoring program such as EMAP, which is estimated to cost approximately $2 million per year, as well as an expanded smolt monitoring program and additional water flow monitoring. A defined and limited portion of the income stream could also be used to fund the activities required to analyze data, manage information, and otherwise support the monitoring program. Management of an environmental trust fund would also incur expenses, including investment management, accounting and auditing, that should be factored into the need for annual income.

Potential sources of funding for an endowment include:

- A portion of the federal funding provided for salmon restoration projects;

- A portion of the state funding provided for salmon restoration projects;

- Grants from the federal Environmental Protection Agency for watershed health-related activities;

- Grants from the Northwest Power Planning Council;
- Foundation grants; e.g., from the Bonneville Environmental Foundation;
- A portion of DOT mitigation funds;
- A portion of the existing Marine Fuel Tax (collected for boating activities typically used for fishing);
- An increase in the Real Estate Excise Tax; and
- A portion of new fees for the Hydraulic Permit Program.

Because the goal under this option would be accrual of principal, rather than direct funding of monitoring activities, funding from these sources would not need to be open-ended. Funds would only need to be accrued until the trust fund capitalization goal had been reached. For example, if the state receives $18 million per year of federal funding for salmon restoration over the next ten years as hoped for ($180 million total), 20 percent of the yearly amount could be set aside to build the endowment. At the end of ten years, the endowment would have grown by $36 million from this source alone.

A variation on this option is the creation of a revolving fund that is capitalized with a portion of annual federal appropriations for salmon restoration projects. This money would then be paid out for specified monitoring activities. While perhaps easier to establish than a trust fund, this fund would not provide the long-term stability that is critical to the support of scientifically credible monitoring.

Management Accounts

An alternative to establishing a trust fund would be to create a management account in the State Treasury specifically for monitoring activities into which the Legislature could appropriate funds or SRFB could dedicate a portion of its appropriations.

Joint Funding of Monitoring

Because state agencies have separate mandates and interests, it is often difficult to implement successfully joint agency projects with joint agency participation and funding. Too often the unilateral action of one agency destroys the anticipated benefits of the combined project.

➢ *Recommend tying together funding for natural resource monitoring where the actions are required by two or more agencies. Such funding can be passed through a granting agency, or through some kind of oversight process.*

By tying funding together, there is great incentive to work together, produce joint products, and create efficiencies in staffing, and reporting.

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Accessibility of Monitoring Information

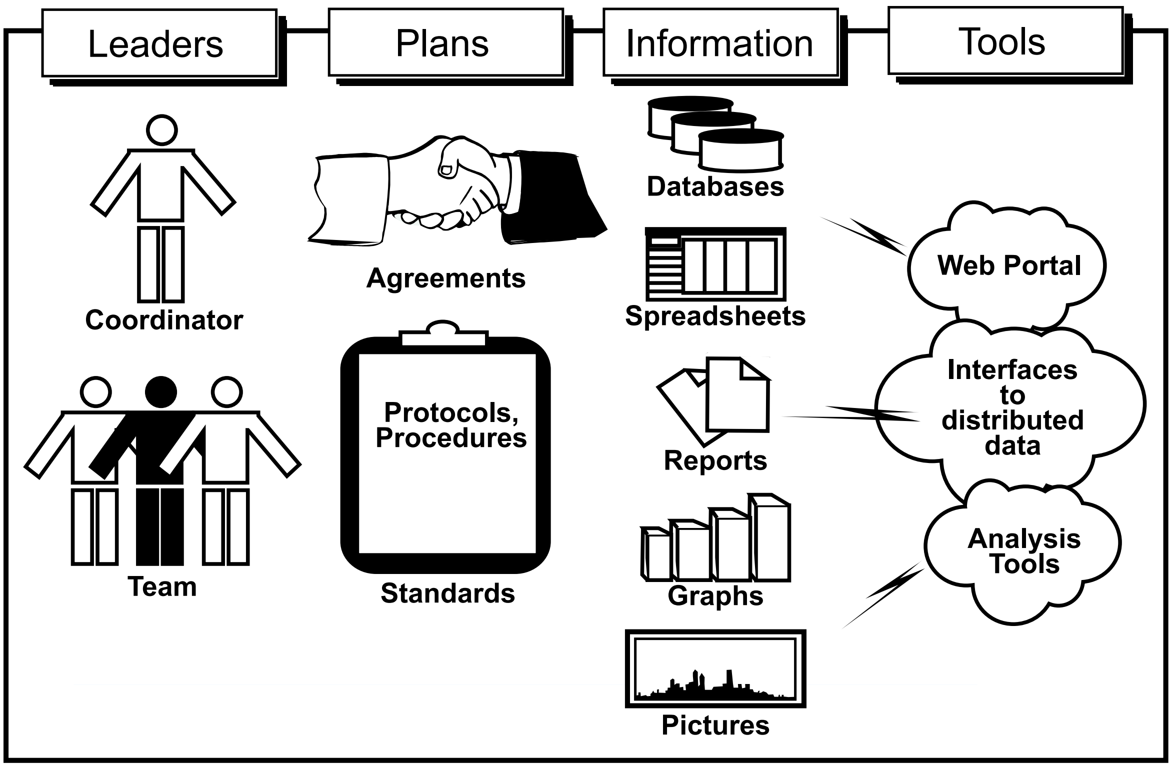
Part V

Strategy for Data Coordination

Access to information related to salmon recovery and watershed health is a critical unmet need for many of the partners working to save our precious resources. The Joint Natural Resources Cabinet (JNRC), the Salmon Recovery Funding Board, and the Salmon and Watershed Information Management Committee (SWIM) have identified access to information as a gap and a primary focus point to improve salmon and watershed information management.

The CMS proposes a strategy that supports easy access, sharing, and coordination among different collectors and users of salmon and watershed data. The required structure is defined in this report and illustrated in Figure 7.

Figure 7. Elements of Effective Data Sharing



After the initial structure is in place and other components of the monitoring strategy are implemented, more work will be needed to define and implement the details of data integration.

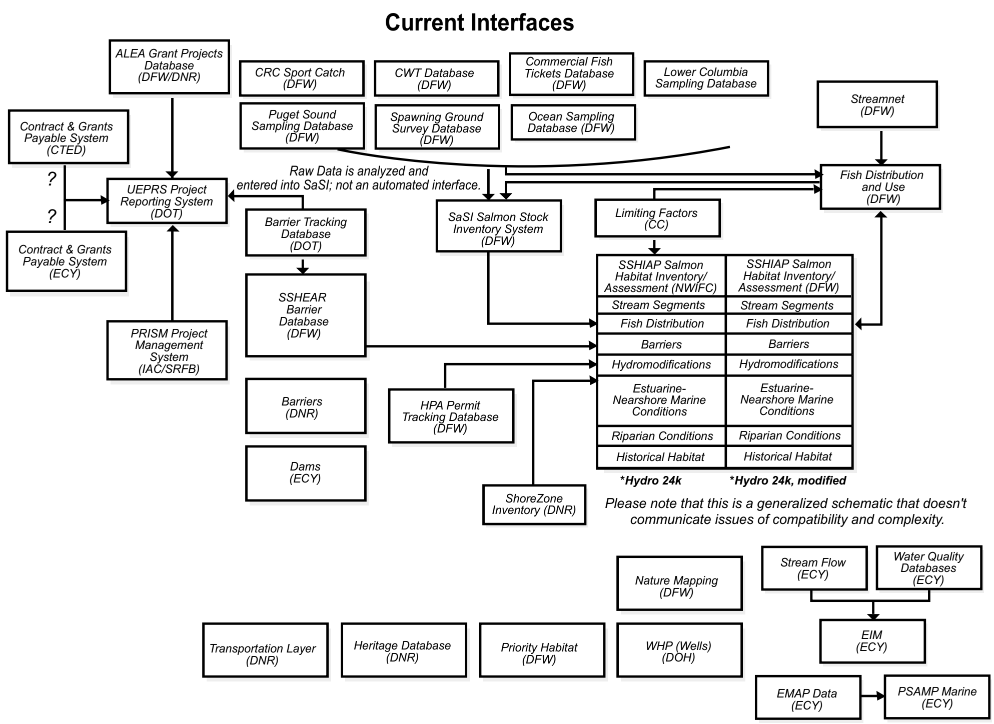
Current Data Resources

Every agency and group involved in salmon recovery has data in different forms. Much of it is in database or spreadsheet format, both of which are conducive to reporting and analysis. Geographically referenced spatial data for use with Geographic Information Systems (GIS) is becoming more available. Every agency is planning or in the process of improving their own access to their own data, and many are making data available on their agency web sites. This is a crucial opportunity to standardize formats and metadata to increase the usability of the data, and to improve the future efficiency of government by producing an integrated data network.

The matrix titled "Summary of Current Watershed Health and Salmon Monitoring" in the Action Plan (Volume 3) lists a sample of currently available data resources to support monitoring efforts. This list was compiled from results of the Survey of Environmental Monitoring Programs within Washington State (2001/02). This list is not to be considered a complete list of all data resources, since not all data stewards responded to the survey.

Figure 8 below shows current relationships between systems or databases. State agencies do already share data, but there is a need to improve data sharing and coordination. Limitations of the current interfaces are documented throughout this chapter.

Figure 8. Relationships between systems or databases.



Current Challenges to Accessing and Sharing Data

Many different agencies and organizations are working on salmon recovery and/or watershed health issues. It is difficult for people to discover the many different datasets that may be available and to understand if the datasets will be of use in their particular area or analysis.

Watershed management and salmon recovery issues by nature are multi-dimensional and cross jurisdictions. No one entity or organization has all of the information they would like to have when making environmental decisions. As a result, other entities' data are sought for additional information. This routinely results in variable levels of satisfaction and redundant work efforts for both data suppliers and requestors. This situation is not unique and solutions are being explored.

Agency staff estimates that a large amount of environmental data collected in the field is never available for state agency use. Either it is never written up or it is never submitted for widespread review.

Currently, agencies maintain related and sometimes overlapping datasets. For example, at least four state agencies collect some level of information about barriers. Some databases contain many more details than others; each meets the varying needs of the different organizations. There is often overlapping information collected by state, local, tribal, and federal agencies.

Some data is maintained for use by a single agency when it would be more appropriate to coordinate and share with other agencies. It takes more time to coordinate, and agencies try to be efficient and keep the costs down.

Geospatial information is critical to an effective salmon restoration strategy. Unfortunately, far too often the existence of needed geospatial information is unknown (or lacking), the information is poorly documented, and it is difficult to access and integrate with other geospatial data due to scale and format differences.

At present, data resources are managed and accessed in disparate formats and methods across the agencies. Once found and obtained, the information must be integrated for the user's specific interest/purpose. This frequently requires format conversion, filtering, and other steps.

Many users are asking the same questions but for different locations. For example, local watershed planners want to integrate information about fish presence, fish passage barriers, and water quality in their watershed. Currently they can get some information from StreamNet, some from WDFW, some from Ecology, hydrography from DNR, some from their local resource groups, and so on. Great efficiencies would result if data were maintained with standard format and metadata, organized to meet common needs, and available through a single interface.

Many organizations are building or planning to build Internet portals or repositories. There's a potential duplication of effort, as well as confusion in trying to determine which of the many portals/sites has access to the "best" data.

Information Gaps/Overlaps

In addition to data gaps identified in other sections of this report, there are major gaps in consolidating information from multiple sources. For example, there is no single database that shows all proposed/active/completed projects and activities that may impact a stream. The Uniform Environmental Project Reporting System (UEPRS), developed by DOT in 2000, has not been adequately populated with project data by state agencies, and was not designed to include projects funded by local, tribal, or private organizations or projects in the proposal stage. The HPA database maintained by WDFW is not readily accessible in its current format, and does not include projects in proposal stage or upland projects.

Project effectiveness is not tracked at present. Once the strategies to accomplish this are determined and the procedures implemented, project databases need to be updated to store and report this summary level information.

Not all agencies and local watershed groups have access to the state's habitat information. WDFW and NWIFC both maintain an implementation of the spatial habitat characteristics system, SSHIAP, but data is not yet complete for all WRIAs.

The GIS line work depicting rivers, streams, and lakes in the state, or hydrography, is a major stumbling block in data coordination and sharing. Many entities (state and non-state) maintain their own set of hydrography and associated attributes, adding and deleting streams as new information arises. There are differences in scale and format, which create further inconsistencies. The regional Hydro Framework Group has developed a common hydrography data structure, but it will be one or more years before it is widely used. It is critical that GIS work done by all cooperating agencies use the same hydrography.

Local agencies and groups closely involved in habitat improvement and monitoring in their areas cannot provide their data directly to state systems. In some cases the data never gets into the state databases. There is ample opportunity to improve sharing and coordination.

Federal agencies also are collecting and storing monitoring data. This data is available to other agencies in varying degrees. The scale of interest for federal agencies is often different, but there is an opportunity for sharing relevant data.

Recommendations for a Comprehensive Data Sharing Framework

There is significant opportunity to improve data coordination between agencies and other organizations. As the Comprehensive Monitoring Strategy is implemented, much more monitoring data will be collected. This is a crucial time to develop standards and plans for storing, maintaining, and sharing this information.

The single-agency mindset should be expanded to include other agencies and organizations with interest in the data. Policies, procedures, and plans must be updated to reflect this. It may cost more money up front to coordinate, but the potential long-term cost savings are huge, and the value of integrated information is high.

Many strategies for data coordination are recommended here. They fall into the following categories:

(1) Data Management for Monitoring.

(2) Standards for Data and Metadata.

(3) Communication and Coordination.

(4) Natural Resources Data Portal.

(5) Universal interfaces to Project, Barrier, Habitat, Fish, and Air/Water/Land information.

Data Management for Monitoring

In defining the strategy, the Data Development Group (DDG), a subcommittee of the MOC, solicited information from many organizations and reviewed many sources of salmon and watershed data. These data resources represent a wide range of uses driven by diverse organizational business needs. The DDG has not yet completed its evaluation of the extent to which these data sources meet projected monitoring needs. The DDG therefore cannot make firm statements about the quality of the data sources with reference to monitoring, the ability of data sources to address monitoring questions, or the comparative merits of investing additional resources in specific data resources. All of the data sources address legitimate needs. One focus of the information coordinator position recommended in a following section is to lead the continuing investigation of available data.

Ecology stores some EMAP data (data collected following the EMAP methodology governing sampling design and protocols). The Nature Mapping web application, housed at UW, tracks presence/absence data collected by volunteer organizations (mostly school groups).

Recommendations for data management

- ➢ *Recommend a continuing interagency committee to make decisions regarding monitoring data, including storage of raw data, data standards and metrics, and access.* This is a crucial piece of the CMS and some work has been done.

- ➢ *Recommend the fish and water technical teams provide the DDG a summary of the metrics for their monitoring indicators.* The metrics are documented throughout the strategy text and references, but need to be pulled into a standard spreadsheet format. The DDG can then analyze the data standards.

- *Recommend that tabular data be tied to the Northwest Hydrography Framework.*

- *Recommend a planning project around volunteer collected data, to determine what makes the most sense for volunteers to do.* If clear guidelines are established for use of this data, and information systems have appropriate quality control processes built in, this data could be usable for gap analysis. May need disclaimers about not using it for regulatory decisions, since data may not have the required rigor. The Nature Mapping Program has experience in this area.

- *Recommend a planning project to analyze where detailed monitoring data should be stored.* For example, projects will be producing data such as measurements. A database such as IAC's PRISM would store project results, but probably not the raw data. Raw data could be stored with water characteristics. Integrate data through the data portal / universal interfaces.

- *Recommend an evaluation of where information like stream or WRIA level assessments should be maintained.* Since they are not at a project level, they are not included in any of the databases already addressed.

- *Recommend the Department of Ecology develop and implement an external data collection strategy and related Internet tools that local grant recipients can use to submit their water quality data to Ecology's Environmental Information Management system.*

Standards for Data and Metadata

Data standards facilitate efficient data integration and information sharing. There is a crucial opportunity to set standards now for monitoring data being collected in the field. Access, analysis, and collaboration will be greatly improved by agencies using standard formats for their data collection methods, data exchange, and metadata. (Metadata is data about data: the date monitoring data was collected, for example.)

Agencies use a vast array of software tools to manage their data, and it is not necessary to control the format in which they store their data. Data collectors need the flexibility to decide how to store and maintain their data to meet their internal business needs. However, standardizing the formats for data exchange will benefit everyone involved in coordinated salmon recovery. All data collectors should be encouraged to support the following standards.

Recommendations for data exchange

- *Recommend that the Data Development Group of the Monitoring Oversight Committee or some other designated group continue to define recommended exchange data types and formats for commonly used fields, and distribute recommendations to all data collectors.*

- *Recommend encouraging data collectors to export/download their data in one of the following acceptable formats:*

- *Recommend obtaining policy-level commitment to data exchange standards from agencies managing datasets of interest.*

Table 5. Recommended export/ download formats.

Spatial data:	XML, E00, DLG, DWG, SDTS, SHP (vector), ADRG, BIL, TIFF (raster).
Tabular data:	XML, spreadsheets: xls (MS Excel), Quattro, and databases: mdb (MS Access), dbf (Dbase). Data should also be offered in CSV or comma/quote delimited ASCII for users without access to the proprietary products.
Text:	ASCII, HTML, PDF. RTF, doc (MS Word), and wpd (WordPerfect)
Graphics:	Pdf, HTML, jpg, gif, tif, png, svg

- *Recommend data providers offer multiple formats to make it easier for people with different software to access the data.*

- *Recommend setting up a funding pool and a process for agencies to apply for it to help complete cleaning and preparation of data for exchange.* This can include creating metadata as well as getting data into the standard exchange format.

Recommendations for spatial data format

It is imperative to resolve the issue of different agencies using different datum, projection, and tiling of their spatial data. This includes organizations at the state, local, tribal, private, and federal levels. To truly collaborate and share data, it must be comparable and accurate. Vendors are promising automatic re-projection capabilities in the future. Until then, agreement on a standard is necessary. The Monitoring Data Development Group reviewed other standardization efforts, such as the National Environmental Data Standards Council, while defining these recommended standards. The Geographic Information Technology sub-committee of the Information Services Board (ISB) intends to review potential GIS technical standards by the end of 2002, after which final determination can be made.

- *Recommend adoption of the 1991 adjustment of the "North American Datum 1983" (also known as HARN, High Accuracy Rectangular Network; and HPGN, High Precision GIS Network), as the standard horizontal control network.* This datum is published by the National Geodetic Survey of the United States Department of Commerce.

- *Recommend adoption of the Washington State Plane South as the standard projection and coordinate system.* This system of plane coordinates has been established by the national geodetic survey for defining the positions of points on the surface of the earth.

  If State Plane coordinates are not available, the Latitude/Longitude coordinate system in degrees/minutes/seconds or decimal degrees could be used.

- *Recommend adoption of feet as the base unit.*

  Note that the Monitoring Data Development Group did not come to consensus on this issue. Some agencies currently store meters since it is the default unit for the HARN datum and matches the federal data. Even though most Washington state agencies prefer (and currently store) feet, they would be willing to change to meters if it becomes a clear standard.

  Conversions between feet and meters should be based on the length of a meter being equal to exactly 39.37 inches (RCW 58.20.190)

- *Recommend adoption of the LLID (Longitude Latitude Identifier) as the standard stream identifier for data exchange.* When it is not available, the Stream Catalog identifiers should be used.

- *Recommend educating people about scale issues.* Different scale is needed for different uses of data. Counties may use fine scale 1:2400 data, which is not currently feasible for state agencies. The 1:24k scale is used by many state agency data projects, including the hydrography layer. An even coarser scale is acceptable for screening projects using remote sensing or other methods. Users need to be aware of scale differences when integrating data, and be knowledgeable about how to interpret the results.

Recommendations for metadata

An important purpose of metadata is to help users determine which data will be most useful to their needs, and to help ensure data is used correctly. It provides for data discovery.

- *Recommend that the metadata standard format developed by the Federal Geographic Data Council (FGDC) be used for all types of data.* It was designed for spatial datasets and there will be some blank fields when describing tabular, text, and graphics data. That drawback seems small when compared to the benefit of one standard format. This recommendation includes use of the standard data element names.

➢ *Recommend that migration tools be provided to data stewards as the FGDC standard migrates to an international standard (ISO) in the next few years.*

➢ *Recommend that state agencies pool resources to acquire software that simplifies the process of entering and editing FGDC style documentation.* Check into providing this software for local, private, and tribal partners. Note that the Washington State Geospatial Clearinghouse provides a data entry tool for basic metadata.

➢ *Recommend that metadata be sent whenever data is exchanged.*

➢ *Recommend that the data development group identify and promote standards for theme and place keywords: a keyword thesaurus.*

➢ *Recommend that metadata, at a minimum, always include the following basic elements:*
  a. Title of dataset
  b. Brief description of dataset content and purpose
  c. Contact name, phone number, email address, position, and organization
  d. Begin and end date of content
  e. Theme and place keywords.

➢ *Recommend that metadata always include the following where applicable:*
  a. Purpose
  b. Data collection methods
  c. Use constraints
  d. Spatial reference, datum, and coordinate system.

Recommendations for data licensing

Different agencies have different policies regarding providing data to other organizations. For one or two agencies, it will take some time to work out the issues surrounding data agreements and licenses to use data. As the portal develops, it is imperative that these issues be resolved.

➢ *Recommend that agencies adopt an online data agreement process rather than requiring signed paper agreements. This will facilitate the distribution and exchange of data over the Internet.*

➢ *Recommend a task force to work with agency attorneys to ensure their liability, licensing, and non-disclosure needs are covered when data is provided through the web.*

Communication and Coordination

➢ *Recommend establishing a permanent full time position of Natural Resources Information Coordinator.* This leadership position is essential to successful implementation of data sharing strategies. Tasks would include coordinating the monitoring data team (maintaining standards and protocols, refining metrics, etc.), promoting data standards, data integrity, and data sharing, communicating with staff from all levels of government and public, coordinating with other portals, clearinghouses, and web based systems, coordinating the portal team (prioritizing enhancements, dealing with funding or management issues, etc.), promoting use of portal and other tools, and working for continuing executive support for data coordination tools and strategies.

➢ *Recommend designating a neutral agency to manage the Information Coordinator position, possibly IAC/SRFB or GSRO.*

➢ *Recommend that salmon recovery partners receive materials describing data exchange standards and metadata content and format instructions.* Provide training and support as partners are encouraged to meet these standards.

➢ *Recommend that before creating a new dataset, agency staff search the data portal and other clearinghouses to see if the data* *already exists and work to coordinate, not duplicate.* Use of standard keywords in a proposal will help grant reviewers locate related existing work.

- ➢ *Recommend providing incentives for data collectors to share their data.* Work with the Salmon Recovery Funding Board as well as other salmon recovery partners to design win-win incentive programs.

- ➢ *Recommend that the proposed Information Coordinator communicate, educate, and promote these standards and incentives and act as liaison with the natural resource cabinet agencies, the Office of Financial Management, WAGIC and other appropriate forums.*

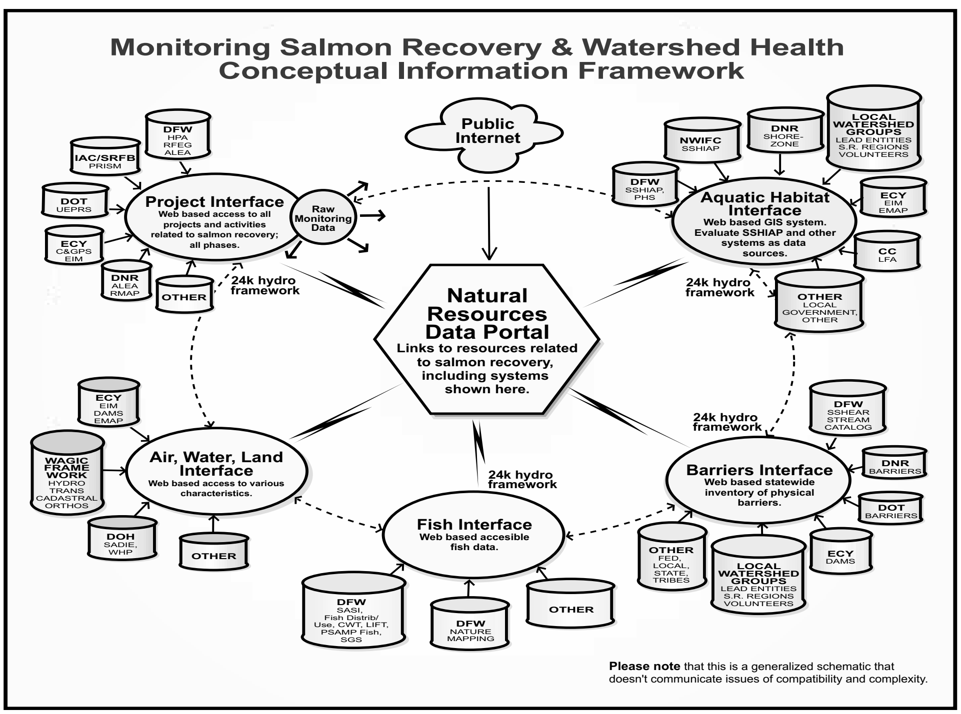
Natural Resources Data Portal

A portal is a web interface to a variety of distributed data, information, and tools. The portal will be a single place to discover, learn about, and access individual datasets related to Washington State natural resources and salmon recovery efforts. It will be an inventory that can grow as data and products become available. Spatial, tabular, textual and graphical data can all be accessed through the portal. The portal will link to geographic layers, features, raw and analyzed data, monitoring plans and reports, and organization information.

The Data Portal concept of information exchange is based on the strengths of the web and can be scaled as opportunity, interest, ability, and data needs grow. It requires adherence to a few basic protocols and operational tenets, and can be built using open non-proprietary tools. It encourages data stewards to document information in a consistent manner. It allows information to remain in current systems and formats. E-business has been using the technology for some time and now natural resource data users across the nation are beginning to use the technology to facilitate data exchange.

The SWIM Data Portal Action team was formed to develop the decision package that resulted in a budget of $200,000 to plan and develop a Natural Resources Data Portal in fiscal years 2002 and 2003. Planning and scoping of the portal was done during May through July 2002. This project is funded, with initial development planned for fall/winter 2002.

Figure 9. Conceptual data sharing framework for CMS.



The portal is intended to eventually meet the following functions:

(1) Data discovery,

(2) Dataset download,

(3) Canned data products (such as maps and charts),

(4) Ad hoc query into selected datasets,

(5) Access to non-state data resources (such as federal and local), and

(6) Feedback.

Data complexity, condition, type, availability/data distribution requirements, technology, priority, and available resources will determine progress in each of these functional areas. Additional information on each of the intended functions can be found in "Plans for the Natural Resources Data Portal" on page 60.

Determination of whether the portal is specifically useful for the interactive functions desired for monitoring will depend on further development of the monitoring strategy and the data resources needed to support it.

In planning the portal, costs and benefits of three alternatives were analyzed:

(A) Building a simple links-only data portal and maintaining it,

(B) Building a simple data portal in phase 1 then adding custom query, interactive mapping and graphing features in later phases, (see Table 6) and

(C) Building a full featured data portal with a partner such as NMFS, EPA, or Washington Geospatial Data Clearinghouse. (see Table 7 on page 62)

A phased implementation is defined for alternatives B and C. All three alternatives start with the same first phase.

Table 6. Portal Phases Alternative B

Phase 1 (implement before June 30, 2003)	Links to individual datasets (spatial, tabular, reports and plans), as well as organizations.
This phase is funded.	Keyword searches of summary text. Full metadata available on link (usually), not on portal. Feedback form.
Phase 2 (implement after July 1, 2003)	Small warehouse with download capabilities for information NOT available on steward's site. Some canned reports, maps, graphs to answer frequently asked questions. (Study feasibility and pilot universal interfaces.)
Phase 3 (implement after July 1, 2005)	Interactive maps and graphs. Distributed queries; integrated data. "Universal interfaces".

Recommendations for portal development

The following recommendations appear in their order of importance.

- *Recommend appointing a Project Coordinator in September 2002 to manage the vendor selection, finalize the data catalog, and oversee the phase 1 portal development.*

- *Recommend implementation of Phase 1 of the Natural Resources Data Portal* (already funded out of the Technology Pool). See "Plans for the Natural Resources Data Portal" on page 58 for more detail.

- *Recommend investigating partnerships with other organizations building portals or repositories of natural resources data.* Communicate and coordinate to avoid duplication of effort and potential confusion to data users.

- *Recommend using Technology Pool funds to make the following datasets downloadable from agency web sites, linked to the portal: Department of Natural Resources' (DNR) Watershed Administrative Units (WAU), DNR Major Public Lands (MPL), DNR Soils, SaSI (already in progress), and DNR Geology.*

- *Recommend adding portal to Access Washington site, using standard templates for web page design, and encouraging linked sites to provide reciprocal links to the Data Portal.*

- *Recommend each data steward provide access to the data according to their own policies.* The Phase 1 portal will simply provide a link.

- *Recommend linking to the primary data source of a dataset whenever possible.* While agencies may host each other's datasets on their sites, the portal link will be to the originator of the data or the web page recommended by the data steward.

- *Recommend that funding for portal maintenance be added as a line item on the managing agency's budget.* Other agencies should provide in kind services, such as sending staff to meetings, preparing data and making it available on their web sites.

- *Recommend planning phase 2 of the Data Portal at the end of the Phase 1 implementation project.* May not want to spend state resources on features like queries and mapping when other sites are doing the same. Determine if a partnership if feasible.

- *Recommend phase 3 of the Data Portal include the universal interfaces described later in this section.*

- *Recommend incorporating WAGIC Clearinghouse data discovery capabilities in web portal if technically appropriate.*

- *Recommend the portal be designed to comply with statewide Internet standards.*

Recommendations for portal hosting and management

Once the portal is implemented, many responsibilities must be undertaken to ensure a useful, dynamic web site.

- *Recommend that a neutral party manages portal, performing webmaster tasks (either IAC/SRFB or GSRO).* Webmaster tasks include maintaining site, maintaining links, reviewing and responding to feedback, providing help desk functions (resolving problems, finding data, etc.), and maintaining list of proposed enhancements.

- *Recommend IAC/SRFB or DIS hosts portal.* Hosting tasks include providing server space, managing the network, researching & installing software patches & service packs, monitoring server status, maintaining/monitoring server security, monitoring log files (db and webserver) and tuning database.

The portal will provide an important central site for natural resources data sharing.

Universal Interfaces to Interagency Data (Portal Phase 3)

Many agencies recognize the need to integrate project, habitat, and monitoring data for the purpose of reporting on watershed health and supporting decisions about future watershed investments. To that end, an integrated framework of interfaces to pertinent data is envisioned. See Figure 9 on page 51. The framework would involve more than links and information about individual datasets as provided on the phase 1 Data Portal, adding real time access to distributed data, overlaying of multiple datasets into online maps, and other analysis tools like graphs and reports.

Goals of these interfaces include data sharing, efficiency, and transparency. Duplication of effort can be reduced. It is possible to use technology to navigate a distributed web-based network of information sources. This distributed data access could appear seamless to the user. Agencies would continue to maintain their own data, but unlike now, others would be able to view data from different agencies together in one place, in one view. Appropriate filters and security would be applied.

Interactive mapping features, charting tools, and query code could be shared by all of these interfaces, saving time and money.

The EPA is already building a network of distributed nodes of environmental data, and ESRI has a distributed geography network in operation. Their blueprints and lessons learned could be used when designing Washington State's universal interfaces.

Five universal interfaces are described here. None of these have yet been analyzed in detail.

➢ *Recommend completing a Feasibility Study to define the needs, vision, scope, risks, users, solutions, and costs of the universal interfaces, and to decide whether to proceed.* Analyze how to integrate habitat, project, barriers, fish, air/land/water data for mapping and reporting.

Universal interface to project information

Project information is tracked by many agencies and organizations. Some have simple tracking systems; others have comprehensive management systems. It is not feasible to try to build one system that meets everyone's needs. Instead, the concept developed of a universal interface; one that reads data in distributed databases and compiles it into reports, maps, and charts. Whether a data warehouse is required has not been determined. Depending on timing and technology, the interfaces could possibly gather data from distributed datasets at the time of query and present them as a unified response. More research is needed to determine feasibility.

A significant challenge will be to collect data about projects that are not yet captured in any database. Volunteer projects may not be included in any agency system. And as an example, only about 25% of the projects that fix culverts under SSHEAR are tracked by the SSHEAR database. We must address the gap between projects done and projects currently tracked.

The WDFW is presently migrating the Hydraulics Project Approval (HPA) permit tracking database to Microsoft Access. Since all projects and activities that deal with water are required to get an HPA, this is the one database that contains the whole universe of projects within the high water mark: those funded by state, federal, local, tribal, and private organizations. It has some limitations; only newer entries have geographic coordinates (older ones track township / section /range); only work legally carried out and permitted are in the database; only projects carried out within the high water mark are required to obtain an HPA. The data is entered after the permit is issued, so it doesn't currently track proposed projects. It contains records and information not pertinent to monitoring or natural resource needs. It doesn't track anything about results. It doesn't include upland projects designed to improve instream conditions. It may not include denied permits. There is often no project follow-up information.

Recommendations for interfaces

➢ *Recommend building an online application process for HPA permits.* This ensures that proposed approved and denied water-related projects and activities are in the HPA database.

- *Recommend the Feasibility Study evaluate the use of existing systems as the basis for a universal interface.* Include analysis of alternatives such as feeding HPA data into PRISM or UEPRS rather than building a new summary project reporting system. UEPRS (DOT's Uniform Environmental Project Reporting System) is a web-based reporting system with interactive mapping features. The IAC's PRISM is a project management system with interactive mapping features, but is not yet web based. Both currently track state funded projects only. Another alternative is to utilize components of UEPRS to build the new statewide project system, thereby gaining the use of its interactive mapping capabilities.

- *Recommend investigating the use of EPA's RAINS system to provide mapping and query capabilities.*

- *Recommend building a web system that provides search and reporting of summary data for all habitat and restoration projects/activities.* Users would include staff in all types of organizations involved in salmon recovery. This information would be useful to project planners, legislators, and the Salmon Recovery Funding Board. Interactive maps showing project locations would be popular. Ability to view summary information about proposed, active, completed, and denied projects would be useful. The web system could filter out any projects, activities, and information from the HPA database that are not applicable to salmon recovery or that need to be secured from viewing by the general public. Information could be imported from IAC's PRISM if we want project details. This project interface could be used to randomly select projects to be inspected for protocol compliance.

- R*ecommend updating feeder systems, such as HPA and PRISM, to track project status (whether it was completed), results, and effectiveness.* Additional database design, data entry, and maintenance would be required. This will connect implementation and effectiveness monitoring.

- *Recommend that the effort to collect results and effectiveness data be fully funded.*

- *Recommend that strong mandates be implemented requiring all project sponsors to provide data in an accessible dataset.*

Universal interface to barrier information

Quality barrier information is a high priority to agency management and legislators. Several agencies currently track barrier inventories or barrier projects, including WDFW, DNR, IAC/SRFB, USFS, USFWS, as well as local agencies. Different business needs drive the different barrier databases, and a variety of elements are tracked about each barrier. There are different definitions of what constitutes a barrier.

There is no comprehensive inventory. It is even difficult to assess what areas have been inventoried. The best barrier inventory for Washington State is WDFW's SSHEAR database, but it contains information on only 10-15% of the potential culvert crossings in the state.

Agencies at all levels would like barrier locations and details available for mapping and analysis. Consolidated information is needed for quality evaluation and prioritization of proposed projects. Landowners affected by road abandonment plans need information on barrier removal priorities and other details. To be useful, barrier data must be integrated with habitat, project, and monitoring data.

The inter-agency technical group meeting to address the culverts lawsuit aims to improve cooperation and sharing of barrier data. This group plans to develop an annual report on barriers.

Accessibility of Monitoring Information

Recommendations for barrier interface

- *Recommend that a list be built of barrier inventories done by various data collectors in the state (state, federal, forest, city, county, tribal, private).* Recommend making available information about which areas have been inventoried, the scope of the inventory, the methodology used, and other useful information about it. This will help determine what the data gaps are, and where new physical inventories are needed. Start with high priority watersheds.

- *Recommend an effort to complete a statewide barrier inventory, as already defined in the chapter on Fish Passage (where it's called a "census").* Recommend it include all stream crossings in the state, including bridges and railroads. Recommend including dams. Phase the inventory by priority areas.

- *Recommend a standard agreed-upon prioritization scheme identified and shared with agencies at all levels of salmon recovery.* Possibly use the WDFW Priority Index system.

- *Recommend the Feasibility Study evaluate how to bring data together rather than dictating how agencies store barrier data and what they store.* This interface could meet the need of integrating barrier data with habitat, project, fish, and air/water/land data.

- *Recommend evaluating whether the statewide inventory should be virtual rather than physical.* Continue to have data collectors track barrier data in their own databases, since different needs drive different databases. Promote stewardship of data. Recommend barrier data be made available in a standard exchange format for consolidation, mapping, and analysis. Most likely a subset of data from each database will be exchanged.

- *Recommend implementing the selected solution as defined in the Feasibility Study.*

- *Recommend building a user-friendly interface to the data for public as well as agency use.*

- *Recommend better coordination between SSHEAR, SSHIAP, and LFA so local agencies have to provide data to just one system.*

- *Recommend procedures and tools are developed to manage the physical or virtual consolidation of existing barrier data.* This can be included in the Universal Interface to Barrier Data as defined previously.

- *Recommend procedures and tools are developed to manage the update of barrier data.* This can be included in the Universal Interface to Barrier Data as defined previously.

- *Recommend WDFW manage the aforementioned lists, procedures, and tools, with additional funding.*

- *Recommend each stream crossing in the statewide inventory be spatially referenced so barriers can be accessed by watershed, county, etc.* Recommend using the spatial data protocols defined in the strategy.

- *Recommend keeping fixed barriers in databases for analysis (that is, not removing a record after the barrier has been fixed).*

- *Recommend proposed projects get points if they provide a comprehensive barrier inventory.*

- *Recommend that any agency or entity that receives state or federal funding to study, inventory, or modify barriers be required to contribute all barrier data to the statewide inventory using the standard tools, procedures and electronic formats.*

- *Recommend considering the inclusion of DNR information on derelict vessels, since they are barriers to fish passage.*

- *Recommend update of Natural Barriers data.* This layer is 30 years old. Volunteers could be organized to verify waterfalls and other natural barriers. The SSHIAP database tracks natural barriers, with some data coming from field biologists. Many are simple gradient barriers that are discovered when methodologies are applied.

Universal interface to habitat information

The Salmon and Steelhead Habitat Inventory and Assessment Program, a cooperative project of WDFW and the NWIFC, is a spatial data system which includes relational databases. SSHIAP is primarily intended to provide a framework for spatial data relevant to salmon. The cornerstone of this system is a cleaned, routed and segmented statewide hydrological layer at 1:24,000 scale. Data linked to this layer include fish distribution, barriers, stream gradient, confinement, and habitat type. Secondary attributes such as stream width, hydromodifications, and riparian condition are available for some WRIAs.

SSHIAP offers data on a small set of habitat characteristics that have mostly been obtained through remote sensing (topographical maps, aerial photography, satellite imagery, digital elevation models). SSHIAP can be readily adapted to monitor changes in indicators at this scale (i.e., changes in broad scale land use through time). Higher resolution data that comes from monitoring work can also be attached to the SSHIAP routed hydrolayer as points, lines or polygons for viewing and analysis. SSHIAP data can be used until higher resolution data becomes available just as StreamNet data (1:100,000) data is/was used until SSHIAP data becomes available.

Existing data are currently available by contacting the responsible agency; both agencies are working on providing web access to the data.

Recommendations for habitat interface

- *Recommend combining SSHIAP.* There are currently two versions of the SSHIAP database. NWIFC is the data steward for WRIAs 1-23 and stores data in Access databases and ArcInfo coverage. WDFW manages data for WRIAs 24-62 and uses Arc Info tables and coverage. The versions are managed under different funding sources with a focus on the needs of slightly different customers. Primary differences are in segmenting methodologies, attributes and data storage. It is possible and essential that these two versions be combined into one consistent and accessible version. The segmentation, attribute, and storage issues can be resolved so that SSHIAP becomes a valuable statewide habitat data management tool.

- *Recommend completion of effort to add confinement data to WRIAs 24-62, model width and flow for WRIAs 1-23 and 30-62, and continue to update fish distribution data.*

- *Recommend completing efforts to provide web accessible download of selected spatial and tabular data from SSHIAP, such as gradient / confinement maps and barriers, and basic queries.* Link through the portal.

- *Recommend tracking status and trends data.*

- *Recommend the Feasibility Study evaluate SSHIAP and other systems as sources of data and software components for the universal interface.* This interface could meet the need of integrating habitat data with project, barrier, fish, and air/water/land data.

- *Recommend implementing the selected solution as defined in the Feasibility study.*

- *Recommend building links to local entities that collect and maintain data on conditions in their watersheds.* Consolidated information should be available for mapping, reporting, and analysis. Appropriate quality assurance measures will have to be implemented.

➢ *Recommend the Conservation Commission move some of the Limiting Factor text data into separate fields so it is easier to search and analyze.* A data design should be developed before the next update of limiting factors data, so data collected is in the new format.

Universal interface to fish information

The WDFW manages many sets of fish data. They are currently building a new fish distribution and use database, and a web site, SalmonScape, to provide access to useful statewide data such as SaSI and SSHIAP.

Recommendation for fish interface

➢ *Recommend the Feasibility Study evaluate WDFW's SalmonScape site as a potential universal interface to fish data.* This interface could meet the need of integrating fish data with habitat, project, barrier, and air/water/land data.

➢ *Recommend implementing the selected solution as defined in the Feasibility Study.*

Universal interface to air/water/land information

Ecology maintains detailed information about air and water characteristics. Most of it is available through their web site, and the new Environmental Information Management (EIM) system in development will provide analysis tools. Other agencies maintain and allow access to land characteristics such as topographical and transportation features.

Recommendations for air/water/land information

➢ *Recommend the Feasibility Study evaluate Ecology's EIM site as a potential universal interface to air, water, and land data.* This interface could meet the need of integrating air/water/land data with habitat, project, barrier, and fish data.

➢ *Recommend implementing the selected solution as defined in the Feasibility Study.*

Universal data entry interface

A standardized data entry tool where local, tribal, and other partners enter data is of high priority. (Note that the five universal interfaces described previously are presentation sites, not data entry sites.) An Internet site could be developed that would be available through the portal, designed for end users, and a single interface to all state-managed natural resources / salmon recovery monitoring data. It would be integrated with the other interfaces (project, habitat, barrier, fish, air/land/water).

The long term vision is to let an entity enter project or activity data. If it were a barrier removal project, they would be prompted to enter details about the project. The system would know to store the project information in IAC's PRISM projects database on the IAC/SFRB server, and to store the barrier information in the barrier database on the WDFW server, and maybe to update the HPA database also. Data would have to pass a quality assurance process before being added to each official statewide dataset.

Design, development, and operation of this integrated data entry site would require close cooperation from several state agencies.

Recommendation for data entry interface

➢ Recommend implementing the selected solution as defined in the Feasibility Study.

Plans for the Natural Resources Data Portal

Vision

The Washington State Natural Resources Data Portal will be a single place to discover, learn about, and access available data related to Washington State natural resources and salmon recovery efforts.

The initial phase of the portal will include simple links to datasets and their associated metadata, reports, studies, and other information that is readily available, with emphasis on supporting monitoring data. Data that is not available for download or viewing on the Internet will be listed with contact name, address, phone, etc.

The portal will emphasize monitoring data, even though not much is currently available. As the recommended standards and protocols are incorporated into practice, and as more monitoring data is collected and available, more attention will be given to incorporating it into the portal features.

Subsequent releases of the portal may add features such as direct download, canned reports, interactive mapping, structured ad hoc queries, and analytical tools such as graphs. Approaches to implementation of the previously described universal interfaces will be determined in the Feasibility Study. Partnering with another agency (state or federal) or a clearinghouse will be investigated to avoid duplication of effort.

Success factors for the portal include a meaningful data catalog and a plan to maintain it, a user-friendly interface, executive support, ongoing funding, and clearly defined management responsibilities.

Ongoing success will be measured by site "hit" statistics, by feedback that indicates the portal is meeting users' needs, and by feedback asking for additional data and /or features to be deployed.

Functions

Data discovery – a catalog listing with links to documented and available natural resources-related datasets and references. Data resources will be listed, defined for coverage, age, content, and conditions of use. Links will be made to data access locations, data stewards or the responsible agency. Data may not be available for immediate download, but the user knows it exists and may request the information.

Complete data set retrieval – Complete data sets are available for download. This will include GIS or tabular data sets, documents or images.

Selected "canned" data products – Selected datasets will be combined to address audiences with specific needs or analytical questions by location. These would include the more routine watershed related questions, indicator reports or other products that have set analytical procedures and data sources.

Ad hoc data query/mining – Select datasets will be available for ad hoc queries. Results may be downloaded or rendered into a map.

Access to non-state data resources – Access/links to federal, tribal, local, private, and volunteer-based data sources will be encouraged.

Feedback (survey of data users) – The Salmon Recovery Scorecard initiated the concept of surveying data users to determine and evaluate what data are needed, how well data needs are being met, and what are the priority areas of investment. The Portal would include a survey form to gather information about data accessed, its relative importance, and the importance of any gaps.

Benefits

The portal will provide a single place to access information on salmon recovery and watershed health.

The portal will provide information about many different datasets to help users understand if the datasets will be of use in their particular area or analysis.

Use of the portal will improve collaboration between organizations at all levels involved in salmon recovery.

Use of the portal will support better trend analysis by encouraging standard methods and data formats.

Use of the portal will support better selection of projects by providing all available information for an area.

Users

The user base for the web portal is large. Expected users include local watershed planners, lead entities, land managers and regulators, environmental groups, utilities, and consultants, as well as state agency staff, federal agency staff, local agency staff, tribal staff, legislators, and the general public.

User expertise will most likely range from novice to expert. The portal will be designed with a very user-friendly entrance, with paths to more expert features.

Conceptual Solution

Build a Web site accessible through Access Washington, agency websites, and other portals and clearinghouses.

Use templates provided by the state portal, Access Washington, for a consistent look and feel.

For phase 1, use distributed management of data. Leave data in current systems and format; don't require agencies to feed data to portal. Leave each agency accountable for own data. Make sure data stewards are clearly defined.

Document information in a consistent manner, following FGDC guidelines for full metadata.

Connect and coordinate with other entities developing web portals. Investigate partnerships.

Use a phased approach to development, with Phase 1 simple and cost efficient. Add datasets as they become available for viewing or download on the Internet. Evaluate use and needs and enhance accordingly.

Include links to information from the monitoring survey, which includes mostly monitoring plans, studies, and reports. Watch for overlap with agency sites.

Include links from Pacific Salmon Information Network, which includes organizations, documents, surveys, and studies, as well as detailed monitoring data and spatial datasets.

In Phase 2, provide warehousing and download functions for data not available from the owning agency's site. Agencies do not need to provide a download from the portal if they already provide data on their own site.

Currently, there are no plans to use cookies, to personalize a user's visit to the portal, or to require a login to access the portal links.

Scope

Only phase 1 is funded at this time. Phase 2 feasibility and scope will be analyzed at the end of phase 1 implementation.

Table 7. Portal Phases Alternative C

Phase 1 (implement before June 30, 2003)	Links to spatial datasets, tabular datasets, reports and plans, and organizations. Links from clearinghouses and other portals.
This phase is funded.	Keyword searches of summary text. Full metadata available on link (usually), not on portal. Download available on link, not from portal. Feedback form.
Phase 2 (implement after July 1, 2003)	Small warehouse with download capabilities for information NOT available on steward's site. Some canned reports, maps, graphs to answer frequently asked questions.
Phase 3 (implement after July 1, 2005)	Interactive maps and graphs. Distributed queries.

Datasets must:
(1) Include natural resources data or reference data such as WRIA boundaries,

(2) Be related to Washington State, and

(3) Be available to users. Links will be provided to data available for download or viewing on the web, otherwise contact information will be provided.

Monitoring data will become a high priority to add to the portal as it becomes available.

When multiple dataset versions exist, descriptive information will be included to help users select the best information for their needs. Last update dates will be included whenever possible.

Risks and Issues

Various risks and issues were analyzed when planning the data portal. They are summarized here:

Table 8. Risks and Issues

Risk / Issue	Decision
Monitoring protocols and standards may not yet be in place when the portal is implemented.	Phase 1 of the portal will be links only; include monitoring data when available. Write summary descriptions. Plan on periodic evaluation and enhancements, with focus on monitoring information.
By spreading development over 3 biennia, may not want to use the phase 1 portal as basis for phase 2 / 3. Technology changes, mapping software requirements, or partner requirements may cause a decision to dismantle phase 1.	The value of phase 1 is in building a consolidated catalog of information, standardizing formats, updating metadata, and coordinating between agencies, all of which will still provide value in phase 2 and 3, regardless of whether the phase 1 software is used or not. Phase 1 costs will be minimized by building reusable components whenever possible.
Agencies are sometimes reluctant to share data.	Since Phase 1 is a links-only portal, it encourages people to participate without giving up any control of their data.
Agencies may be reluctant to share data because of fears that it will be misused or misrepresented.	During the portal design phase, care will be taken to add descriptive information about how to use the data. Agencies may decide to filter out data that is most likely to be misused.
Funding for future phases of the portal may not be available.	The phase 1 portal will be a stand-alone tool that meets specific objectives. It needs maintenance and management funding, but additional phases are optional.

Accessibility of Monitoring Information

Requirements

Below is a summary of phase 1 portal requirements:

- Must be easy to find information. Design for novice users but also provide features for expert GIS users.
- Provide easy to read, summary data about each link. The full FGDC metadata will often be available at the linked-to site. Summary data should describe any peculiarities about downloading the data.
- For spatial data, make sure scale information is noticeable in the data description.
- Provide a user-friendly tutorial and other ways to educate people about scale issues. Users need to be aware of scale differences when integrating data, and be knowledgeable about how to interpret the results. Things may not line up as expected.
- Include a feedback feature to make it easy for portal users to comment on their use of the portal, describe any problems they had, and ask for additional links or features to be added.
- Make it easy to browse the links by category, agency, and or location (WRIA or county). Provide keyword search.
- Indicate for each link if it is available for download, online viewing, or online ordering.
- Track hits to each link.
- Provide a Frequently Asked Questions page.
- Use scaleable architecture that provides for future expansion.

A summary of phase 2 portal requirements:

- Add small data warehouse to store pertinent data that is not available at the steward's site. Provide download function.
- Build several canned reports, maps, and graphs that answer routine questions.
- Possibly partner with EPA / RAINS or other agency/system for these features.

A summary of phase 3 portal requirements:

- Implement interactive mapping capabilities.
- Implement distributed queries, with results rendered into a map or report available for download.
- Implement interactive charting capabilities.
- Possibly partner with EPA / RAINS or other agency/system for these features.

Part VI

Salmon Recovery Funding Entities

Question 21: Are habitat improvement projects effective?

Objective 21A: Provide guidance to the Salmon Recovery Funding Board (SRFB) and other funding entities for best monitoring protocols for habitat projects.

Objective 21B: Determine whether habitat improvement projects are effective in increasing the number of salmon produced.

Objective 21C: Determine what kinds of salmon recovery habitat projects are the most effective.

Objective 21D: Determine whether habitat improvement projects were properly implemented.

Background Information

Preservation and restoration of habitat necessary for watershed health, wildlife, and salmon recovery has been important to Washington State for a number of years, although there has not been a focus on salmon-specific projects until the past three years. Habitat restoration and preservation projects have been funded through various sources. Since 1990, the state's primary means for funding habitat projects for fish as well as upland wildlife resources has been through the following programs:

- The Aquatic Lands Enhancement Act program,
- The Trust Lands Transfer program,
- The Washington Wildlife and Recreation Program, and
- Various individual projects proposed for funding as part of the state capital budget.

Federal agencies have historically provided funding for habitat preservation and restoration. In the past, the U.S. Forest Service has dedicated significant funding to restore habitat impacted by logging activities and other actions. The Northwest Power Planning Council (NWPPC) through the Bonneville Power Administration (BPA), and Army Corps of Engineers (ACE) have funded numerous salmon recovery and watershed health projects as part of an ongoing responsibility to mitigate the impacts of hydroelectric facilities on the Columbia River. The US Fish and Wildlife Service has provided grants under National Wetlands programs to estuaries along the coast and Puget Sound, and under programs such as Conservation Reserve Enhancement Program (CREP). The agricultural community has received USDA assistance.

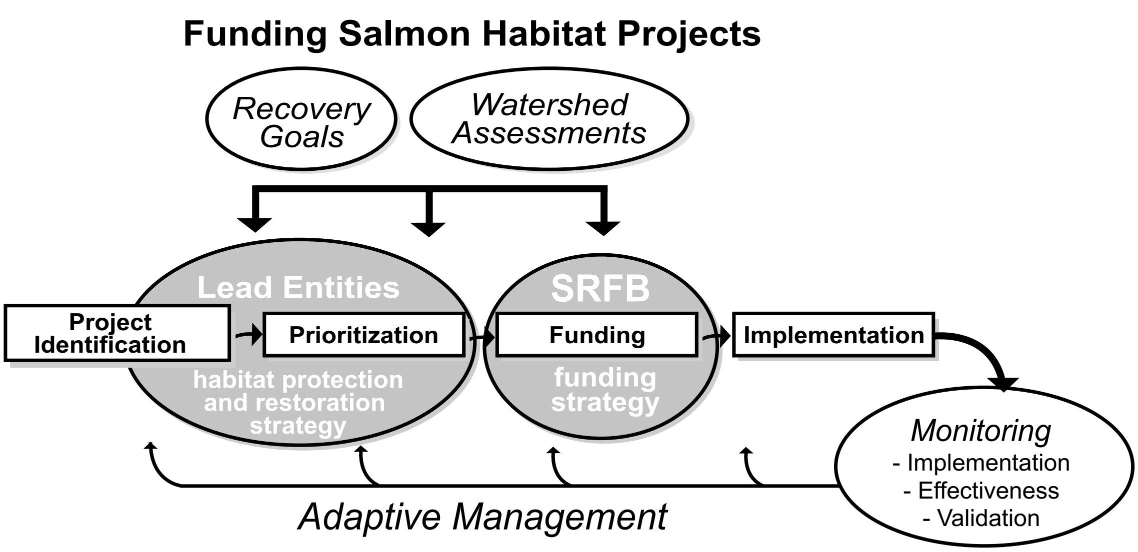
With the listing of several west coast salmon species as Threatened or Endangered under the Endangered Species Act, governors, and legislators have sought to obtain funding to restore salmon populations and obtain economic relief for the region through de-listing of ESA species. In both Washington and Oregon, funding bodies were established to evaluate projects and issue funds – Washington's' SRFB and Oregon's "OWEB" (Oregon Watershed Enhancement Board). Both states' funding boards work closely with a network of local watershed organizations. In Washington, these organizations are known as *lead entities*, and help identify project proposals from their local areas. Recognizing the need for energizing the grass roots as well, non-profit organizations such as "For The Sake of the Salmon" and "People for Salmon" were established to help identify funding sources and provide local assistance and outreach. In Washington, salmon recovery concerns in part also spurred enactment of the Forests and Fish agreement, a landmark accord among industry, government, tribes and environmental concerns to help preserve fish habitat while providing for continued forestry.

Salmon Recovery Funding Board – Habitat Projects

In 1999, the Washington State Legislature established the SRFB, to evaluate habitat projects and distribute funds in an open public manner. The Salmon Recovery Funding Board's mission is to "support salmon recovery by funding habitat protection and restoration projects, and related programs and activities that produce **sustainable and measurable benefit** for the fish and their habitat." [Emphasis added.]

Habitat protection and restoration projects are submitted to the SRFB for funding by lead entities. Lead entities are watershed-based voluntary organizations. The term "lead entity" means the local agencies, citizens committee, technical advisory group, and lead agency that represent one or more watersheds (WRIAs) and submit prioritized lists of projects to the SRFB for funding. Lead entities can define their geographic scope and are encouraged to match watershed boundaries. Lead entity responsibilities and tasks are described in "Working Paper on Lead Entities: Range of Activities, and Necessary Funding Levels," produced by the Lead Entity Advisory Group (LEAG). All lead entities have a set of technical experts that assist in development of habitat restoration and protection strategies, and identification and prioritization of projects. The lead entity citizen committee is responsible under state law for developing the final prioritized project list and submitting it to the SRFB for funding consideration. Together the lead entity and SRFB processes provide the means to identify the most important habitat protection and restoration projects in a watershed and prioritize those projects for funding and implementation. This process, guided by recovery goals and habitat assessments, is illustrated in Figure 10 below.

Figure 10. SRFB Funding process for habitat restoration projects.



The above figure is an example of an adaptive management process and how monitoring should fit into decision-making and evaluation. The diagram indicates that three kinds of monitoring would occur associated with projects:

- Implementation – Whether a project has been implemented as originally stated: "The fish screen was installed."

- Effectiveness – Whether the implemented project is effective in its stated goals: "The installed fish screen is working to bar juveniles from entering the ditch." Note that this level of monitoring may be appropriate for groups of projects or sites rather than on an individual project basis.

- Validation – Whether the implemented and effective project is restoring fish: "The installed fish screen, by barring juveniles, provides measurable benefit to the stream's salmon populations."

Under Principle 7 of the *SRFB Mission, Roles and Responsibilities, and Funding Strategy* adopted by the SRFB June 15, 2001 and amended September 7, 2001, the SRFB will prioritize funding based upon watershed assessments and well thought out strategies by lead entities until the federal agencies have established recovery goals for salmon populations and habitat.

The SRFB has received 993 project applications since it was established in 1999. It has funded 658 projects (66%). The following table summarizes categories of projects, and amounts awarded:

Table 9. 1999-2002 Project Awards.

Project Type	# of Projects	Percent of Total Projects	Funds Awarded	Percent of Total Funds Awarded
Habitat Acquisition	74	11.3	29,346,301	20.1
Habitat Restoration*	365	55.6	45,051,500	30.8
Both Acquisition and Restoration*	36	5.5	16,211,596	11.1
Assessments/Capacity	152	23.2	16,698,194	11.4
Acquisition/Assessments	3	0.5	1,552,932	1.1
Programmatic Activities	26	3.9	37,212,033	25.5
TOTAL	656	100.0	146,072,556	100.0

** A total of $61,263,096 has been spent restoring habitat*

Source: IAC/SRFB

The 1999 habitat restoration and acquisition and restoration projects totaling $12.7 million were not broken down by project category. However, in grant rounds 1-3, FY 2000-2002, projects totaling $48.5 million were categorized. In those years, 221 projects dealt with either habitat restoration or restoration combined with acquisition. Breaking out the specific type of "habitat restoration" shows the number of projects and amounts awarded:

Table 10. 2000-2002 Restoration Projects – Detailed Types.

Category	Number of Projects	Funds Awarded	Percent of Total
Estuarine/Marine	17	3,327,201	6.8
In-Stream Diversion	10	1,695,203	3.5
In-Stream Habitat	79	17,494,252	36.1
In-Stream Passage	70	14,175,220	29.2
Riparian Habitat	31	8,084,114	16.7
Upland Habitat	24	3,751,562	7.7
TOTAL	221	48,527,552	100.0

Source: IAC/SRFB

These statistics can be used to establish meaningful monitoring programs based upon the major types of project categories.

Northwest Power Planning Council

The Northwest Power Planning Council is a four-state, federally chartered body that advises the Bonneville Power Administration, among other things, on the priorities for investments of BPA habitat improvement and mitigation funds. The NWPPC document 94-55 1994 Fish and Wildlife Program, Section 3 states:

> *"The Council recognizes the need to employ a system-wide approach to address the needs of Columbia River Basin fish and wildlife. To accomplish this, a coordinated implementation, research, monitoring and evaluation process is essential. This process should be flexible enough to evolve over time. It should facilitate identification of priorities. It should provide coordination at levels needed to accomplish basin-wide as well as local watershed objectives. Coordination also must encompass all programs, plans, policies and statutes that affect fish and wildlife produced in the Columbia River Basin. It must allow all affected parties meaningful participation, encourage local implementation and guidance and provide needed regional coordination. The approach should also provide a mechanism for accountability."*

Since the document's publication, the NWPPC has been working with the lead entities and various federal and state agencies to develop a monitoring program. Basin plans are being developed to identify needed monitoring. To give watershed planning a head start, the Council has called for a model watersheds program, in which watershed-oriented monitoring techniques can be pioneered and evaluated. Promising developments can then be incorporated into the sub-regional process. Fishery managers are to use updated sub-basin plans and acknowledged local watershed plans, where available, to develop a project-specific implementation plan. The revised 10-year implementation plan is to be submitted to the Council for review a by March 1 of each year. Once the plan is operational, it will be used to identify projects for specific fish populations.

In FY 2002, BPA dedicated $257,325,934 for:

- Fish and wildlife projects to implement the Columbia River Basin Fish and Wildlife Program (developed by the NWPPC, Figure 11),

- The 2000 Biological Opinions, and
- The FCRPS developed by the National Marine Fisheries Service and the U.S. Fish and Wildlife Service.

The Council allocates direct funding to three major categories: anadromous fish, resident fish, and wildlife. Of 397 overall NWPPC-funded projects basin-wide for FY 2002, 39% are habitat projects. Within Washington, there are 86 active projects funded for FY 2002. Of these, 27 are habitat projects (31%). Within the habitat projects, 17 (63%) are restoration and enhancement projects and 4 (15%) are tributary passage projects. Total funds allocated by NWPPC for habitat improvement for FY 2002 in Washington are $10,085,120.

Funded habitat restoration projects are to be reviewed in the context of the following guidelines:

- Give highest priority to habitat protection and improvement in areas of the Columbia Basin where low or medium habitat productivity or low pre-spawning survival for identified weak populations are limiting factors.
- Give priority to habitat projects that have been integrated into broader watershed improvement efforts and that promote cooperative agreements with private landowners.
- For actions that increase habitat productivity or quantity, give priority to actions that maximize the desired result per dollar spent.
- Also, give higher priority to actions that have a high probability of succeeding at a reasonable cost over those that have great cost and highly uncertain success.
- Encourage the involvement of volunteers and educational institutions in cooperative habitat enhancement projects.
- Promote public outreach and encourage education in watershed and resource management and protection throughout the basin.

The NWPPC trend has been toward increased funding for habitat restoration projects. In the upcoming round of new project applications, many are habitat improvement projects. However, monitoring, other than implementation monitoring, does not appear to be a requirement for funding at this time.

Bonneville Environmental Foundation (BEF)

The Bonneville Environmental Foundation is a non-profit organization established to collect and invest premiums from the sale of environmentally superior “green” power. It provides grants for restoring damaged watershed ecosystems. It requires long-term (10 year) monitoring and restoration plans, and has targeted habitat restoration and monitoring at small watersheds where the effectiveness of actions taken can be documented.

Aquatic Lands Enhancement Account (ALEA)

The Washington Department of Natural Resources (DNR) Aquatic Lands Enhancement Account (ALEA) Grant Program is directed by statute to invest in projects that enhance and protect wildlife and fish habitat and provide places for people to enjoy Washington’s salt and fresh water shore lands and tidelands. The ALEA funding comes from a percentage of revenue generated by DNR-managed geoduck harvesting and leases on state-owned aquatic lands. To be eligible for ALEA grant funding, the properties and projects must be on or associated with navigable waters. Cities, counties, ports, state agencies, tribes, and special purpose districts are eligible to apply. In the 2001-03 biennium, $5.6 million in projects were funded. Of these projects, four have strong salmon habitat restoration goals and total $1.6 million. Most of the remaining projects are for habitat acquisition.

Figure 11. Columbia River Basin Fish & Wildlife Program/FY'02 Monitoring

Data source: Northwest Power Planning Council

Guidance for Habitat Project Protocols

Objective: 21A: Provide guidance to the Salmon Recovery Funding Board and other funding entities for best monitoring protocols for habitat projects.

Monitoring indicators

The SRFB, NWPPC and other funding entities have typically supported a range of on-the-ground restoration and/or protection projects. Indicators for monitoring restoration projects are tied to project type. Therefore, for each of the project types listed below there are numerous habitat indicators that could be monitored. For a list of the actual indicators for measuring habitat associated with these projects (large woody debris, sedimentation, riparian cover), see "H. Nearshore Marine Areas" on page 196, "B. Freshwater Habitat/Landscape Forming Processes" on page 99, "C. Fish Passage Barriers" on page 138, and "D. Habitat Connectivity" on page 147, all in Part VII of this Strategy.

Typical restoration projects funded by SRFB and the other funding entities include:

- Estuarine/Marine nearshore projects, such as beach nourishment, bulkhead removal, and eel grass bed restoration projects;
- In-stream diversions, including diversion dam removal and fish bypass;
- In-stream habitat restoration projects, including bank stabilization, channel connectivity, and livestock fencing;
- Projects designed to restore/improve in-stream passage, including bridge projects, culvert improvements, and fishway construction ;
- Riparian habitat, including livestock exclusion fencing, riparian plantings, and wetland restorations; and
- Upland habitat projects, including erosion control, impervious surface removal, and road abandonment.

Current monitoring activity

There are currently no SRFB, ALEA, or NWPPC adopted protocols for funded projects to conduct habitat or fish population monitoring. However, monitoring (undefined) is usually stated as a project requirement.

NWPPC/BPA

The NWPPC staff has been interested in establishing monitoring protocols that can be applied throughout the Columbia River basin. The work of Johnson et. al. (2001) has been integrated into the NWPPC project review process. Development of recommended protocols and standards for fish and wildlife monitoring has been funded and are underway. Independent science review has been implemented to help evaluate proposed monitoring funded by NWPPC.

The NWPPC has also been developing a Coordinated Information System, which is considered an integral part of the Council's monitoring and evaluation program. It is considered essential to the efficient collection and dissemination of information produced as a result of monitoring. The NWPPC has been developing performance measures to track the effectiveness of actions in a timely manner. Performance standards for each action or set of actions are to be developed that provide an easily measurable index that relates to the type of biological or physical change intended. These performance standards are intended to provide a point of reference against which to monitor change and units of measure to define change. They are not intended to state or limit obligations or to resolve technical uncertainties.

The BPA is considering adopting a small suite of about 10 core physical attributes (perhaps adding some biological attributes) and protocols that would be used universally. The BPA would like to ask for and promote such a core suite as an essential minimum in BPA-funded projects, while leaving open for discussion (and potential funding) broader sets of locally-favored variables for which standardization would not necessarily be sought. In addition to ensuring that this core set is a part of larger monitoring programs, BPA would also try to ensure that the resulting data is complementary-i.e., comparable-with analogous data being collected by other significant programs (e.g., USFS) in each sub-basin. By comparable, it is meant that data are either directly transferable between programs (because the same protocols were used) or translatable (because correlations have been defined). A small core suite would make standardization more attainable and acceptable.

SRFB

There are currently no SRFB adopted monitoring protocols for habitat restoration or acquisition projects. The SRFB relies upon lead entities to bring their highest priority projects to the Board for funding, including their proposed sampling protocols and designs as part of the project submittal process.

Essential tools

The essential tool for settling upon accepted protocols is for the proposed Watershed Monitoring Council to convene the interested parties and facilitate reaching consent on the protocols that will be adopted and formalized.

Recommended sampling protocols

The development of standardized protocols is a goal expressed to the MOC by many individuals and agencies while developing this strategy. However, we found that the difficulty and controversy associated with this task will require more time to reach agreement on standardized sampling and data protocols. For this reason, and because the legislated deadlines associated with this strategy were necessarily short, specific monitoring product recommendations are not available to the SRFB at this time for the wide variety of projects funded.

➢ *Recommend, as an interim measure, future projects dealing with habitat employ the standard measurements developed by the US EPA for their Environmental Monitoring and Assessment Program (EMAP) where applicable.*

We believe this will provide future comparability of data between habitat restoration projects, and between data collected through SRFB and NWPPC funding and future data available through a statewide status and trend monitoring program. It would also allow direct comparisons with federal U.S. Forest Service measures using EMAP protocols and with Oregon's Watershed Enhancement Board (OWEB) approach to measuring habitat in Oregon in response to the ESA.

As can be surmised from the descriptions provided at the beginning of the chapter, a huge variety of habitat projects have been funded. Some coordination is already occurring between the SRFB and the NWPPC.

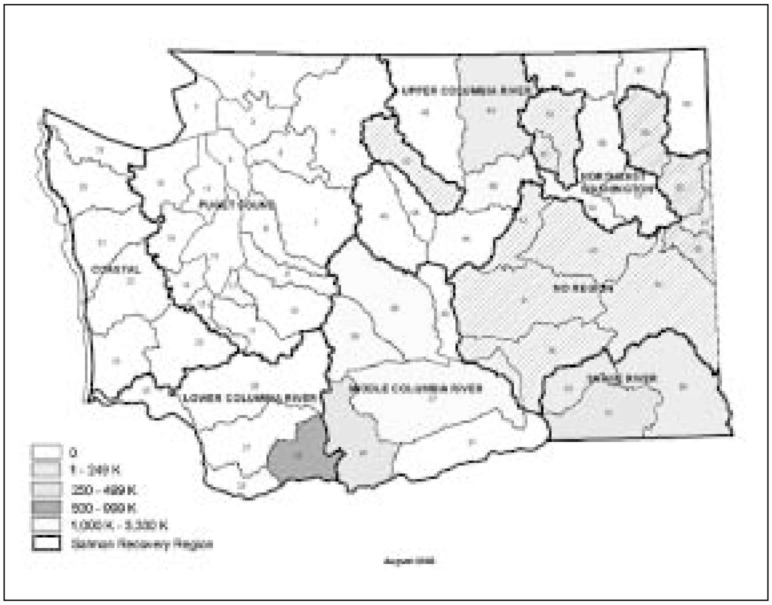
➢ *Recommend that representatives from the SRFB, NWPPC, BPA, and Corps of Engineers develop with input from the SRRs and lead entities, regional priorities for prioritizing the types of projects funded in each region and in intensively monitored watersheds.*

Performance benchmarks

Performance benchmarks for evaluating prioritized projects could include evaluating whether the target percentage of projects in a certain category was reached. Another possible benchmark might compare the number of projects and funding expended by WRIA to priorities set for WRIAs that will have the most impact upon salmon recovery and delisting. Prioritizations could be used to compare and guide projects funded for NWPPC (Figure 12 and SRFB restoration projects (Figure 13).

The SSRS (GSRO 1999) provides a list of prioritized watersheds where instream flows are of high concern (Figure 14). A document prepared by the Interagency Science Advisory Team for the Washington Joint Natural Resources Cabinet (ISAT 1999) provides prioritized watersheds for each of the western Washington Salmon Recovery Regions (Figure 15).

Figure 12. Northwest Power Planning Council FY-2002 Habitat Restoration Project Funds Awarded



Data source: Northwest Power Planning Council

Figure 13. SRFB Funded Restoration Projects by WRIA 1999-2002

Data source: Interagency Committee for Outdoor Recreation

Quality assurance/Quality control

The SRFB/NWPPC could report annually on the number of projects awarded that met the priorities set by the SRFB/NWPPC for each category and geographic area. This analysis could be combined with outcomes from effectiveness monitoring and status and trend monitoring of habitat to evaluate improvements in habitat and to reprioritize project categories.

➢ *Recommend the funding entities adopt the standardized definitions and categories of projects used by the SRFB through the PRISM database so that a composite understanding of habitat restoration efforts and monitoring can be developed throughout Washington and the Pacific Northwest.*

➢ *Recommend that each grant contract distributed to salmon recovery partners contain an attachment describing data and metadata content and format requirements.*

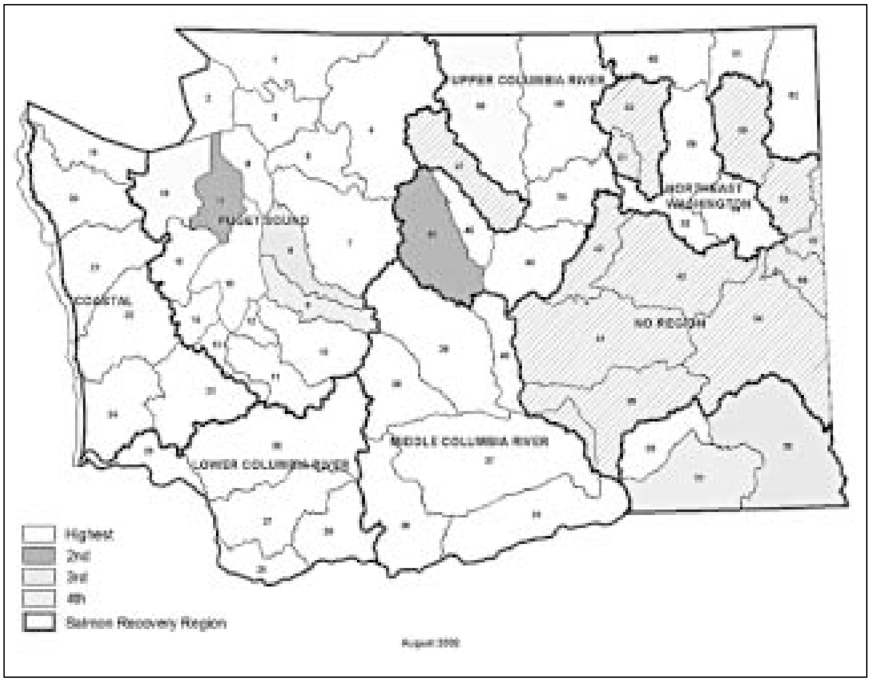
Identified agencies

Statewide entities, such as the state conservation commissions or other appropriate bodies have been identified to facilitate coordinated habitat protection and improvement with private landowners. The Council has also attempted to collaborate with local watershed committees in watershed planning and implementation, and provide funding, technical advice and assistance.

Risks

The prioritization of habitat projects by category or some other way could reduce local involvement in improving watershed health if the projects in their geographic area were considered low priority. On the other hand, unless there is a holistic approach to evaluating and categorizing projects, no clear picture of funding needs and effectiveness can be obtained.

Figure 14. Top 4 Westside & Eastside WRIAs for Protection/Restoration of Instream Flows (SSRS.1999)



Data source: Governor's Salmon Recovery Office (1999)

Figure 15. Western Washington Prioritized Salmon Restoration WRIAs (1999 JNRC Report)

Data source: ISAT (1999)

Validation Monitoring (Cause and Effect)

Objective 21B: Determine whether habitat improvement projects are effective in increasing the number of salmon produced.

Current monitoring activity

SRFB

There currently is no monitoring of the effectiveness of habitat restoration projects funded by the SRFB in increasing the overall numbers of salmon produced. This is not surprising in that the methods needed to evaluate the ability of projects to increase fish populations requires rigorous experimental designs in watersheds where all salmon production factors are intensively monitored.

NWPPC/BPA

The NWPPC has indicated that it intends to establish a limited number of indicator salmon populations that will be the focus of intensive monitoring. The purpose of indicator population monitoring is not only to provide detailed stock status information on these particular populations, but also to provide basic life history and survival information that will be applicable to all populations within the larger population.

The Council has been exploring alternative procedures for funding high priority habitat projects expeditiously.

The effectiveness/validation monitoring/research that has occurred has rarely, if ever, attempted to measure a fish response to the action, primarily because of the difficulty (hence, cost) of doing so credibly. However, BPA, in collaboration with the other Action Agencies, NMFS, and project sponsors (i.e. local co-managers), is now trying to begin validation (intensive) monitoring, because the NMFS BiOp requires an effectiveness monitoring program (RPA 183), because the Independent Science Review Panel has long sought demonstrations of effectiveness (fish responses) for Fish and Wildlife Projects, and because BPA desires documentation that their investments are producing results. The John Day, Wenatchee, and probably other sub-basins are being chosen as incubators for status monitoring projects, not for effectiveness/validation monitoring/research. The BPA is inventorying and evaluating existing habitat projects to determine where effectiveness/validation monitoring could be added to, or built upon, already-funded habitat actions to meet the rigorous standards of BiOp RPA 183.

ALEA

There currently is no monitoring of the effectiveness of habitat restoration projects funded by ALEA in increasing the overall numbers of salmon produced as a result of improved habitat.

Monitoring design

The NWPPC has indicated that each state should identify at least one focus sub-basin to apply the approaches developed in the model watersheds portion of their plan.

The NWPPC expects the coordinating entity to ensure that each model watershed accomplishes the following critical elements:

- Identifies all parties with an interest in each model watershed. Established procedures to ensure that *all* these parties have the opportunity to participate fully in the development and implementation of the model watershed. Convenes a watershed conference that includes *all* parties with an interest in the model watershed.

- Compiles all existing plans, programs, policies, laws and other appropriate authorities that relate to comprehensive watershed management in each model watershed.

- Identifies gaps and conflicts in the existing plans, programs, policies, laws and other appropriate authorities that hinder comprehensive watershed management in each model watershed.

- Sets out a path and procedures for filling gaps and addressing conflicts.
- Identifies key factors limiting salmon and steelhead productivity.
- Identifies priority on-the-ground actions to address key limiting factors.
- Compiles a list of all human and fiscal resources that are potentially available for protection and improvement of habitat for the model watershed. Include on the list all potential federal, state, local government, and other public sources as well as private sources such as local businesses that rely on natural resources in those watersheds. Coordinate this activity on a regional and state level, as appropriate.
- Provides for the involvement of volunteers and educational institutions in the implementation of projects.
- In Part VII of the CMS, it is recommended that one or more intensively monitored watersheds should be identified.

➢ *Recommend the SRFB and the NWPPC/BPA coordinate funding of habitat restoration projects such that in intensively monitored watersheds (see Part VII), projects can be clustered in such a manner that the probability of detecting significant changes in fish numbers can be improved.*

The approach is described in greater detail in Part VIII. The specifics of designs will need to be developed on a case by case basis.

Statistical Criteria

The project leaders for monitoring in intensively monitored watersheds will need to determine the expected level of certainty their experimental design can detect for changes in habitat and fish populations. This should be based upon the known variances in fish population numbers, and the number of projects needed to change or significantly modify appropriate attributes of the stream such that changes in the basic habitat parameters can be detected.

Recommended sampling protocols

Sampling protocols should be standardized to the greatest extent possible in order to allow comparisons between intensively monitored basins and between SRRs over time.

Protocols outlined by the USEPA in EMAP and by Johnson et al. (2001) should be consulted as a starting point for developing accepted procedures for validation monitoring. Fish population sampling should follow the protocols outlined in Part VII - I (Salmon Abundance).

Performance benchmarks

Performance benchmarks for validating the effectiveness of projects in producing more salmon will depend upon measuring the conditions accurately prior to completing the projects in both treatment and control streams within the watershed. See part VIII.

Identified monitoring gaps/overlaps

The results from intensively monitored watersheds should evaluate the overall changes observed in the productivity of the watershed in terms of juvenile salmon produced. Whether the results will be able to be correlated to explicit project types or cumulative effects will depend upon designs, and how the SRFB, NWPPC, and other funding entities decide to cluster projects within the intensively monitored watersheds. The ability to directly tie habitat improvements to measured improvement in salmon numbers is of keen interest to the legislature and the congress. Obtaining results will require a long term commitment to funding and evaluating intensively monitored watersheds.

Identified agencies

The NWPPC, SRFB, Salmon Recovery Regions, Watershed Leads, Lead Entities, federal and local agencies and tribes.

Quality assurance/Quality control

A Quality Assurance (QA) Project Plan should be developed by each entity conducting intensive monitoring that will include integrated analysis and reporting mechanisms.

The QA Project Plan will describe the objectives of the study and the procedures to be followed to achieve those objectives. The preparation of a QA Project Plan helps focus and guide the planning process and promotes communication among those who contribute to the study. The completed plan is a guide to those who carry out the study and forms the basis for written reports on the outcome. Quality assurance for sample survey designs should include a patterned revisit to sites both within the index period of a given year and revisits to sites across years to evaluation the different components of variation. Lombard and Kirchmer (2001) present detailed guidance on the preparation of QA Project Plans. They describe 14 elements to be addressed in the plan and provide supporting information and examples relevant to the content of each element.

Risks

Without adequate designs in intensively monitored watersheds, it will not be possible to determine what the response of fish is to our salmon restoration investments (ISP 2002). For example, the risks are high that a type 2 error will occur. A type 2 error occurs when data indicates that no change has occurred when in fact it did. In other words, there may be a real change in the number of salmon produced as a result of the habitat improvement projects, but the ability to measure the change is obscured by the background natural variations in the size of the salmon populations and in the habitat parameters being measured. Unless all of the known parameters that affect salmon populations are measured for the watershed or basin under study, there is a risk that the true cause of improvement or lack of improvement is due to other parameters not measured, or some other influence outside the basin where the projects are being evaluated.

Determine Effective Habitat Projects

Objective 21C: Determine what kinds of salmon recovery habitat projects are the most effective.

Current monitoring activity

SRFB

The SRFB has not conducted effectiveness monitoring with SRFB staff. Effectiveness monitoring has been delegated to project proponents based upon their project proposals.

Of the habitat restoration projects proposed, project proponents have specifically identified $588,000 per year to be spent to determine whether the project is effective in meeting the desired output or outcomes that led to the funding of the project. If this amount is applied over the four years of SRFB project funding, then up to $2,352,000 may have been spent to monitor project effectiveness.

However, there are no programs in place by the SRFB to track the projects either before or after they have been implemented, to determine:

(1) Whether the project proponent or other identified monitoring entity actually used the funds identified for effectiveness monitoring for monitoring purposes;

(2) Whether the project was effective in creating the desired output or outcome; and

(3) Whether some projects were more effective than others.

Also, because the type of project varies, some monitoring will require years prior to expecting a significant change. Consequently, reporting of monitoring successes will exceed the current project tracking timeline of five years.

A preliminary evaluation of 50 completed projects revealed that 94% of the project proponents intended to monitor whether the project was effective. Of these projects, 54% intended to monitor fish abundance, 25%

habitat, and 25% water quality or flow. The proposed monitoring time frame varied from one year to 15 years.

NWPPC/BPA
Some level of effectiveness monitoring has been included in many habitat projects, most notably for wildlife habitat acquisitions. However, the NWPPC and BPA have not required effectiveness monitoring as part of the project costs for habitat restoration. In recent years this type of monitoring and evaluation has been sought, but not always required or funded, by the NWPPC/BPA. There generally does not appear to be a high level of scientific rigor for effectiveness monitoring/research that has occurred for habitat projects.

Separate effectiveness monitoring project funding proposals have been evaluated for funding. We could find only one monitoring project ($103,000) funded for FY2002 that evaluates the effectiveness of a habitat restoration project. This project implemented fish passage improvements at four irrigation dams on the Yakima River at a cost of $5.3 million and was initially funded in FY1985. The project was evaluated for post-construction approach and sweeping velocities at fish screening facilities.

BEF
Bonneville Environmental Foundation is monitoring effectiveness of watershed projects in six small watersheds in Washington. Monitoring is designed to continue for a minimum of ten years. Small watersheds were chosen in order to be able to detect actual effectiveness of projects in altering habitat, and to create strong community involvement in the future of the watershed. Fish populations are not monitored as part of an intensively monitored watershed approach.

ALEA
There currently is no monitoring of the effectiveness of habitat restoration projects funded by ALEA in improving habitat.

Recommended sampling protocols
Protocols vary from project to project depending upon the type of project and individual preferences of the project applicant. The BEF has established standard protocols for their projects.

Identified monitoring gaps/overlaps
There is no structured approach to monitoring and reporting the effectiveness of projects sponsored by the SRFB or the NWPPC.

Quality assurance/Quality control
There are currently no written policies or procedures in place to check the quality of data for projects involving effectiveness monitoring.

Data have not been collected and categorized in the PRISM database or the NWPPC/BPA database for effectiveness monitoring. However, recent steps have been taken to begin collecting this information for SRFB projects.

Recommended Strategy for Effectiveness Monitoring of Habitat Restoration Projects

Monitoring indicators

SRFB
The two options described below are the recommended sampling strategy for monitoring project effectiveness. The two options are not mutually exclusive.

- Option 1 (100% sampling of projects) – The SRFB could require, as part of funding provided to the project applicant, monitoring of the effectiveness of the outcome that the project was designed to produce. This would mean that 100% of all restoration projects would be required to conduct effectiveness monitoring and report back to the SRFB the results of their monitoring. For example, a project may involve replacing a culvert considered a barrier to salmon. The hypothesis is that the new bottomless culvert will provide upstream passage and that the salmon will migrate into the new area and begin to produce more salmon than before. There are three levels of effectiveness:

a. Is the culvert able to pass fish?
b. Is the habitat upstream being utilized?
c. Have more fish been produced as a result of this project?

The latter question is usually considered validation monitoring in that it validates the original hypothesis that fixing a culvert will produce more fish and is addressed in Part VIII - Intensively Monitored Watersheds. Under this option, all project applicants would be required to measure effectiveness in terms of pre- and post-project conditions for the first two levels. This option requires some method for obtaining compliance with the monitoring requirement. This could occur through holding some project funds until the required monitoring has been reported, or some other method.

- Option 2 Recommended (Sampling by project categories) – A separate monitoring fund could be used to fund, design, and implement an approach to sample effectiveness of projects. The projects would be stratified based upon the major categories (e.g., estuarine/marine, in-stream habitat, in-stream passage, upland habitat, in-stream diversions, and riparian habitat). Projects would be sampled using adopted protocols and indicators both before and after the project. Reports and evaluations would occur annually to compare project costs to the observed effects. This type of monitoring will require varying amounts of time to observe results. Some categories of projects may require 10 or more years to determine if they are effective. Some aspects of others may be reportable within the same year.

➢ *Recommend the SRFB set aside a specific amount of restoration project funds for independent monitoring of project effectiveness.*

The SRFB should develop a structured programmatic approach to monitoring effectiveness of habitat restoration projects.

NWPPC

➢ *Recommend the NWPPC consider the recommendations provided to the SRFB and in view of the action items detailed in the Biological Opinion.*

BEF

➢ *Recommend coordinating small watershed restoration projects with the Comprehensive Strategy in order to maximize benefits to watershed monitoring.*

ALEA

➢ *Recommend DNR coordinate watershed restoration projects with the Comprehensive Strategy in order to maximize benefits to watershed monitoring.*

Monitoring design

Under Option 2, where there is not a 100% sampling of projects for effectiveness, a random sampling regime should be applied to estimate the overall percentage of projects that were effective by category such that we can be 95% confident that the percentage is within 10% of the true value. The reporting time period will vary from project type to project type.

Recommended sampling protocols

➢ *Recommend standardizing sampling protocols to the greatest extent possible in order to allow comparisons between projects over time.*

Protocols outlined by USEPA EMAP and Johnson et al. (2001) should be consulted as a starting point for developing accepted procedures for effectiveness monitoring. Fish population sampling should follow the protocols outlined in "I. Salmon Abundance, Productivity, Distribution and Diversity" on page 206 in Part VII of this document.

Performance benchmarks

Performance benchmarks for evaluating project effectiveness will depend upon measuring the conditions accurately prior to completing the projects. In the example of a culvert replacement, an accurate survey of fish presence or absence upstream of the culvert prior to construction would need to be made in order to determine the effectiveness of the project.

➢ *Recommend SRFB and NWPPC/BPA standardize project categories so that evaluations of project effectiveness can be reported holistically on a periodic basis.*

The analysis should review the percent of projects effective by category. The relative effectiveness of projects should be evaluated for cause and reported so that the funding entity can evaluate whether future project selection criteria should be modified, and to evaluate which projects were most cost effective.

➢ *Recommend modification of databases to accept project effectiveness information.*

Quality assurance/Quality control

The QA Project Plan will describe the objectives of the study and the procedures to be followed to achieve those objectives. The preparation of a QA Project Plan helps focus and guide the planning process and promotes communication among those who contribute to the study. The completed plan is a guide to those who carry out the study and forms the basis for written reports on the outcome. Quality assurance for sample survey designs should include a patterned revisit to sites both within the index period of a given year and revisits to sites across years to evaluate the different components of variation. Lombard and Kirchmer (2001) present detailed guidance on the preparation of QA Project Plans. They describe 14 elements to be addressed in the plan and provide supporting information and examples relevant to the content of each element.

Risks

Without project effectiveness programs, accountability cannot be obtained. The central risks under Option 1 would appear to be whether project applicants have the expertise and long term organizational structure to monitor the effectiveness of their project. Coupled with this is the risk that the project applicant will lose incentive to expend additional time and money to monitor their project once the project is completed.

Risks under Option 2 appear to be less because the long term effectiveness monitoring needed is provided up front prior to funding projects. Reporting is independent of the project applicant's vested interests, and local abilities in terms of maintaining databases, expertise, and funding.

Implementation Monitoring

Objective 21D: Determine whether habitat improvement projects were properly implemented.

Current monitoring activity

SRFB

Since 2000, the SRFB has authorized 401 projects that involve restoration of habitat. The SRFB (through the offices of the Interagency Committee for Outdoor Recreation) has a staff of five people to process and monitor project implementation. Approximately 15% of staff time is involved in actual inspection of projects to determine if the project had been implemented as proposed. This equates to an expenditure of $68,000 annually or about $272,000 since 1999. This represents about 0.2% of the total funds available to the SRFB.

There currently is no need for a sampling approach to monitoring project implementation. All projects are to be checked for implementation upon notification by the project applicant that the project has been completed or upon requesting final payment for the project. Currently, 44% of the projects have been completed and verified as implemented. An estimated 6% of the ongoing projects have been delayed by logistical or permitting issues, but are expected to be completed within the contract period. The remaining 50% are in progress and on schedule. Each project has a 5-year completion window. None of the projects have reached the end of their contract.

Based upon this information, it appears that implementation monitoring has been appropriate and effective in tracking project implementation. There are no statistical certainty or precision issues because a full census of all projects is being conducted.

NWPPC/BPA

The NWPPC/BPA track expenditures of contracts carefully and monitor whether projects have been implemented. Projects are tracked by federal fiscal year, and there is strong competition for funding new projects. The BPA relies upon the contracted cooperating agencies to check for implementation. Various contracted agencies may differ in the degree that projects implementation was monitored.

BEF

The foundation works carefully with their projects to provide oversight and monitor implementation.

Quality assurance/Quality control

There are currently written SRFB procedures detailed in the PRISM User Guide under "Inspections" where a final inspection form must be completed before receiving the final 10% of project funds. There is also reference to implementation monitoring in the *"Policies and Project Selection Grants Manual."* However, there could be more specific guidelines written for what constitutes a user manual for inspecting projects for completion.

The SRFB utilizes the projects tracking system known as PRISM. This database provides excellent information about project costs, project implementation, locations, and other budgetary information.

The NWPPC/BPA projects are tracked through their Fish and Wildlife Budget tracking report and through the Columbia Basin Fish and Wildlife Authority (CBFWA).

Recommended Strategy for Implementation Monitoring of Habitat Restoration/ Improvement Projects

Monitoring design

➢ *Recommend continuing with present strategy of monitoring 100% of projects for completion.*

In the event that the number of projects exceeds the ability of current staffing to monitor the implementation of 100% of the projects, the SRFB should determine whether to increase staffing, or to sample projects for implementation.

Statistical Criteria

If the SRFB chooses to sample, it is recommended that the sample size should produce an estimate of the implementation rate such that the SRFB can be 95% confident that the percentage of implemented projects as a whole for any year sampled is accurate within 2%.

Performance benchmarks

Annual performance can be compared to historic levels of projects implementation success.

Evaluation of project implementation could be conducted annually to review the percent of projects implemented on time, percent not implemented within the five year contract, and those delayed due to cause. The SRFB could use this information to evaluate whether contract time frames are appropriate, and whether certain types of projects are more apt to be delayed or cancelled.

Quality assurance/Quality control

➢ *Recommend checking quality of Implementation monitoring through a periodic performance audit coupled with a financial audit.*

Risks

Since the annual expenditures for restoration projects have been approximately 15 million dollars per year, a sampling regime with a 2% error would mean that on the average, $305,000 could be underutilized or misdirected without detection because the project by random chance would not have been sampled. This would necessarily be a policy decision by the SRFB whether a risk that size was appropriate in lieu of adding additional staff.

Monitoring Guidelines for Watershed Planning Units

Washington State residents are faced with an increasing number of challenges related to water resources. These challenges include limited water supplies to meet current and future needs, water quality degradation, and the recent listings of salmon under the Endangered Species Act (ESA). Left unresolved, these issues will have a broad and far-reaching affect on the economic and environmental health of the state.

In 1998, the Washington State legislature passed Engrossed Substitute House Bill 2514, codified as RCW 90.82, known as the Watershed Management Act. This Act included a grant-funding element requiring completion of a Watershed Management Plan within four years of receipt of grant funding. The Act provides a framework to better understand the nature and extent of water resource management issues and to locally plan and implement solutions to identified problems. Participation in the process is voluntary.

Over the next few years, decisions will be made and plans developed and implemented regarding the water resources of watersheds. These decisions and plans will coordinate the land use/resource management planning under the Growth Management Act, the Shorelines Management Act, and other similar Acts, along with planning/projects in response to the ESA salmon listings.

These decisions will largely determine the landscape, the environmental health, and the economic future of watershed residents. Federal, tribal, state, and local governments are authorized to make these decisions. The state legislature, with agreements from federal agencies, has provided an opportunity for watershed management decisions to be made locally.

The Watershed Management Act requires the development and implementation of a Watershed Management Plan that:

- Balances competing resource demands in the watershed;
- Provides for the economic well-being of the citizenry and community;
- Protects existing water rights;
- Is consistent with current law;
- Does not conflict with existing state statutes, federal laws, tribal laws, and tribal treaty rights; and
- Provides local citizens with the maximum possible input concerning their goals and objectives for water resource management and development.

Many jurisdictions are making the voluntary decision to engage in the Watershed Management Process because of the increasing number of water problems their communities are facing. Competing demands for the finite water resources pose a host of interconnected, serious challenges that threaten the environment and the economy.

The demands for water include the needs of fish for sufficient water in streams to enable migration and propagation. Since several salmon populations have been listed under the ESA and jurisdictions must find a means to ensure that there is sufficient water available for fish. In addition, tribal treaty rights include the right to harvest fish at all usual and accustomed grounds and stations throughout the state. Meanwhile, growth demands water for farming, homes, businesses, and industries.

The quality of the State's water is also a problem. Human activities affect both surface and ground water quality and have lowered water quality below that necessary to support beneficial uses in many areas. The immediate challenge is to collect or generate sufficient information upon which to base rational water resource management decisions. Jurisdictions need information about water quantity, water quality and habitat needed to support all water users, including humans and fish. In addition, the extent to which ground and surface are interconnected varies throughout watersheds.

Because the elements of watershed management (quantity, quality, and habitat) are physically, chemically, and biologically interconnected throughout the watershed, any successful management plan should address all of these components. Because water resource issues and policies are both complex and contentious, a collaborative decision making model holds the greatest promise for developing a watershed management plan that will be successful over time. This collaborative effort should be conducted in a manner that does not violate tribal government principles.

The geographic scope of Watershed Planning Projects is the Water Resource Inventory Areas defined in state rule (Chapter 173-500 WAC). The scope of issues to be addressed under the Watershed Planning Act must include water quantity, but may also include water quality, instream flows, and habitat. Most of the initiating governments have chosen to address all four components.

Under the Watershed Planning Act, a proposed plan that has been approved by the Planning Unit must be submitted to the Lead Agency within four years of the date that the Planning Unit first received funding. Implementation, monitoring, and evaluation of the Plan will continue indefinitely into the future. Affected parties include: all federal, tribal, and state agencies, local governments, and private water resource interests within the watersheds.

Each Watershed Planning Unit prepares a scope of work to outline the general process, strategy, and actions necessary to address water resource issues in the watershed, including the actions taken to date. It provides the framework from which more detailed work plans will be developed and implemented. These work plans include goals/objectives, specific tasks, budgets, who implements the plan, work products, and schedules. Specific tasks should be clearly linked to the requirements specified in the RCW, MOAs, contracts, or other agreed upon documents. Where appropriate, work plans will include design parameters such as time step, probable error, and expected contribution to satisfying specific information needs. Some of this may not be known until the work plans are implemented. The standard usually established is the use of "best available science," defined as objective and repeatable analysis based on adequate empirical data collected with appropriate quality assurance/ quality control procedures in place.

In many cases, Technical Teams are formed to facilitate the development and implementation of specific work plans. Technical Teams will generally be composed of representatives from the Initiating Governments and Planning Unit or their designees, and other technical experts. Representation on the Teams is determined by each caucus/ interest. The Technical Teams report to and receive direction from the Initiating Governments and Planning Unit. The Technical Teams may choose to develop and implement specific work plans themselves or they may recommend which community members, private consultants and/or government agencies assist.

Goals and Purposes of Watershed Management Planning

The goals and purposes of Watershed Management Plans are defined by the state rule and other legal agreements, such as intergovernmental memoranda of agreements. In addition, the local interests and needs of the public participating in the project also help shape the project goals. As the project evolves and new information is obtained, these interests and needs may be modified. In general, the goals of the Watershed Management Plans are to have water of sufficient quantity and quality to meet the needs of current and future human generations, including the restoration of salmon to healthy and harvestable levels and the improvement of habitats on which fish rely. More specifically, the Plans may address the following specific goals and purposes for each of the four components identified in the Watershed Management Act:

- Water Quantity: The goal of the water quantity component is to assess water supply and use and to develop strategies to meet current and future needs. The strategies should retain or provide adequate amounts of water to protect and restore fish habitat, provide water for future out-of-stream uses and to ensure that adequate water supplies are available for agriculture, energy production, and population and economic growth under the requirements of the state's growth management act.

- Water Quality: The goal of the water quality component is to ensure that the quality of our water is sufficient for current and future uses. This includes restoring and protecting water quality to meet the needs of salmon and shellfish, contact recreational uses, cultural uses, wildlife, safe domestic water supplies, and other beneficial uses. The initial objectives of the water quality management strategy will be to meet the water quality standards.

- Instream Flow: The goal of the instream flow component is to supply sufficient water quantities to restore salmon, steelhead, and trout populations to healthy and harvestable levels and improve habitat.

- Fish Habitat: The goal of the fish habitat component is to protect or enhance fish habitat in the management area. This includes restoring salmon, steelhead, and trout populations to healthy and harvestable levels and improving habitat on which fish rely.

These Plans should recognize that the four project components are highly interconnected. Actions intended to affect change in one component may affect one or more of the components. The approach used should capitalize on the interrelationships between the four identified project components by systematically integrating the data collection and analysis efforts. The effort should be coordinated with other resource management efforts.

The Watershed Management Act provides a framework for citizens, interest groups, and government organizations to collaboratively identify and solve water-related issues in each of the 62 watersheds of the state. The guidance manual prepared to assist the planning process describes the use of a Technical Analysis Process that includes use and collection of water monitoring data. The approach uses technical staff to compile existing water data and collect new data within the watershed to address specific planning and management objectives. The process coordinates the use and collection of water data from stakeholders participating in the process.

Watershed Monitoring to Support a Management Information System

Watershed management requires data and trend information. It also includes compliance with established standards and an understanding of the causes of problems detected. For example, the federal Clean Water Act requires monitoring information to comply with various legally mandated programs, such as the reporting of current water quality conditions required by Section 305(b) of the federal Clean Water Act and the Total Maximum Daily Load (TMDL) listing requirements of Section 303(d).

The exact form of the information demanded by laws is often unclear. There are often limitations of monitoring to produce "management" oriented information. For example, RCW 90.48.010 states that the "state of Washington will exercise its powers ... to retain and secure high quality for all waters of the state." What information supplied by monitoring can best demonstrate the effectiveness of management in meeting this state policy? What information best tells watershed managers and the public how the water quality of Washington is behaving relative to societal goals, as expressed by the applicable laws? Monitoring can measure the trends in watershed health indicators, the proportion of samples that exceed established standards, or the number of stations at which at least one standard is exceeded. However, the interpretation of this monitoring information, in the context of management decisions, is often left to the staff of the management agency.

Ott (1978) notes that the public and their elected representatives want to know if the watershed health is getting better or worse and the answer must be in the simplest form. The scientist operating the monitoring system may feel that the answer to the question is complex, "requiring the interpretation of hundreds of thousands of measurements of different variables, sometimes, compounded by missing data, inconsistencies, and quality control problems, and often giving vague or uncertain results." The public will not be satisfied with the raw data, time series plots, or statistical analyses. The public wants a simple answer.

It is in this situation that "indicators" or "indices" can play an important communications role. The role of an indicator or index is to simplify or reduce large quantities of data down to its simplest form, while retaining the essence of the information contained in the data relative to the questions being asked. In the process of simplification, some information is lost. Hopefully, if the index is designed properly, the lost information will not seriously distort the answer to the question. Unfortunately, one may not know in advance what question will be asked. This situation creates the hazard that the index will be used for purposes other than those for which it was designed. Ott (1978) takes the position that index development must begin with a carefully defined concept of the purpose of the index, and the original purpose must be respected when the index is being used.

Many indicators are valid approaches to summarizing watershed health data relative to established standards. In assessing which best serves as a management performance measure, the questions arise: What are management's goals? Have these goals been agreed to by those who evaluate management performance? Without a carefully defined, legally justified, well documented, and peer reviewed (U.S. EPA 1998) statement of management's purpose and goals, it is not possible to declare, scientifically, which indicators best serve as a management indicator. An evaluation has been recently conducted of the indicators used by the Department of Ecology to articulate watershed health for management and the public (Ward 2001). Many of the recommendations and rationale presented in this chapter are a result from that evaluation.

Obtaining Accountability for Effectiveness of State and Federal Investments

There are many types and forms of watershed health indicators and indices in the literature that might be suitable as a measure of management performance. Which are most policy-relevant to the goals? For example, RCW 90.48.010 states that the "state of Washington will exercise its powers… to **retain and secure** high quality for all waters of the state." (Emphasis added) This statement can be interpreted as a management goal. The law may yield other management goals after careful review and evaluation.

Using the "retain and secure" water quality as an example of a legal goal, additional indicator design issues follow. Can standards compliance be used to imply that water quality is retained and secured? Or are positive (secure) or level (retain) trends in water quality concentrations the proper measure of management success? If standard compliance is selected, should an indicator of compliance be based on proportion of samples violating standards or proportion of stations with any constituent violating its standard?

In recent years, monitoring system design has evolved to include carefully documenting management information needs as well as gaining understanding and agreement among those asking the questions. The goal is to carefully construct the monitoring (information system), including the methods for analyzing the data to produce sought after information, around specific questions relevant to managers and the public.

The question often posed concerning watershed health data relates to a measure of management's performance. The goal against which performance is being measured appears to be attainment of water quality standards, although there could be a number of alternative expressions of management goals. The management goal should be well articulated and documented in order to serve as a useful information goal.

Improving Water Quality Information and Reporting

Watershed health monitoring should be viewed more as an information system than a means of monitoring the misbehavior of companies or individuals regarding wastewater discharges or water withdrawals. This view reflects the increasing sophistication of management programs today as well as demand from the public for accountability. Monitoring, for many management functions, retains its research heritage-the scientist retains the right to use data analysis methods of his/her choice-but a growing need for management information is demanding more consistency and comparability in data analysis methods as well as brevity in the information provided.

In viewing monitoring as an information system in support of management, it is first necessary to define *monitoring*. There are a number of ways to view the acquisition of information about water quality. If the information goal is to produce an accurate understanding of conditions in a particular watershed, then the design of the information system must begin with a clear statement of the understanding sought. Ward et al. (1990) presents a set of monitoring system design steps that work from an information goal perspective through the monitoring system:

(1) Define and documenting the understanding sought,

(2) Define the reporting formats that convey the understanding,

(3) Specify the data analysis methods that will produce the report's contents, including statistics and indicators,

(4) Design the sampling approach (e.g., where, what and when to sample), and

(5) Define the operational aspects of the information system (e.g., laboratory analysis methods, quality control procedures, and data storage and retrieval).

The key step in the successful design of a monitoring system that proactively supports management is specifically defining the information sought. This key step is often overlooked until the data are available and someone forces it to be analyzed. The person assigned to analyze the data must choose data analysis methods and the means to convey the resulting information to managers and the public. The decision on what method to use can only be made by assuming what information is relevant to management and the public. As Griffith et al. (2001) notes, there are no established standard methods for analyzing water quality data for management purposes. Thus, it is not surprising that arguments develop when data are to be analyzed in support of management.

When data analysis methods are not identified along with clear information goals before data are collected, the results of the data analysis and reporting efforts are intermingled with the arguments over which methods to use. It becomes difficult to separate the management impacts of the information from the science of the data analysis methods.

Ideally, the information sought would be identified, quantified and documented before the methods to be used to analyze the data are selected. In addition, the methods to be used to analyze the data are selected and documented before data are collected. This permits a more scientific approach to selecting data analysis methods since the goal is to utilize the best science without the results of the methods being known, which may confound the selection of the data analysis methods.

It is recommended that the Watershed Planning Unit identify, quantify, and document the information needed by management and the public for purposes of assessing management performance. A report on the methods, results, and information expectations should receive independent peer review. Peers for this purpose should come from a wide audience of interested stakeholders, including managers, scientists, data analysts, journalists, and the public.

With information goals documented and agreed upon, it is possible to focus evaluation and selection of reporting and data analysis methods. This will help narrow the discussion over the best indicator. Multiple methods, resulting in multiple lines of evidence, may be deemed most appropriate to provide the relevant management performance information. Again, independent peer review should play a major role in the identification, evaluation and final selection of the methods employed to convert the data to information. Knowing the data analysis methods and the information sought, it is possible to quantify the sampling sites, the constituents to be measured, and the frequency of sampling. This approach gives a strong information rationale for specifying these three dimensions of monitoring design.

Obtaining Indicators of Management Performance from Monitoring Data

There is considerable literature available that discusses construction, selection, and use of indicators for purposes of measuring management performance. Compared to reporting economic indicators (e.g. performance measures of a stock market or business activity) or converting meteorological data into weather forecasts seen in all newspapers and TV news reports, environmental reporting is in its infancy. Given the more than 100 years head start in economic and weather reporting, this is not surprising.

It is also not surprising that an organization developing watershed management performance measures today would be struggling to determine which best serves as a management performance measure. For example, water quality management, in its current form, was not created until the early 1970s. The Dow Jones Index was 30 years old before it was widely accepted as a measure of the performance of the New York Stock Exchange (Rosenberg 1982).

Watershed health monitoring is only recently being viewed as an integrated information system, although the need to report management's success has been recognized for many years (Brown et al. 1970; Ott 1978; Thomas 1976; and U.S. Senate 1973). Use of the "public right-to-know" concept in the 1986 SARA Act Amendments (with chemical release inventories) and the 1996 Safe Drinking Water Act Amendments (in describing the quality of public drinking water in a Consumer Confidence Report) suggests a strong need to inform the public. In addition, the Government Performance and Results Act of 1993 suggests that management must be accountable to goals established for the actual quality of environment. Performance measures are a key component of any watershed health information system.

Unfortunately, as with many efforts to measure environmental conditions, the scale of the population that must be sampled to obtain an accurate measure is beyond the budget of the agencies. The number of stream miles in a watershed, the number and size of lakes, aquifers, and estuaries is beyond the ability of an agency to sample thoroughly. Thus, performance measures are developed from sparse data, from limited sites, and without any standard indices widely accepted in the field of watershed health management. Deciding on which indicator, or measure, best serves as a management performance measure is not a simple task (PEER 1999; GAO 2000).

Further complicating the issue is the wide number of interpretations that could form the basis of an indicator. Should a particular aquatic organism be an indicator for the quality of water? Should the concentration of a chemical constituent be the indicator for the quality of water? Should the number of times an established standard is exceeded be the indicator for health of the watershed? If the last is chosen, should the number of times the standard is exceeded be tabulated by sampling sites, or by the indicators measured?

Several efforts have been undertaken to develop broad-based indicators of environmental conditions. The President's Council on Sustainable Development has proposed *sustainable development* indicators-a blend of economic and environmental indicators. The Heinz Center is developing environmental reporting strategies focused on the public. The Heinz Center, however, has yet to develop watershed indicators. The Center employs peer review of its data and information presentation formats. The U.S. Environmental Protection Agency has presented 18 environmental indicators of water quality nationwide.

A brief review of indicator and index literature quickly reveals the many ways to construct an index or select an indicator. From the standpoint of developing a scientifically sound information system, there is considerable background analysis needed before it is possible to conclude which indicator best serves as a measure of management effectiveness. Ott (1978) existing approaches to construction of indices.

The debate surrounding development of indicators of management performance should occur an open, peer reviewed, scientific arena, rather than within the confines of agencies where the demand for "simple" information on management performance is responded to in an ad hoc manner. Use of the term "ad hoc" is not meant to demean individual efforts to develop indicators of management performance, but rather to emphasize the omission of the broader monitoring profession in addressing, collectively, the increasingly contentious issue of management performance indicators in a scientifically sound, peer reviewed manner.

In seeking to identify, define, document and peer review the most appropriate indicator to measure management effectiveness, it is recommended that a process be initiated to both identify and quantify the information goals that best serves this purpose. Indicators must be selected in ways that they are logically tied to the legal goals of the agency and peer reviewed by stakeholders. While this will not eliminate future arguments over selection of the indicator, it does suggest that a systematic, logical, documented, and peer reviewed method was employed in developing an indicator of management performance. Other ad hoc indicators, thus, must be balanced against the systematic and peer reviewed process employed by the agency in selecting its indicators.

A number of methods for analyzing and reporting watershed health data have been developed in this Comprehensive Monitoring Strategy to meet the various reporting requirements placed on the managers. As would be expected, no one method of data analysis or one indicator is able to meet all information needs. However, if a variety of data analysis methods and indicators are used, there is a chance that the information generated from the monitoring data is not providing consistent information (Griffith et al. 2001). In fact, the results may appear to portray quite different conditions of the watershed, depending upon the data analysis method or indicator used.

How does a Watershed Planning Unit obtain consistency in the watershed information generated to answer the various questions asked by the managers and public as well as provide a scientifically sound management performance measure? Given Griffith et al. (2001) findings, the current state-of-the-art in watershed data analysis, for management purposes, does not provide any one method that is best. There is a lack of scientific peer review in defining general data analysis methods and indicators for watershed management purposes.

Griffith et al. (2001) noted that after reviewing the use of statistics in five years of peer reviewed journal articles, the greatest commonality in methods selected for analyzing watershed data was from the U.S. Geological Survey. For example, the Seasonal Kendall trend test is consistently employed by U.S. Geological Survey scientists in determining trends. Beyond this one agency, there is no common approach to analyzing watershed data. Recently, even the use of such trend tests has been criticized (McBride 1998). Given the lack of agreement among scientists in methods employed for analyzing watershed data, it is not possible to define methods and indicators that best measure management performance that would not be subject to scientific challenge.

Why are economists able to develop and report economic indicators without being challenged on the indicator, index, or method employed to analyze the data? Identification of the indicator or index and the data analysis methods employed are established by panels of economists specializing in producing information for the public in scientifically sound ways. In fact, government agencies are established for this purpose (e.g. the Bureau of Economic Analysis and the Bureau of Labor Statistics). No such initiative has been undertaken in environmental management.

Recommended Approach to Establish Management Performance Indicators

Each Watershed Planning Unit should establish a Technical Team that has the charge to develop watershed indicators with corresponding methods of data analysis that meets the particular information needs of managers and the public. To establish an information-focused monitoring system, it is necessary to design each component of a monitoring system in a highly integrated manner. It is recommended that Technical Team conduct a systematic, information focused, scientifically sound, peer reviewed, and documented watershed health information system design. The design process will lead to an improvement in all aspects of the monitoring program, including identifying indicators the public can understand as well as indicators that measure well-defined goals associated with management performance.

Below are the steps recommended to establish a watershed information system that focuses on management performance measures. The steps must blend the science of designing monitoring systems with documented information goals. The information system also must be peer reviewed and transparent if it is to be widely accepted and creditable.

Step 1: Answer the following question in a documented and 'peer reviewed' manner: What watershed information do managers and the public want to receive and are capable of understanding?

To develop an unbiased and effective watershed health information system, one must begin with a definition of the information goal – what does the public want to know? The public, in general, will not be able to directly answer this question. What existing laws suggest are the management goals with respect to the watershed conditions and trends? The laws likely contain a number of statements that enunciate policy, goals, management functions and powers, and explicit information requirements that can be carefully interpreted regarding information relevant to the public. Consider, for example, the policy statement in the Revised Code of Washington, RCW 90.48.010: "...the state of Washington will exercise its powers, as fully and as effectively as possible, to r*etain and secure* high quality for all water of the state."(Emphasis added). This statement, from a management performance measure perspective, indicates that trends in water quality should either be moving toward a higher quality level (improving implies securing) or holding steady (retaining implies that conditions are not declining). Thus, a measure of management performance becomes a statement that all constituents measured, at representative sites around the state, are either improving or holding steady, per the requirements of Washington law.

Defining and documenting the information goals of a monitoring program designed to measure management performance will require considerable interpretation of legally expressed goals, as well as agreement that the interpretation is acceptable for the purpose for which it is intended. There are many accountability issues watershed managers will have to face as their efforts are measured in terms of actual conditions. Problems with many efforts to measure and report watershed health conditions stem from a lack of upfront information goal definition and documentation, as well as a peer review of the final product. The Comprehensive Monitoring Strategy describes many goals for watershed health that can be reviewed as a starting point for relevance for a particular watershed.

Step 2: How should the agreed upon information be reported?

The health of economies are described with a number of indicators released in a regular pattern over time and over the general economic landscape: unemployment statistics, housing starts, stock indices, Gross National Product, and sales tax receipts, for example. Weather and air quality data are analyzed and presented daily. The nature of watershed health data and information (related to uses and, perhaps, consisting of a few measurements at representative sites) will require careful consideration of the manner in which they are reported. Should newspapers prepare environmental sections of the local paper, similar to the sports and business sections? Should there be an index, followed by an assessment of the meaning of the index, and ending with a presentation of the data used to compile the index?

Beyond determining what information is to be obtained, there is a need to peer review the reporting format, distributing media, content, level of generalization, and ability to deconstruct the information, if so desired. The peer review should include the scientists who collect and analyze the data, technical journalists, managers, and the public.

Step 3: How should data be converted into the desired information?

To obtain comparable watershed health information that supports management decision-making, it is not possible to permit ad hoc choices of data analysis methods. Given the findings of Griffith et al (2001) there is a question about whether science can agree on a common way to analyze watershed health data to produce comparable information to support management decision-making. It is suggested here that scientists working with the Technical Team can explore available indicators and develop an indicator of management performance to meet the information goals and reporting formats defined in Steps 1 and 2. The Comprehensive Monitoring Strategy describes many watershed health indicators that can be reviewed as a starting point.

Another alternative involves computing a index for each sampling site that is a combination of several single indicators, similar to the Dow Jones Index for tracking performance of industrial stocks on the New York Stock Exchange. There are many alternatives for constructing water quality indices, many of which are described in Ott (1978).

Constructing an index involves questions other than its construction. What specific waters will be reported? Will the index be computed only for existing sampling sites? Will an index be computed using both the agency monitoring data and volunteer monitoring data? Will separate indices be computed for lakes, groundwater, marine waters, and rivers? Should the indices be reported by subwatershed, for the entire watershed, or both? If an index will be used for reporting watershed health, the Technical Team should address these and similar questions.

Step 4: How should the large volumes of watershed health data be managed?

Watershed data are stored in a variety of formats, using a variety of software packages, and on a variety of computer hardware systems. What combination of formats, software and hardware best supports efforts to produce the information identified in Step 1, that is to be reported by the means identified in Step 2, using the data analysis methods described in Step 3?

Can an agreement be made on a common way to store and retrieve watershed data? How will such an effort be funded? What agency will be responsible for managing a database designed specifically to inform the public? Will the data be available on the internet? The Technical Team will need members with expertise in information technology to design this step of a watershed health information system. The Comprehensive Monitoring Strategy recommends data transfer protocols to support easy access, sharing, and coordination among different collectors and uses of watershed health data.

Step 5: How is comparable data obtained in a watershed to support management decisions?

For an indicator to reflect changes over time there is a need to insure that sampling methods, field measurements, sample handling procedures, laboratory methods, and quality assurance are all documented and implemented by a well trained technical staff. The monitoring system design should be implemented and functioning in a consistent manner producing comparable data over time and space, so that any variation in the data due to operation of the monitoring system itself is minimized.

Monitoring Design Approaches

To conduct the design tasks described above will require that the Technical Team that has the time, resources, and access to peer reviewers to complete each of the tasks. The Technical Team will be accountable for producing a report on how to design a watershed health quality information system. How much money and time are needed to develop a peer reviewed and documented watershed health information system? Consider the amount of money expected to be spent on the monitoring program each year. Multiply that amount by the life of the monitoring design (the period of time after which it will be reviewed). Take 10% of the total and consider this amount of money needed for the design. Given the tasks and peer review suggested, it is expected that at least a year would be required to produce a documented, peer reviewed, information system design.

Obtaining Accountability for Effectiveness of State and Federal Investments

To initiate the discussions of the Technical Team, it is recommended that the information needed by the Watershed Planning Unit address the following multiple lines of evidence about the watershed health. Below are several types of monitoring design questions that can be used for discussion by the technical design team discussion. A further discussion of design aspect for specific goals and objective can be found in other chapters of the Comprehensive Monitoring Strategy.

Detecting trends

Often watershed monitoring is conducted to detect trends. There are specific statistical approaches that should be used for trend detection, the most popular being the Seasonal Kendall test. The sampling approach needs to be designed specifically for trend evaluation. In order to have enough power in the statistical test, samples need to be collected over a long term (typically five years for monthly water quality data, for example). Collection frequency must be adjusted for to account for serial autocorrelation so that samples contain independent information. If the trend is being evaluated for impacts from human activities, trends caused by natural factors must be removed from the data. For example, changes in flows due to year-to-year climatic conditions can be accounted for as natural variation. All too often, assessments of data collected for trends are subject to the invalid method of plotting a time series and visual inspection for general inclinations.

Regional Characterization

Often watershed monitoring is conducted to characterize a particular region (e.g., a specific subwatershed). Characterization can often have different meaning based on the different types of objectives. One objective might be to answer questions such as:

- What is the level of aquatic life use in the watershed?
- How many miles of streams support
- How many lakes are impaired due to excess nutrients?

Since it is impossible to sample all of the waters in these areas, a sample survey monitoring approach is needed. This requires sampling stations that are selected randomly so that estimates can be made for waters throughout the watershed with a known statistical certainty.

Another objective commonly described under watershed characterization might be to locate where problems exist. The monitoring design usually directs a synoptic survey, which involves targeting station locations based on professional judgment. Samples are usually collected once at each station to provide a snapshot of conditions in a particular region. This type of approach is often used to help define target areas for further monitoring.

Assessing Compliance

Often watershed monitoring is conducted to assess compliance with environmental laws. Some examples include determining compliance with instream flows or water quality standards (e.g., Section 303(d)), assessing the effectiveness of pollution controls (e.g., TMDLs), or evaluating compliance with permit conditions. These types of monitoring require routine collection of sufficient samples to answer the questions. Monitoring design should establish the statistical limits of confidence and power to determine appropriate sample sizes. Often only a simple percentage of samples exceeding a criterion are used without specifying the confidence of the decision.

Special Investigations

Watershed monitoring is often conducted for a narrowly defined special purpose. For example, data collected to calibrate and validate a predictive model will often require information at specific locations and times. Monitoring will often be conducted to represent model segments at a particular time of year. Another common type of investigative monitoring is to test for differences in populations. Generally representative samples are taken from a control location and treatment location. This type of monitoring requires routine monitoring to collect sufficient samples to conduct the hypothesis test. Monitoring design should establish the statistical limits of confidence and power to determine appropriate sample sizes.

Environmental Education

Watershed monitoring is often conducted by citizen volunteers. The objective of most volunteer monitoring is to provide environmental education and build stewardship. Quality assurance plans are rarely prepared and protocols can differ considerably with volunteer collected data. Site selection is commonly based on the interest of sampler, usually close to a home or a school. The information collected is usually not entered into a data system. Much data collected with good intentions are simply based on monitoring designs that cannot meet objectives other than education. At most, many of these data may be used for screening and helping design further monitoring plans. Coordination and training of citizen volunteers can alleviate these issues and help provide information that can meet other monitoring objectives.

Coordination of Watershed Monitoring

Efforts have begun at the national level and in several states to better coordinate monitoring practices to support enhanced sharing of watershed data and information. The rationale for data sharing stems from the realization that to manage monitoring and data is beyond the capabilities of any one agency. Monitoring councils undertake the dialogue, education and training needed to move toward comparability of methods.

Monitoring coordination can take many other forms. For example, the monitoring of ambient conditions is useful for evaluating changes over time, but not necessarily helpful in understanding basic processes that affect watersheds as a whole. As groups begin to share data, some framework from which to connect the various forms of data and information can be helpful to the discussions. For example, once it is known what the water quality in a stream is, (that a particular water quality trend is negative), the immediate next question is: “why?” The monitoring program may not able to answer such questions as directly as a special study.

The coordination of “what” and “why” monitoring needs further clarification if the trends observed in data are to be understood and management actions directed in an effective manner. The monitoring conducted to measure management performance is often associated with measuring long term trends (consistent methods of measurement, at the same sites, over long periods of time). Monitoring developed for explaining “why” is more process oriented (i.e. short term, intensive, special studies). Both are integral parts of a total monitoring system supporting the broad range of information demanded by watershed managers.

Establishing a Watershed Monitoring Council

The Comprehensive Monitoring Strategy recommends establishing a Watershed Monitoring Council to help needs statewide. A review of the organizational and operational experience of the monitoring councils elsewhere in the country is useful to guide establishing a similar council in Washington State.

In 1992, the United States’ Office of Management and Budget issued an official statement requiring the review and evaluation of national watershed monitoring activities and to make recommendations for improvements. As a result, the Intergovernmental Task Force on Monitoring (ITFM 1995) was formed to develop a voluntary, integrated, nationwide monitoring strategy. The ITFM was a partnership with representatives from federal, state, tribal, and private sector organizations that included nine working groups to address specific issues.

Obtaining Accountability for Effectiveness of State and Federal Investments

After three years of work, the ITFM produced its final report containing principal recommendations on many issues including the monitoring framework, data-collection methods, environmental indicators, data management, and assessment and reporting approaches. One of the principal conclusions was that true collaboration among monitoring programs is possible if there is the technical and institutional framework to promote data comparability to assure data of known quality.

In 1997, the National Water Quality Monitoring Council and the Methods and Data Comparability Board were chartered under the Federal Advisory Committee Act. The monitoring council's charge is to implement a nationwide strategy improve water quality monitoring, assessment, and reporting and to oversee the activities of the Methods Board. The Methods Board's charge is to identify, examine, and recommend watershed monitoring approaches that facilitate collaboration among data gathering organizations to yield comparable data and assessment results.

Within the past few years, a number of state and regional-based watershed monitoring councils have formed and operated with mixed success. Most of these councils have derived goals similar to the national monitoring council and Methods Board. With the voluntary nature of these councils, they tend to be organized and operated to meet local needs with local resources. While the national monitoring council supports the formation of state councils, no guidelines have been recommended. Below is a brief review of these state and regional efforts at establishing and operating these watershed monitoring councils.

A regional Water Monitoring Council was formed representing states and federal agencies in the southeastern U.S. The regional council was formed by use of a steering committee to draft a charter and identify potential members. The goals of the regional council mirrored that of the national monitoring council. Federal representatives from the Tennessee Valley Authority and the Environmental Protection Agency Regional Office were elected as co-chairs to the council.

Several obstacles to achieving these goals were identified by the regional council that included the following:

- Lack of funding to allow member participation in meetings,
- Difficulty and cost to implement changes in monitoring practices already in place,
- Fragmentation of monitoring responsibilities among member organizations,
- Differences in monitoring goals, methods, level of funding, and enabling authorities,
- Adversarial relationships between the regulators and the regulated, and
- Difficulty in ensuring the quality of monitoring data collected by volunteers.

The regional council began to have regular meetings and set up task groups to address specific issues. However, despite the enthusiasm of the scientific staff on the council, institutional and bureaucratic barriers proved fatal to the new organization. Full resource commitments and staff time from senior managers of the council members were often withdrawn or lacking. One of the co-chairs was required to resign due to a change in job responsibilities and no other member was available for replacement. The lack of a funding source made it difficult to get voluntary support to run meetings and precluded the attendance of members. Senior managers often viewed the un-mandated, non-regulatory program as an "unaffordable scientific luxury." As a result of these and other problems, the regional council was discontinued after only one year.

Another regional council was formed with a focus on Lake Michigan. In 1999, the Lake Michigan Monitoring Coordination Council was established jointly by various federal, state, tribal and other parties involved with environmental protection efforts in the Lake Michigan basin. The council operates under a formal agreement with appointed members serving specified terms. Funding to support the operations of the council is provided by the Great Lakes Commission. Workgroups are formed as needed to address specific issues. Recommendations of the council are advisory to the member's representative organizations.

Monitoring councils formed at the state level have found better success. The Maryland Water Monitoring Council is represented by technical staff of agencies involved in water monitoring. The council operates under a charter and set of bylaws and is directed by an executive board that is appointed by the head of the Department of Natural Resources. The full council meets only once a year, but operates through five standing committees. Work products include conducting workshops on monitoring, publication of a "Directory of Monitoring Programs," and integration of monitoring programs within a specific county.

The Texas Water Monitoring Council was formed as a result of recommendations from a monitoring conference. Three state agencies entered into a memorandum of understanding that defines the goals of the council. The council is funded by direct appropriations from the legislature. Membership on the council is not limited in size and it continues to recruit and welcome new members. The criterion for membership is a written commitment from the representative agency to dedicate the staff time and travel to the meetings. The council meets quarterly, and operates with four standing committees. The council hosts a biennial "Water Monitoring Congress" and its proceedings are published.

Oklahoma established a Water Monitoring Council to address a state law that requires the Secretary of the Environment to coordinate efforts to reduce the cost of environmental management, including water quality monitoring. Funding is appropriated to manage a coordinated watershed monitoring program and improve the ability for sharing data. The Council membership includes technical staff responsible for monitoring from state and federal agencies, local government, tribal government, volunteer groups, and academia. An executive advisory committee governs the activities of the council and gives final approval to all council recommendations. Most council work is conducted through one of 4 subcommittees: Monitoring Sampling Design, GIS and Data Storage, Education and Outreach, and Quality Assurance.

In Virginia, the Water Monitoring Council was formed in 1999 in response to legislation mandating a watershed monitoring plan be created. An advisory committee was formed to study and make recommendation on how the state can be more efficient at complying with existing laws and regulations that require monitoring. Membership is open to any person, organization or agency responsible for, or with an interest in, watershed monitoring. Council activities are implemented through working committees. A steering committee facilitates the activities of the council.

In Colorado, organizational meetings have begun to create a Water Monitoring Council. The emphasis has been on designing a coordination program to share available watershed data without having to increase the cost of monitoring. Concerns that increased availability of data through data sharing will provide more opportunity for enforcement by regulatory agencies have hampered efforts to formalize the council.

Within Washington State, there have been many successful efforts at coordinating water monitoring. The Watershed Management Act provides a framework for citizens, interest groups, and government organizations to collaboratively identify and solve water-related issues in each of the 62 watersheds (Water Resource Inventory Areas) of the state. The guidance manual prepared to assist the planning process describes the use of a Technical Analysis Process that includes use and collection of water monitoring data. The approach uses technical staff to compile existing water data and collect new data within the watershed to address specific planning and management objectives. The process coordinates the use and collection water data from stakeholders participating in the process.

The review of other states' efforts at establishing watershed monitoring councils shows that those with well defined roles and responsibilities are successful. Without clear direction, the participants lose interest and resources become directed away from the effort. Guidance from the national monitoring council provides objectives that state councils could address. Potential issues that a statewide Watershed Monitoring Council could pursue are discussed below.

Collaboration Among Monitoring Organizations

The national monitoring council recommends that state level monitoring councils be formed to provide a forum for effective communication and cooperation among individuals and organizations involved in watershed health monitoring. Collaboration between monitoring organizations is essential since no single agency can afford to gather the diverse information needed for informed decision-making. Integration of monitoring efforts can be established by developing partnerships of multi-organizational groups at national, state, tribal, and local levels. The Watershed Monitoring Council would promote these partnerships by routinely bringing together staff from monitoring organizations statewide for communication.

Document Monitoring Activities for Exchange of Information

The national monitoring council recommends that state level monitoring councils be formed to identify, evaluate and share information on watershed health data availability. The vast amount of information collected by public and private organizations is not often easily accessible to users outside the collecting organizations. The efforts in developing the Comprehensive Monitoring Strategy took the first step by documenting from various organizations the types of monitoring being conducted, locations of sampling stations, data management approaches being used, data quality objectives, and methods of data access. This information is stored in a clearinghouse database that could be used to promote development of compatible data management systems for improved information sharing. A Watershed Monitoring Council could serve to promote both the continued documentation of monitoring efforts and the development of compatible data management systems.

Communication and Presentation of Watershed Health Information to the Public

The national monitoring council recommends that state level monitoring councils be formed to increase the level of public awareness and stakeholder involvement in watershed health monitoring issues. The Watershed Monitoring Council could develop materials designed to inform stakeholders on the value of monitoring and serve as a clearinghouse to direct the stakeholders to available watershed information. The Watershed Monitoring Council could also develop and recommend policy-relevant indicators to measure progress in meeting watershed health goals.

Development of Data Quality Objectives

One of the purposes of the Watershed Monitoring Council should be to develop and promote qualitative and quantitative data quality objectives to serve various management purposes. These data quality objectives could include defining levels of precision, bias, representative ness, completeness, and comparability. The data quality objectives are expected be different depending on the purpose of the collected data. The Watershed Monitoring Council could help define specific levels of data quality objectives for the different monitoring objectives of various programs in the state.

Development of Quality Management Guidelines

One of the purposes of the Watershed Monitoring Council should be to develop quality control and quality assurance guidelines for the collection, analysis, and interpretation of watershed health data. Many guidelines have been published to assist monitoring programs develop quality assurance project plans. The Watershed Monitoring Council could assist in developing and review of quality assurance project plans for comparability among the different monitoring programs in the state.

Assessment of the Use-based Water Quality Standards

The Department of Ecology is proposing to change the water quality standards to protect specific beneficial water uses. If the proposed water quality standards are adopted into rule, there will be a need for developing monitoring strategies and guidelines for the establishing designated uses for particular waters. Use Attainability Analyses are required by the U.S. EPA to change the designation of uses. Due to the onerous requirements of the U.S. EPA, significant monitoring of the watershed will need to be conducted for Use Attainability Analyses. The Watershed Monitoring Council could help develop a strategy for this necessary monitoring and coordinate the collection and analysis of the information.

Conclusions and Recommendations

The following conclusions can be drawn from the above discussion to assist Watershed Planning Units in developing a management information systems to monitor watershed health:

(1) Without a statement of management goals (with stakeholder review and agreement), it is not possible to recommend a 'best' indicator for measuring management performance.

(2) There is a need for Watershed Planning Units establish specific management goals for the purpose of designing a watershed health information system to provide a measure of management performance.

(3) With clearly defined and documented management goals, it is recommended that the Watershed Planning Unit form a Technical Team to design a systematic, well documented and peer reviewed watershed health quality information system.

(4) The recommended Washington State Watershed Monitoring Council could assist in coordinating monitoring programs and sharing of information statewide, thus reducing duplication of monitoring efforts and improving efficiency.

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Part VII

A. Ocean Conditions and Climate

Question 4: *What are the trends in the climate of the Pacific Northwest that will allow the State to anticipate and account for such conditions in initiating and monitoring management actions for watershed health and salmon recovery? What trends in climate may mask or expose the status of freshwater habitat and its role in salmon recovery?*

Objective 4A: Determine the status and trends of climate and ocean conditions affecting Washington salmon production.

The following summary is taken from information produced by the Joint Scientific Institute For Research Oceans, Climate Impacts Group located at the University of Washington.[5]

Though scientists are not certain of all the factors controlling salmon marine survival in the Pacific Northwest, several ocean-climate events have been linked with fluctuations in Northwest salmon health and abundance. These include: El Niño/La Niña, the Pacific Decadal Oscillation, the Aleutian Low, and coastal upwelling. Each of these features of the climate system influences the character and quality of marine (and freshwater) habitat experienced by Pacific salmon.

Cooler than average coastal ocean temperatures prevailed from the mid-1940 s through 1976, while relatively warm conditions prevailed from 1925 to1945 and again from 1977 to 1998. The decades-long climate cycles have been linked with the Pacific Decadal Oscillation, an especially long-lived El Niño-like feature of Pacific climate. In the past century, warm ocean temperature eras coincided with relatively poor ocean conditions for many Pacific Northwest salmon stocks, while cool ocean temperature eras coincided with relatively good ocean conditions for Northwest salmon.

Pacific climate changes beginning in late 1998 indicate that the post-1977 era of unusually warm coastal ocean temperatures may have ended. Coincident with the demise of the extreme 1997-98 (tropical) El Niño, ocean temperatures all along the Pacific coast of North America cooled to near or below average values, and this situation has generally persisted to date. Recent climate forecasts, largely based on expectations for continued but weakening (tropical) La Niña conditions, suggest that the cool coastal SSTs are likely to persist. There are no strong indications that major changes in the ocean state should be expected. If the recent past is a useful guide to the future, one might surmise that there is a reasonably good chance that cool coastal ocean temperatures will persist for the next twenty to thirty years. On the other hand, there has been no demonstrated skill in North Pacific climate predictions beyond about one year lead times. The next five to seven years may provide information that will allow more confidence in predicting coastal ocean temperatures and coastal marine habitat quality.

Scientists have determined that El Niño plays an important role in North Pacific climate, but it is only one piece of a more complicated climate-ecology puzzle.

El Niño is Earth's dominant source of year-to-year climate variations. This phenomenon is understood to be a natural part of this planet's climate that spontaneously arises from interactions between the Pacific Trade Winds and ocean surface temperatures and currents near the equator. It is important to keep in mind that the "essence" of El Niño is contained within the tropics, thousands of miles to the south of where any North Pacific salmon ever

5 Reproduced from the Climate Impacts Group website.

swims. However, swings between El Niño, and its cold counterpart La Niña, have consequences for climate around the world. Massive changes in the distribution of tropical rainfall, which are directly related to changing ocean temperatures in the tropical Pacific, influence atmospheric pressure patterns, winds and storm tracks thousands of miles away. These changes over the North Pacific and North America are especially strong in the months from October through March. During these months, El Niño influences the character of the dominant feature of North Pacific weather, the Aleutian Low pressure cell.

Aleutian Low

The Aleutian Low is a semi-permanent atmospheric pressure cell that settles over much of the North Pacific from late fall to spring. The exact position and intensity of the Aleutian Low varies greatly from week-to-week, year-to-year, and even decade-to-decade.

An intense Aleutian Low favors northward winds along the Pacific coast, and causes relatively dry, mild winter and spring weather. Of special significance to the Pacific Northwest's coastal ocean is the fact that relatively warm northward blowing near-shore winds caused by a strong Aleutian Low tend to drive surface waters, piling up relatively warm nutrient poor water in the coastal zone.

On the other hand, periods with a relatively weak Aleutian Low favor onshore coastal winds that move surface currents to the south. Periods with a weak Aleutian Low typically bring relatively wet and cool winters to the Pacific Northwest region. In weak circulation periods, the coastal ocean surface waters are cooler, less stratified, and richer in nutrients because onshore currents are relatively weak. Off the coast of Northern California, the strong high pressure cell causes southward upwelling winds even in the winter months.

Pacific climate events in the past few years have followed an often observed pattern: the 1997-98 tropical El Niño favored an intense Aleutian Low, while the 1998-2000 La Niña favored a relatively weak Aleutian Low. Additionally, El Niño sends coastal currents from the tropics that travel northward along the coast of North America. These also warm and stratify the near-shore coastal waters, reinforcing the wind-driven warming and stratification brought by the intense Aleutian Low. Likewise, La Niña produces coastal currents that cool and weaken the stratification in the surface waters, reinforcing the La Niña-influenced, wind-driven cooling. In both El Niño and La Niña, the Pacific Northwest's coastal ocean is affected by changes in the oceanic and atmospheric circulation that can be traced to the equatorial Pacific; a long-range double whammy.

Upwelling and Coastal Productivity

As the spring/summer upwelling season approaches, the coastal ocean is often primed for either rich or poor biological productivity. Clearly, the coastal ecosystem will be strongly influenced by the presence or lack of upwelling winds, but it will also depend upon the character of the preceding winter/spring Aleutian Low circulation and related ocean conditions. Following a weak Aleutian Low, cool and weakly stratified surface waters favor an especially productive food web because upwelling winds are able to tap into the nutrient rich subsurface waters with little resistance. Conversely, following an intense Aleutian Low, warm and sharply stratified surface waters tend to have poor biological productivity even in the presence of strong upwelling winds. The warm stratified upper ocean effectively caps the nutrient rich waters at depth. Upwelling in a sharply stratified ocean simply recycles the same depleted water in the surface layer repeatedly, never replenishing the nutrients that are quickly used up by phytoplankton.

Low phytoplankton production cascades through the zooplankton and small fish that feed on plankton become scarce, resulting in low food production for salmon. For juvenile salmon, this low productivity may result in slow growth, which can also make them more vulnerable to predation, leading to lower smolt survival rates. In addition, during warm years many fish from subtropical waters, such as mackerel, migrate into coastal waters of the Pacific Northwest from the south. These fish may compete with young salmon for food, and in some cases even target juvenile salmon as prey.

Pacific Decadal Oscillation

Typically, individual El Niño or La Niña events play out over the course of eight to 14 months. However, climate records kept over the past century document decades-long warm and cool eras in the Pacific Northwest's coastal ocean that are superimposed upon the year-to-year changes associated with El Niño and La Niña. Recent research points to a second important player in North Pacific climate, the recently named Pacific Decadal Oscillation, or PDO.

The PDO has been described as a long-lived El Niño-like pattern of Pacific climate variability. Extremes in the PDO pattern are marked by most of the same Pacific climate changes caused by El Niño and La Niña. Two main features distinguish the PDO from El Niño. First, typical PDO "events" are much longer-lived than a typical El Niño. In the past century, major PDO regimes have persisted for 20 to 30 years. Second, evidence of the PDO is most visible in the North Pacific/ North America sector, while secondary signatures exist in the tropics; the opposite is true for El Niño. In short, warm and cool eras of the PDO do most of the same things to Pacific climate that swings between El Niño and La Niña do, but the PDO does them for 20 to 30 years at a time.

Several independent studies find evidence for just two full PDO cycles in the past century: cool coastal ocean regimes for the Pacific Northwest prevailed from about 1890-1924 and again from 1947-1976, while warm coastal ocean regimes dominated from 1925-1946 and from 1977 through 1998. Climate reconstructions based on tree-rings from the Pacific Northwest suggest that the PDO has been an important player in Pacific climate for at least the past few centuries, and that 20 to 30 year climate regimes are normal.

Because causes for PDO climate cycles are not understood, it is now impossible to predict a PDO change before it occurs, or to accurately detect a PDO change while it occurs. The recent shifts to cooler ocean temperatures along the Pacific coast are one of the signals we expect to see with a shift from a warm to cool PDO regime. However, no one is certain if the recent cooling will fade away when the current La Niña leaves us, or whether this coastal ocean cooling will remain for the next 20 or 30 years as part of a cool PDO regime.

An interesting finding is that the biologically unproductive periods in the Pacific Northwest coincide with production booms in the Gulf of Alaska. Likewise, periods with especially high coastal ocean (and salmon) production in the northwest have coincided with low-production eras in Alaska. This north-south "inverse" production pattern is thought to arise in part because a warmer, more stratified ocean in the coastal waters of Alaska benefits phytoplankton and zooplankton production. The cool waters in the north are most always nutrient rich, but strong stratification is needed to keep phytoplankton near the surface where the energy from the high-latitude sunshine is limited. Whereas, in the coastal ocean of southern British Columbia, Washington, and Oregon, lack of nutrients from increased stratification is most often the limiting factor in phytoplankton production.

Monitoring indicators

- Analysis of water chemistry and physical properties collected by National Oceanic and Atmospheric Administration (NOAA) at Pacific Ocean sea buoys.

Annual variations in ocean/sea surface temperature have been shown to reflect El Nino events and other more long-term events that affect ocean productivity and predation. These data are available from NOAA and from specific universities.

Understanding climate has overarching implications for many other patterns in environmental data. Climate influences many environmental attributes (e.g., hydrology, vegetative and terrestrial/aquatic species assemblages) and thus can influence human activities (e.g., patterns of population growth and development, fisheries). This indicator will utilize the work of others (e.g., National Oceanic and Atmospheric Administration, university resources - Joint Scientific Institute for Research Oceans, Climate Impacts Group) relevant to the Pacific Northwest.

Current monitoring activity

The National Oceanic and Atmospheric Administration has established a series of programs to track weather and climate conditions.

Weather and air quality research labs

These facilities conduct weather and air quality research. This program is responsible for the NOAA satellite space weather program.

Weather and climate super computing

The NWS supercomputer is the foundation for all NOAA National Weather Service weather and climate forecasts. It synthesizes information from numerous monitoring sources.

Coastal ocean remote sensing

This NOAA program provides continuous high resolution monitoring of terrestrial features such as vegetation changes, flooding, wild fires, volcanic eruptions, and ash cloud transport. The program continuously monitors coastal ocean areas for harmful algal blooms, coral reef deterioration, fisheries management, and pollution changes.

Climate change research initiative

Under President Bush's new initiative, NOAA is proposing to monitor changes in ocean heat, carbon, and sea level.

Climate monitoring and ocean observations

This program includes the global Ocean Observing System, Global Air Sampling Network, and the Tropical Atmosphere Ocean Array (TAO). It develops information about the status and trends in ocean atmospheric conditions and the presence of El Nino events.

Essential tools

Essential tools for monitoring large scale climate and ocean conditions in the North Pacific include the national ocean buoy program, the Global Ocean Observing System, Global Air Sampling Network, and TAO.

Monitoring design

Monitoring design is under the purview of the NOAA. The MOC is not offering a monitoring design because it is outside the scope of the state's resources and jurisdiction.

The CMS recommends Washington State agencies make themselves aware of the ongoing research and results of large scale climate and ocean conditions to predict and proactively react to key Washington State issues affected by climate. These include:

- Low flow conditions that are exacerbated due to Pacific decadal oscillations and El Nino events. A recent example was the wholesale brownouts in California and the resultant demand for hydroelectric power from the Columbia River. This one instance of drought neutralized restrictions under the Endangered Species Act on the spilling of Columbia River water at several projects and subsequently affected smolt passage and survival in 2001.

- Late flow conditions where precipitation and snow pack occurs later in the year can lead to the scouring of salmon redds and major reductions in the survival of eggs and fry in the early spring.

- Harvest agreements under the Pacific Salmon Treaty have been promulgated based upon models that predict sharing and salmon production at different levels based upon historic information. Changes in the productivity of Alaskan and northern British Columbia ocean conditions will affect future harvest of Washington salmon and potentially force additional constraints upon Washington and Oregon harvests and potentially create conditions that would lead to fewer spawners to seed Washington habitat.

Identified agencies

The National Oceanic and Atmospheric Administration (NOAA) and Sea Grant universities, Washington Department of Fish and Wildlife (WDFW), Washington Department of Natural Resources (DNR), and Washington Department of Ecology (Ecology) are participating agencies.

Recommended sampling protocols

Development of sampling protocols is under the purview of the NOAA. The MOC is not offering a monitoring design because it is outside the scope of the state's resources and jurisdiction.

Performance benchmarks

Performance of large scale ocean and climate conditions can only be compared to current and historic information available. For example, it has only been very recently that a decadal oscillation of ocean productivity has been documented and can be used as a reference or benchmark for future observations.

Identified monitoring gaps/overlaps

There are major gaps in our ability to monitor the ocean and climate. Many of these gaps are addressed in recent NOAA budget requests for additional funding.

Quality assurance/Quality control

There appears to be a strong basis for science in the NOAA data and in the use by this data by universities. We offer no advice on this subject.

Risks

The risks associated with not having ocean and climate information are difficult to assess. We may not anticipate major shifts in ocean productivity and climate that could lead to additional stresses upon Washington water supplies, fire danger, freshwater salmon productivity, marine salmon productivity, and available salmon for harvest.

References

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Website University of Washington Joint Scientific Institute For Research Oceans, Climate Impacts Group. http://tao.atmos.washington.edu/PNWimpacts/

B. Freshwater Habitat/Landscape Forming Processes

Question 17: What are the overall impacts of human activities on freshwater habitat and landscape processes as they relate to watershed health and salmon recovery?

Landscape forming processes are physical agents of landscape pattern formation and maintenance such as the natural rates of delivery of water, sediment, heat, organic materials, nutrients, and other dissolved materials. Such processes operate across spatial scales, involving terrestrial, freshwater, and marine systems. These processes create and maintain habitat characteristics that are important to salmon and ecosystem functions.

The above question is fundamental to many aspects of the Comprehensive Monitoring Strategy (CMS). It supports multiple monitoring questions, objectives, and associated policy decisions. To address the question, this chapter emphasizes monitoring of physical habitat, and effectiveness of management actions in forested, agricultural, and urban landscapes. It is important to note that water quality monitoring is linked with habitat and will be measured concurrently. Information on water quality monitoring is presented in Part VII G.

This section describes the following two types of monitoring:
(1) Habitat status and trends monitoring, and

(2) Program/project effectiveness monitoring.

Recommendations for habitat status and trends monitoring, effectiveness monitoring for forested, agricultural, and urban lands, and intensive monitoring are outlined below and cross-referenced as appropriate to other pertinent chapters.

Habitat Status and Trends Monitoring

Objective 17A: Measure status of identified freshwater habitat indicators in agricultural, forest, and urban lands; and trends. Evaluate whether they are improving.

This part of the strategy addresses the following sub-questions:

- What are the status and trends in habitat quality and quantity within each salmon recovery region and watershed?
- What is the nature of those trends in urban, agricultural, and forested lands?
- To what extent are trends in freshwater habitat conditions reflected in trends in fish abundance, distribution, and diversity?

Monitoring indicators

It is recommended that habitat status and trends information be obtained using both remote sensing and on-the-ground field sampling methods. Whereas field sampling typically occurs frequently (annually) and at particular sites or reaches, remote sensing information is generally obtained infrequently and at coarser landscape scales, to address questions of a more general nature and to provide essential information for design and analysis of field efforts.

Identified remotely sensed indicators include:

- Land use/land cover (including impervious surfaces),
- Geomorphology/geomorphic index (including floodplain lateral connectivity),
- Road density,
- Landslides, and
- Wetlands.

The collection of physical habitat indicators and metrics used under the Environmental Protection Agency's Environmental Monitoring and Assessment Program (EMAP) is large. Technical information about those indicators and associated metrics are described in Kaufmann et al. (1999) for wadeable streams, and in Lazorchak et al. (2000) for non-wadeable streams.

Key freshwater physical habitat indicators recommended as priorities for the CMS are:

- Geomorphic index (including floodplain lateral connectivity),
- Riparian cover and condition,
- Large wood,
- Pools, and
- Stream substrate.

In addition, basic information for classification and stratification purposes is needed, such as:

- Eco-region,
- Gradient,
- Elevation,
- Area and relief,
- Stream order,
- Channel type,
- Valley bottom and containment, and
- Hydro layers.

Additional information on physical habitat indicators related to the CMS is presented in Table 11. For more information on the different types of physical habitat indicators and how the CMS proposes to use them in an integrated status and trend monitoring approach, see Appendix 1.

Current monitoring activity

For some parts of the state physical habitat status and trend information has been collected through the Department of Ecology's (Ecology) EMAP program. Ecology is currently in partnership with the EPA to conduct an integrated and comprehensive assessment of streams. That program employs a probability-based sampling design and random sampling to estimate the condition freshwater resources. Collection of habitat information is limited. Other than Ecology's limited work, no status and trend monitoring of physical habitat state occurs statewide. Some habitat monitoring occurs on federal lands as part of the Northwest Forest Plan, and the PacFish/InFish Biological Opinion.

Table 11 provides more detailed information on key physical habitat indicators for status and trend monitoring identified by the Comprehensive Monitoring Strategy. It does not include water or fish indicators.

Basic geomorphic information to support monitoring design, implementation, analysis and interpretation will support sampling design and monitoring of status and trend indicators below will be available. This geomorphic information results from inventories and analyses of various landscape attributes. It typically does not change as a result of management actions, and is not typically a result of environmental "monitoring." Such information includes: ecoregion; watershed area and relief; valley bottom type, width, gradient, containment; elevation; channel type and gradient; routed stream coverage (hydro layer); stream order; and land use type.

Table 11. Overview of indicators, metrics, and sampling methods for status and trend monitoring of physical habitat

Indicator	Indicator description	Metric(s)	Method(s)	Frequency	Scale(s)
Land Use/ Land Cover	Type and stage of vegetative cover (e.g., non-forest, mixed, conifer, seral stage) and type of land use (e.g., forested, urban, agriculture, open) across the landscape. Hard surfaces such as roads, rooftops, and parking lots, which affect the pattern and extent of factors such as surface runoff (hydrograph), sedimentation, and stream temperature.	Riparian patterns and vegetative cover: % of geographic area by vegetative classification (seral stage, including elevation, distribution) and land use type Impervious surface focuses on extent and type of vegetative cover % impervious cover	Remote sensing – aerial and satellite imagery Some field information from EMAP (See also Part V of the CMS)	Coarse scale – every 5-10 years	Coarse scale low resolution Statewide Regional 1:24,000 4m pixels
Geomorphology (including floodplain)	Characterizes stream channel structure in floodplain areas and connectivity to floodplain	Bankful width Channel slope Channel sinuosity – calculated from longitudinal channel profile Bankfull width /depth ratio Channel incision height % stream length with modified bank (armoring) Channel migration /avulsion rate Floodplain width Height of adjacent terraces Amount of off channel habitat (e.g., alcoves, backwaters, isolated pools)	Some information from remote sensing – aerial and satellite imagery Field sampling via EMAP Connectivity inventory – SSHIAP hydro-modification methodology	Annual	Regional Watershed

Indicator	Indicator description	Metric(s)	Method(s)	Frequency	Scale(s)
Riparian condition	Riparian areas are complex ecological systems that are important for maintaining the vitality streams. They assert strong influences on streams by influencing hydrological patterns, recruitment of LWD, stabilizing banks, sequestering nutrients, control of light regime, and seasonal nutrient contribution to organisms.	Riparian canopy type (e.g., deciduous, mixed, conifer), and tree size 30m either side of stream Canopy density	Some information from remote sensing (land cover) Field sampling via EMAP	Annual	Regional Watershed
Large wood	Large wood affects channel hydraulics, energy dissipation and sediment effect on channel complexity. The location, number, area, and volume of pools and substrate/gravel is affected by large wood.	LWD in active channel # of pieces by size (diameter, length) category, configuration and location Volume of LWD in active channel (m3/m2) #/100m by size	Field sampling via EMAP	Annual	Regional Watershed
Pools	Important habitat features where channel deepens and flow slows; essential for salmon during both juvenile rearing and adult migration.	Pool type Residual pool depth Pool length and area Pool frequency	Field sampling via EMAP	Annual	Regional Watershed
Substrate	Result of stream geomorphology and interacting habitat-forming processes. Substrate composition (e.g., gravel, embeddedness) can be highly variable across small spatial scales. Salmon require suitable gravels for spawning, incubation, and early rearing.	% composition by size	Field sampling via EMAP	Annual	Regional Watershed
Total or partial blockages	Obstructions to juvenile and adult salmon migration.	Frequency of barriers by type and level of obstruction (total or partial)	Field sampling Barrier inventory – WDFW/DOT methods	Annual	Statewide Regional Watershed
Restored miles utilized by salmon	Habitats that were blocked by passage obstructions that are reconnected and successfully used by juvenile and adult salmon	Lineal miles of restored habitat	Effectiveness monitoring Field sampling		

Indicator	Indicator description	Metric(s)	Method(s)	Frequency	Scale(s)
Road density	Roads in floodplain areas reduce the quantity and quality of floodplain areas, and can preclude access to important habitats for salmon. In upland and other areas, roads affect runoff and can contribute to sediment loading. Roads classified by type (e.g., interstate highway, state highway, paved road, unpaved road).	Road miles/mi2 Stream adjacent road miles /mi2 Road crossings/ stream mile	Remote sensing – aerial and satellite imagery (1:24,000)	Every 5 years	Regional Watershed
Landslides	Occur naturally but human activities have affected the frequency and extent of occurrences. Landslides can contribute large amounts of sediments from upslope areas to stream channels.	Frequency: mean # events/year by landslide type (e.g. shallow rapid) Return interval: years between events Extent: area disturbed per time period or event % landslide prone geology % steep slopes (>70%)	Remote sensing Noted in field surveys		
Bank condition	Bank stability and erodability; relates to channel integrity and riparian areas (shading). Field sampling	% unstable banks (sum of lineal distance of actively eroding banks along both sides of each measured unit) Bank angle	Field sampling via EMAP	Annual	Regional Watershed
Freshwater biological indicators (vegetation)	Native and exotic aquatic vegetation.	Presence/absence (area of occurrence) of specific native and exotic species. % stream area w/ filamentous algae cover	Field sampling via EMAP	Annual	Regional Watershed

Table 12. Comparative overview of metrics used by some major monitoring efforts in the Pacific Northwest associate with key physical habitat indicators for status and trend monitoring identified by the Comprehensive Monitoring Strategy.[1] Note this is a general overview only; not all metrics are included for all indicators.

Indicator	EMAP - Ecology/ EPA WADEABLE[2]	EMAP - Ecology /EPA RIVER [2]	OREGON	USFWS	USFS (AREMP)	FORESTS and FISH (MDT)
INFORMATION FROM REMOTE SENSING AND FIELD SAMPLING						
Land use/ land cover [3]	Rip Dist—Sum All Types (ProxWt Pres) Rip Dist—Sum NonAg Types (ProxWt Pres) Rip Dist—Sum Agric Types (ProxWt Pres) - W [5]; RS [6] Rip Dist—Wall/Bank Revet. (Prox Wt Pres) Rip Dist—Pipes infl/effl (Prox Wt Pres) - W; F	weighted sum of fracs of all dist. noted weighted sum of fracs of all non-ag seen weighted sum of fracs of all ag noted - W [5]; RS [6] weighted sum of fracs of reach w riprap weighted sum of fracs of reach w pipes - W; F	Oregon Watershed Assessment Manual (OWEB-WA). Vegetation coverage from Coastal Landscape Analysis and Modeling Study (CLAMS) in coast range watersheds, otherwise as available. Land Use from Oregon Geograpic Information Center– local verification. Location and area extent by Forestry (industrial-non-industrial), Crop-land, Grazing, Feedlots and Dairies, Urban, Mining, Irrigation and Road Networks.	Prop. of geographic area by classification (by elevation distribution)	Vegetation[4], Seral Stage Vegetation was classified into the following categories: Non -Forested/Grass -Forb – Deciduous -Stands composed of > 90 % deciduous species. Mixed – Stands that contain both conifer and hardwood species. Conifer – Stands composed of at least 90% coniferous species. Conifers in both pure and mixed stands were classified by seral stage using the following definitions: Early Seral – recent clear cuts to stands with trees less than 25 cm (10 in) diameter at breast height (dbh). Approximate stand ages from 0 to 24 years old. Mid Seral – Stands trees from 26 cm to 52 cm (10 - 20 in) dbh. Approximate stand ages from 24 to 80 years old. Late Seral – Stands with trees greater than 53 cm (20 in) dbh. Approximate stand	No systematic cover typing. In Intensively Monitored Basins (IMB) (a maximum of 12, 30,000 ac basins) land cover will be assessed by seral stage (cover types to be determined). For trend (extensive) monitoring, we will be assessing land cover types (seral stages) in basins in which thermometers are installed (cover types to be determined).

Indicator	EMAP - Ecology/ EPA WADEABLE[2]	EMAP - Ecology /EPA RIVER [2]	OREGON	USFWS	USFS (AREMP)	FORESTS and FISH (MDT)
					ages>80 years old.	
Impervious surface [subset of land use/ land cover]	Rip Can & MidLayer Present (Prop reach) Riparian 3-Layers Present (Prop reach) Riparian Canopy >.3m DBH (Cover) Rip Ground Layer Barren (Cover) Riparian Veg Canopy Cover Riparian Veg Ground Layer Cover Rip Veg Canopy +Mid Layer Woody Cover Rip Veg Canopy +Mid+Ground Woody Cover Riparian Canopy Coniferous (Prop reach) - R; RS	frac with both canopy and understory frac with all three veg classes present frac of reach covered by big tree canopy frac of reach without ground cover frac of reach covered by canopy frac of reach covered by groundcover frac of reach covered by large woody veg frac of reach covered by any woody veg frac of reach with coniferous dom canopy - R; RS	Use Road coverage to calculate% Impervious cover (incomplete)	% impervious over	Not measured	Not measured
Information From Field Sampling						
Geomorphic index (floodplains)	Bank full Width —Mean (m) – W; F Bank full Height-Mean (m) Channel Incision Ht.-Mean (m)	percent of bank angles 30-75% percent of bank angles 5-30% percent of bank angles>75%	Active channel (bank full) width Active channel (bank full) height Active channel width to depth ratio Terrace width and height	channel sinuosity width/ depth ratio channel incision % stream length with	Channel sinuosity -calculated from longitudinal channel profile Bank full width/depth ratio Entrenchment ratio – calculated as valley width divided by channel	No statewide measurements. In IMB, all shown under EMAP – Ecology /EPA (WADEABLE) may be done and them some since fish use (density) will

Indicator	EMAP - Ecology/ EPA WADEABLE[2]	EMAP - Ecology /EPA RIVER [2]	OREGON	USFWS	USFS (AREMP)	FORESTS and FISH (MDT)
	Channel Sinuosity (m/m) Channel Slope-- reach mean (%) W; RS Wetted Width – Mean (m) – W; F Mean Width* Depth Product (m2) Std Dev of Width*Depth Product (m2) Residual Mean Depth (cm or m2/100m) Falls (% of reach) Fast Wtr Hab (% riffle & faster) Slow Wtr Hab (% Glide & Pool) Dry Channel or Subsurf Flow (%)	percent of bank angles < 5% bank full width mean – W; F bank full height mean channel incision mean mean slope of entire reach - W; RS mean depth stdev of depth mean wetted width – W; F mean product: wetted width * depth mean ratio: wetted width/ depth – W; F stdev of product: wetted width *depth percent of reach with falls percent of reach with fast water types	entrenchment ratio average gradient of entire reach mean wetted width channel and valley morphology (type of landform constraints)	modified bank (armoring) USFWS uses average wetted width/ ma x. depth ratio in scour pools by reach and channel type (sloughs, side channel, braided or main channel)	width	be included by reach type.

Indicator	EMAP - Ecology/ EPA WADEABLE[2]	EMAP - Ecology /EPA RIVER [2]	OREGON	USFWS	USFS (AREMP)	FORESTS and FISH (MDT)
		percent of reach with slow water types				
Lateral connectivity [related to geomorphic index (floodplain)]	% incision height	% walls	width of floodplain height of adjacent terraces percent of secondary channels amount of off channel habitat- alcoves, backwaters, isolated pools riparian zone vegetation	% of watershed (including off-channel areas) not isolated (by dams, diversions, culverts and degraded mainstem habitats)	Channel cross sections Longitudinal channel profile Sinuosity Entrenchment Ratio	No statewide measurements. In IMB, may use all as noted in USFWS /AREMP columns. Canopy Density (%)
Riparian condition	Mean Bank Canopy Density (%) W; RS/F Mean Mid – Channel Can-opy Density (%)W; RS/F Fish Cvr— Overhang Veg (Areal Prop) Riparian Canopy Deciduous (Prop reach) Rip Canopy Mix Conif-Decid (Prop reach) – R; RS	mean percent of canopy cover-R;RS frac of reach area covered by over-hang	Vegetation Class and Shade (Canopy Closure) from Air Photo Interpretation – Adjacent landforms floodplain/terrace /hill slope: 30m either side of stream, slope of adjacent landforms Tree size and type: conifer/hardwood, size classes Ground cover – grass/shrub Non-vegetative ground cover Canopy cover in riparian zone Shade over stream	Streamside vegetation type and stage category TFW Ambient Monitoring Protocol USFWS considers the potential woody debris recruitment in assessments % riparian cover visual estimates	Vegitation Type Seral Stage<100 m from the stream channel See land use/land cover discussion above.	No statewide measurements. In IMB at least all as shown for EMAP – Ecology/EPA (WADEABLE). May include recruitment rate of LWD to stream, tree growth rates and other stand dynamics. In addition, for water temperature sites (extensive monitoring), riparian condition will be assessed, probably using the DNR Watershed Analysis riparian condition methodolgy.

Indicator	EMAP - Ecology/ EPA WADEABLE[2]	EMAP - Ecology /EPA RIVER [2]	OREGON	USFWS	USFS (AREMP)	FORESTS and FISH (MDT)
Large wood	Fish Cvr—Large Woody Debris (Areal Prop Fish Cvr—Brush & Small Debris (Areal Pr LWD Vol in act chnl (m3/m2-all sizes) – W; F LWD Vol in act chnl (m3/m2 -L, X) LWD in act chnl (#/100m-all sizes) – W; F LWD in act chnl (#/100m-S,M, L,X) LWD in act chn (#/100m-M,L,X) LWD in act chnl (#/100m-L,X) LWD in act chnl (#/100m-X) #LWD pieces per 100m very small only #LWD pieces per 100m small only #LWD pieces per 100m med only #LWD pieces per 100m large only #LWD pieces	fraction of reach area covered by lwd Fraction of reach area covered by brush	OWEB-WA: Use ODFW Stream Survey Data Size, position in channel, type: diameter and length, natural or cut piece, configuration (single, accumulation, jam) position in channel: side, middle, full span, over channel root wad or piece.	Number of pieces by size category and location of wood; TFW Ambient Monitoring Protocol. USFWS considers >24" diameter and >50' in length as large wood and assesses the potential short and long term recruitment of wood to assess project impacts. # of key pieces and location; TFW Ambient Monitoring Protocol Complexity of cover provided by piece/jam; Surface area	Number of pieces of large wood at and at least 0.3 m in diameter at DBH.	No statewide measurements. least 3 m in length In IMB, at least all as shown for EMAP – Ecology/EPA – (WADEABLE). In addition fish and amphibian use of LWD created/ maintained habitat may be included.

Indicator	EMAP - Ecology/ EPA WADEABLE[2]	EMAP - Ecology /EPA RIVER [2]	OREGON	USFWS	USFS (AREMP)	FORESTS and FISH (MDT)
	per 100m very large only					
Pools	Resid Pools > 75cm deep (number/reach) - R; F Mean profile area of resid pools (m2/pool Maximum residual depth in reach (cm /pool Pools – All Types (% of reach) – R; RS/F Resid Pools > 50cm deep (number/reach) Mean length of resid pools (m/pool)	number of pools deeper than 0.75 m maximum depth in any pool in reach in m mean pool area, in m^2 percent of reach with pools – R; RS	OWEB-WA Use ODFW Stream Survey Data Pool type: nine different pool types Percent pool Pool area Pools per km # pools > 1m depth per km % slow water or offchannel pools Residual pool depth	Max. pool depth pool outlet depth pool surface area, cause of pool formation, pool frequency by stream size category (wetted width), pool cover (veg., undercut banks..) TFW AMP & USFWS use #pools/mile to assess bull trout impacts	Pool defined as being longer than the average wetted width and habitat unit has to be channel-spanning Pool Tail CrestMax Pool Depth Residual Pool Volume Pool frequency	No statewide measurements. In IMB, at least all as shown for EMAP Ecology/EPA – (WADEABLE). In addition, fish and amphibian use of pools may be measured.
Substrate	Log10 est substrate geom mean diam (mm) Substrate Sand – .06-2 mm (%) Substrate Fines – Silt/Clay/Muck(%) Substrate Hardpan – (%)	frac of reach area covered by boulder log 10 (est geom mean substr dia) unitless area per 100 m of reach in m^2 %dom bottom that is fines	OWEB-WA Use ODFW stream Survey Data Surface area % substrate size classes Substrate can be desribed by unit type averaged by reach: silt, sand, gravel, cobble, boulder, bedrock	Surface are – % dominant and sub-dominant substrate size classes by habitat unit (riffle, pool, etc.) using TFWAMP-pebble counts, visual estimates.	Percent surface fines in pool tail areas using USFS R5 SCI protocol. Substrate particle size (D50, and D84) determined by measuring 10 particles at systematic intervals within the 11 cross section transects using EMAP protocols.	No statewide mesurements. In IMB, at least all as shown for EMAP Ecology/EPA (WADEABLE and RIVER). In addition, fish and amphibian use by substrate type may be measured.

Indicator	EMAP - Ecology/ EPA WADEABLE[2]	EMAP - Ecology /EPA RIVER [2]	OREGON	USFWS	USFS (AREMP)	FORESTS and FISH (MDT)
	Hardpan – (%) Substrate Concrete (%) Substrate Sand & Fines – <2 mm (%) - W; F Substrate <= Fine Gravel <16 mm (%) Substrate >= Coarse Gravel >16 mm (%) – R; F Substrate Bedrock (%) – W; F Substrate Wood or Detritus – (%)	%dom bottom that is sand %dom bottom that is bedrock %dom bottom that is organic matter %dom bottom that is hardpan %dom bottom classified as sand or fines %dom bottom smaller than coarse gravel - R; F %dom bottom that is rough or smooth bedrock - R; F %sec bottom that is fines - W; F %sec bottom that is sand	# boulders > 0.5m diameter, % fines in riffle (1-2% gradient) units, % gravel in riffle units	counts, visual estimates. USFWS uses reach embeddedness (%) in rearing areas to assess impacts. Volumetric measurements – % by substrate size class and habitat unit (not visual estimates); bulk samples, such as core samples (TFW). Estimated % of fines. Spawning habitat – Total surfce area of potential spawning habitat in bank full channel; Surface area and distribution of individual spawning habitat		

Indicator	EMAP - Ecology/ EPA WADEABLE[2]	EMAP - Ecology /EPA RIVER [2]	OREGON	USFWS	USFS (AREMP)	FORESTS and FISH (MDT)
		%sec bottom that is organic matter %sec bottom that is hardpan %sec bottom that is bedrock %sec bottom classified as sand or fines %sec bottom smaller than coarse gravel – R; F %sec bottom thats rough or smooth bedrock % of reach substrate that is hardpan % of reach substrate that is sand		patches in wetted channel; Salmonid spawning gravel scour – % scour, depth of scour using scour chains (TFWAMP) embeddd radio tags (USFWS), at various levels of flow.		

Indicator	EMAP - Ecology/ EPA WADEABLE[2]	EMAP - Ecology /EPA RIVER [2]	OREGON	USFWS	USFS (AREMP)	FORESTS and FISH (MDT)
		% of reach substrate that is fines – W;F %substrate classified as sand or fines % substrate smaller than cobbles – W;F %substrate larger than fine gravel				
Total or partial blockages			OWEB-WA # Stream-Road Crossings/square mile Culvert Inventories	Freq. of barriers by type and level of obstruction (total or partial) WDFW protocol is used by USFWS	Not measured in AREMP. FS maintains an inventory of partial and complete culvert blockages	Statewide for Forests and Fish lands, trends in restoring fish passage and creation of new blockages using SSHEAR level B assessment.
Restored miles utilized by salmon			OWEB Restoration Database Restored stream miles Restored road miles (retirement, drainage improve-ment)	Lineal miles of restored habitat	Not measured in AREMP FS maintains an inventory of partial and complete culvert blockages	No statewide measurements. In IMB, distribution of fish and amphibians through time would be recorded.
Road density			OWEB-WA Roads/mile2 Stream Adjacent roads/mile2 using best sources available GIS 1:24k, ODF and county road coverage	Roads/mi^2 Stream adjacent road miles/mi^2 USFWS uses #road	Road density (miles of road per square mile of watershed) was calculated for both the upslope (> 100 m from stream) and riparian area (< 100m from stream). For these	No statewide measure. Changes in new and restored roads in IMB.

Indicator	EMAP - Ecology/ EPA WADEABLE[2]	EMAP - Ecology /EPA RIVER [2]	OREGON	USFWS	USFS (AREMP)	FORESTS and FISH (MDT)
			Used primarily with slope stability assessment to identify failure-prone areas	miles/miles 2, and whether it is a "valley bottom" road or not Road crossings/ stream mile Location of roads	analyses, the stream layer was buffered 100 meters each side and overlaid with the roads to calculate road density. See above	
Landslides			OWEB-WA Indirect from road and slope stability analysis for identifying sediment sources Debris Flow Hazard Zones from Oregon Dept. Geology & Mineral Industries (DOGAMI) GIS Coverage and landslide reports Noted if observed from stream Type: earth flow, landslide avalanche Condition	Frequency by type, size and location of landslide Extent: area disturbed per time period or event – Stream length disturbed and height of disturbed area estimated using TFW AM protocols	Still under development	To be determined.
Wetlands			OWEB-WA Area and % cover by wetland types From National Wetland Inventory, Landsat, Air Photos, varies Noted if observed from stream, described in riparian	% wetland cover by wetland type % vegetation (dominant species)	Not measured	No statewide measure. No IMB measure.

Indicator	EMAP - Ecology/ EPA WADEABLE[2]	EMAP - Ecology /EPA RIVER [2]	OREGON	USFWS	USFS (AREMP)	FORESTS and FISH (MDT)
			surveys or as part of floodplain			
Bank condition	Bank Angle—mean (degrees) – W; F Undercut Distance — Mean (m)	frac of reach area covered by overhang %dom bottom thats rough or smooth bedroc %dom shore that is fines %dom shore that is sand %dom shore that is hardpan %dom shore that is bedrock %dom shore that is organic matter %dom shore classified as sand or fines – R; F %dom shore smaller than coarse gravel %sec shore that is sand %sec shore that is fines %sec shore that is organic matter %sec shore that is bedrock – W; F	OWEB-WA from ODFW Stream Surveys Percent of eroding bank Percent of undercut bank	% of stream length with unstable banks (landslides, or lacking vegetation) % bank with vegetation by vegetation type and stage % of stream length with bank stabilization (by category, i.e.: rip rap, rip rap with logs, etc.)	Not measured	No statewide measure. Bank condition to be determined in IMB.

Indicator	EMAP - Ecology/ EPA WADEABLE[2]	EMAP - Ecology /EPA RIVER [2]	OREGON	USFWS	USFS (AREMP)	FORESTS and FISH (MDT)
		%sec shore that is hardpan %sec shore classified as sand or fines – W;F %sec shore smaller than coarse gravel %sec shore that's rough or smooth bedrock – W;F				
Freshwater biological indicators (vegetation)	Fish Cvr—Filamentous Algae (Areal Prop) Fish Cvr—Aq. Macrophytes (Areal Prop)	fraction of reach area covered by algal frac of reach area covered by macrophyte	none	plants & animals – Presence/ absence of specific native and exotic veg. Species	Fish and Aquatic Amphibians. A single pass with an electrofisher is made between each transect. All animals identified and enumerated. Approximately 10-20% of the fish are measured, and their condition estimated using displacement. Snout-vent lengths are measured for all aquatic amphibians. Snorkeling is used to determine fish and aquatic amphibian presence where TES fish species are present. Periphyton: The periphyton protocol is the same as that outlined by the EPA EMAP (Peck et al. 1999). Benthic periphyton samples were collected at all sites.	Density of fish and selected amphibian species will be monitored in IMB.

Indicator	EMAP - Ecology/ EPA WADEABLE[2]	EMAP - Ecology /EPA RIVER [2]	OREGON	USFWS	USFS (AREMP)	FORESTS and FISH (MDT)
					sites. At each transect, periphyton was removed from a 12-cm 2 area. Subsamples from the transects were composited into a single sample for the reach.	
Extent of areas reconnected utilized by salmon					FS maintains IRDA database to trak fish passage improvements on federal lands.	No statewide measure. In IMB, distribution will be measured through time.

Footnotes to Table 12:

1 *Column headings: EMAP=Environmental Monitoring and Assessment Program associated with the Department of Ecology and the Environmental Protection Agency; Oregon=Oregon Plan for Salmon and Watersheds; USFWS =U.S. Fish and Wildlife Service; USFS (AREMP) = U.S. Forest Service (Aquatic and Riparian Effectiveness Monitoring Program); Forests and Fish (MDT, Monitoring Design Team).*

2 *"Land Use" characteristics focus on riparian patterns; "Impervious Surface" characteristics focus on extent and type of vegetation cover.*

3 *NOTE: In addition to monitored land use/land cover (LULC), basic geomorphic information is needed to support monitoring design, implementation, analysis and interpretation. This information results from inventories and analyses of various landscape attributes. It typically does not change as a result of management actions, and is not typically a result of environmental "monitoring." Such information includes: ecoregion; watershed area and relief; valley bottom type, width, gradient, containment; elevation; channel type and gradient; routed stream coverage (hydro layer); stream order; and land use type.*

4 *Upslope vegetation (all vegetation > 100 m from the stream channel) and riparian vegetation data (all vegetation < 100 m from the stream channel) were collected from the vegetation layer developed by the Interagency Vegetation Mapping Project (IVMP) in Oregon and Washington, and the CalVeg layer developed in California. Both layers were constructed using Landsat Thematic Mapper remote sensing data.*

5 *W indicates watershed/reach scale, and R indicates regional/landscape scales.*

6 *RS indicates metrics that can be acquired through remote sensing; F indicates metrics acquired through field sampling at the reach scale.*

Proposed monitoring

A major gap in monitoring watershed health and salmon recovery is measuring the status and changes to freshwater habitat and land-scape forming processes at scales that are useful. One of the greatest needs is the ability to describe with some degree of certainty what changes have occurred in the status and trends of habitat conditions affecting watershed health and salmon recovery statewide, within salmon recovery regions, and Water Resource Inventory Area (WRIA) or watersheds.

It is important to note that the habitat status and trend monitoring outlined here is similar to the "Tier 1" (broad scale monitoring of ecosystem status typically using remote sensing), and "Tier 2" (annual probabilistic monitoring of fish and habitat) components of the monitoring framework identified by the Federal Caucus (FCRPS Biological Opinion, NMFS 2000), and other draft planning guidance for the Columbia River. In addition, the habitat status and trends monitoring is complementary to "Extensive" monitoring aspects of the Forests and Fish Draft Monitoring Design.

➢ *Based on a review of monitoring approaches (e.g., Forests and Fish Agreement, EMAP/EPA, Oregon Plan for Salmon and Watersheds, U.S. Forest Service (USFS) Aquatic and Riparian Effectiveness Monitoring Program) a statistically-based probabilistic sampling design and site selection approach using sampling site selection and protocols of EPA's EMAP program is recommended to systematically identify and sample stream habitat, water quality, and resident trout at the scales of Salmon Recovery Regions (SRR) and watersheds throughout the state.*

➢ *It is further recommended that the CMS build upon the current EMAP approach utilized by the Washington State Department of Ecology (Ecology). The agreement is due to expire in 2004, but the data obtained from sampling EMAP sites since 1993 should be incorporated into the new strategy to increase efficiency and obtain answers in amore timely and cost efficient manner. Sample sites and sizes will be assigned using EMAP protocols according to CMS design specifications (see below) and cost constraints. Sampling will occur on an annual basis. Identified key habitat indicators will be sampled, along with juvenile resident salmonid abundance and common freshwater water quality indicators. It is expected that applying the same design for selection of sampling locations will provide efficiency and long-term correlations among variables.*

Design specifications will allow some comparisons and inferences within and between urban, forested, and agricultural land categories. Stratification will be used to account for variation between eco-regions and other variables, and to characterize waters containing anadromous and non-anadromous fish.

➢ *It is recommended that the "extensive" monitoring locations proposed by the Forests and Fish Monitoring Design Team be incorporated as part of the CMS to ensure a coordinated approach to measuring habitat improvements both on and off of private forest lands.*

➢ *It is also recommended that the federal land managers (e.g., U.S. Forest Service and the Bureau of Land Management) use a more consistent approach in EMAP-based monitoring of habitat on federal lands in western and eastern Washington. It is also recommended that federal landowners coordinate their EMAP site locations to avoid duplication and improve coverage.*

Rotating Panel Design: The CMS proposes to use a rotating panel design that combines repeated sampling at the same sites for trend detection, with sampling of other sites to determine status – balancing trend with status monitoring. Panels will involve different repeat intervals. A similar approach has been used as part of the Oregon Plan for Salmon and

Watersheds and is appropriate for Washington. It will create some consistency between the states and within the Columbia River Basin. This approach spreads sites across the landscape, representing habitat conditions within the scales of interest, and reducing overall sampling variance.

Sites will be distributed geographically within the distribution of fish (including bull trout and cutthroat trout) as identified on a 1:100,000 USGS stream layer. Additional technical design information such as target populations, sampling frame, and stratification will be further worked out as planning proceeds.

The intensity of sampling (e.g., number of samples) is directly related to desired statistical criteria at scales of interest (e.g., region, watershed). Recommended target statistical criteria are to be 90% confident in detecting change in a habitat indicator accurately with + 26% precision at the WRIA scale over a 10 to 20 year timeframe, depending upon the indicator. In general, precision at the regional scale would be ± 9%. Higher levels of precision or shorter timeframes for change detection demand higher sampling effort and cost. WRIAs will be sampled on a 5-year rotation (12 WRIAs per year). A total of ten sites will be sampled annually within each WRIA. In addition to habitat, water quality, resident fish and biological indicators will also be measured annually statewide at 16 sites as stratified by each of eight ecoregions, to reduce variance and enable faster detection of trends.

Identified agencies

A high level of expertise is needed to implement this part of the monitoring strategy. The Department of Ecology and WDFW will be co-leads. Ecology will be responsible for water quality and physical habitat monitoring and will provide design support and analysis. Fish and Wildlife will be responsible for fish monitoring and analysis. Both will collaborate and perform integrated analyses and interpretation. Other parties include participants in the Forests and Fish Agreement, tribal, and federal land management agencies.

It is expected that state, counties, watershed groups, and others may desire to improve the sampling intensity at the watershed level on a prioritized basis in order to obtain data of interest in a shorter time frame or at smaller scales than outlined here. Therefore, the CMS includes sampling design guidance, protocols, and estimated sample sizes suitable for answering questions about the status and trends in habitat at the watershed level.

Recommended sampling protocols

Habitat status and trends monitoring will use EPA EMAP design and sampling protocols in Lazorchak et al. (2000) for wadeable streams (sampled reach length is 40 times the wetted channel width). Where non-wadeable waters are sampled (100 times the wetted channel width), protocols outlined in Lazorchak et al. (1998) are recommended. Protocols for relevant water quality and fish indicators protocols are listed elsewhere in this document.

Performance benchmarks

Delineation of specific performance benchmarks is difficult because habitat conditions are not static over time due to various naturally occurring events (e.g., changes in short and long-term climate, disturbance cycles). No benchmarks for habitat indicators conditions have been broadly agreed upon.

It is recommended that further work be pursued to explore and identify benchmarks for habitat conditions. A recommended alternative is to use information obtained from initial habitat surveys as a quantitative baseline from which to make comparisons with future habitat conditions over time. Moreover, analysis of sites randomly selected for status and trends monitoring will reveal sites across the spectrum of quality. It is recommended that post-hoc analysis be used to discern the highest quality sites and that these be used as “reference” sites over the long term. These reference sites would represent what would be expected in areas having lower impact from human activities (e.g., development, roads, forest management, and hydraulic modification).

Quality control/quality assurance:

A Quality Assurance (QA) Plan should be developed. The QA Plan should describe the objectives of the monitoring and the procedures to be followed to achieve those objectives (including training and supervision). The preparation of a QA Plan helps focus and guide the planning process and promotes communication among participants. The completed plan is a guide to those who carry out the work and forms the basis for written reports on the outcome. Quality assurance for sampling designs should include random re-sampling of 10% of the sites by a separate crew within a given year and across years to evaluate the different components of variation and precision. Lombard and Kirchner (2001) present detailed guidance on the preparation of QA Plans.

Analysis, interpretation and decision-making

Status refers to a frequency distribution of indicator scores (or their interpretation into classes like good, fair, poor) for a scale of interest (e.g., watershed, region) as obtained from a sample of sites at that scale. Trends can be characterized in multiple ways, such as a consistent pattern of change in an average condition of an indicator of interest, or a consistent pattern of change of parts of the frequency distribution for an indicator.

The Departments of Ecology and Fish and Wildlife, in consultation with other contributing partners, if any (e.g., tribes, federal land managers) will develop a framework for coordinated and integrated analysis, interpretation, and reporting of results. In addition, results within each watershed and salmon recovery region will be integrated. Data from each sample site will be compiled and key characteristics will be summarized. Results will be statistically analyzed as means and variances and will be graphically expressed at the appropriate scales. Data will be integrated in ArcInfo GIS to display locations and attributes of sites for comparison purposes. From these data, habitat and water quality characteristics can be determined on an annual basis and trends can be detected over time. Analytical products include but are not limited to:

- Cumulative distributions of frequency,
- Quartile calculations, and
- Maps of habitat characteristics.

Post-stratification of results will be performed to interpret conditions among urban, agricultural, and forested land use types.

Habitat Effectiveness Monitoring

In contrast to monitoring of the status and trends in key habitat indicators, habitat effectiveness monitoring addresses whether habitat management activities achieved their desired goal or effect (physical or chemical). Success may be measured against "initial, or baseline conditions" or "desired future conditions." Project monitoring, a type of effectiveness monitoring, addresses the effectiveness of a particular project or classes of projects. For example, in projects involving tree planting to reduce water temperature, did the trees survive and were they actually effective in reducing water temperature?

The CMS proposes monitoring to evaluate the effectiveness of management actions identified in the *"Statewide Strategy to Recovery Salmon."* This includes monitoring indicators that can be used to evaluate the effectiveness of management programs, individual habitat projects, and classes of projects.

The following addresses effectiveness monitoring associated with:

- Small scale habitat projects
- Washington State Department of Natural Resources (DNR) forested lands
- Private forested lands
- Federal forested lands
- Agricultural lands
- Urban lands

Forested lands were organized into three different sections associated with land ownership (state, private, federal) and monitoring on forested lands operates at every scale and reflects the divergent objectives of the agencies and groups. A common vision is that a landscape or watershed scale is the common level of integration. However, funding and traditional approaches to monitoring and monitoring objectives require much of the current or proposed monitoring to operate below the watershed scale.

As indicated below, monitoring on state forest lands focuses on questions related to adaptive management on a stream reach scale. Only on a very limited basis will monitoring be scaled to the watershed. Plans for monitoring on private forest lands have a central goal of intensively monitored watersheds that are more limited in scope than the federal effort. Monitoring on federal lands is undertaking an unprecedented scale of watershed monitoring. There are many partnering opportunities among the efforts. Differences in fundamental mandates and information needs between organizations will limit options in adopting a common monitoring framework.

Small Scale Habitat Projects

Much restoration/enhancement work consists of individual small-scale projects with site-specific objectives for habitat, water and fish. In order to efficiently allocate resources it is critical to know whether groups of such projects have attained their immediate objectives within reasonable time frames.

Recommendations for monitoring the effectiveness of habitat projects are summarized elsewhere in the CMS, including:

(1) Proposed use of intensively monitored watersheds, as outlined in (Part VIII), and

(2) Salmon recovery funding entities (Part VI).

State Forest Lands – Department of Natural Resources

Objective 17E: Measure how effectively DNR Habitat Conservation Plan (HCP) management actions contribute to restoring and enhancing salmonid habitat as measured by indicators. Evaluate status and trends.

Current monitoring

Pilot studies are being conducted on DNR lands to test the feasibility of proposed monitoring methods and other analysis that will allow the completion and approval of the specific study plans. The DNR is working with eighteen different organizations (including Universities, State and Federal Agencies and tribes) to cooperatively fund and conduct the pilot studies.

The following section describes actives related to riparian monitoring priorities identified in the HCP:

Pilot Monitoring of Windthrow in Riparian Areas. Initiated in 1998 and continued in 1999 the information from this project was used to redesign the monitoring approach and will help in the design of future experimental tests of wind buffers. The objectives of the pilot project were to:

(1) Develop an appropriate study design,

(2) Evaluate approaches to quantify and characterize windthrow,

(3) Identify ecological factors associated with windthrow,

(4) Characterize statistical sampling properties of different data sets to be collected, and

(5) Conduct cost benefit analysis of alternative designs and sampling strategies.

The Riparian Management Zones (RMZ) were adjacent to units harvested less than five years prior, and data was collected on a total of 62 sites bordering Type 1-3 streams across four ecoregions of western Washington.

Small Stream Hydrologic Function. Jointly funded by the DNR and the U.S. Forest Service, this project, initiated in 2001, tests methods to monitor the effects on different management options on Type 5 streams. Currently 10 sets of streams are included in the design.

Riparian Adaptive Management Support Tools. Jointly funded by the Biological Services Division of the U.S. Geological Survey and DNR, this project was initiated in 1998. The project calibrates a decision support tool for the synthesis of existing information on the impacts of forest management and natural processes on the quality of fish habitats on the western Olympic Peninsula.

Type 5 Stream Literature Review. The project completed in 2001, analyzed the existing scientific information on the ecology and management of Type 5 streams. The information will be used for the basis of Type 5 research and the development of the Type 5 stream conservation strategy.

Type 5 Stream Mapping Calibration. Jointly funded by Duke University and DNR in 2001, the project sub-sampled small watersheds to allow better prediction of Type 5 stream occurrence and compared findings to existing stream maps.

Characterization of Stream Temperature Variation. Jointly funded by NMFS and EPA, this study, initiated in 2001 and 2002, obtains data to determine the required monitoring sample sizes for the in-stream habitat conditions and trends effectiveness monitoring.

Ecosystems Diagnostics and Treatment (EDT) Method on the Clearwater River Watershed. The EDT method (Mobrand 1999) provides a way to analyze the biological performance of salmon at various life stages in comparison with historical and future habitat conditions. Model results will be used to refine proposed riparian validation monitoring.

Feasibility Assessment and Design of a Low Cost Escapement Estimation Method for Coho Salmon in the Clallam River. Jointly funded by the University of Washington and DNR, this project, initiated in 2001, tests proposed methods that may be of use for riparian validation monitoring.

Restoring Riparian Ecosystems. One project jointly funded by the U.S. Fish and Wildlife Service (USFWS) and DNR was initiated on the Olympic Experimental State Forest (OESF) in the summer of 1998. Another project was initiated in 1999 in Northwest Region with funding from the Stillaguamish Tribe. Both projects test four prescriptions to convert hardwood dominated riparian areas to conifer stands.

Proposed monitoring strategy

In January 1997, the DNR signed the implementation agreement for its Habitat Conservation Plan (DNR 1997). The co-signers were the USFWS and the NMFS. A HCP is the principal document supporting the application for incidental “take” permits and unlisted species agreements pursuant to Section 10 of the federal Endangered Species Act (ESA). One of the criteria for the issuance of an incidental take permit or unlisted species agreement is that the HCP satisfy “such other measures that the secretary may require as being necessary and appropriate for purposes of the plan.” Invariably, the federal agencies issuing the permits require that applicants monitor their HCP (USFWS and NMFS 1996). The federal agencies want reassurances that a HCP is implemented as written, and has the anticipated affect on fish and wildlife habitats.

The following monitoring is proposed for the DNR Riparian Conservation Strategy (RCS):

(1) Effectiveness Monitoring of Riparian Silviculture

(2) Effectiveness Monitoring of Wind Buffers

(3) Effectiveness Monitoring of instream riparian conditions and trends

(4) Validation Monitoring of the Olympic Experimental State Forest Riparian Ecosystem Conservation Strategy

The primary purpose of research and monitoring in a HCP is to provide information for improving forest management. Plans should be developed with this purpose in mind. The DNR proposed monitoring plans do not focus on natural resources (e.g., water quality, fish and wildlife habitat). Instead, monitoring focuses on management activities that are intended to reach the conservation goals. An emphasis on monitoring management rather than monitoring natural resources will profoundly influence the character of a monitoring plan, and should lead to information that identifies management problems and suggests how to fix those problems.

Monitoring which addresses questions such as "does water quality meet regulatory standards," or "what is the condition of salmon habitat," yields descriptions of the environment. Answers to these questions may provide a timely warning that resources are degraded, but they provide scant information for management improvement. A more useful monitoring program would yield information about how or why human activities are altering the environment. Ideally, a monitoring program would establish causality between particular human activities and specific adverse changes in the environment. A monitoring program which addresses the more complex "how" and "why" questions will be more expensive in the short term, but yield much greater benefits over the long term.

The size of DNR's HCP poses significant challenges. The HCP Riparian Conservation Strategies encompasses over 14,000 linear stream miles and about 1.4 million acres (including the OESF). The HCP Spotted Owl Conservation Strategies designates over 684,000 acres for habitat management (including the OESF) in four different ecoregions. The term of the Implementation Agreement is 70 years, and monitoring could possibly occur during the entire time period.

Proposed adequate monitoring

Riparian conservation strategy effectiveness monitoring consists of two parts. First, monitoring of management of riparian forests and management in relation to wind throw is given special consideration, because it is the single greatest threat to effectiveness of the strategy. Second, tracking of in-stream habitat conditions and trends will provide data on how the riparian forest and watershed components of the riparian strategy result in stream habitat condition. Riparian validation monitoring will attempt to relate management on select OESF watersheds to in-stream fish populations.

Effectiveness monitoring

The highest priorities for effectiveness monitoring are:

(1) Managed riparian buffers along Type 1, 2, 3, and 4 waters, and

(2) Wind buffers along Type 1, 2, and 3 waters.

These components of the riparian conservation strategies have the highest risk or uncertainty. Medium priorities for effectiveness monitoring are:

(3) Unmanaged Type 4 riparian buffers,

(4) Avoiding unstable hill slopes, and

(5) Managed wetland buffers.

These medium priorities will be addressed as funding allows.

Monitoring of managed riparian buffers translates to monitoring of riparian silviculture. The DNR is concerned about the effects of silviculture on riparian forests and how the structure and composition of riparian forests influences the quality of salmonid habitat. The monitoring of wind buffers is a subset of a larger issue; riparian forest integrity. Wind buffers are designed to protect the riparian buffer from increased rates of windthrow, but other environmental factors, such as intense sunlight (i.e., sun scald) and runoff from adjacent harvest units. These factors can degrade the condition of forests in riparian buffers. For this reason, DNR will expand the monitoring of windthrow to encompass other aspects of riparian forest integrity.

The priorities for effectiveness monitoring were established according to risk and uncertainty, but they make sense for another reason too. In the context of complex ecosystems, monitoring should occur close to the source of impacts. Each of the monitoring priorities riparian silviculture, riparian forest integrity, and road design can be monitored exactly where the management activity occurs. This should greatly reduce the confounding effects of other management activities on state trust lands, the activities of neighboring land managers, and natural changes occurring upstream in a watershed. This will increase our ability to make strong inferences from the monitoring data and make solid recommendations for improving management practices.

Riparian forest management

The within-RMZ sampling design will enable:

(1) an accurate estimates of forest characteristics within each treatment,

(2) estimates of source distances for Large Woody Debris (LWD),

(3) quantitative relationships between forest characteristics and LWD recruitment, and

(4) descriptions of vegetation gradients across the RMZ.

The DNR HCP effectiveness monitoring for riparian silviculture will be conducted by comparing side-by-side alternative riparian forest management. We anticipate that each RMZ will be divided into three or four treatment areas. A sampling area will be centered within each treatment area. The sampling area must be at least 330 ft (100 m) long, and there must be at least 66 ft (20 m) between both ends of a sampling area and the ends of a treatment area. Within each sampling area, 10 m wide sampling plots will traverse the RMZ from the stream to the RMZ's outer edge. Each sampling area will have at least two but more than three of these sampling plots. The starting point for plots will be a randomly-placed within the first 30m of the RMZ after a 20m offset from the edge with systematic sample of exactly 50 m between plots. This design results in a sampling intensity equal to approximately 20 percent of the sampling area.

Permanent plots will be used to monitor tree growth, forest development, and LWD recruitment. Permanent fixed-area plots yield more precise parameter estimates than temporary or variable-radius plots (Curtis 1983). The choice between temporary and permanent plots depends on the degree of correlation between repeated measurements over time (Freese 1962). If a high positive correlation is expected, then permanent plots are preferred for their greater precision, which is needed to detect trends. The increased precision results the repeated measurement of the same collection of trees, snags, and other structural characteristics within the plot. Permanent plots are needed to detect differences in stand responses to different silvicultural treatments. Permanent plots are needed to detect differences in stand responses to different silvicultural treatments if more precise information about tree growth and/or coarse woody dynamics is desired, then individual trees, and/or coarse woody debris can be labeled with numbered aluminum tags. Either all or a subsample of trees and woody debris could be labeled. Accurate measurement of LWD recruitment to the stream channel probably will require tagging individual pieces of wood. Tagging would enable an exact tally of live trees and snags that were recruited and transported away from the monitoring site.

Data management

Field data will be recorded by technicians onto custom data forms. There will be unique forms for each type of nested plot. Data quality will be periodically checked in the field by the DNR scientist responsible for effectiveness monitoring. A relational database will be constructed. To enter data into the database there are three options:

(1) Field technicians are responsible for entering their data,

(2) Clerical staff will be assigned the task of entering data, or

(3) DNR contracts a private firm to enter the data.

Funding will determine which option is chosen. Spatial data such as RMZ boundaries and plot locations will be stored in Arc/Info. Information about prescriptions will be maintained in DNR's Planning and Tracking System.

Evaluation of effectiveness monitoring

Since we are interested in which prescription is most effective, the main analysis entails a comparison of treatments, including controls. Analysis of variance (ANOVA) will be the statistical test used to look for significant differences among prescriptions. Separate ANOVAs are necessary for each forest attribute (seedling mortality, sapling height growth, tree diameter growth, tree mortality rates, windthrow rates, etc). Significantly different prescriptions can be ranked in order of effectiveness. The control is the standard of comparison. Additional comparisons between prescriptions may be necessary to correct the significance level of ANOVAs (Sokal and Rohlf 1995). Non-parametric tests (e.g., Mann-Whitney two-sample test) may be more appropriate for some parameters.

An additional evaluation of effectiveness entails determining how each prescription effects stand growth and development. That is, a comparison of stand characteristics before and after treatment might be performed. This can be accomplished with a two-tailed Student's t-test of the null hypothesis:

$$H0: \mu T = \mu C$$

where μT is the sample mean for the replicated treatment and μC is the sample mean of the replicated control.

For these evaluations α could be set at a 0.10 probability of a Type I error. The t-test would be performed for only particular forest attributes such as rate of diameter growth and rate of height growth. When the null hypothesis is accepted a power analysis will be done to determine $, the probability of a Type II error. Nonparametric tests (e.g., Wilcoxon paired-sample test) may be more appropriate for some parameters.

Much of the information for improving prescriptions will come from multivariable regression. Multivariable regression may lead to insights about specific ecological relationships that can contribute to better prescriptions. More importantly, regression enables investigations into the relationships between independent variables, such as planting density, overstory relative density, and dependent variables, such as seedling mortality and tree growth rates.

Wind buffer monitoring

The scope of effectiveness monitoring for riparian forest integrity includes the OESF and the five westside DNR planning units, covering four ecoregions and five forest zones. Monitoring efforts will be concentrated within the OESF, and remaining effort apportioned among other regions according to need. Effectiveness monitoring will examine both historic and future rates of windthrow in managed riparian forests. Monitoring data will be collected mainly through photogrammetric analysis of gap dynamics and stand stability. For different objectives, the design for effectiveness monitoring will include:

(1) A landscape-level population inventory of historic (pre-HCP) patterns of windthrow, and

(2) A watershed sample of future patterns of post-harvest windthrow in HCP-compliant RMZs.

For the landscape inventory, historic patterns of riparian forest integrity will be quantified using visual inspection of orthophotos (scale 1:3200 and 1:63000) and resource aerial photos (scale 1:12000).

For the watershed inventory, photogrammetric data on windthrow patterns will be collected from the set of harvested HCP-compliant riparian buffers, with and without adjacent wind buffers, beginning with stands scheduled for sale/harvest in 2001-2003. Watersheds will be randomly selected in relation to landscape proportion, across three blocking strata:
(1) Ecoregion,

(2) Forest zone, and

(3) Site productivity.

Minimum criteria for candidate riparian buffer/wind buffer monitoring sites include:
(1) RMZs and wind buffers are HCP-compliant, and

(2) RMZs must have a minimum length of 1,400 ft.

Windthrow gaps will be measured on digital orthophotos (1:12000), using photogrammetric measurement techniques available in SocetSet software (LH Systems). Watersheds will be re-evaluated at approximate 6-year intervals corresponding to the standard aerial survey flight schedule for the DNR Regions. Field surveys will be used to establish baseline information on the integrity of riparian stands immediately after harvest and to evaluate conditions related to significant windthrow events. The effects of windthrow on present and future riparian forest integrity will be quantified using a model such as Forest Vegetation Simulator to assess stand dynamics.

Data collected for effectiveness monitoring of riparian forest integrity will be useful to a variety of HCP research and monitoring efforts including riparian silviculture, riparian habitat trends, and spotted owl habitat. In providing fundamental information to support the adaptive management process, effectiveness monitoring of riparian forest integrity will be highly efficient and cost-effective means of evaluating the effects of HCP-based management practices on riparian habitat conditions.

Instream monitoring

Thus far, effectiveness monitoring priorities will be addressed by two separate monitoring plans:
(1) Riparian silviculture and

(2) Riparian forest integrity.

However, DNR recognizes that these monitoring plans do not address the cumulative effects of forest management. Furthermore, DNR recognizes that the monitoring plans do not address the ultimate beneficiary of the DNR riparian conservation strategy, which is the condition of salmonid habitat. For these reasons, DNR will add a third component to effectiveness monitoring-habitat conditions and trends. This approach has some drawbacks. First, at present, we do not know how rapidly salmon habitat on state trust lands should recover from its current degraded state. Hence, we have no reference for evaluating effectiveness. And second, many programs that monitor habitat condition and trends are unable to determine the causes of habitat trends. If habitat does not recover, then we cannot determine why. Is it due to RMZ management, road management, upland forest management, global climate change, or some combination of all of these? The DNR must consider these drawbacks when developing a monitoring plan for habitat conditions and trends.

The purpose of the instream habitat monitoring effectiveness program is to determine if instream habitat conditions are improving, primarily for the benefit of salmonids. Included in the HCP is the Riparian Conservation Strategy, which describes how riparian and upland management will be implemented such that instream habitat improves. The

HCP does not proposed direct improvements to stream habitat, rather, it is through implementation of the RCS that instream habitat conditions are expected to improve.

The hypothesized outcome many management actions envisioned in the RCS is a return to natural instream conditions. That is, implicit in the conservation objectives of the RCS is that the quantity, quality and timing of sediment, wood, thermal energy and water delivered to streams will eventually be similar to unmanaged streams. For many watersheds, if this occurs at all, it will not occur for decades or even centuries for some parameters. Therefore, monitoring efforts need to monitor the trajectory of (hopefully improving) habitat conditions in order to determine if they are improving at the predicted rate. Thus a monitoring plan must not simply hypothesize that habitat will return to natural conditions if certain management actions are implemented, but must also hypothesize the time it will take to return to natural conditions and the rate at which conditions will improve. This is essential because the HCP requires that monitoring occur over short time periods of 1-3 years as well as longer periods. Thus both long- and short-term monitoring will need to determine if habitat conditions are improving along expected trajectories so that management can be adapted as necessary in order to meet desired RCS objectives.

Validation monitoring

The proposed DNR validation monitoring will be conducted for the following purposes:

(1) To evaluate cause-and-effect relationships between salmon habitat conditions resulting from the conservation strategies and the salmon populations these strategies are intended to benefit,

(2) To support explanations of the causal links between the OESF riparian management strategy, habitat conditions, and fish populations and describe the target conditions of aquatic habitat and salmon productivity, and

(3) To provide validation of effectiveness monitoring findings and support the adaptive management process at the watershed-scale.

The approach to validation monitoring outlined in this plan begins with site selection and developing sampling methodology for long-term monitoring. To understand those conditions and formulate specific hypotheses, the validation monitoring will use a three-phased approach. These phases are:

(1) An assessment phase that describes and tests candidate watershed's characteristics for similarity (to provide paired-watersheds for experimentation),

(2) A pilot phase that characterizes habitat and salmon relationships, refines monitoring methods, and documents initial conditions, proposes target conditions, and,

(3) A full implementation phase that will evaluate the effects of the RCS (the "Treatment") on salmon habitat and populations.

There are many challenges to this type of monitoring including:

- Natural variation in watershed types, fish population, and habitat conditions,
- Sampling error in standard escapement estimation and habitat assessment techniques,
- Accounting for the influences of past management,
- Determination when, or if, habitat conditions have responded to the conservation strategy treatments, and when, or if, these responses have been fully elaborated (responses may not be detectable for several years or decades after implementation).

These challenges necessitate assessment and pilot monitoring phases and the development of a framework for generating precise hypotheses to account for these factors.

The dependence of salmon on ecosystems and their sensitivity to processes beyond the areas influenced by land management requires a comprehensive, multiple-scale approach to evaluate the effects of the conservation strategy. During the assessment phase, watershed characteristics will be screened to identify appropriate watershed pairings for treatment and control in experimentation. This process includes physical and ecological evaluations of habitat and fish population status and a description of historical conditions in regards to these. Also, a conceptual watershed-fisheries model will be constructed to describe the relationships between the management strategies and the responses by the physical environment and fish. This will evolve into a mechanistically-based simulation model for predicting responses by different abiotic and biotic variables to each other and to “treatments”. This model will be refined through pilot monitoring and full implementation monitoring and serve as the primary tool for evaluating responses of selected variables in treatment and control watersheds. Pilot monitoring will evaluate the strength of fish-habitat correlations and the degree of variation in fish abundance will determine the appropriate use of particular fish population metrics (smolt/adult ratios, life stage survival, etc.) as validation monitoring tools.

In an adaptive management strategy, there is a need to describe the range of environmental conditions that could occur in the system being monitored. In the proposed “space-for-time” format, assessing several similar watersheds should provide a range of environmental conditions due to their various stages of disturbance. The extreme values help define the range of expected habitat conditions (compared to long periods of pre-treatment monitoring at a single site to describe the variability). Evaluation of historical physical habitat and fish population characteristics, and assessment of current conditions during pilot validation monitoring, will establish the template for long-term monitoring.

Validation monitoring will be approached in a manner conducive to applications of rapidly improving remote sensing techniques such as data extraction from digital stereo photogrammetry, videography, and digital satellite imaging. Fish evaluation will incorporate appropriate fish marking/counting techniques, including review of the feasibility of using existing spawner escapement techniques and, if necessary, development of an appropriate technique for measuring adults. Data management, recording, and reporting will be GIS-based products.

Private Forest Lands

Objective 17G: Measure how effective modifications of the FPA, established under ESHB 2091 (also known as the Forests and Fish Agreement), are in improving status of identified forest habitat.

Current monitoring activity

Since the early 1990s, the Cooperative Monitoring Evaluation, and Research (CMER) Committee of the Timber, Fish and Wildlife (TFW) Program has conducted effectiveness monitoring (now referred to as prescription monitoring) which is used to determine how forest practice rules affect fish and wildlife on private and state forestlands. Most of these studies focused on the site-specific effects of timber harvest and road construction on stream input processes (also termed habitat-forming processes, watershed processes), including water, heat, sediment, coarse woody debris, and to a lesser degree nutrients. There was little or no trend or validation monitoring to this work even though some studies sites have been used over multiple years. Much of the monitoring results were used to test assumptions about the effects of single forest practices on aquatic habitat (e.g., the effects of shade on stream temperature). In addition, some work has been used to create management tools such as those used in the Washington State Watershed Analysis procedures.

With the signing of the Forest and Fish Agreement (FFA) in 2000, TFW was tasked with developing a more comprehensive monitoring strategy for private forest lands. This monitoring strategy will include effectiveness monitoring similar to the work conducted by CMER in the 1990s. In addition, implementation (or compliance), status and trend, validation, and cumulative effects monitoring programs are currently being developed. Implementation monitoring is the responsibility of Department of Natural Resources, whereas the three other types of monitoring (described below) are the purview of CMER.

Prescription (effectiveness) monitoring projects

The process of developing prescription monitoring questions and study designs is ongoing within CMER. A short description of work to date is provided below.

Bull Trout Overlay. This study will test the effectiveness of the "all available shade" rule versus standard forest and fish riparian management prescriptions in eastern Washington for maintaining or restoring water temperatures necessary for bull trout. This study will use a treatment/control experimental design.

Hardwood Conversion. This project will determine the effectiveness of hardwood conversion rules in meeting short-term water temperature requirements, and long-term desired future conditions (DFC) and LWD requirements. Hardwood conversion is the process of replacing stands whose canopy is dominated by hardwoods to stands dominated by conifers. This study will use a treatment/control experimental design.

Amphibian Use of Seeps. This study will test the effectiveness of headwater (nonfish bearing perennial) stream buffers for protecting the viability of six species (now seven species as tailed frog was split into two species) of stream-associated amphibians. Initial phases of the study will look at amphibian use of seeps versus other aquatic habitats in headwater basins to determine:

(1) The general value of seeps to amphibians,

(2) If seeps act as salamander breeding sites, and

(3) The value of seeps to amphibians as a function of seep density and location.

Later phases of the study will determine local extinction and recolonization events at the harvest unit scale (Stream Type N scale).

Road Maintenance and Abandonment Plans (RMAPS). The purpose of this study is to test the effectiveness of Road Maintenance and Abandonment Plans (RMAPs) to reduce road generated fine sediment and runoff, and to reduce the incidence of mass wasting associated with roads. This study will evaluate RMAPs at the basin scale and will test effectiveness in different physiographic regions and landowner planning areas.

Effectiveness of Specific Road Best Management Practices (BMPs). This study will test the effectiveness of site scale BMPs (e.g. culvert spacing) at reducing the delivery of road generated fine sediment and water to streams. The study will test the effectiveness of current rules as well as alternative prescriptions using a treatment/control experimental design.

Fish and Amphibian Passage. This study will investigate resident salmonid movement behavior in small streams and determine how culverts affect fish movement in a variety of situations. The ultimate goal of this study is to provide a means to rate the significance of a given culvert in affecting fish movement in order to prioritize the order in which culvert repairs will be conducted. The specific objectives are:

(1) Investigate how stream crossing structures affect the volitional upstream movement of fish and amphibians, and

(2) Evaluate the association among structural and hydraulic features of culverts, barrier status (passable/impassable), and fish movement.

Mass Wasting. Specific prescriptions governing forest practices for mass wasting are not defined at the present time, therefore an effectiveness study will be deferred until the prescriptions are identified. Initially research is focused on developing landslide screening tools, protocols for identifying unstable landforms, and measurable metrics for classifying landslides. Some initial components of these studies have been completed by the DNR and are in technical review.

Streambank/Surface Erosion. This study is focused on evaluating stream bank erosion and surface erosion associated with timber yarding corridors, and patch buffers in perennial nonfish-bearing streams (Np) in eastern and western Washington. This study will be a component of the Type N/F (i.e., fish/nonfish) Stream Prescription Effectiveness study.

Runoff in the Rain on Snow Zone. This study will test the effectiveness of rain-on-snow prescriptions in meeting peak flow targets.

Forest Regeneration in Wetlands. This project will evaluate the effectiveness of forest regeneration in harvested forest wetlands. Regeneration will be compared to surrounding non-wetland sites to determine if wetlands regenerate more slowly than upland forest, and if wetlands have different forest successional dynamics than adjacent upland forests. A retrospective analysis of forest regeneration using historical aerial photos will form the basis of this study.

Groundwater Conceptual Models. This study will:

(1) develop a conceptual model(s) to evaluate cause and effect relationships between forest practices and groundwater temperatures,

(2) identify hypotheses about forest practice influences on groundwater temperatures at site and watershed scales, based on the information learned from the conceptual model(s),

(3) develop experimental designs for testing the priority hypotheses, and

(4) develop cost estimates for the experimental designs.

Habitat Conservation Plan (section 4(d)) Population Response and Effectiveness Monitoring. These studies would provide baseline populations for bull trout, against which the effectiveness of the Forest and Fish Report can be measured. The population response of bull trout in typical watersheds (i.e., intensively monitored watershed) and relate it to habitat response across the broader array of watersheds (i.e., extensively monitored watersheds). The CMER will initiate projects to address the following needs:

(1) Baseline population data to determine and track amount of incidental take authorized,

(2) Population abundance would be monitored in the Intensively Monitored Watersheds identified by the Forests and Fish Monitoring Design Team (MDT).

Proposed extensive monitoring

Extensive monitoring is the MDT's version of status and trend monitoring and is named for the spatial scale at which at which this type of monitoring occurs. Answers to the prescription level monitoring (see project descriptions above) questions will be valuable for understanding the status and trend data obtained from the extensive monitoring component.

Given the tradeoffs among between the resolution of data and cost, the MDT has recommended extensive monitoring only on the most important indicators of change that are necessary to satisfy regulatory agencies that progress is consistent with expectations on private forestlands. The MDT also limited extensive indicators to those that could be collected relatively easily (by remote means in some cases), and with relatively low sampling error.

Scale is the common feature of the extensive monitoring elements. All will produce an estimate of status and trends at a statewide scale on private forestland covered by the FFR. The monitoring plans do not, by design, share sites or monitoring indicators. Data collection in each element is tailored to the specific resource conditions. The indicators are similar to those monitored in the Intensive and Prescription scale monitoring but are measured at different spatial and temporal intensities. Information flow among the elements of extensive monitoring and among the three scales of monitoring is critical to the interpretation of the monitoring data and in feeding the adaptive management loop.

Extensive monitoring will measure the success of the FFR in meeting performance targets that were developed in FFR or that will be developed as part of the adaptive management program. In some cases, extensive monitoring will provide data to help establish or validate performance targets and resource objectives. This could be accomplished by including extensive monitoring sites in relatively undisturbed areas (reference sites) that could serve as reasonable estimates of potential conditions. The fundamental questions addressed in extensive monitoring are:

- Is the proportion of fish passage structures that provide for fish passage at all life stages increasing through time?

- Are fish-bearing stream temperatures decreasing and shade to fish bearing streams increasing in ways that are consistent with our expectations?

- Do the data provide the assurance of regulatory compliance needed for the Clean Water Act?

- *Potential extensive monitoring question 1.* Is the length of roadway delivering fine sediments to streams per mile of stream meeting performance targets outline in the FFR?

- *Potential extensive monitoring question 2.* Is the rate of management induced mass wasting events the same as background levels?

Proposed intensive monitoring

Intensive monitoring as part of a monitoring design provides the ability to better identify interacting factors influencing aquatic habitat quality and distribution and generates information of sufficient detail to begin to develop some understanding of the biological effects of FFR. Intensive monitoring provides the best avenue to evaluate the interaction of individual prescriptions, enabling the results of prescription effectiveness studies to be interpreted in terms of the contribution of prescriptions to habitat quality and biological condition. Without the detailed information generated by intensive monitoring, the causative agents of many of the patterns of change observed through extensive monitoring cannot be identified.

Intensive research and monitoring in a single location has provided results that have been very influential in guiding the evolution of forestry practices. Some of the earliest intensive monitoring efforts in forested landscapes were instituted by the U.S. Forest Service in the 1950s to better understand hydrologic responses to logging. Efforts at these sites expanded over time to encompass chemical and biological responses as well. Changes in forest practices nationwide have been based on studies conducted at experimental watersheds like the H.J. Andrews Experimental Forest in Oregon, the Hubbard Brook Experimental Forest in New Hampshire and the Coweeta Experimental Forest in North Carolina.

The success of these efforts spawned a number of intensive, watershed-level research efforts in the Pacific Northwest to evaluate the response of salmon to forest practices. The Alsea Watershed Study, which was initiated in the 1960s and continues today, evaluated the response of coho salmon and cutthroat trout to various logging methods in a series of small watersheds on the Oregon coast (Bisson in press). Early results from this study provided some of the impetus for the revision of laws governing forest practices in Oregon and Washington in the early 1970s. In the 1970s an ambitious watershed-level project was initiated at Carnation Creek on Vancouver Island, British Columbia that evaluated the response of coho and chum salmon to the logging of a previously unlogged watershed. The results of this study led to a revision of the forestry code for British Columbia and also influenced revisions to forest practice rules in other areas of the Pacific Northwest. The influence of these types of monitoring efforts emphasizes the value of dedicating a portion of monitoring resources to intensive monitoring.

Questions addressed with intensive monitoring

Closely spaced measurements in space and time are often required to develop a thorough understanding of the processes responsible for a system response to a management action. Concentration of monitoring effort in a relatively small area is an efficient method of achieving the level of sampling intensity necessary to determine the full nature of a response. This level of monitoring intensity, and the in-depth understanding that it provides, enables the evaluation of two important aspects of the effectiveness of forest practices that cannot be addressed with other approaches: cumulative effects of multiple practices and biological responses. Evaluation of cumulative effects of multiple management actions on a system requires an understanding of how individual actions influence a site and how those responses propagate through the system.

This understanding will enable the evaluation of the effectiveness of management practices applied at multiple locations over time. This sophisticated level of understanding can only be achieved with an intensive, integrated, monitoring effort. Evaluating biological responses is similarly complicated, requiring an understanding of how various management actions interact to affect habitat conditions and how system biology responds to these habitat changes. The complexity of evaluating biological response is illustrated for example, by the diversity of habitat types required by coho salmon to complete freshwater rearing (Table 13). The response of the fish is dependent on the relative availability of the numerous habitat types it requires and the sensitivity of these habitat types to forest practices, which will vary depending on the practice and habitat type. The issue is further complicated as the importance of each habitat type and the effects of forest practices on these habitats change from year-to-year due to variations in weather, abundance of fish spawning within the watershed and other factors. For example, smolt production can be dictated by spawning habitat availability and quality during years when flood flows occur during incubation and greatly decrease egg survival (Pess *in press*). However, during years of more benign flow conditions, population performance may be more influenced by the availability of food during spring and summer or adequate winter habitat.

Table 13. Changes in the habitat requirements of coho salmon during freshwater rearing. The changing requirements of the fish stress the need to develop monitoring designs that evaluate responses at a spatial scale large enough to encompass the full range of habitat types required by the fish to complete freshwater rearing.

Life history stage	Habitat
Spawning and egg incubation	Riffle and pool tail outs in proximity of cover suitable for adult spawners (e.g., deep pools, undercut banks, debris jams)
Early fry rearing	Low velocity with cover in close proximity to food source typically associated with shallow, channel margin habitat with cover from wood and overhanging vegetation
Summer rearing	Pool habitat with cover in close proximity to food source typically associated with low gradient channels, pool riffle morphology, streams in flood plain valley type
Winter rearing	Low velocity refuge with cover typically associated with off-channel habitat on floodplains including low gradi ent tributaries, secondary channels and ponds

Untangling the various factors that determine performance of the salmon and how these attributes are influenced by forestry can only be accomplished with an intensive monitoring approach. As the biological response is the ultimate measure of the success or failure of the FFR prescription package, developing this level of understanding is critically important for evaluating the effectiveness of the new rules. Concentrated sampling in a series of intensively monitored Watershed Administrative Units (WAU) can provide the type of comprehensive data needed to understand these relationships.

In addition to providing detailed cause and effect information on system response to FFR prescriptions, intensive monitoring also can provide information that can help in refining performance standards and desired future conditions. The intensively monitored WAUs will provide detailed data on the relationship between physical and biological attributes and how they respond to FFR prescriptions. This type of information will enable the determination of whether the application of a suite of prescriptions actually has the intended effect on the ultimate resources being managed (fish, amphibians, other aquatic biota and water quality). Specific characteristics of an intensive monitoring effort will depend upon the questions being addressed (MDT 2002).

Federal Forest Lands

Objective 17H: Determine status of the identified freshwater habitat and landscape forming indicators identified in the Aquatic/Riparian Effectiveness Monitoring Plan (AREMP) and PacFish/InFish (PIBO) in federal lands in Washington; and trends. Evaluate whether the indicators are improving.

Objective 17J: Determine how effective treatments described in the Northwest Forest Plan and PacFish/InFish are in improving the status of identified habitat and landscape forming indicators.

Washington State contains six national forests comprising over 9 million acres of forest and range lands. Approximately 30% of the forest lands in Washington are under federal ownership. Many watersheds within each of the State's Salmon Recovery Regions contain significant amounts of National Forest lands, which provide much of the remaining quality fish habitat.

Recommendations for Monitoring Habitat, Water and Fish

Past forest management, range management, and road construction activities have impacted watershed processes and fish habitat both within and downstream of National Forest lands. The recent Northwest Forest Plan and Columbia Basin PacFish/InFish plans have refocused efforts toward restoring watershed conditions and fish habitat. For the past decade, the Forest Service has been heavily involved in an extensive watershed restoration program to improve watershed conditions and habitat for aquatic species, especially listed species. It is crucial to salmon recovery success and watershed health that the state partnership to the extent possible with the U.S. Forest Service, Bureau of Land Management and other federal land owners.

Monitoring Indicators

Information from many indicators is obtained through the Federal Forests monitoring program. Indicators that are most closely aligned with those identified for CMS status and trend monitoring include:
Vegetation type and seral stage. This information describes the type and age of vegetative cover across the landscape. Information for the Northwest Forest Plan area will be obtained by remote sensing through the Interagency Vegetation Mapping Project.

Road density. This information describes the density of roads, their surface types, location, maintenance levels, and distance to stream channels.

Landslides. This information describes the frequency, type, and location of landslides across the landscape.

Channel sinuosity. Channel sinuosity (stream length divided by valley length) describes channel complexity, channel function, and alterations.

Large wood. This information is a count of large wood pieces within the surveyed reach. Pools. This information describes the frequency, depth, and residual volume of pools within the surveyed reach.

Substrate. Wolman pebble counts describe the percent fines and median size of substrate particles within the surveyed reach.

Channel connectivity. The entrenchment ratio (valley width divided by channel width) is a measure of channel connectivity with the floodplain in unconfined stream reaches.

Blockages to salmon migration. This information describes the number, location, and extent of identified culvert fish passage barriers on National Forest roads.

Current monitoring activity

See discussion of Aquatic and Riparian Effectiveness Monitoring Plan for the Northwest Forest Plan (AREMP) and PacFish/InFish Monitoring Program (PIBO) in the following section.

Stream inventory

Since the early 1990s, the U.S. Forest Service (USFS) has been conducting basin-wide stream inventories within national forests in Washington State. The inventories follow a standardized Region 6 Level II protocol based on the Hankin-Reeves sampling methodology. They collect extensive stream channel, riparian, and aquatic habitat condition information including aquatic habitat dimensions, streambed substrate, large wood pieces, riparian vegetation, and bank stability.

Approximately 4,450 stream miles have been surveyed with Level II stream inventories on federal forest lands in Washington State. The data has been used to establish baseline conditions and identify restoration opportunities. Approximately 140 stream miles are surveyed or resurveyed each year to establish baseline conditions or monitor changes in instream habitat conditions.

Aquatic and riparian effectiveness monitoring Plan for the Northwest Forest Plan (AREMP)

The Aquatic and Riparian Effectiveness Monitoring Plan (AREMP) was developed by a multi-agency federal team to evaluate the effectiveness of the Northwest Forest Plan throughout western Washington, Oregon, and northern California. It characterizes the ecological condition of watersheds and aquatic ecosystems at a regional scale by evaluating status and trends of watershed, stream, and riparian conditions over time.

Sub-watersheds (6th field hydrological unit, HUC6) form the basic geographic unit for monitoring. A minimum of 50 sub-watersheds will be sampled annually throughout the Forest Plan area. Over a five-year period, a total of 250 watersheds would be sampled (approximately 10% of the estimated number of sub-watersheds within the Forest Plan area). About 16 sub-watersheds will be sampled in Washington each year. At this time, neither the strategy for sampling the 6th field HUCs from year to year (random selection, rotating panel) or the individual 6th field HUCs to be sampled in Washington have been identified.

Each of the selected 6th field HUCs will be sampled for 20 indicators of watershed health. Overall watershed condition will be assessed by using a decision support model (DSM) with relationships developed by provincial and regional experts. Results will be presented in the form of frequency distributions of the regional aggregation of watershed condition. Because watershed processes operate over long timeframes (decades to centuries), trends may not be observed for 10-20 years.

The AREMP is currently entering the third and final year of an initial startup period. Full implementation of AREMP could occur as soon as 2003, pending adequate funding.

PacFish/InFish monitoring program (PIBO)

The PacFish/InFish Monitoring Program (PIBO) was developed by a multi-agency federal team to evaluate the effectiveness of Land Management Plans in protecting and improving aquatic and riparian resources on federal lands throughout eastern Washington, eastern Oregon, Idaho, and parts of Montana. It tracks the condition of aquatic and riparian ecosystems at a regional scale and sub-watershed scale by evaluating status and trends of stream and riparian conditions over time.

Sub-watersheds (6th field hydrological unit, HUC6) form the basic geographic unit for monitoring. Approximately 250 sub-watersheds with greater than 50% federal ownership will be sampled annually throughout the PacFish/InFish area using a rotating panel design. Over a five-year period, a total of 1250 watersheds would be sampled (approximately 30% of the sub-watersheds within the PacFish/InFish area). A number sub-watersheds are sampled in Washington each year. The individual 6th field HUCs to be sampled in Washington over the next 5 years will be identified by April 2003.

One point (the lowest unconfined reach) is sampled within each of the selected 6th field HUCs. More than 25 indicators of stream and riparian habitat are collected including road and culvert information, landslide frequency, forest condition, riparian vegetation and connectivity, instream characteristics, and macro-invertebrate communities. Status and trends of aquatic and riparian conditions will be analyzed using frequency distributions of various indicators. Conditions in managed watersheds will be compared to undisturbed reference reaches to determine management impacts. Over time, conditions in managed watersheds are expected to approach conditions in reference reaches.

The PIBO is currently entering the third year of an initial startup period. Full implementation of PIBO is anticipated in 2003, pending adequate funding. Full implementation of the PIBO plan (250 sub-watersheds per year) would cost approximately $1.2 million per year.

Culvert fish passage inventory

In 2000 and 2001 the U.S. Forest Service conducted comprehensive inventories of all fish passage problem culverts within national forests in Washington State. The inventories followed a standardized Region 6 protocol and collected information on culvert characteristics, stream characteristics, and potential passage problems. Fish passage determinations were based on the FISHPASS computer model.

Approximately 1,305 fish passage culverts have been inventoried on National Forest roads in Washington State. The data has been used to establish baseline conditions, identify restoration needs, and track fish passage accomplishments.

Proposed monitoring strategy

Proposed monitoring includes fully implementing AREMP and PIBO monitoring programs, collaborating with Washington State on the AREMP watershed selections, and sampling strategy to realize cooperative opportunities.

Agricultural Lands

Objective 17C: Determine how effective agricultural conservation practices are in improving status of habitat as shown by their indicators.

Objective: Identify current status of identified habitat indicators and trends using remote sensing and current data such as limiting factors analysis.

Monitoring indicators

- Riparian amount and condition
- Geomorphic index
- Instream conditions (use standard measurements)
- LWD
- Pools
- Substrate
- Bank conditions
- Blockages
- Flow

Current monitoring activity

A need exists to determine the type and extent of current state, federal and local monitoring activity in basins where various restoration projects and programs are conducted. The Conservation Commission Limited Factors Analysis will be invaluable for basins where it is complete.

Proposed monitoring strategy

A key need is to determine data gaps based on current efforts and historical data and fill them. The amount of monitoring needed for valid trend determination also needs to be determined.

The Agricultural Strategy in the context of the SSRS is designed to provide compliance with the Clean Water Act and Endangered Species Act through implementation of conservation practices that have been upgraded, if necessary, to meet the needs of these acts. It is a voluntary, incentive-based program that primarily uses federal farm-bill programs such as the Conservation Reserve Enhancement Program. It is based on whole farm plans but many farmers may choose to selectively implement conservation practices outside the farm plan model.

Measuring the success of the Agricultural Strategy will require implementation, effectiveness and validation monitoring.

The Governor’s Salmon Recovery Strategy calls for implementation monitoring to be coordinated by the state Conservation Commission. Individual Conservation Districts will track implementation at the local level and feed the information to the Conservation Commission, which will track it at the statewide level.

The primary contribution of the Agricultural Strategy to physical habitat pertains to riparian buffers on agricultural lands. It will be critical to determine if the buffer models proposed and funded by the state and federal agencies are adequate to provide the needed functions to streams. Effectiveness monitoring projects will need to be designed to determine if the state supported buffers work. This will be a long-term affair, since some functions such as large wood recruitment may take one hundred years to develop.

Validation monitoring will also be necessary to determine if the cumulative effect of conservation practices lead to the clean, cool water and physical habitat needed for recovery.

Urban Lands

Objective 17L:Determine how effective urban resource conservation measures have been in improving status of identified freshwater habitat and landscape forming indicators.

Urbanization degrades the natural functions of streams, wetlands and estuaries. Degradation occurs by changing the natural hydrological cycle, altering river and floodplain structure through channelization and diking, and armoring of shoreline areas. Hydrological changes result from vegetation removal, altering the native soil structure, modifying surface drainage patterns, and adding impervious surfaces (e.g., roads, rooftops, and compacted soils).

The focus of this section is on the effects of urban storm water runoff, with emphasis on physical stream habitat. Status and trends monitoring of habitat and landscape processes was previously described in this chapter. Similarly, a variety of effectiveness monitoring activities associated with urban lands is found in the following chapters:

- Water quality (Part VII G),
- Water quantity (Part VII F),
- Habitat connectivity (Part VII D), and
- Nearshore marine/estuaries (Part VII H).

It is important to note that the effects of urbanization are not measurable at a scale as large as a watershed or WRIA, monitoring of urban effects must occur at sub-watershed scales.

Monitoring indicators

Most of the indicators identified above for status and trend monitoring also apply to effectiveness monitoring in urban areas. These include:

- Land use/land cover,
- Hydrology,
- Riparian cover,
- Biota (B-IBI),
- Geomorphology and channel geometry,
- Large Woody Debris,
- Bank condition,
- Pools, and
- Substrate.

Current monitoring activity

Limited effectiveness monitoring of urban storm water is currently conducted by the Puget Sound Water Quality Management Plan (PSWQMP) and Puget Sound Ambient Monitoring Program (PSAMP) and the National Pollutant Discharge Elimination System (NPDES). The NPDES storm water permit program is a regulatory tool under the Clean Water Act for urbanized areas to achieve both water quality and salmon habitat objectives. The University of Washington has performed focused storm water research.

Essential tools

Storm water Management Manual for Western Washington and Eastern Washington (when available), GIS information, and NPDES permits.

Monitoring design

Not identified.

Identified agencies

The Department of Ecology, Puget Sound Water Quality Action Team, local jurisdictions, and universities are participating agencies.

Recommended sampling protocols

The Urban Storm water component of the SSRS is designed to provide compliance with the Clean Water Act and support salmon recovery by integrating urban storm water strategies into watershed planning (see Part VI), providing assistance and incentives for voluntary action, and support through a variety of state and local actions.

State actions include publication of a revised western Washington storm water manual to provide guidance for municipalities and completion of an eastern Washington manual. The western Washington manual includes minimum requirements and Best Management Practices (BMPs). The guidance in the manual becomes requirements for projects through permits issued by local, state, and federal governments.

Measuring the success of the Urban Storm water component will require implementation, effectiveness and validation monitoring. This is consistent with the monitoring recommendations provided by the Storm water Policy Advisory Committee (2001).

It is recommended that local storm water programs consistent with the PSWQMP and compliance with NPDES storm water permits be monitored. It is anticipated that the following NPDES storm water permits will likely require monitoring:

- General Industrial Storm water Permits
- Individual Industrial Storm water Permits
- General Construction Storm water Permits
- Phase I Municipal Storm water Permits

BMP monitoring

Assessing the effectiveness of the various structural and source control tools used to mitigate storm water impacts is necessary for making links with habitat status and trends, and for evaluating which BMPs to continue using, or to modify or eliminate.

Monitoring of BMPs can include:

- Measuring pollutant removal efficiency or structural treatment BMPs,
- Implementing monitoring to discern if BMPs are being applied, or
- Assessing ordinance implementation by checking inspection records.

Validation (cause-effect) monitoring will also be necessary to determine if the cumulative effects of urban conservation practices adequately contribute to water quality, hydrology and physical habitat needed for salmon recovery. Intensive (cause-effect) monitoring in urban areas will be considered as part of the use of Intensively Monitored Watersheds (IMWs) (see Part VIII).

Performance benchmarks

No information.

Identified monitoring gaps/overlaps

Effectiveness and validation monitoring of urban storm water management programs have been identified as a need but comprehensive programs are not in place.

Quality assurance/Quality control

No information.

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C. Fish Passage Barriers

Question 19: What is the progress of the state in restoring fish passage at barriers

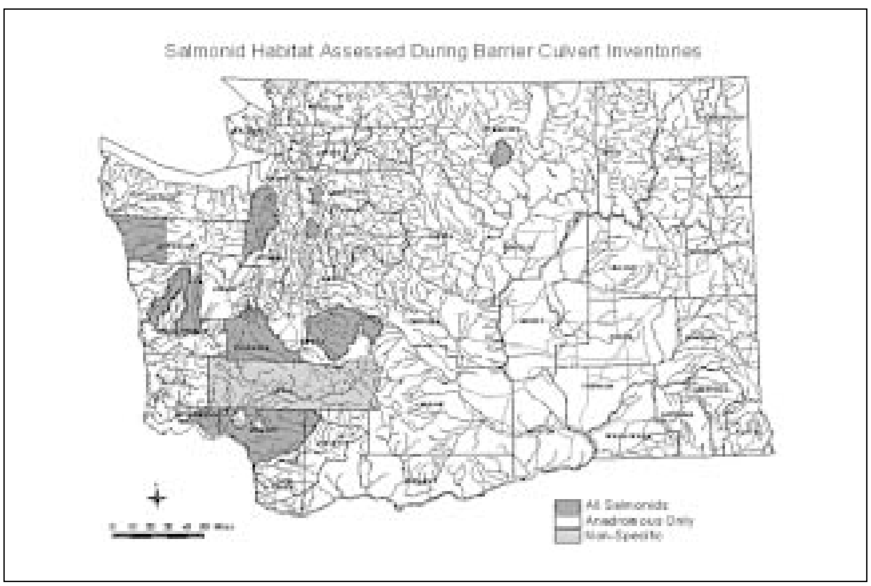
Objective 19A: Determine the current number of human-caused fish passage barriers statewide. Determine and evaluate trends in fish passage barriers (i.e., are they increasing or declining).

Objective 19B: Measure the status fish passage at identified human-caused passage barriers statewide. Evaluate their status, and the trends.

Objective 19C: Determine how effective restoring fish passage at human-caused barriers has been in increasing the geographic distribution and production of salmon as measured by the identified indicators.

Objective 19D: Measure the state's rate of compliance with fish screening requirements at human-caused barriers.

Figure 16. Example of differing culvert barrier assessment protocols



Data source: Washington Department of Fish and Wildlife SSHEAR database

Barrier Inventory

Objective 19A: Determine the current number of human-caused fish passage barriers statewide. Determine and evaluate trends in fish passage barriers (i.e., are they increasing or declining).

Monitoring indicators

The number of human-caused barriers that block or hinder fish passage.

Current monitoring activity

A number of monitoring plans and proposals have been developed to monitor fish passage (e.g. figure 16). To date, however, none have been implemented on a large scale.

The Salmonid Screening, Habitat Enhancement and Restoration (SSHEAR) database at WDFW contains and maintains information about fish passage barriers statewide. Data regarding the status of passability of barriers (total, partial, not blocking) is contained in the database for culverts and other barriers under a number of jurisdictions.

The information varies widely by WRIA and other jurisdictional boundaries. For example, some surveys have been conducted only at state highway crossings, some surveys are encompassed by county boundaries, and some by watershed boundaries.

Barrier inventories are inconsistently applied as they relate to individual species and life history stages. Some inventories are species-specific, while some size specific. A number have looked at resident fish passage, while few survey for passability for juveniles.

Essential tools

To evaluate passage problems on an annual basis will require management of a barrier database and habitat project interface to track changes to the status of barriers in real time across agencies.

Monitoring design

A comprehensive strategy for monitoring progress in removing fish passage barriers could begin with a comprehensive and consistently applied inventory of fish passage statewide. The inventory should be at the WRIA scale to accurately determine the extent of fish passage issues within Salmon Recovery Regions (SRR). All WRIAs within a particular SRR should have completed barrier inventories.

Identified agencies

The WDFW, DNR, and Washington Department of Transportation (WSDOT), USFS and the USFWS are participating agencies.

Recommended sampling protocols

Because this is an inventory, the main protocol is centered on what is considered to be a barrier. The definition of a fish barrier changes from agency to agency. The protocol should be standardized to avoid confusion and poor decisions when prioritizing projects for restoration.

➢ *Recommend using WDFW/WSDOT protocols (Washington Department of Fish and Wildlife, 1998).*

Performance benchmarks

The performance benchmark for an inventory would be the number of human caused barriers in existence.

The metric, numbers of human-caused barriers that block or hinder fish passage, can be expressed in a number of ways. Simple total number by WRIA or SRR, numbers of barriers per mile of potential habitat, or numbers of barriers per area measurement (square miles, for example).

An alternate metric is the total amount of potential habitat within a WRIA, by habitat type, that is currently blocked but could be productive if fish passage is restored at a barrier. This can also be expressed in a number of ways.

Identified monitoring gaps/ overlaps

Most WRIAs do not have comprehensive and consistently applied fish passage barrier inventories completed. There is also no combined statewide inventory of barriers.

Quality assurance/Quality control

➢ *It is recommended that a Quality Assurance (QA) Project Plan be developed by each entity conducting barrier monitoring.*

The QA Project Plan will describe the objectives of the study and the procedures to be followed to achieve those objectives. The preparation of a QA Project Plan helps focus and guide the planning process and promotes communication among those who contribute to the study. The completed plan is a guide to those who carry out the study and forms the basis for written reports on the outcome. Quality assurance for sample survey designs should include a patterned revisit to sites both within the index period of a given year and revisits to sites across years to evaluate the different components of variation. Lombard and Kirchmer (2001) present detailed guidance on the preparation of QA Project Plans. They describe 14 elements to be addressed in the plan and provide supporting information and examples relevant to the content of each element:

Risks

None identified.

Status and Trends

Objective 19B:Measure how effective the state has been in restoring fish passage at identified human-caused passage barriers statewide. Evaluate their status, and the trends.

Monitoring indicators

The annual rate of change in passability at currently identified human-caused barriers.

Current monitoring activity

A number of monitoring plans and proposals have been developed to monitor fish passage. To date, however, none have been implemented on a large scale.

The Salmonid Screening, Habitat Enhancement and Restoration (SSHEAR) database at WDFW contains and maintains information about fish passage barriers statewide. Data regarding the status of passability of barriers (total, partial, not blocking) is contained in the database for culverts and other barriers under a number of jurisdictions.

The information varies widely by WRIA and other jurisdictional boundaries. For example, some surveys have been conducted only at state highway crossings, some surveys are encompassed by county boundaries, and some by watershed boundaries.

Essential tools

- Total number of known fish passage projects by all agencies.
- Total number of identified barriers.
- Database interface that will allow tracking of fish passage projects.

Monitoring design

➢ *It is recommended that an annual enumeration of known fish passage barriers and completed projects be evaluated.*

Entry of this information into a composite database or interface, will allow tracking changes in the status of passage at human-caused barriers. This, in turn, would allow a rate of change to be calculated.

An alternate metric is the annual change in amounts and types of habitat accessible to salmon.

Identified agencies

The WDFW, DNR, and WSDOT, USFS and the USFWS are participating agencies.

Recommended sampling protocols
The definition of a fish barrier varies from agency to agency. Protocols should be standardized to avoid confusion and poor decisions when prioritizing projects for restoration.

Performance benchmarks
The performance benchmark would be the number of human caused barriers in existence that currently have not been corrected. As barriers are corrected, there should be an improvement in the overall status by showing a reduction in remaining identified barriers.

Identified monitoring gaps/overlaps
Current databases are not combined through an interface that will allow for tracking of all known barriers.

Quality assurance/Quality control
See recommendation under Objective 19A.

Risks
None identified.

Effectiveness of Barrier Removal Projects
Objective 19C: Determine how effective restoring fish passage at human-caused barriers has been in increasing the geographic distribution of salmon as measured by the identified indicators. This requires more than effectiveness monitoring, that is the thrust of the below.

Monitoring indicators
- Numbers, species, age, and physical distribution of salmonids above and below barriers with restored fish passage.

Current monitoring activity
Some monitoring of the effectiveness of barrier removal projects is underway by WDFW's SSHEAR program and others. However, there is not a coordinated approach to monitoring the effectiveness of barrier removal.

Essential tools
Sampling surveys using snorkeling or electrofishing to determine presence/absence of salmon above the barriers and mapping of locations of use.

Monitoring design
Monitoring for effectiveness of individual barrier restoration/replacement efforts, and determining changes in geographic distribution of fish resulting from barrier work, is often difficult. There are proposed methods identified in *Monitoring Approach and Procedures to Evaluate Effectiveness of Culverts in Providing Upstream Passage of Salmonids* (Cupp et al. 1999), that may be adaptable for these purposes.

Three monitoring options for measuring fish passage effectiveness are recommended below; they are not mutually exclusive.

Option one (Preferred)
We propose to measure fish use of the area upstream of the barrier through a salmon presence/absence survey. The presence of juvenile and adult fish upstream of a barrier would indicate the passage project was effective. The absence of fish upstream of a project would indicate the project was not effective. However, there is a risk of error associated with concluding that the project was not effective when no fish were found. Using fish presence/distribution as a metric for determining effectiveness of fish passage improvements has been problematic due to the many other factors affecting salmon life histories. Ocean conditions, fishery impacts, fresh water conditions, stream flows, climate, estuarine conditions, etc. all have an impact on whether fish exist in adequate numbers to utilize the rearing and spawning areas opened up. Absence, or low numbers, of fish may lead to a determination of ineffectiveness of a particular fish passage restoration effort when, in fact, the project is working fine and there simply are insufficient fish currently returning to the site for whatever reasons.

If staff and resources are available, a complete survey of all fish passage projects could be made for effectiveness. However, a less expensive, but reliable sampling regime could be implemented. It would randomly select projects and evaluate their effectiveness in passing fish. The sample size should be based upon being 95% confident that the percentage of projects found effective was within 10% of the true value. Initial sampling would only determine whether fish were present or absent above the barrier after one, two, and three years.

Option two

Relative numbers of fish upstream and downstream of barriers at which fish passage is restored may be a better approach than simply measuring presence/absence of fish. This would allow for years when there are few or no fish returning to the site. All else being equal, in years when there are more fish below a "fixed" fish passage barrier, there should be a similar number of fish above.

Option three

A third approach would be to estimate the amount of habitat of certain types available to salmon above and below barriers with restored fish passage. This approach would compare estimates of habitat availability without the inherent difficulties and costs of directly measuring anadromous salmon populations in the freshwater environment. The amounts and types of habitat above barriers with restored fish passage could be submitted to a universal habitat database. It would allow a calculation of habitat availability alone, and/or estimated numbers of smolts produced in combination with the habitat gradient and habitat type values.

Identified agencies

The WDFW, Treaty Tribes, WDNR, WSDOT, and USFS are participating agencies.

Recommended sampling protocols

Protocols have not been identified for either electrofisher or snorkeling "presence/absence" surveying.

➢ *It is recommended that spawner survey protocols (detailed in the Fish Abundance chapter) be followed for spawner abundance estimates.*

Performance benchmarks

The performance benchmark would be the number of human-caused barriers in existence that currently have the targeted species of fish utilizing habitat above the barrier as compared to a time designated as the baseline year.

Identified monitoring gaps/overlaps

There is currently no structured approach to measuring success.

Quality assurance/Quality control

See recommendation under Objective 19A.

Risks

As new habitat is made available for wild salmon production, escapement goals should be modified to reflect changes in overall watershed production capabilities. If effectiveness of barrier removal projects is not evaluated, we cannot achieve accountability for these investments. In addition, a basis for modifying spawner escapement goals will, at least in part, not be available.

Compliance Monitoring

Objective 19D: Measure the state's rate of compliance with fish screening requirements at human-caused barriers.

Monitoring indicators

Installations of fish screens.

Current monitoring activity

Placement of screening at water diversions and other instream structures is required by state law. RCW 77.55.040 states "A diversion device used for conducting water from a lake, river, or stream for any purpose shall be equipped with a fish guard approved by the director to prevent the passage of fish into the diversion device. The fish guard shall be maintained at all times when water is taken into the diversion device. The fish guards shall be installed at places and times prescribed by the director upon thirty days' notice to the owner of the diversion device."

The Department of Ecology and the WDFW attempt to monitor water withdrawals and fish screening projects. Currently screen inventories have only been completed for parts of the Columbia, and only for anadromous species (Figure 17).

Essential tools

Inventory of fish screens.

Monitoring design

Comprehensive tracking of the percentage of structures complying with fish-screening requirements will require comprehensive inventories.

- ➢ *Recommended sampling annually the known number of fish diversions for proper screening to develop a compliance rate for identified water diversions and other instream structures.*
- ➢ *Recommend sampling be conducted in a manner that a sufficient number off diversion projects are randomly selected each year to be 95% confident that the observed compliance rate is within 10% of the true compliance rate for known diversions.*
- ➢ *Recommend that stream segment surveys be randomly conducted across the state to determine the ratio of unreported to reported water diversions and instream structures.*

This statistic will allow the extrapolation of the overall compliance rate of water diversions in the state. Sampled stream segments could be incorporated into other monitoring such as EMAP to derive the ratio.

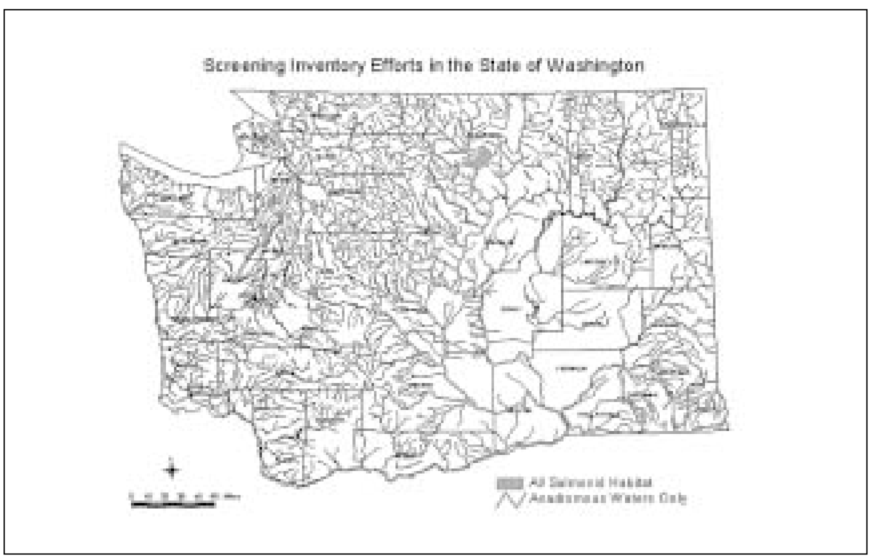
Identified agencies

The WDFW, Treaty Tribes, DNR, WSDOT, and USFS are participating agencies.

Recommended sampling protocols

None recommended at this time. Sampling protocols may have to be developed for testing screening at diversions.

Figure 17. Example of available fish screening inventories.



Data source: Washington Department of Fish and Wildlife SSHEAR database

Performance benchmarks

Performance should be measured based upon the first year of information as a baseline statistic of compliance. A policy decision can be made at that time as to what level of non-compliance the State would wish to tolerate. This would then be the benchmark for future measures of compliance success. If compliance fell below the benchmark, then additional enforcement actions may be required to bring compliance rate back in line with the compliance policy.

Identified monitoring gaps/overlaps

Fish screening inventories are not available for the majority of the state. There is no reliable water diversion screening compliance information.

The SSHIAP, which may be a valuable tool to assess monitoring information and perhaps provide a number of the metrics for measuring indicators, is currently only available for WRIAs 1-30. Much work is needed to provide this data on a statewide basis.

Quality assurance/Quality control

Quality control procedures should be developed as part of the comprehensive monitoring design.

Phased Approach

Implementing the scope of monitoring needed to adequately answer all five monitoring questions described in this document would be prohibitively expensive. It is recommended that a phased approach be undertaken. The primary focus of the initial phase should be to get a handle on the scope of the problem, and form a baseline of data for additional future monitoring.

Phase 1:

Phase 1 will conduct statistically valid random sampling of fish passage barriers that have been “fixed” to test their effectiveness in increasing the geographic distribution and production of salmonids. This will include a long-term approach to determine effectiveness of particular measures taken at fish passage barriers over time. This can be a fish enumeration approach, or a “fish production potential” approach. If it is decided to utilize the SSHIAP database, financial resources and effort will be required to provide this data for WRIAs 31-62.

Phase 2:

Conduct comprehensive and consistently applied barrier inventories in all WRIAs using WDFW/WSDOT methodologies. All information from these surveys should be housed and maintained in the SSHEAR barrier database at WDFW. Prioritizing WRIAs and Salmon Recovery Regions will be required for completion of inventories in a strategic manner as it is expensive to hire and train the staff required to ensure useful data gathering.

Data needs to be updated and maintained in real time, and annual surveys will be required to allow for monitoring of trends in fish passage restoration.

Risks

Failure to track our success in addressing fish passage at barriers and diversions could lead to lack of funding for future restoration projects because we will be unable to say whether the extensive funding already utilized has improved the status of salmon.

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D. Habitat Connectivity

Question 20: What is the progress of the state in restoring connectivity of freshwater fish habitat?

Objective 20A: Determine the current amount of freshwater fish habitat that has been disconnected by human-caused activities. Determine and evaluate trends in freshwater fish habitat connectivity.

Objective 20B: Measure how successful the state has been in implementing freshwater fish habitat connectivity restoration projects statewide.

Objective 20C: Determine how effective restoring freshwater fish habitat connectivity has been in increasing the production of salmon as measured by the identified indicators.

Objective 20D: Determine whether the measures taken at specific sites to restore freshwater fish habitat connectivity have been effective over time.

Monitoring Indicators

Monitoring progress in restoring connectivity of freshwater fish habitat is difficult, as there are many aspects to connectivity. These specific aspects are related to differences between:

(1) Species,

(2) Life history stages,

(3) Stream geomorphology,

(4) Flow regimes, and

(5) Seasonal variations.

The following are monitoring indicators for objectives 20A – 20D:

- Lateral connectivity with side channels, meander bends, old oxbows, and wetlands. This connectivity involves seasonal water flow and drainage patterns, fish distribution, and sediment transport and deposition.

Table 14. Indicators for monitoring progress in restoring freshwater fish habitat connectivity (See also Part VII B, Freshwater Habitat/Landscape Forming Processes)

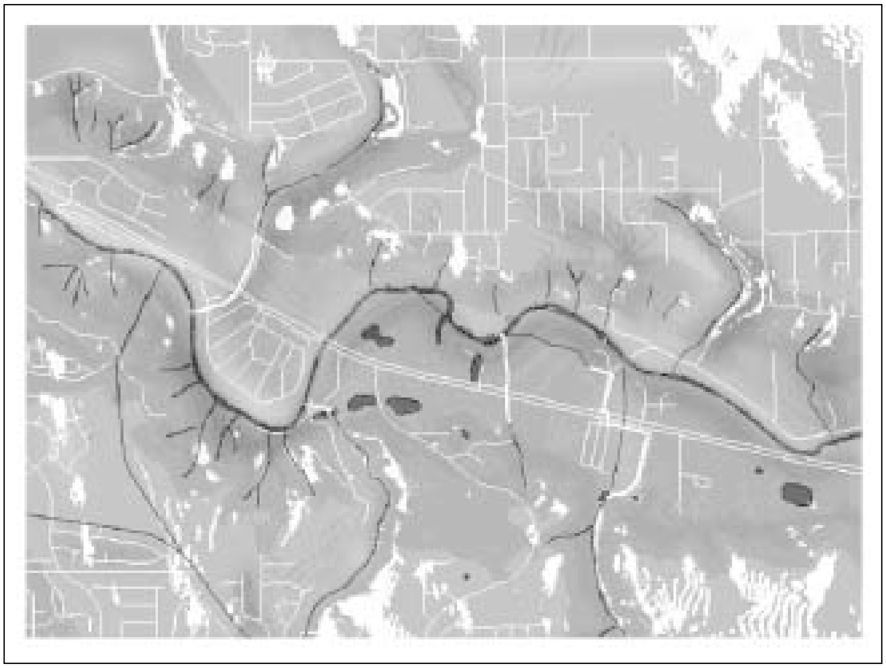
Indicator	Metric(s)	Scale(s)	Method(s)	Frequency	Type
20A: The amount of fresh – water habitat, and the type of habitat (gradient, confinement, side channel, wetland, etc.) that has been disconnected as a result of human-caused activities such as diking, roads, ditching, etc. The annual change in amounts and types of habitat lost or gained. **(Phase 1)**	Linear or area measurement of specific habitat types disconn-ected	1:24,000 WRIA ESU SRR Statewide	SSHIAP Hydro modification Assessment (Alternately some newly developed remote sensing GIS-based tool)	Annual	Professional training required

Indicator	Metric(s)	Scale(s)	Method(s)	Frequency	Type
20B: The general trend in freshwater habitat connectivity. Are we gaining or losing ground over time? **(Phase 1)**	General overall linear or area measurements Lost/gained habitat	1:24,000 WRIA ESU SRR Statewide	SSHIAP (Alternately some newly developed remote sensing GIS-based tool)	Annual	Professional training required
20C: Changes in the distribution of salmon as a result of work done to restore freshwater habitat connectivity. **(Phase 2)**	Counts of fish (juvenile/adult)	1:24,000 Site specific	To be determined with fish group	Before and after	Professional training required
20D: The annual rate of change in amount and types of freshwater fish habitat for a given restoration treatment. **(Phase 3)**	Specific linear or area measurements	1:24,000 1:12,000 Site specific	TBD	Annual	Professional training required

Current monitoring activity

Connectivity of freshwater fish habitat has been steadily compromised over the past hundred years. Development in floodplains, construction of roads, dikes and levees, ditching, and draining of wetlands have taken a toll on habitat connectivity. Habitat has been physically isolated, lost, or degraded, and flood flows have been confined to the main channel, changing the overall riverine ecosystem (Figure 18). To date, there has been very little monitoring of freshwater habitat connectivity status.

Figure 18. Depiction of loss of lateral connectivity within the floodplain. Shows diking of the mainstem, ditching of tributaries, and constructing of roads.



Data source: Northwest Indian Fisheries Commission SSHIAP database

The SSHIAP (Salmon and Steelhead Habitat Inventory and Assessment Program), a cooperative project between the WDFW and the Northwest Indian Fisheries Commission (NWIFC) for WRIA's 1-23, is a database and GIS system framework for stream habitat assessment at the 1:24,000 scale. It has been used to prioritize restoration projects, particularly culvert repair and replacements.

The SSHIAP has segmented all 1:24,000 streams from the WDNR GIS hydrology layer using TFW methodologies in WRIA's 1-23, and using a more automated method at WDFW for WRIA's 24-30. Stream segments are based on gradient, confinement, and habitat type. The project is also piloting methodologies to conduct "Hydro modification" assessments within the floodplain. This information can be used as the baseline inventory for habitat connectivity issues within a WRIA.

Methodologies to determine impacts to the hydrological regime and fish use will need to be explored jointly with other groups.

Habitat Connectivity Inventory

Objective 20A: Determine the current amount of freshwater fish habitat that has been disconnected by human-caused activities. Determine and evaluate trends in freshwater fish habitat connectivity.

Inaccessibility, or disconnectivity, of high quality and important habitats is an important factor to address with salmon restoration resources.

Essential tools

There are few tools identified for monitoring habitat connectivity. On the ground surveys are a necessity to determine the extent of the problem and to document where the future projects will be located. Remote sensing technologies are essential.

Monitoring design

➢ *Recommend implementation of a consistently applied inventory of the amounts and types of disconnected freshwater habitat.*

Inventory production will be time consuming and expensive, as much of this work cannot be done with remote sensing techniques. The SSHIAP floodplain hydro modification methodology can be used for this inventory, but is also time consuming and expensive. Work needs to be done to research a remotely sensed GIS based approach for a phase-one, broad scale look at the issue.

Identified agencies

The WDFW, tribes, and the Department of Ecology are participating agencies.

Recommended sampling protocols

Sampling protocols should be developed for tracking loss of habitat connectivity.

Performance benchmarks

Performance benchmarks in an inventory would be couched in terms of the proportion of the state where inventory has been completed.

Identified monitoring gaps/overlaps

Most WRIA’s do not have comprehensive and consistently applied inventories of the extent of disconnectivity of freshwater habitat. There is a large gap in information, and no known overlaps. Hydrology is one of the aspects of connectivity, and it is appropriate to check with the appropriate water agencies to determine their approach.

Habitat Connectivity Implementation Monitoring

For effectiveness monitoring to be most accurate, monitoring should be done after an inventory has been completed as discussed above. General trends in habitat connectivity can be used to monitor implementation of connectivity restoration efforts on a broad scale.

Objective 20B: Measure how successful the state has been in implementing freshwater fish habitat connectivity restoration projects statewide.

Monitoring indicators

Diked areas, tide gates, etc. where horseshoe bends and wetlands have been isolated from stream channels and tidal marshes. Measured in terms of linear or area measurement of specific habitat types disconnected.

Current monitoring activity

There has been very little implementation monitoring of freshwater habitat connectivity projects on a statewide basis. Some information exists in SSHIAP. The SSHIAP maintains data for WRIA’s 1-23. It is a database and GIS system framework for stream habitat assessment at the 1:24,000 scale. It has been used to prioritize restoration projects, particularly culvert repair and replacements. The project is piloting methodologies to conduct “Hydro modification” assessments within the floodplain. This information can be used as the baseline inventory for habitat connectivity implementation monitoring within WRIAs.

Essential tools
No tools are identified for monitoring habitat connectivity project implementation. Reviews of project documents and on-the-ground surveys are a necessity.

Monitoring design
➢ *It is recommended that the total number of currently identified habitat connectivity projects be compiled annually.*

The sample size should be based upon a level that will produce with 95% confidence an estimate of the percent change in the number of habitat connectivity projects implemented.

Identified agencies
The WDFW, Tribes, Lead Entities, and various counties are participating agencies.

Recommended sampling protocols
Implementation monitoring protocols should be developed.

Performance benchmarks
Performance benchmarks in habitat connectivity monitoring would be couched in terms of the baseline year proportion of the habitat connectivity projects where connectivity has been restored.

Identified monitoring gaps/overlaps
Projects are tracked by funding agencies to determine if they have been implemented. However, this information is scattered throughout various agencies and has not been compiled on a statewide basis.

Quality assurance/Quality control
A Quality Assurance/Quality Control protocol should be developed.

Risks
Since chinook salmon spawn in the lower reaches of the larger streams, habitat connectivity is very important for restoring chinook rearing areas. It is also important for coho, pink and chum salmon juveniles as well. Failure to restore channel connectivity involves a risk that other actions taken will not be in themselves sufficient to restore salmon populations.

Habitat Connectivity Validation Monitoring
Objective 20C: Determine how effective restoring freshwater fish habitat connectivity has been in increasing the production of salmon as measured by the identified indicators.

Monitoring indicators
Habitat indicators are shown in Table 14. Presence and production of salmon in areas previously disconnected and total numbers of salmon produced in the stream.

Current monitoring activity
There is no known validation monitoring occurring for habitat connectivity projects.

Essential tools
Remote sensing technologies are essential, and field surveys of habitat connectivity are also required. Estimates of the following are considered essential tools:

- Total harvest,
- Total spawners,
- Total juvenile migrants produced, and
- Total juvenile migrant produced by channel connectivity projects.

Intensively Monitored Watersheds (see Part VIII).

Monitoring design
Monitoring designs for habitat connectivity validation monitoring will depend on specific watershed circumstances in order to demonstrate cause and effect between restoration projects and fish produced. See Part VIII – Intensively Monitored Watersheds for greater details.

Identified agencies

The WDFW, Lead Entities, Salmon Recovery Regions, SRFB, and others are participating agencies.

Recommended sampling protocols

Sampling protocols should be identified as part of project design. See Part VIII.

Performance benchmarks

Performance benchmarks should be based upon what would be considered a statistically significant increase in the numbers of juvenile salmon produced. See Part VIII.

Identified monitoring gaps/overlaps

Currently there is no validation monitoring for habitat connectivity.

Quality assurance/Quality control

Procedures for Quality assurance/Quality control would be developed as part of the experimental design. See Part VIII.

Risks

It is not possible to say definitively whether projects that restore habitat connectivity actually will increase the number of salmon produced in the watershed.

Habitat Connectivity Effectiveness Monitoring

Objective 20D: Determine whether the measures taken at specific sites to restore freshwater fish habitat connectivity have been effective over time.

Monitoring indicators

Habitat indicators are found in Table 14. Presence of salmon in the restored area.

Current monitoring activity

Some effectiveness monitoring of habitat connectivity projects is occurring, but it is scattered and there is presently no way of evaluating overall progress in addressing habitat connectivity issues.

Essential tools

No essential tools for effectiveness monitoring of habitat connectivity projects. On-the-ground surveys by funding agencies are a necessity to determine the extent to which connectivity projects are effective. This will require application of the SSHIAP methods, or something similar, done at least at the 1:24,000 scale using remote sensitivity and other mapping resources.

Monitoring design

If staff and resources are available, a complete survey of all implemented habitat connectivity projects could be made for effectiveness. However, a less expensive but reliable sampling regime can be implemented that would randomly select projects for testing their effectiveness in restoring connectivity. The sample size should be based upon being 95% confident that the percentage of projects found effective was within 10% of the true value. Level one sampling would only determine whether fish were present or absent in the disconnected habitat after one, two, and three years.

Identified agencies

The WDFW, Lead Entities, Salmon Recovery Regions, and SRFB are participating agencies.

Recommended sampling protocols

Sampling protocols should be developed for effectiveness monitoring of habitat connectivity efforts.

Performance benchmarks

The performance benchmark would be the number of completed disconnected habitat projects in existence that currently have the targeted species of fish utilizing re-connected habitat.

Identified monitoring gaps/overlaps

There currently is no statewide effectiveness monitoring of habitat connectivity in existence. Some projects have monitored their effectiveness but the results are not reported.

Quality assurance/Quality control

As part of the comprehensive monitoring design, quality assurance and quality control procedures should be developed. Habitat connectivity summary recommendations

Implementing the scope of monitoring needed to adequately address habitat connectivity would be prohibitively expensive. It is recommended that a phased approach be undertaken.

Habitat Connectivity Recommendations

Phase 1 – The primary focus of the initial phase should be to get a handle on the scope of the problem, and form a baseline of data for additional future monitoring. Conduct implementation and effectiveness monitoring of already implemented projects.

Phase 2 – Conduct comprehensive and consistently applied connectivity inventories in all WRIA’s using SSHIAP floodplain hydro modification methodologies. If this proves too time consuming or costly, research is needed to determine a remotely sensed GIS based method that can provide the information at coarser scales as part of the phase one approach.

Data need to be updated and maintained in real time, and annual surveys/updates will be required to monitor trends.

Phase 3 – Conduct intensive validation studies at specific sites where restoration efforts have been targeted at reconnecting habitat, such as levee breeches, etc. These may be able to be linked with intensively monitored watersheds (see Part VIII) so that fish production changes over time can be detected and evaluated.

Risks

Without effectiveness monitoring programs, accountability cannot be obtained. In addition, failure to track our success in restoring habitat connectivity could lead to lack of funding for future restoration projects because we will be unable to say whether the extensive funding already utilized has improved the connectivity of habitat, and the status of salmon.

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E. Hydropower

Question 8: What hydroelectric facilities in each ESU are being operated and/or modified in a manner that is compatible with salmon recovery and what facilities are not?

Objective 8A: Measure the current status of major hydropower projects in regard to impacts upon salmon survival and recovery; and determine the trends. Evaluate whether they are improving.

Objective 8B: Determine how many major hydropower projects have fully implemented fish recovery measures into their operations as required in their license. Determine their status and the trends.

Objective 8C: Measure whether mitigation actions at hydro projects have been effective in restoring fish passage and other salmon recovery goals.

Monitoring Indicators

The following are monitoring indicators for Question 8:

Adult fish survival
Percent survival of adult fish through the entire project (includes tailrace, powerhouse, dam, reservoir, and all other project facilities).

Adult fish passage
Hydroelectric facilities affect the efficiency of adult passage. Projects cause fall back (the length of delay) and injuries to fish.

Juvenile fish survival
Percent survival of juvenile fish through the entire project.

Juvenile fish passage
Hydroelectric facilities impact residualism rates, delays in migration, injuries, and increase predation. Measures taken by the operator to improve fish bypass effectiveness and turbine design are also important factors for this indicator.

Water quality
The affect of the project upon water quality (i.e., temperature, dissolved gases, and dissolved oxygen).

In-stream flow regulation
Compliance with in-stream minimum flow targets, compliance with ramping rates, and impacts of reservoir management upon flow.

Fish mitigation
Evaluate whether fish mitigation meets the biological objects stated in the license agreement.

Adequacy of license
Analysis of whether the operator guidelines meet relevant biological objectives, whether it includes state agencies recommendations, whether it includes a functional monitoring and evaluation program with adaptive management and whether funding is available for all purposes including operation and maintenance and equipment.

Cumulative impacts
The number of projects upstream or downstream within the same watershed that impact fish.

Current monitoring activity

Federal Energy Regulation Commission (FERC)
Monitoring of non-federal hydroelectric facilities is currently being accomplished on a project by project basis as negotiated settlements have been reached with FERC

licensees. The Electric Consumers Protection Act of 1986, which amended Section 10 of the Federal Power Act (FPA), requires FERC, before licensing, to consider each proposed hydropower project's consistency with relevant state or Federal comprehensive plans for developing or conserving a waterway.

On April 27, 1988, the Commission issued Order No. 481-A, establishing that the Commission will accord FPA Section 10(a)(2)(A) comprehensive plan status to any Federal or state plan that:

(1) Is a comprehensive study of one or more of the beneficial uses of a waterway or waterways;

(2) Specifies the standards, the data, and the methodology used, and

(3) Is filed with the Secretary of the Commission.

Among the Federal plans in the FERC library are: watershed plans and related environmental assessments prepared by the Department of the Army, Corps of Engineers Districts and the Department of Agriculture's Natural Resources Conservation Service, plans for the protection of migratory waterfowl and unique ecosystems published by the U.S. Fish and Wildlife Service, and land and resource management plans (and related environmental impact statements) prepared by the National Forests and the Bureau of Land Management.

Examples of state-prepared plans in the FERC library are: studies of water quantity, water quality, fish management, and scenic resources of selected rivers or river segments, comprehensive management plans of river segments included in statewide scenic river systems, and state comprehensive outdoor recreation plans. Under 18 CFR, Section 4.38, each license application must identify relevant comprehensive plans and explain how and why a proposed project would, or would not, comply with such plans.

As part of FERC environmental assessments, they identify and examine relevant comprehensive plans. In each license, they include a discussion of a proposed project's consistency or inconsistency with relevant plans, and FERC may recommend mitigation measures to reduce a proposed project's conflicts with the goals of accepted plans. The Commission may include these measures in licenses. When there are major project-plan conflicts that cannot be resolved with mitigation, FERC may recommend an alternative project design or license denial.

There are at least 78 Comprehensive Plans filed with FERC pursuant to Section 10(a)(2)(A) of the Federal Power Act affecting Washington State as of April 2002. (See Appendix 3.)

Private and local projects

There are 54 private or locally owned and operated hydroelectric projects registered with FERC for Washington State waters. These projects range from major facilities such as Priest Rapids (that generates 1,755 megawatts) on the Columbia River, to small hydroprojects such as a micro hydro on Burnham Creek in Pacific County (that generates 23 kilowatts). They are distributed across Washington's Salmon Recovery Regions. (See Table 15.)

Table 15. Number of hydroelectric facilities by Salmon Recovery Region.

Salmon Recovery Region	# of hydroelectric facilities
Puget Sound	18
Coast	2
Lower Columbia	8
Mid Columbia	9
Upper Columbia	5
Northeast	5
Non Recovery Area	7

Data source: U.S. Army corps of Engineers and Federal Energy Regulatory Commission

Current monitoring occurs as part of compliance with license requirements. Licenses are issued for 50 years, so any changes to licenses have long lasting effects. The hydroelectric projects (see Table 16) will have licenses that expire on or before 2010. Projects with asterisks directly affect anadromous species.

Table 16. Licensed hydroelectric projects and expiration dates.

Facility	Expiration Date	River	Ownereship
Condit Dam*	12/31/1993	White Salmon River	PacifiCorp
Snoqualmie Falls	12/31/1993	Snoqualmie River	Puget Sound Energy
Yale*	4/30/2001	Lewis River	PacifiCorp
Trinity	11/01/2002	Phelps Creek	Trinity Conservancy Inc.
Lake Chelan*	3/31/2004	Chelan River	Chelan Co PUD #1
Priest Rapids*	10/31/2005	Columbia River	Grant Co PUD #2
Wanapum*	10/31/2005	Columbia River	Grant Co PUD #2
Merwin*	4/30/2006	Lewis River	PacifiCorp
Swift #1	4/30/2006	Lewis River	PacifiCorp
Swift #2	4/30/2006	Lewis River	PacifiCorp
Baker*	4/30/2006	Baker River	Puget Sd Power & Light
Rocky Reach*	4/30/2006	Columbia River	Chelan Co PUD #1
Sullivan Lake	9/30/2008	Sullivan Creek	Pend Oreille Co PUD #1
Packwood Lake	2/28/2010	Lake Creek	Wa Public Power Supply System

Data source: Federal Energy Regulatory Commission

State agencies, including the WDFW and Ecology, seek to condition FERC licenses with measures to protect fish, wildlife, instream flows and water quality. In the past, provisions to measure effectiveness of mitigation have been important elements of licenses. Because FERC is a federal agency, it does not necessarily have to heed recommendations of the state. Project owners have resisted efforts to require monitoring of status or trends in fish populations or habitat, seeking to keep their responsibilities to monitoring implementation and effectiveness of mitigation measures. As a result, there are no established overall monitoring programs for measuring the status of FERC licensed hydro projects as a whole in Washington State.

Federal projects

In addition to private and local hydropower projects, there are another 10 hydro projects located on the mainstem Columbia and the Snake River that do not have FERC licenses because they are federally funded and federally operated entities. The U.S. Army Corps of Engineers (Corps) operates 9 dams on the lower Columbia and Snake Rivers, and Chief Joseph Dam in the upper Columbia River. The Corps has created a Fish Management Division to evaluate fish passage operations at the dams and to act as a liaison with state agencies. The Corps is charged with monitoring fish passage, water quality, and instream flows at their facilities.

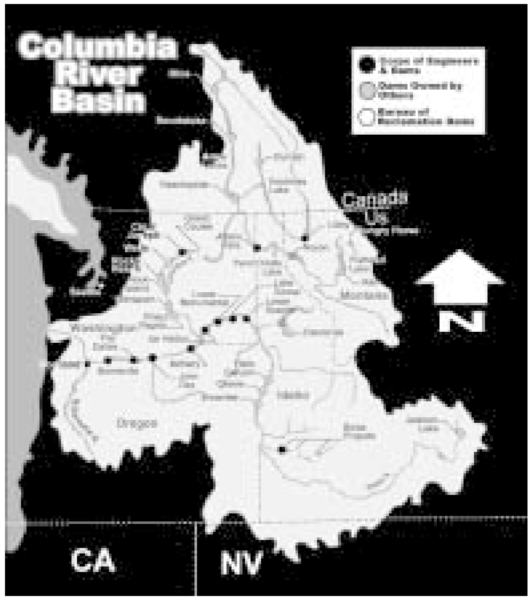
The Bureau of Reclamation operates the Grand Coulee Dam and approximately 180 other projects in the 17 Western States. The Columbia Basin Project began with fund allocation for Grand Coulee Dam pursuant to the National Industrial Recovery Act of June 16, 1933. The project was specifically authorized for construction by the Rivers and Harbors Act approved August 30, 1935. The Columbia Basin Project Act of March 10, 1943 (57 Stat. 14), reauthorized the project, bringing it under the provisions of the Reclamation Project Act of 1939. All fish are blocked from further upstream passage, so monitoring is focused upon flow and water quality requirements such as nitrogen supersaturation. Because Grand Coulee is so large, it is a major player in regulating flow on the Columbia River and providing flows for fish passage throughout the system (Figure 19).

Bonneville Power Administration (BPA)

The BPA was created in 1937 to market power produced by Bonneville and Grand Coulee dams constructed in 1938 and 1941 respectively. Today, BPA markets the power generated at 30 federal dams, one nonfederal nuclear plant at Hanford, Washington, and some nonfederal power plants, such as wind projects. The BPA funds about 500 fish and wildlife projects a year, from repairing spawning habitats to studying fish diseases and controlling predators. Projects for BPA funding are identified by the Northwest Power Planning Council's fish and wildlife program and are reviewed by an independent scientific review panel (see Part VI).

The BPA is required to protect and rebuild species listed under the ESA. In recent years, they have been required to release billions of gallons of water, once stored for winter power, from reservoirs each spring and early summer to speed the migration of young fish to the ocean and forego generation to spill water to help juvenile fish traverse the dams more safely. (The exception is in severe drought years where electricity reliability is threatened.)

Figure 19. Location of major hydropower dams within the Columbia River basin



Data source: Army Corps of Engineers

Northwest Power Planning Council (NWPPC)

The NWPPC was created by Congress to give the citizens of Idaho, Montana, Oregon and Washington a stronger voice in determining the future of key resources common to all four states, namely, the electricity generated at and fish and wildlife affected by the Columbia River Basin hydropower dams[6].

The Act is intended to:

- Assure that the Pacific Northwest have an adequate, efficient, economical and reliable power supply,
- Provide participation and consultation of Pacific Northwest states, local governments, consumers, customers, users of the Columbia River System (including federal and state fish and wildlife agencies and Indian tribes), and the public,
- Ensure development of regional plans and programs related to energy conservation, renewable and other resources, facilitating the planning of the region's power system, and providing environmental quality, and
- Protect, mitigate and enhance fish and wildlife (particularly anadromous fish) including related habitat and spawning grounds, of the Columbia River and its tributaries.

The Fish and Wildlife program of the NWPPC must:

(1) complement activities of the federal and state fish and wildlife agencies and Treaty Tribes,

(2) be based on the Best Available Science,

(3 use the least costly but most effective means of achieving biological objectives,

(4) be consistent with the legal rights of Treaty Tribes, and

(5) provide improved survival of anadromous fish and sufficient flows between facilities.

The NWPPC is required to submit an annual report to Congress that describes:

- The actions taken and to be taken by the NWPPC,

6 *Northwest Power Act and the NWPPC website (www.nwcouncil.org).*

- The effectiveness of the fish and wildlife program, and
- Potential revisions or modifications to the program.

As a result, the NWPPC has been more involved in recent years in monitoring the effectiveness of their programs.

Essential tools

None have been identified.

Monitoring design

➢ *We recommend measuring and reporting on the cumulative annual scores of the FERC licensed and federally operated hydropower projects in the state on a biennial basis per Salmon Recovery Region. By scoring each project for the key indicators, a cumulative score can be obtained as outlined in Table 17.*

Note: A score of not applicable (NA) can be used where appropriate. Where information is not available, or limited for a factor the project score for that factor should be 1 and denoted with a "?".

Table 17. Scorecard for monitoring hydropower indicators.

Criteria	5	4	SCORE 3	2	1
1.0 Adult Survival					
1.1 Survival through the project	98+%	96+%	94+%	92+%	92-%
2.0 Adult Passage (If data is available for factor 1.0 then skip factor 2.0)					
2.1 Passage efficiency	100 %	98+%	96+%	94+%	94-%
2.2 Passage type	Multiple routes w/ auxiliary water	Singe route w/ auxiliary water	Singe route w/o auxiliary water, or good Trap and Haul	limited option of passage facilities	none (if criteria 2.2 is none, then proceed to criteria 3.0)
2.3 Fallback rate	None	10%	10-15%	15-25%	25+%
2.4 Delay caused by the project	None	1-2 days	2-4 days	4-6 days	6+ days
2.5 Extent of Injury, including gas bubble trauma	None	less than 1%	1-5%	5-10%	10+%
3.0 Juvenile Survival					
3.1 Survival through the project	98+%	95+%	90+%	80+%	80-%
4.0 Juvenile Passage (If data is available for factor 3.0 then skip factor 4.0)					
4.1 Residualism	0 %	5-%	15-%	25-%	25+%
4.2 Delay caused by the project- includes tailrace and pool	12 hours or less	less than 24 hours	1-3 days	3-5 days	over 5 days
4.3 Bypass system or program effectiveness – spill or mechanical methods	95+%	90+%	80+%	70+%	70-%
4.4 Extent of injury, including gas bubble trauma	none	2% or less	5% or less	10% or less	10% or greater
4.5 Turbine type	none or not operational during passage	Improved Kaplan	Standard Kaplan	Francis	Pelton

Criteria	5	4	SCORE 3	2	1
4.6 Presence and efficiency of predators, caused by project	0%	< 2%	< 5%	< 10%	> 10%
5.0 Water Quality (Including impacts of total project – reservoir and dam and power) -B No data, or not known = 1					
5.1 Temperature	Takes action to enhance water quality for the benefit of salmonids beyond conditions mandated by standards	Meets applicable water body standards	X	Efforts to meet applicable water body standards are being made, but are falling short of the standards	Doesn't meet applicable water body standards
5.2 Dissolved gasses (TDG)	Takes action to enhance water quality for the benefit of salmonids beyond conditions mandated by standards	Meets applicable water body standards	X	Efforts to meet applicable water body standards are being made, but are falling short of the standards	Doesn't meet applicable water body standards
6.0 Flow Regulation					
6.1 Includes minimum flow targets that meet resource objectives for all life stages	all species	all salmonids and ESA listed fish	most salmonids	some salmonids	none
6.2 Compliance with meeting minimum flow targets, over 2-5 years, or since the last ranking. (either as a percentage of time or/and percentage of flows)	100%	95+%	90+%	80+%	80-%
6.3 Includes criteria regarding the rate of change in stream-flow that meets resource objectives-Considers both amplitude and rate	natural river conditions	site specific based on a ramping study(s)	state rates	some restrictions	none
6.4 Compliance with meeting flow fluctuation targets – considers both amplitude and rate over 2-5 years, or since the last ranking. (as a percentage of time)	100%	95+%	90+%	80+%	80-%
6.5 Reservoir management (impacts to reservoir rearing fish includes lack of access to tributaries, due to the project)	No project impacts to reservoir rearing fish, reservoir migrating fish, and fish below project.	Balancing of reservoir management for reservoir rearing fish, migrating fish, and fish rearing downstream of reservoir.	Impacts to only one of the following groups of fish: 1) resident fish, 2) migrating fish, 3) fish below reservoir, 4) spawning fish.	Impacts to two or more of the following groups of fish: 1) resident fish, 2) migrating fish, 3) fish below reservoir, 4) spawning fish.	No reservoir management consideration for fish, and major impacts to fish.

Criteria	5	4	SCORE 3	2	1
7.0 Mitigation For Salmonid Production And/Or Habitat Loss					
7.1 Uses native stock in artificial production program	local native stock	non local native stock	mix of hatchery and native	some native stocks used	hatchery stock
7.2 Artificial production program meets fish production goals, including naturalized production (e.g. nature ponds)	100%	95+%	90+%	80+%	80-%
7.3 Includes habitat restoration measures	100% of impacts	95+% of impacts	90+% of impacts	80+% of impacts	80-% of impacts
7.4 Meets biological objectives	100%	95+%	90+%	80+%	80-%
8.0 Adequate License Or Operation Guidelines					
8.1 Meets relevant biological objectives	100%	95+%	90+%	80+%	80-%
8.2 Includes state agencies' recommendations	All	most	some	few	none
8.3 Functional monitoring and evaluation program with adaptive management	all fish and wildlife aspects	key fish and wildlife species	fish or wildlife	little	none
8.4 Adequate funding available – includes funding for O&M and equipment	100%	95+%	90+%	80+%	80-%
9.0 Cumulative Impacts					
9.1 Cumulative impacts Impacts at other projects (either upstream or downstream) to fish that are affected by this project.	none, No other projects in watershed	minor, approximately 1-2 other projects in watershed	significant, approximately 3 other projects in watershed	major, approximately 4-5 other projects in watershed	severe, approximately 5+ other projects in watershed

Statistical criteria:

Because there are only 54 FERC hydro projects, a full census of the projects may be possible. If not, the sample design should be implemented that randomly selects a sub-sample of the FERC licensed and federal projects on a random basis such that we can be 95% certain that the status of hydropower projects in terms of fish friendliness as measured by a cumulative annual average score is within 5% of the true average score.

Identified agencies

The WDFW and Ecology are participating agencies.

Recommended sampling protocols

Refer to Table 17.

Performance benchmarks

Performance will be measured against the current conditions as a benchmark for future improvements.

Identified monitoring gaps/overlaps

There currently is not a comprehensive monitoring program in existence that reviews the status or trends in the progress of federal hydropower projects in meeting the needs of salmon recovery.

Although the federal agencies have been struggling with monitoring issues for many years, a monitoring strategy and approach is just now being developed. Both the states of Oregon and Washington have invited the NWPPC to be active participants in developing the state strategies for monitoring. It is hoped that this coordination will occur.

Quality assurance/Quality control

None identified at this time.

Risks

Without monitoring of the overall status of hydropower projects, it is difficult to determine if any progress is being made to improve survival of fish around and through hydropower projects. Since hydropower projects account for up to 90% of the juvenile mortality for some portions of the state, lack of monitoring could result in long term undetected resource damage.

F. Monitoring Stream Flow

Watershed planning strategies need adequate measurement of stream flow. In order to avoid future listings under the federal Endangered Species Act and to reduce conflicts with water users, measuring flow is a necessity. Flow gauging stations provide continuous status information, and can provide trend information in 3-5 years.

Question 13: Where have standards for water quantity been established?

Objective 13A: Measure the quantity of instream flow necessary for support of all salmon life stages.

Monitoring indicators

Derive the index of the change in usable habitat relative to the change in flow Weighted Useable Area (WUA) using the standardized approach in Stalnaker e. al. (1995).

Current monitoring activity

Instream flow monitoring for evaluating fish habitat has been conducted at 110 locations throughout Washington State. Most of these instream flow measurements were determined using the Instream Flow Incremental Methodology (IFIM) and the Toe-Width Method.

Essential tools

Instream Flow Increment Methodology and Toe-Width Method

Monitoring design

The IFIM is used nationwide and is accepted by the Department of Ecology and others as the best available tool for broadly determining the relationship between flows and fish habitat. The IFIM is a process for evaluating instream flows in the context of the entire watershed, including hydrology, geography, and biology (Stalnaker et al. 1995). The IFIM method is utilized in stream reaches that encompass a variety of life history stages. The IFIM provides more detailed information than the Toe-Width method.

The Toe-Width method was a precursor to the IFIM. The Toe-Width Method was developed in the 1970s by the former Department of Fisheries (WDF), the former Department of Game (WDG), and the U.S. Geological Service (USGS). It was developed in response to the state Legislatures request to determine minimum instream flows for fish. After the legislature passed the Minimum Water Flows and Levels law in 1969 and the Water Resources Act of 1971, the USGS collected water depths and velocities along transects over known spawning areas.

The IFIM and Toe-Width methods can be utilized once and the results are considered valid until future land use within the basin greatly alters run-off characteristics.

To fully answer Question 13, all salmon streams would need to be monitored. However, financial resources are lacking to fully implement this design. The design can be implemented in phases until resources become available to fully implement monitoring.

The following is an example of how to implement a monitoring design in phases:

- ➢ *Recommend as Phase 1: IFIM monitoring be conducted on all mainstem rivers and major tributary streams for critical watersheds identified by the Department of Ecology.*
- ➢ *Recommend as Phase 2: IFIM monitoring be conducted on all mainstem rivers and major tributary streams in remaining watersheds.*

Identified agencies

The WDFW and Ecology are participating agencies.

Recommended sampling protocols

1. Instream Flow Incremental Methodology and Physical Habitat Simulation (PHABSIM)

The IFIM involves placing site-specific stream flow and habitat data into a group of models collectively called PHABSIM (physical habitat simulation). The PHABSIM is a modeling approach and tool for use within (or separate from) IFIM.

Within IFIM are models of fish habitat as affected by hydraulics. The most common hydraulic model is IFG4, which uses multiple transects (stream cross-sections) to predict depths and velocities in a river over a range of flows. IFG4 creates a cell for each measured point along the transect or cross-section. Each cell has an average water depth and water velocity associated with a type of substrate or cover for a particular flow. The cell's area is measured in square feet. Fish habitat is defined in the computer model by the variables of velocity, depth, substrate, and/or cover. These are important habitat variables that can be measured, quantified, and predicted. When calibrating the hydraulic model, the velocity adjustment factors are limited to extrapolation between 0.80 and 1.20.

The IFM uses only four variables in hydraulic simulation. At certain flows, such as extreme low flows, other variables such as fish passage, food supply, water quality, competition between fish species, and predators may be of overriding importance. In addition to the PHABSIM models, IFIM may include reviewing water quality, sediment load, channel stability, temperature, hydrology, and other variables that affect fish production.

After the IFG4 model is calibrated and run, its output is entered into another model (HABTAT) with data describing fish habitat preferences in terms of depth, velocity, substrate, and cover. Preferences vary according to species, life-stage, and location.

The output of the HABTAT model is an index of fish habitat called Weighted Useable Area. The preference factor for each variable at a cell is multiplied by the other variables to arrive at a composite, weighted preference factor for that cell. For example, a velocity preference of 1.0 multiplied by a depth preference of 0.9, then multiplied by a substrate preference of 0.8 equals a composite factor of 0.72 for that cell. This composite-preference factor is multiplied by the number of square feet of area in that cell. When deriving fish habitat preference, the null expectation of the number of fish in each depth range is 5, based on a chi-square test.

A summation of all the transect cells' areas results in the total number of square feet of preferred habitat available at a specified flow. This quantity is normalized to 1,000 feet of stream or river. The final model result is a listing of fish habitat values, or WUA, in units of square feet per 1,000 feet of stream. The WUA values are listed with their corresponding flows (given in cubic feet per second). A WUA/flow relationship is produced for each fish species and life stage of interest.

Information generated must be evaluated with actual stream flow information to derive instream flow recommendations. The IFIM output is an evaluation tool for analyzing the habitat protected by various levels of flow.

2. Toe-Width Method

The toe-width is the distance from the toe of one stream bank to the toe of the other stream bank across the stream channel. This width of the stream is used in a power function equation to derive the flow needed for spawning and rearing salmon and steelhead.

The WDF and WDG provided the criteria and locations for salmon and steelhead spawning and rearing areas for use in this method.

The preferred spawning area, depth and velocity for each species and life stage are used to calculate the square feet of habitat at each measured flow. Points of habitat quantity at different flows are connected to create a fish habitat versus stream flow relationship. Fish habitat relationships are then compared to many different variables in the watershed to determine if there were any correlations.

The following references describe the toe-width method in detail:

(1) Swift, C.H. III. 1979. Preferred Stream Discharges for Salmon Spawning and Rearing in Washington. USGS Open-file Report 77-422. Prepared in cooperation with the State of Washington Department of Fisheries. 51 pp.

(2) Swift, C.H. III. 1976. Estimation of Stream Discharges Preferred by Steelhead Trout for Spawning and Rearing in Western Washington. USGS Open-file Report 75-155. Prepared in cooperation with the State of Washington Department of Game. 50 pp.

Performance benchmarks

Ecology is required by law to protect instream flows by adopting regulations and to manage water uses that affect stream flows. The legal and administrative definition of "instream flow" is different from base flow or stream flow. Instream flows are set through a process which engages affected parties in discussion of water management goals and the scientific data collected.

Identified monitoring gaps/overlaps

Numerous watersheds statewide have not been monitored for determining minimum instream flows for fish habitat.

Quality assurance/Quality control

The quality of data produced from IFIM, toe width, or discrete flow measurements depends largely upon the precision and reliability of the equipment used, cross section location, and sampling method.

Risks

Ecology is required by law to protect instream flows by adopting regulations and to manage water uses that affect stream flows. If instream flows are not established, there is a risk that water rights can be issued beyond the capacity of the stream to support the needs of salmon.

Once adopted, an instream flow rule acquires a priority date similar to that associated with a water right. Water rights existing at the time an instream flow rule is adopted are unaffected by the rule. Water rights issued after the rule adoption are subject to the requirements of the new instream flow rule. A "junior" water right would contain provisions requiring the diversion of water authorized by the water right to cease when the stream flow drops to the levels protected by the rule.

The State is vulnerable to litigation without a comprehensive monitoring program that establishes instream flows and assesses compliance with continuous flow measurement and metering of withdrawals.

Question 14: Where do water quantity and flow characteristics limit salmon productivity?

Objective 14A: Derive indicators of flow characteristics related to salmon productivity.

Monitoring indicators

The following indicators require the monitoring of continuous flow:

(1) Measure the annual 7-day low flow period,

(2) Derive the mean annual runoff,

(3) Derive the ratio of peak water-year flow to September 1 flow,

(4) Measure peak flow events,

(5) Derive the frequency of flows which cause redd scour,

(6) Assess the timing of the 10-day running mean flow for salmon productivity, and

(7) Assess the timing of spring (March 1-July 15) peak 10-day running mean flow for salmon productivity.

Current monitoring activity

Stream gauging for continuous flow occurs at 242 locations in the state.

Essential tools

Continuous measurement of flow is required. Information on single measurements of instantaneous flows has little value in answering Question 14 other than to establish rating curves.

Monitoring design

To fully answer Question 14, all streams with salmon would need to be monitored. However, financial resources are lacking to fully implement this design. The design can be implemented in phases until resources become fully available.

The following is an example of how to implement a monitoring design in phases:

➢ *Recommend as Phase 1: Increase the number of locations where stream flow monitoring is conducted on mainstem rivers and major tributary streams priority watersheds with insufficient gauges identified by the Department of Ecology.*

➢ *Recommend as Phase 2: Increase the number of locations where stream flow monitoring is conducted on all mainstem rivers and major tributary streams in remaining watersheds with insufficient gauges.*

Recommended sampling protocols

A single gauging station is adequate for most basins, however large watersheds with numerous salmon-bearing tributaries may require several stations to adequately characterize flow regimes.

There are two means to establish stream gauge measurements:

(1) Measuring river stage height, and

(2) Instantaneous flow measurement.

The river stage height is measured and recorded by data on a set time interval. Stream gauging is conducted with automated stage height recorders (with discrete flow measurements). This method establishes rating curves that can then be applied to instrument records which produces continuous hydrographic records.

Instantaneous stream flows are measured at least four to six times a year, and the corresponding river stage height is recorded. The instantaneous flow measurements are then plotted against river stage height to develop a rating curve. Ideally, this rating curve covers the full range of river stage height recorded during the sampling period.

While constructing regression curves or rating tables relating stage height, reference point distance, or pressure to discharge, a coefficient of determination (R-squared value) is determined that describes the unexplained variance. The probability of the regression gives a relative index of the accuracy of the determined regression. Regression curves or rating tables are not used to estimate flows that are two-times greater than the highest flow measured.

Measuring river stage height

There are three methods used to establish river stage height: (1) reference point measurement, (2) wire weight gages, and (3) staff gages:

Reference Point Measurement

A reference point (RP) is a fixed point or datum on a structure from which a measurement can made to the water's surface under all flow conditions. The distance from the RP to the water's surface is measured with a weighted fiberglass measuring tape using the following sampling method:

(1) Locate RP mark on structure (directions provided on run sheets).

(2) Lower the weighted tape until it just touches the water (a distinctive "V" should form downstream of the weight).

(3) Read the tape at the edge of the RP to nearest 100th of a foot.

(4) Record the time, RP measurement and the correction factor for the tape (written on the side of the tape) in the yellow flow book.

Wire Weight Gage

The process of measuring river stage height with a wire weight gage is almost identical to that used with RP. The only minor differences are the wire weight gage has a greater level of accuracy than does the weighted fiberglass tape and the reference point for a wire weight gage is within the gage box itself.

A wire weight gage is a self-contained, weighted, measuring device that is permanently attached to a structure. The following sampling method describes measuring river stage height with a wire weight gage:

(1) Open the Wire Weight Gage box.

(2) Take the C-Bar measurement.

(3) Lower the weight until it just touches the water (a distinctive “V” should form downstream of the weight).

(4) Read the measurement as described in B3 above.

(5) Engage the cog on the right side of the gage and wind up the weight.

(6) Record the time and the measurement in the yellow flow book.

Staff Gage

A staff gage is a graduated measuring device securely fixed to a permanent structure in the streambed from which river stage height can be read directly to the 100th of a foot. Where the flows fluctuate greatly, it may be necessary to set staff gages in series to accommodate a variety of stream levels. The following methods should be used to record staff gage measurements:

(1) Read the mean water level on the staff gage (binoculars may be required).

(2) Record the time and measurement in the yellow flow book.

Instantaneous Flow Measurement

Instantaneous flow measurements are obtained from water depth and velocity measurements. Five different sampling methods are used:

(1) Wading,

(2) From a bridge,

(3) From a boat,

(4) From a boat using a 5/8-inch sectional dod and a USGS top set wading rod, and

(5) Acoustic doppler current profiler.

Measuring Water Depths and Velocities by Wading

Equipment

- 150 ft rope
- Life vest
- Safety harness
- Swoffer Meter Model 2100
- Wading rod w/Swoffer adapter
- Flow Recording Sheet
- 300 ft Measuring Tape (Graduated in 1/10th ft)
- 100 ft Weighted Tape (Graduated in 1/10th ft)
- 2-3ft Stakes
- Garden rake
- Chest waders
- Shovel
- Machete
- Keys for USGS gages

Site selection can be the most important factor in developing accurate flow information. The following characteristics should be present at the "ideal" cross section:

(1) The stream channel should be relatively straight, non-turbulent, and free flowing for 200-300 ft both upstream and downstream of the measurement site.

(2) The stream channel should be free in-water vegetation and other in-water structures.

(3) The steam bed should be relatively uniform with only minor irregularities (no large cobble or boulders).

(4) During low flow conditions (typically Aug-Oct) the stream channel should be confined to a single course.

(5) The stream bank should be relatively stable and able to contain the maximum stream discharge (floods) and free from major seasonal scouring or deposition of bed material.

It is unrealistic to assume all stream cross sections will meet all of these characteristics. Therefore, complete and accurate field notes describing the cross section are vital when determining the relative accuracy of the discharge measurement.

Site preparation

If the cross section has excessive aquatic vegetation, large woody debris, or minor stream bed irregularities, an attempt should be made to minimize their impact on flow measurements.

This may require physical removal of interference and minor alterations of the streambed with the aid of a garden rake or shovel. After the cross section has been cleared the stream banks are inspected to insure they are confining enough to provide a distinct edge. If the streambed has a gentle sloping bank, rocks or other available material are used to make a defined steam edge. Care should be taken to insure that minimal water by-passes these structures. Do not change the section after starting a measurement as this will alter the flow characteristics and therefore the accuracy of your measurement.

Dividing the stream channel into segments

Stream discharge is approximated by multiplying the average velocity by the cross sectional area of the stream. Because most stream velocity and bottom contours vary, the cross section is divided into manageable segments. A measuring tape (tagline) is stretched across the stream perpendicular to the cross section. The tape is anchored to the surrounding vegetation\debris or to stakes driven in for attachment points. Width of the stream channel is noted and divided into conveniently measurable segments.

Ideally the total number of segments should be large enough to ensure no more than 10% of the total flow is from any one segment. For example, if the stream is relatively uniform with a width of 12 feet the distance between segment of 1 or 0.5 ft would be sufficient. If, however, the flow is unequally distributed, measuring points should be closer together where velocity or bottom irregularities are the greatest. In this case the distance would be 1 ft for uniform segments and 0.5 ft near the area of greatest variability.

Measuring stream velocity of the stream segments

Stream velocities also vary vertically. Currently two methods are used to address vertical variability within a segment, one applies with stream depths less than 1.5 feet and the other for streams over 1.5 feet in depth. For stream segments under 1.5 feet in depth the velocity is measured at sixth-tenths of the depth (six-tenths method). For streams with depths greater than 1.5 feet the velocity is measured at two-tenth and eight-tenths of the depth and the results are averaged (two-tenths/eight-tenths method).

Summary of Measuring Water Depths and Velocities by Wading

(1) Record station information.

(2) Measure and record stage height in the proper column.

(3) Select a suitable stream cross section for measurement.

(4) Determine which safety requirements are warranted based on in stream conditions.

(5) Prepare cross section by removing debris, rocks and confining stream edges.

(6) Stretch measuring tape across the stream channel perpendicular to stream flow and note total stream width.

(7) Divide stream with into segments (18-20) with no more than 10 percent in any one.

(8) Turn knob on Swoffer meter to Calibration. It should read 185-186. If it is does not change the 9 volt battery. Record the Calibration # in the proper space on the Flow Measurement Form.

(9) Install the propeller on the wading rod and tighten the Allen screw.

(10) Turn the knob on the Swoffer meter to average velocity.

(11) Measure the depth of the first segment by reading the water level on the wading rod.

(12) Adjust the wading rod to the proper depth.

a. For < 1.5 feet total depth use the scale on the wading rod to place the Swoffer sensor at 6 tenths depth.

b. For > 1.5 feet total depth, adjust the wading rod so that the Swoffer sensor is at half the total depth for the 8 tenths depth and double the total depth for 2 tenths depth.

(13) Press the start button on the Swoffer meter.

(14) Record the velocity.

(15) Continue to measure velocities by pressing the start button until 2 measurements are within 0.05 of each other or a maximum of 4 measurements have been recorded.

(16) Proceed across the stream and repeating steps 11-15 at each segment.

(17) Upon completion of the flow measurement turn the knob on the Swoffer meter to Calibration and record the number.

(18) Remove the propeller assembly from the wading rod.

(19) Measure and record the stage height.

2. Measuring Water Depths and Velocities From a Bridge

Equipment

- Bridge Board or Crane with attachments
- Type “A” or Type “B” Reel
- Swoffer Meter Model 2100
- Flow Recording Sheet
- 300 ft Measuring Tape (Graduated in 1/10th ft)
- 100 ft Weighted Tape(Graduated in 1/10th ft)
- Lead fish
- Warning Signs and Cones
- Keys for USGS Gages
- Weighted Tape

Measuring stream velocity and dividing the stream channel into segments

Measuring discharge from a bridge is almost identical to the in-stream discharge measurement discussed above, the only difference being the equipment used to position the flow measuring sensor. The bridge method also uses the Swoffer current meter to determine in-stream velocities. The flow sensor is suspended below weighted lead fish (Columbus or C-type weights) and is raised and lowered using a type "A" or type "B" USGS reel attached to a bridge board or portable bridge crane. The stream is divided into segments and velocities with respect to depths are measured the same when measuring from a bridge or when wading.

Summary of Measuring Water Depths and Velocities from a Bridge

(1) Record station information.

(2) Measure and record stage height in the proper column.

(3) Determine which safety requirements are warranted based on bridge walkways

(4) Determine the weight of the lead fish required to measure the flow.

(5) If the lead weight is < 50 lbs a bridge board should be used. If the lead weight is > 50 lbs then the bridge crane should be used.

(6) Stretch measuring tape across the stream channel perpendicular to stream flow and note total stream width.

(7) Divide stream with into segments (18-20) with no more than 10 percent in any one.

(8) Turn knob on Swoffer meter to Calibration. It should read 185-186. If it is does not change the 9 volt battery. Record the Calibration # in the proper space on the Flow Measurement Form.

(9) Install the propeller on the wading rod and tighten the Allen screw.

(10) Turn the knob on the Swoffer meter to Ave. Velocity.

(11) Measure the depth of the first segment by zeroing the depth dial at the water surface (back fin of the weight is level with the water surface) and lower the weight until it touches the stream bottom.

(12) Record the depth in the proper column of the Discharge Measurement Notes Form.

(13) Adjust the lead fish to proper depth. See Flow Depth Correction Sheets.

a. For < 2.5 feet total depth use the 6 tenths depth correction sheets.

b. For > 2.5 feet total depth use the 8 tenths depth and 2 tenths depth correction sheets.

(14) Press the start button on the Swoffer meter.

(15) Record the velocity.

(16) Continue to measure velocities by pressing the start button until 2 measurements are within 0.05 of each other or at least 4 measurements have been recorded.

(17) Proceed across the stream and repeating steps 11-15 at each segment.

(18) Upon completion of the flow measurement turn the knob on the Swoffer meter to Calibration and record the number.

(19) Remove the propeller assembly from the lead fish.

(20) Measure and record the stage height.

Measuring Water Depths and Velocities From a Boat

Equipment

- USGS Boat Equipment-Model 4600 (boom and cross-piece assembly
- USGS Type "A" or "B" sounding reel
- Swoffer Flow Meter Model 2100
- Marsh-McBirney Model 2000 flow meter (used under special situations)
- 5/8-inch aluminum hand held top-set flow measuring rod (4 ft sections)
- USGS Top Setting Wading Rod
- 300 ft measuring tape (graduated in 1/10th ft)
- 100 ft measuring tape (graduated in 1/10th ft)
- Kevlar rope (tag-line) and spool
- Nylon straps
- Kevlar boat tagline cable harness
- USGS sounding weights (lead fish) available in 7, 15, 30, 50, or 75 lbs
- Cable grips
- Fence posts and maul
- Warning floats and anchors

Boat Measurement Equipment Set-up

(1) After locating a suitable cross section for flow monitoring, anchor the warnings floats approximately 500 feet above and below the intended cross-section or if necessary, use a spotter.

(2) On shore, insert the boom and cross-piece assembly into the oar-lock sockets and secure with the through bolts and nuts. When assembled, the boom should lie atop of the bow and be secured to the cross-piece assembly. Arrows drawn on the cross-piece assembly identify which side of the assembly faces toward the bow of the boat.

(3) The flow gear set-up starts from the opposite shore from where you intend to start the flow measurement, working from the downstream side of the cross-section with the bow orientated upstream.

(4) The deck hand locates the tree to be used, or drives a fence post at an angle slightly away from the stream when trees are not available. Wrap a nylon strap around the tree, connect the Kevlar cable harness and then attach the end of the Kevlar rope (tag line) into the harness. Persons handling the tag line should always wear gloves made of leather or cotton.

(5) With the deck hand in the bow of the boat holding the tag line and spool, the boat operator maneuvers the boat across the stream while maintaining an upstream orientation.

(6) On the opposite bank, attach the second nylon strap to an available tree or fence post. Attach the cable harness and come-along to the strap. Pulling the tag line to take up slack, place the line into the cable harness. Crank in the come-along to tighten the tag line firmly enough to not allow up and downstream movement of the boat. For visibility the tag line should be flagged with brightly colored surveyor tape at about 2-meter intervals.

(7) With the boat facing upstream, hook the tag line to one side of the guide spindle and clamp into position. Repeat the procedure with the opposite guide spindle. This allows horizontal movement along the cross section by hand pulling the tag line to position the boat. To maintain position along the tag line, the cable clamp affixed to the crosspiece should be clamped to the tag line.

Measuring Water Depth and Velocity from a Boat using The Boat Measurement Equipment. Measuring discharge from a boat is almost identical to the in-stream discharge measurement discussed above, the only difference being a boat is used to position the flow measuring sensor with respect to the streams cross section.

The Boat Measurement Method also uses the Swoffer current meter suspended below weighted lead fish (Columbus or C-type weights) that is raised and lowered using a type "A" or type "B" USGS reel. The stream is divided into segments and velocities with respect to depths are measured the same when measuring from a bridge or when wading. For conditions which the 5/8-inch top-set rod and USGS rod cannot be used (depth > 10 ft or velocities > 2 feet per second), use the boom and cross-piece assembly gear, sounding-reel, and appropriate weighted fish.

The operating procedures for this equipment are described in the previous section. The deck hand can verify the fish (and velocity sensor) is oriented upstream when the fish contacts the water surface. This is particularly important in streams with low velocities. In fact, even when the fish is not visible, the deck hand can hold the cable from the velocity sensor forward (upstream), ensuring proper orientation. When a single operator is alone in the boat the tender verifies fish orientation and when the fish contacts the water surface.

Summary of Measuring Water Depths and Velocities from a Boat

(1) Record station information.

(2) Measure and record stage height in the proper column.

(3) Determine which safety requirements based on in-stream conditions.

(4) Determine the weight of the lead fish required to measure the flow.

(5) Divide stream with into segments (18-20) with no more than 10 percent in any one.

(6) Turn knob on Swoffer meter to Calibration. It should read 185-186. If it is does not change the 9 volt battery. Record the Calibration number.

(7) Install the propeller on the wading rod and tighten the Allen screw.

(8) Turn the knob on the Swoffer meter to Ave. Velocity.

(9) Measure the depth of the first segment by zeroing the depth dial at the water surface (back fin of the weight is level with the water surface) and lower the weight until it touches the stream bottom.

(10) Record the depth.

(11) Adjust the lead fish to proper depth. See Flow Depth Correction Sheets
   a. For < 2.5 feet total depth use the 6 tenths depth correction sheets.
   b. For > 2.5 feet total depth use the 8 tenths depth and 2 tenths depth correction sheets.

(12) Press the start button on the Swoffer meter.

(13) Record the velocity.

(14) Continue to measure velocities by pressing the start button until 2 measurements are within 0.05 of each other or a maximum of 4 measurements have been recorded.

(15) Proceed across the stream and repeating steps 11-15 at each segment.

(16) Upon completion of the flow measurement, turn the knob on the Swoffer meter to Calibration and record number.

(17) Remove the propeller assembly from the lead fish.

(18) Measure and record the stage height.

Measuring Water Depth and Velocity from a Boat using a 5/8-inch Sectional Rod and a USGS Top Set Wading Rod

Equipment

- USGS Top-Set Wading Rod – For depths up to 4 feet and velocities less than 4 feet per second the USGS top-set wading rod can be used. To use the USGS top set rod from a boat is identical to that used while wading. The total depth is measured directly from the rod and the scale on the wading rod is used as a guide to adjust the sensor to the proper depth. For stream segments under 1.5 feet in depth the velocity is measured at sixth-tenths of the depth (six-tenths method). For streams with depths greater than 1.5 feet the velocity is measured at two-tenth and eight-tenths of the depth and the results are averaged (two-tenths/ eight-tenths method).

- Sectional 5/8- inch Rod- The 5/8-inch top-set wading rod can be used within cross-sections up to 10 feet deep with velocities less than 2 feet per second. The rod is pieced together with 4 feet sections. Depth is measured by lowering the rod to the stream bottom then reading the 1/10ths ft increments graduated on the rod. Once depth is known, the operator raises the rod to the surface and sets the adjustable sensor unit to the appropriate depth. For depths less than 1.5 feet, the 6/10ths setting is used. For depths greater than 1.5 feet, set the sensor at the 2/10ths and 8/10ths locations on the graduated rod. Note: Calculate Depths Directly Do Not Use Flow Depth Correction Sheets. Once both measurements are achieved move to the next measuring location.

Measuring Water Depth and Velocity from a Boat using The Boat Measurement Equipment.

Measuring discharge from a boat is almost identical to the in-stream discharge measurement discussed above, the only difference being a boat is used to position the flow measuring sensor with respect to the streams cross section. The Boat Measurement Method also uses the Swoffer current meter suspended below weighted lead fish (Columbus or C-type weights) that is raised and lowered using a type “A” or type “B” USGS reel.

The stream is divided into segments and velocities with respect to depths are measured the same when measuring from a bridge or when wading. For conditions which the 5/8-inch top-set rod and USGS rod cannot be used (depth > 10 ft or velocities > 2 feet per second), use the boom and cross-piece assembly gear, sounding-reel, and appropriate weighted fish.

The operating procedures for this equipment are described in the previous section. The deck hand can verify the fish (and velocity sensor) is oriented upstream when the fish contacts the water surface. This is particularly important in streams with low velocities. In fact, even when the fish is not visible, the deck hand can hold the cable from the velocity sensor forward (upstream), ensuring proper orientation. When a single operator is alone in the boat the tender verifies fish orientation and when the fish contacts the water surface.

Summary of Measuring Water Depths and Velocities from a Boat using a 5/8-inch Sectional Rod and a USGS Top Set Wading Rod.

(1) Record station information.

(2) Measure and record stage height in the proper column.

(3) Determine which safety requirements based on in-stream conditions.

(4) Divide stream with into segments (18-20) with no more than 10 percent in any one.

(5) Turn knob on Swoffer meter to Calibration. It should read 185-186. If it is does not change the 9 volt battery. Record the Calibration number.

(6) For 5/8 -inch Rod Only – Determine the number of section of rod you will need for the depth of the stream.

(7) For 5/8-inch Rod Only – Install Swoffer sensor in plastic housing and adjust thumb screw.

(8) Install the propeller on the rod assembly and tighten the Allen screw.

(9) Record the depth.

(10) Adjust the Swoffer sensor to proper depth.
  a. For < 1.5 feet total depth use the 6 tenths depth correction sheets.
  b. For > 1.5 feet total depth use the 8 tenths depth and 2 tenths depth.

(11) Press the start button on the Swoffer meter.

(12) Record the velocity.

(13) Continue to measure velocities by pressing the start button until 2 measurements are within 0.05 of each other or a maximum of 4 measurements have been recorded.

(14) Proceed across the stream and repeating steps 11-15 at each segment.

(15) Upon completion of the flow measurement turn the knob on the Swoffer meter to Calibration and record the number.

(16) Remove the propeller assembly from the rod assembly.

(17) Measure and record the stage height.

Calculating Stream Discharge

A rating curve is developed that relates river stage height to instantaneous flow. Instantaneous flow measurements and corresponding stage heights are taken four to six times a year. The rating curve is produced using regression analysis of instantaneous flow measurement and stage height.

Providing the timing of these four to six instantaneous measurements covers the entire range of stage heights measured during the year. If the stream bed has been unaltered by sediment deposition or erosion, a reasonably accurate rating curve can be expected.

If the rating curve does not cover the full range of the stage recorded, the curve can be extended to equal twice the lowest or highest measurement recorded. Any extension of the curves beyond this will only be used to estimate flow and the corresponding flow numbers will be qualified to signify they are only an estimate.

Performance benchmarks

Identified indicators are simple metrics which can be derived from continuous flow records.

There are no widely accepted benchmarks that relate these metrics to specific salmon productivity.

Identified monitoring gaps/overlaps

Numerous mainstem rivers and major tributary streams in the state do not currently have stream gauging of continuous flows.

Quality assurance/Quality control

Quality assurance and quality control include three main elements:

(1) A written procedure manual – Ecology has a written protocol for flow measuring work. This protocol is reviewed semi-annually to ensure it remains current. New personnel are required to read the document before they begin training. All staff are required to attend a field technique review section annually.

(2) A method for tracking calibration of flow meters – Ecology is currently preparing documentation for quality assurance during calibration of flow meters. This documentation is expected by January 2003.

(3) A blind comparison of flow information generated by USGS – Ecology is currently preparing documentation for conducting blind comparisons of flow information generated by different monitoring entities. This documentation is expected by January 2003.

Risks

Ecology needs continuous flows for all mainstem rivers and major tributary streams to comprehensively manage instream flow laws. The State is vulnerable to litigation without a comprehensive monitoring program to assess compliance with measurement of continuous flows.

Question 15: What are the trends in water quantity and flow characteristics?

Objective 15A:Measure the change over time in identified water quantity and flow characteristics.

Monitoring indicators

The following are monitoring indicators for Question 15:

(1) Time series of water quantity measurements are evaluated for trends,

(2) Time series of annual 7-day low flow period evaluated for trends,

(3) Time series of frequency of flows which cause redd scour evaluated for trends,

(4) Time series of peak flow events evaluated for trends,

(5) Time series of mean annual runoff evaluated for trends, and

(6) Time series of ratio of peak water-year flow to September 1 flow evaluated for trends.

Current monitoring activity

Stream gauging currently occurs at 242 locations throughout the state.

Essential tools

Continuous measurement of flow is required. Information on single measurements of instantaneous flows has little value in answering Question 15 other than to establish rating curves.

Monitoring design

Large watersheds with numerous salmon-bearing tributaries may require several stations to comprehensively characterize flow regimes. Trends in the flow indicators are likely to take more than 10 years to detect due to climatic cycles or because of high annual variability (Konrad and Booth 2002).

Identified agencies

Department of Ecology and Department of Fish and Wildlife.

Recommended sampling protocols

Recommended sampling protocols are the same as described previously for Question 14.

Performance benchmarks

Performance benchmarks are the same as described previously for Question 14.

Identified monitoring gaps/overlaps

Identified monitoring gaps and overlaps are the same as described previously for Question 14.

Quality assurance/Quality control

Quality assurance and controls are the same as described previously for Question 14.

Risks

Ecology needs continuous flow information for all mainstem rivers and major tributary streams to comprehensively manage water resources. Information on trends in flows is needed to evaluate whether water management programs are effective and contribute to recovery of salmon. Without sufficient flows, salmon and other aquatic plants and animals will cease to exist in Washington's rivers and streams.

Question 16: How effective are the State's water resource management programs for protecting and restoring instream flows?

Objective 16A: Measure identified indicators related to the performance of managing water resources.

Monitoring Indicators

The following are monitoring indicators for Question 16:

(1) Measure the number of days annually during which minimum instream flows are met,

(2) Measure the amount of water withdrawn by watershed and compare it to the amount authorized by water rights, and

(3) Derive the volume of water restored to salmon streams where water availability and flows are limiting factors (Salmon Scorecard indicator D1).

Current monitoring activity

Stream gauging for continuous flows occurs at 242 locations throughout the state and monitoring for minimum instream flows has been conducted at 110 locations.

The volume of water restored to salmon streams where water availability and flows are limiting factors is derived for the Salmon scorecard indicator D1.

Essential tools

Continuous measurement of flow is required. Information on single measurements of instantaneous flows has little value in answering Question 14 other than to establish rating curves.

Monitoring design

All of the indicators identified entail the assessment of data collected from stream flow, the metering of water withdrawals, established instream flows, and programmatic information.

Identified agencies

The WDFW and Ecology are participating agencies.

Recommended sampling protocols

Sampling protocols recommended for measuring the quantity of flow required by salmon are discussed in Question 13.

Sampling protocols recommended for measurement of continuous flow measurement are discussed in Question 14.

Performance benchmarks

Ecology is required by law to protect instream flows by adopting regulations and to manage water uses that affect stream flows. All surface waters should have instream flow requirements on representative surface waters.

Ecology is required by law to obtain information on all water withdrawals. All water withdrawals should be metered.

Identified monitoring gaps/overlaps

Numerous watersheds do not have stream gauging for continuous flows Numerous basins statewide have not been monitored to determining minimum instream flows for fish habitat.

Most water withdrawals are not metered. While Ecology is required under RCW 90-82-070 to obtain withdrawal information, efforts are often hampered by the logistical and political difficulties of metering as well as the long-standing problems of adjudication.

Quality assurance/Quality control

Quality assurance and quality control for this question are similar to those previously described in Question 14.

Risks

Risks for this question are similar to those previously described in Question 14.

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G. Monitoring For Clean Water

Quality of Surface Water

Question 9: What is the quality of surface water?

Objective 9A: Measure status of identified water quality indicators.

Objective 9B: Measure status and trends of water quality in agriculture, forest and urban areas.

Monitoring Indicators

The following indicators are currently measured in the field for conventional water quality and assessing the support of aquatic life uses:

(1) Dissolved oxygen,

(2) Temperature,

(3) pH, and

(4) Turbidity.

Sanitary water quality indicators for assessing support of recreational uses are measured in laboratory analysis. These include:

(1) Fecal coliform,

(2) E.coli, and

(3) Enterococci bacteria.

Trophic water quality indicators measured for freshwater include:

(1) Total phosphorus,

(2) Total nitrogen,

(3) Cholorphyll-a, and

(4) Water clarity.

Trophic water quality indicators measured for marine water include:

(1) Dissolved inorganic nitrogen, and

(2) Ammonium.

Ecology and the Puget Sound Action Team (PSAT) have developed several indices which combine several indicator measurements into a single rating:

(1) Stream Water Quality Index (WQI). Multiple indicators of water quality are combined to produce a single score for each stream or river. The index is represented by numbers ranging from 10 to 100 that is intended to represent the general water quality. The higher index numbers are indicative of better water quality.

(2) Marine Water Quality Gradient of Concern. Multiple indicators of marine water quality are combined to produce a relative scale. The "gradient of concern" ranks stations from low to very high based on the summed value of five indicators of environmental status.

(3) Sediment Quality Index. A weight-of-evidence index used to characterize the sediments throughout Puget Sound based on the "sediment quality triad" of chemical contaminant and toxicity levels, and the composition of the invertebrate assemblages living in the sediments.

Biological health indicators are derived from measurements of the following:

(1) Observed stream benthic communities compared to those expected for wadeable streams,

(2) Periphyton assemblage (changes in species composition, cell density, chlorophyll, and enzyme activity, and

(3) Aquatic vertebrate assemblage (species composition, relative abundance, incidence of external pathological conditions).

Current monitoring activity

There are two water monitoring programs in the state with a monitoring design allowing the estimation of conditions over broad areas:

- Ecology is currently in partnership with the EPA to conduct an integrated and comprehensive assessment of streams and marine areas. The Environmental Monitoring and Assessment Program (EMAP) employs a probability-based sampling design, and random sampling to estimate the condition of marine and freshwater resources. The freshwater component measures metrics of benthic macroinvertebrates, aquatic vertebrates, and periphyton in streams and collects limited physical, chemical, and habitat information. The marine water component measures water column indicators, sediment characteristics and toxicity, benthic organisms, and data from fish trawls to describe current conditions.

- Ecology also conducts the Marine Sediment Monitoring Component of the Puget Sound Ambient Monitoring Program (PSAMP). The program uses a sample survey design to estimate the condition of sediment quality in various sampling regions throughout Puget Sound. From this sampling, a baseline of simultaneously sampled sediment chemistry, toxicity, and invertebrate assemblage data is being compiled for Puget Sound.

Essential tools

Appropriate monitoring designs to answer Question 9 are not used for most surface water quality monitoring programs. To answer the question, one must conduct a "representative" assessment of the surface waters of interest.

The sample survey approach is a way of collecting information on a subset of the surface waters to make estimates of the entire population of surface waters. These estimates differ from information obtained through a census because they contain a level of uncertainty based on the sample size.

Monitoring design

Question 9 is phrased as the general public might initially pose the issue. The question serves as the basis for initiating the design of the monitoring program. As the monitoring program is developed, the question will be found to too general to complete the design. The design serves to explicitly define specific parameters related to the question.

The monitoring design for Question 9 focuses on four target populations of surface waters:

(1) Streams,

(2) Rivers,

(3) Lakes (defined as discrete populations),

(4) Estuaries (defined as continuous populations), and

(5) Near coastal waters (defined as continuous populations).

Wetland areas are not included in the target populations. Rivers and streams are divided into 62 sub-populations, based on WRIAs. Lakes are divided into 8 sub-populations based on ecoregions. Estuaries are divided into these 4 sub-populations:

(1) Outer coastal estuaries,

(2) Puget Sound,

(3) Intertidal zone, and

(4) Coastal waters.

Sample frames for target populations are based on 1:100K scale as follows:

(1) Rivers (unwadeable)

(2) Streams (wadeable, perennial waters only),

(3) Lakes (20 acres or larger in area including reservoir impoundments, except those with 15 days or less mean detention time as per WAC 173-201A-20),

(4) Coastal waters (10-120 depth contour of Strait of Juan de Fuca and coast of Washington), and

(5) Intertidal waters (mean low water to mean high water).

Adjustments to the size of the target resource of each subpopulation will be made based proportions found during sampling reconnaissance. For example, streams may be found to be unwadeable or intermittent.

Sampling locations are selected using a spatially-balanced, random selection based on procedures defined by the EMAP Program. Samples are collected during an index period that represents critical conditions for the indicators monitored. The index period for EMAP is from July through September. The index period for PSAMP sediment monitoring is during the month of June.

Post-stratification of the results will be used to infer estimates of conditions in each general land use: agricultural, forested, and urban areas. Sample frames for land use categories are defined as the GIS coverage polygons from the 1997 USGS Generalized Level 1 Land Use/Land Cover. Watersheds with over 50% coverage of a particular land use upstream of the station will be used for estimation of flow condition for that land use.

The condition of the specified subpopulations will be inferred from the sample estimates, with a specified sampling uncertainty. Inferences of conditions will be prepared for the proportion of the subpopulation not meeting the identified performance benchmark. The proportion of the waters in the subpopulation not meeting the identified performance benchmarks will be estimated. Precision of the estimates will be based on resulting sample size with a 90% confidence level.

To fully answer monitoring questions, all 340 indicators (with numeric criteria adopted in State rule or federal regulation) would have to be monitored. However, financial resources are lacking to fully implement this design. The design can be implemented in phases until resources are fully available.

Identified agencies

The DNR and Ecology are participating agencies.

Recommended sampling protocols

Table 18 summarizes protocols for sample measurements and their associated references. See the end of this chapter for full reference section.

Table 18. Protocols for sample measurement.

Parameter measured	Protocol reference
Dissolved oxygen, temperature, pH, turbidity, total phosphorus, total nitrogen, fecal coliform and enterococci bacteria in streams	Ward et al. (2001).
E. coli bacteria in streams	Patterson and Dickes (1993)
Conventional indicators in lakes	Smith el al. (2000)
Sampling of stream benthic macroinvertebrates	Plotnikoff, R. and C. Wiseman. 2001.
Edible fish tissue from freshwater	Serdar et al. (2001)
Identified toxic indicators	Puget Sound Water Quality Action Team. (1997)
Recommendations for Measuring Organic Compounds in Puget Sound Marine Water, Sediment and Tissue Samples	Puget Sound Water Quality Action Team. (1997)
Assessing the Quality of Aquatic Environments	Cusimano (1994)
Standard Methods for the Examination of Water and Wastewater	American Public Health Association. (1998)
Protocols used for assessing shellfish growing waters	National Shellfish Sanitation Program Model Ordinance. (1999)
Recommendations for Sampling Marine Sediment, Water Column, and Tissue in Puget Sound	Puget Sound Water Quality Action Team. (1997)
Protocols for measurement of identified indicators in marine waters	Janzen (1992)
Protocols for measurement of identified indicators needed for the Marine Sediment Quality Index	Dutch, et al.. (1998)

Performance benchmarks

There are numeric criteria for the 4 conventional field indicators (dissolved oxygen, temperature, pH, turbidity, and total dissolved gas) adopted in state rule (Chapter 173-201A-040 WAC). Fecal coliform bacteria are currently the only sanitary indicator currently adopted as in state rule (Chapter 173-201A-040 WAC). The State has additionally proposed adopting numeric criteria for E.coli and enterococci bacteria by 2002.

There are numeric criteria for 28 toxic substances in water adopted in state rule (Chapter 173-201A-040 WAC). Numeric criteria for 47 toxic substances in marine sediments have been adopted in state rule (Chapter 173-201A204-040 WAC).

Numerous pesticides currently being used have no numeric criteria promulgated in state rule. Numeric criteria for indicators of biological health have not been adopted in state rule. However, the narrative criteria in the water quality standards can be used to evaluate if uses designated for protection are impaired (Chapter 173-201A-040 WAC).

Federal regulations have been promulgated for Washington State adopting criteria for freshwater trophic state indicators and toxic substances for protection of human health. The federal regulations summarized in Table 19 apply until the state adopts other criteria as part of the water quality standards.

Table 19. Numeric criteria and associated federal regulation.

# of numeric criteria	Regulation type and number
126 toxic substances in fish tissue	40 CFR Part 131
126 toxic substances in water	40 CFR Part 131
4 trophic state indicators (total phosphorus, total nitrogen, chlorophyll-a, and water clarity) in freshwaters	66 CFR Part 1671

Identified monitoring gaps/overlaps

Most of the indicators identified with regulatory performance benchmarks are not measured using a sample survey design. As such, information about region-wide status and trends is not available for most of these indicators.

Federal regulations for 126 toxic substances in water and tissue can be duplicative if monitored in both media. The performance benchmarks are linked by a bioconcentration factor, so that only one media is needed to be monitored for each indicator.

There are no identified performance benchmarks for indicators of biological health in unwadeable streams and rivers. There are no performance benchmarks for toxic concentrations in tissue to protect aquatic life.

Quality assurance/Quality control

A Quality Assurance (QA) Project Plan should be developed by each monitoring entity. The QA Project Plan should describe the objectives of the study and the procedures to be followed to achieve those objectives. The preparation of a QA Project Plan helps focus and guide the planning process and promotes communication among those who contribute to the study.

The completed plan will serve as a guide for future studies and forms the basis for written reports. Lombard and Kirchmer (2001) presents detailed guidance on the preparation of QA Project Plans. It describes 14 elements to be addressed in the plan and provides supporting information and examples relevant to the content of each element:

To ensure adequate quality assurance and quality control procedures, all indicators requiring laboratory analysis should be sent to an accredited State of Washington laboratory. The Environmental Assessment Program (1994) describes procedures for implementing Ecology's Environmental Laboratory Accreditation Program established under provisions of RCW 43.21A.230 and Chapter 173-50 WAC.

Risks

Without collection of the identified indicators with regulatory performance benchmarks using an appropriate monitoring design (i.e., sample survey), estimates of conditions cannot be made over the scales of interest. Due to the lack of funding for this monitoring, the federal requirements under Section 305(b) of the Clean Water Act (CWA) have never been adequately met by the state.

Changes Over Time of Surface Water Quality

Question 10: How are surface water quality conditions changing over time?

Objective 10A: Measure the trend of identified water quality indicators at stations representing the cumulative effects of human caused impacts and natural conditions.

Objective 10B: Assess the change in the area-wide conditions of identified water quality indicators estimated under Question 9.

Monitoring Indicators

Time series of identified water quality indicator measurements are evaluated for trends.

Current monitoring activity

Ecology evaluates conventional water quality indicators for cumulative effects in rivers from all 62 WRIAs and at 34 locations in marine waters. These long-term monitoring stations are used to evaluate trends in collected water quality indicators.

There are two water monitoring programs in the state with a monitoring design allowing the estimation of conditions over broad areas: The EMAP and Sediment Monitoring Component of the PSAMP. The monitoring design (i.e., sample survey approach) is used to make estimates of the conditions over broad areas.

Essential tools

Appropriate monitoring designs to answer Objective 10B are not used for most surface water quality monitoring programs. To answer the question, one must conduct a "representative" assessment of the surface waters of interest. The sample survey approach is a way of collecting information on a subset of the surface waters to make estimates of the entire population of surface waters. These estimates differ from information obtained through a census because they contain a level of uncertainty based on the sample size.

Monitoring design

For Objective 10A, monitoring should be conducted at targeted locations and specific sampling locations. Areas and sampling locations should be based on professional judgment to represent cumulative effects within a watershed or representative of sampling areas.

Monitoring should be conducted at the minimum frequency required to avoid serial autocorrelation. Lettenmaier (1977) showed that monthly samples were required in water samples to avoid serial autocorrelation for conventional water quality indicators.

Sampling should be conducted at roughly the same daily time period to reduce variance from diel fluctuations.

For Objective 10B, area-wide estimates from the monitoring design described in Question 9 of this chapter should be evaluated for trends. Sampling should be conducted at the same time of year and the same daily time period to reduce temporal variance.

The statistical criteria for objective 10A and 10B should include the ability to detect a measurable change in 5 years. It is important to note that the measurable change will be different for each indicator.

Identified agencies

Department of Ecology.

Recommended sampling protocols

Recommended sampling protocols for identified indicators are described in Question 9 of this chapter.

Performance benchmarks

Numeric criteria for 340 water quality indicators have been adopted in state rule or federal regulation. Criteria for many other indicators have not been adopted yet. Water quality standards criteria can be used to establish site specific numeric criteria (see Chapter 173-201A-070 WAC).

Identified monitoring gaps/overlaps

Periodic measurements are not made for most the identified water quality indicators to assess cumulative effects. Area-wide estimates of conditions for most identified indicators are not available. As such, they cannot be evaluated for trends.

Quality assurance/Quality control

All monitoring should be conducted by following QA Project Plan. In addition, all indicators requiring laboratory analysis should be sent to a State of Washington accredited laboratory. More detail is described in Question 9 of this chapter.

Risks

Washington State is directed under RCW 90.48.010 to "retain and secure high quality for all waters of the state". This statement can be interpreted as a legal management goal. A knowledge of positive (secure) or level (retain) trends will provide a proper measure of management success.

Where Water Quality Does Not Support Life and Recreation

Question 11: Where do the water quality conditions not support aquatic life and recreational uses?

Objective 11A:Identify waters where aquatic life and recreational uses are impaired due to surface water quality conditions.

Monitoring Indicators

Water bodies where measurements of identified indicators do not meet surface water quality criteria (adopted in rule or regulation) to protect and maintain aquatic life and recreational uses.

Current monitoring activity

Every two years, Ecology compiles a list of waters that do not meet State water quality standards (required by Section 303(d) of the CWA. Federal regulations require the state to evaluate "all available data" in development of the list.

Every year, Ecology identifies new stations to monitor for compliance with the CWA. Station selection is based on professional judgment on a 5-year statewide rotating schedule among "Water Quality Management Areas."

Ecology conducts special studies designed to further characterize the extent of conditions and answer case specific questions. These studies collect samples that can also be used to assess support of aquatic life and recreational uses.

Essential tools

Since the monitoring data collected for Question 11 is used for regulatory purposes, data collection and review must follow an adequate QA Project Plan.

Monitoring design

Monitoring should be conducted at targeted locations, based on professional judgment, that indicates aquatic life and recreational uses are impaired. Monitoring should be conducted during periods when critical conditions are expected, both daily and seasonally.

To fully answer Question 11, one would need to monitor all 340 indicators with numeric criteria adopted in State rule or federal regulation. However, lack of financial resources to fully implement the design prohibits a complete analysis. Monitoring programs can be implemented in phases until full funding is available.

The following is an example of how to implement a monitoring design in phases:

➢ *Recommend as Phase 1: Based on professional judgment, monitor only those indicators that may be impairing aquatic life and recreational uses at the targeted locations.*

➢ *Recommend as Phase 2:Monitor all indicators with criteria promulgated or proposed in rule for the protection of aquatic life and recreational uses at the targeted locations.*

Identified agencies
Department of Ecology.

Recommended sampling protocols
Sampling protocols for identified monitoring indicators are described in Question 9.

Performance benchmarks
Numeric criteria for 340 water quality indicators have been adopted in state rule or federal regulation. Criteria for many other indicators have not been adopted yet. Water quality standards criteria can be used to establish site specific numeric criteria (see Chapter 173-201A-070 WAC).

Identified monitoring gaps
Not all surface waters in the state are monitored to assess if water quality standards are being met. It is simply not feasible to census all surface waters for all indicators that have numeric water quality criteria.

Quality assurance/Quality control
See Question 9 of this chapter for more details.

Risks
Without a full census of all waters for all indicators, it is likely that aquatic life and recreational uses will be impaired in some waters. Since these impaired waters are not identified, the state can not take appropriate restorative actions.

Clean Water Programs
Question 12: How effective are clean water programs at meeting water quality criteria?

Objective 12A:Measure the effectiveness of clean water programs (CWP) in meeting surface water quality goals.

Monitoring indicators
The following monitoring indicators are for Question 12:

(1) Number of established Total Maximum Daily Load (TMDL) that meet water quality standards after implementation,

(2) Number of State funded water quality projects that meet water quality standards after implementation,

(3) Percentage of salmon waters that have good water quality index readings (Salmon Scorecard indicator E2),

(4) List of areas closed or restricted to commercial and recreational shellfish harvesting, and

(5) List of waters with fish consumption advisories.

Current monitoring activity
For Monitoring Indicator #1, Ecology conducts monitoring to assess effectiveness of several established TMDLs.

State grant recipients for water quality improvement projects are required to conduct monitoring specific to the project objectives.

The Water Quality Index is derived in each WRIA (62 stations) based on targeted locations representing cumulative effects of human-caused impacts and natural conditions.

The Washington State Department of Health (DOH) monitors fecal coliform pollution in over 100 shellfish-bearing estuaries in Puget Sound and coastal waters to assure the safety of shellfish for human consumption. The DOH uses a systematic random sampling design specified by the National Shellfish Sanitation Program (NSSP) and compiles the total area of shellfish growing areas open to direct harvest and that undergo changes in harvest classification.

The DOH monitors fish tissue at targeted locations to assure the safety of fin fish for human consumption and compiles a list of waters with fish consumption advisories.

Essential tools

Since the monitoring data collected for Question 11 is used for regulatory purposes, data collection and review must follow an adequate QA Project Plan.

Monitoring design

For Monitoring Indicator 1: TMDL Effectiveness

Selection of indicators, sampling locations, scale, and measurement frequency should be based on the objectives of the management activity. Monitoring should be conducted at targeted locations based on professional judgment of where water quality improvements are expected from the management activity.

All indicators relevant to the management activity should be measured.

Monitoring should be conducted during periods when critical conditions are expected, both daily and seasonally.

Ecology policy assumes that all TMDLs are effective at meeting water quality standards, unless there is convincing evidence to the contrary.

Considerations that may lead to a determination that a TMDL is unsuccessful include:

- Required monitoring and other implementation actions as described in the Detailed Implementation Plan are not being conducted or not being conducted in a timely way according to the plan, or efforts to carry out the actions are minimal or not evident,
- Targeted water quality standards have not been achieved by the time projected by the TMDL,
- A major event has dramatically changed the local conditions on which the TMDL was based, making it no longer applicable, or
- New information recognized in the appropriate professional fields and applicable to the specific TMDL and conditions is not being used during required reviews.

For Monitoring Indicator 2: Project Effectiveness

Selection of indicators, sampling locations, scale, and measurement frequency should be based on the objectives of the management activity. Monitoring should be conducted at targeted locations based on professional judgment of where water quality improvements are expected from the management activity.

All indicators relevant to the management activity should be measured.

Monitoring should be conducted during periods when critical conditions are expected, both seasonally and daily.

Ecology policy requires that State funded water quality projects assess effectiveness at meeting water quality standards by developing a monitoring plan in consideration of the following design elements:

- The plan must be problem-specific and site-specific.
- The plan must have reasonable time limits established for correcting the specific problem.
- The plan must have adaptive management to allow for course corrections if necessary.
- The plan must offer assurances that implementation will occur.
- The plan must specifically indicate how the controls and other planned actions will be implemented to achieve attain-

ment of water quality standards by a given date, and the actions must be implemented accordingly.

- Improvement must be assured by enforceable legal or financial guarantees that the planned actions will be performed.

- Monitoring must be scheduled to verify that the water quality standard is attained as expected.

- Modeling may be required to show that attainment of the water quality standard is likely.

For Monitoring Indicator 3: Water Quality Index

- The water quality index is derived from 8 indicators: temperature, dissolved oxygen, pH, fecal coliform bacteria, total nitrogen, total phosphorus, total suspended solids, and turbidity.

- Sampling locations are selected using a spatially-balanced, random selection based on procedures defined by EPA's EMAP Program (i.e. sample survey).

- Monitoring should be conducted during the index period identified in Question 10.

Information collected will be used to derive the water quality index for streams. These results will be extrapolated to provide estimates for each Salmon Recovery Region. Estimates will be provided for length streams with a good water quality index value.

For Monitoring Indicator 4: Harvestable Shellfish Areas

The DOH currently compiles the total area of shellfish growing areas open to direct harvest (http://www.doh.wa.gov/ehp/sf/sfpubs.htm). This activity is adequate to report on the identified indicator.

For Monitoring Indicator 5: Fish Consumption Advisories

The DOH currently compiles the number of waters with fish consumption advisories. This activity is adequate to report on the identified indicator.

Statistical criteria for Monitoring Indicators 1 & 2: TMDL and Project Effectiveness

The sample size must be sufficient to determine with 90% confidence that 10% of samples exceed adopted criteria. This is the confidence level used by Ecology to determine if water quality standards are met.

Statistical criteria for Monitoring Indicator 3: Water Quality Index

The proportion of the waters in the subpopulation not meeting the identified performance benchmarks will be estimated with a +/- 9% precision, with a 90% confidence level at the regional scale. Assuming the maximum variance, the sample size for the subpopulation is 30 this prescribed level of certainty.

Statistical Criteria for Monitoring Indicator 4: Harvestable Shellfish Areas

To be classified "Approved", a shellfish growing area must pass a thorough shoreline survey for pollution sources.

In addition the following numerical fecal coliform criteria must be met:

- The geometric mean is not to exceed 14 most probable number (MPN) of fecal coliforms per 100 milliliters of water sample (applied when point and/or nonpoint sources are present), and

- The ninetieth percentile is not to exceed 43 MPN per 100 milliliters of water sample (applied to areas where only nonpoint sources are present), OR ten percent of results are not to exceed 43 fecal coliforms per 100 milliliters (applied in Conditionally Approved areas and those receiving point-source discharges).

The statistics must be calculated from a minimum of 30 most recently and randomly collected samples.

Statistical criteria for Monitoring Indicator 5: Fish Consumption Advisories

The DOH does not use specific statistical criteria (e.g., one in million risk for cancer) to determine where advisories for fish tissue consumption are issued.

Identified agencies

Department of Ecology

Recommended sampling protocols

Ward (2001) describes protocols for measurement of indicators required to calculate the water quality index.

The National Shellfish Sanitation Program Model Ordinance (1999) provides the protocols used by DOH in assessing shellfish growing waters.

Protocols for measurement of other identified indicators are cited in the description of Question 9 of this chapter.

Performance benchmarks

Numeric criteria for 340 indicators have been adopted in state rule or federal regulation as water quality standards. Numeric criteria for many of the identified indicators of have not been adopted in state rule or federal regulation. However, the narrative criteria in the water quality standards can be used to establish site specific numeric criteria (Chapter 173-201A-070 WAC).

Numeric criteria for fecal coliform have been adopted by reference in Chapter 246-282 WAC and are applied by the Department of Health to classify marine waters for safety of shellfish for human consumption.

Department of Health conducts site-specific risk assessments to determine fish consumption advisories. As such, no specific criteria for contaminant levels in fish tissue have been adopted in state rule.

Identified monitoring gaps/overlaps

The water quality index is derived from stations selected for cumulative effect trend monitoring. These data cannot be extrapolated to provide a statewide estimate as described in the salmon scorecard indicator E2.

There is no current routine monitoring of surface water quality by the State to assess effectiveness of agricultural practices. An interagency Task Force has developed a plan to screen approximately 750 pesticide active ingredients that are currently registered for use in the state. A white paper produced by the Task Force in 2001 describes that a surface water monitoring plan will designed to determine if best management practices are effective in protecting salmon.

Periodic measurements of water quality indicators have not been required for storm water permittees. However, many municipalities do monitoring the condition of storm water for internal management purposes.

Quality assurance/Quality control

All monitoring should be conducted by following QA Project Plans. In addition, all indicators requiring laboratory analysis should be sent to a State of Washington accredited laboratory. More detail is described in Question 10 of this chapter.

Risks

Washington State is directed by law to “retain and secure high quality for all waters of the state” (RCW 90.48.010). This statement can be interpreted as a legal management goal. A knowledge of positive (secure) or level (retain) trends will provide a proper measure of management success. Without comprehensive trend evaluation of specific management activities, one cannot evaluate the extent for which the management goal mandated in state law has been achieved.

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H. Nearshore Marine Areas

Question 18: What are the status and trends in habitat-forming landscape processes in riverine tidal, estuarine, and nearshore ecosystems as they relate to watershed health and salmon recovery?

Objective 18A: Measure the current status and trends of the identified habitat indicators in near shore marine areas. Evaluate whether indicators are improving.

Objective 18B: Determine how effective conservation practices are in improving status of identified near shore marine habitat as determined by key indicators.

The above question frames a monitoring approach that incorporates the systematic measurement of natural and manmade characteristics of marine nearshore, estuarine and riverine tidal habitats encompassed in Puget Sound, the outer coast and Columbia River estuaries.

The natural attributes of these habitats such as submerged and canopy-forming vegetation, substrate, and benthic biological inhabitants provide a number of functions for marine and anadromous species. These attributes provide insight into understanding habitat-forming processes. Similarly, the presence of anthropogenic features in the landscape provide insight into how human development may alter those processes and therefore impede the species that depend on those habitats.

> *The U.S. Army Corps of Engineer's Puget Sound Nearshore Ecosystem Restoration Study (2001) states, "the nearshore is defined as the estuarine/delta and marine shoreline and areas of shallow water from the top of the coastal bank or bluffs water ward to a depth of about 10 meters relative to Mean Lower Low Water (MLLW) defined as the average depth limit of photic zone, thereby incorporating those geological and ecological processes, such as sediment movement, freshwater inputs, and subtidal light penetration, that are key to determining the distribution and condition of aquatic habitats. By our definition, the nearshore extends landward into the tidally influenced freshwater heads of estuaries and coastal streams. This includes the historic floodplains in estuaries that were tidally influenced.*

Washington State contains over two million acres of freshwater and estuarine tidal, nearshore littoral, inland marine, and coastal ocean habitats along 2,300 miles of shoreline that provide support functions essential to various life stages for the anadromous salmonid populations originating from tributary watersheds.

The open ocean coast of the Olympic Peninsula, outer coastal estuaries (Grays Harbor, Willapa Bay), and the Lower Columbia River all contain a variety of habitats that will be included in this strategy.

> *"Estuarine and marine waters of the Puget Sound Basin extend from the city of Olympia at the southern extreme to the Canadian border and westward through the Strait of Juan de Fuca. Technically, Puget Sound is an inland sea that could be considered an "estuarine complex" because it is made up of an intricate mosaic of different kinds of estuaries (drowned river valleys, fjords, bar-build and lagoons). The Puget Sound Nearshore consists of a complex of estuaries, deltas, bays and inlets, lagoons, beaches, bluffs, rocky shores, intertidal flats, and shallow subtidal areas, accompanied by eelgrass beds, seaweeds, kelps and other biological communities. For the sake of simplicity, we can classify these nearshore complexes of habitats into two regimes: 1) Estuaries and deltas – regions of Puget Sound where*

considerable freshwater discharge from land drainage dilutes the more saline waters of the Sound within a semi-enclosed embayment or broad, shallow delta, or where tidal fluctuation occurs (in the absence of salt water) at the watershed terminus of rivers; and 2) Marine Shorelines – shoreline regions of Puget Sound outside estuaries and deltas, where influence from freshwater inputs is reduced or localized."

The Puget Sound Nearshore Ecosystem Restoration Study (ACOE 2001) states the following, "This nearshore 'estuarine-marine continuum' from tidal freshwater to the marine waters... provides fundamental habitat requirements for juvenile salmon. Some salmon (termed 'stream-type') typically are not dependent on this habitat, other than as a short migratory corridor. Other species and life history stages are dependent to varying degrees (i.e., those with 'ocean type' life history patterns) on nearshore habitats utilizing different segments of this continuum to different degrees. The transitions between these segments might be considered disproportionately important to their survival.

Among the breadth of diverse life histories of the five species of Pacific salmon in this region, ocean-type salmon are those that spend relatively short periods in freshwater after hatching and rear extensively in estuarine and marine nearshore environments. In particular, ocean-type populations of juvenile chinook salmon, and all populations of chum and pink salmon, rely extensively on nearshore estuarine-marine habitats during their early life history transition to the ocean. Scientific evidence, albeit not conclusive, suggests that ocean-type salmon use these shallow-water, transitional habitats for physiological adaptation, feeding and to avoid predation.

Because these 'nearshore dependent' salmon are comparatively small when they enter nearshore estuarine-marine environments, their survival is particularly dependent on their ability to grow rapidly and elude predation by occupying shallow waters with ample prey resources and refuge from predators. Thus, depending on the species and life history type, ocean-type juvenile salmon may rear extensively (weeks to months) in nearshore estuarine and marine habitats. Furthermore, due to the dynamic nature of tidal habitats and the often punctuated migration of the juvenile salmon, the distribution and organization of habitats along the nearshore estuarine-marine continuum is important to the continuity of their migratory corridor, especially when bridging extensive rearing habitats (e.g. estuarine wetlands and deltas).

Since state jurisdictional boundaries dissect watershed units, monitoring require coordination among jurisdictions to relate habitat condition and restoration to salmon population's responses. For navigable waters, federal jurisdiction can pre-empt the state; complicating management and monitoring issues. Washington State will measure the ecological status and performance of the state's riverine tidal and estuarine waters of the Lower Columbia River with a coordinated effort on the Oregon side of the river and with the Army Corps of Engineers and EPA (Lower Columbia River Estuary Program 1998). Similarly, monitoring in the Strait of Georgia and the Strait of Juan de Fuca will require coordination with federal and Canadian agencies. Monitoring along the outer Olympic Peninsula will be coordinated with the Olympic Coast National Marine Sanctuary and the National Park Service.

The following outlines two options for nearshore monitoring. Option A utilizes a statistically-based probabilitistic sampling design and site selection approach such as the Environmental Monitoring and Assessment Program (EMAP). This option offers and expansion of the sampling approach already in use by DNR's submerged vegetation monitoring program. Option B expands Option A to include a broader suite of indicators. Specific protocols for temporal sampling will have to be developed, but the basic probabilistic sampling design would remain the same for congruent sampling of all indicators.

Monitoring indicators

Monitoring indicators are based on current knowledge. They are not processes per se but indicators of processes. Further refinement will come through the conceptual model being developed through the PSAMP and ACOE (2001), and through feedback from validation monitoring. The following are recommended monitoring indicators for Objectives 18A and 18B, presented by each option:

Option A

- Eelgrass,
- Floating kelp canopy, and
- Infaunal biota (SCALE).

Option B

- Submerged vegetation (eelgrass, kelp, general seaweeds),
- Floating kelp canopy,
- Infaunal biota (SCALE),
- Substrate,
- Emergent vegetation (salt marsh, spit/berm, forested wetlands),
- Shoreline modifications (fill, bulkheads, overwater structures, clearing, diking), and
- Water quality (e.g., sediment loads, nutrients and pesticides associated with lawn care).

Riparian zone condition and the presence of landslides are appropriate measures of Large Woody Debris recruitment potential and reliable delivery of source material for littoral transport cells.

For riverine deltas, estuarine marshes and similar habitats that do not have a linear distribution pattern on the landscape, status and trends of substrate, intertidal vegetation, extent of fill and diking will be monitored.

To intensively monitor the decline in submerged vegetation, the following additional indicators will be measured:

- Optical characteristics of water column (light penetration), and
- Nutrient loading (marine and terrestrial) and residence time, including seasonal patterns relative to historical baselines (template).

Since restoration projects in estuarine and nearshore areas usually focus on restoring natural processes like tidal inundation or native plant succession, indicators for effectiveness monitoring will be based on the expected conditions outlined in the restoration plan as well as generalized assessments of whether natural processes have been restored to the site that place it on an appropriate restoration trajectory. In some sites, presence of salmonid or other species use could be an additional indicator of habitat function.

New- Bathymetry

Bathymetry- vertical elevations and horizontal coordinates-Scale- to be determined, accuracy- TBD.

New- Synthesis

Indicators in information analyzed.

Current monitoring activity

Option A

Analysis of the data and its use in decision making is done through established protocols (Bailey 1998; Norris et al. 2002; DNR 2002).

Option B

Considerable analysis of remote and field-collected data will be required to ascertain trends in the measured parameters. Arc GIS tools will aid in the analysis of spatially relevant data sets and Access databases will be required to store more detailed information such as water quality data, macroinvertebrate data and site specific monitoring data on restoration projects. Because of the large number of indicators being measured, the monitoring team should prepare summary statistics and apply best professional judgment to the formulation of relevant messages at regular intervals. Since this monitoring project will be concurrent with nearshore studies and restoration projects under the Puget Sound Nearshore Ecosystem Restoration Project, information sharing sessions will be appropriate.

New- Bathymetry
Production of maps and GIS data themes will be used as basemaps for ongoing research and monitoring. The detail (scale) available also will allow visual determination of processes and features not before seen. For example, sand ripples and underwater slides indicate sediment movement.

New- Synthesis
Outcomes from the analysis will be used in an adaptive management structure yet to be defined.

Monitoring design

Option A
Eelgrass abundance and distribution is widely used as a critical ecosystem health indicator (Short and Echeverria 1996). Eelgrass responds to changes in a variety of nearshore processes (light and sediment) over-water structures and water quality degradation due to eutrophication and run-off resulting in habitat loss. Floating kelp also responds to environmental changes, is important habitat for many organisms and is a source of primary production for the entire nearshore food web.

➢ *Recommend a statistically-based probabilistic sampling design and site selection approach such as the Environmental Monitoring and Assessment Program - EMAP (Bailey et al. 1998), be used to select sampling grids.*

This will be an expansion of sampling approach already in use by the DNR's submerged vegetation monitoring program (Norris 2000; DNR 2002) to include not only Puget Sound, but the entire marine shoreline of Washington.

Stratification for tidal elevation, salinity, substrate type and wave exposure will be needed. Eelgrass, floating kelp and infaunal biota using SCALE will be measured.

Area stratification will be based on sub-regions shown in Figure 20.

Figure 20. Regional areas for sampling stratification.

On linear shorelines, a sampling grid will be used of approximately 1000 meters along the shoreline and wide enough to encompass elevations from the top of the bluff or other upland landform to a depth of approximately -10 meters MLLW. In estuarine and riverine tidal areas, similar sized sampling grids will be assigned for the entire study area and distributed geographically from the -10 meter contour to the upstream extent of tidal influence. Actual indicators measured may vary whether the sampling grid is a linear shoreline grid or a flat estuarine or riverine tidal area.

Option B

The option expands Option A to include a broader suite of indicators. Specific protocols for temporal sampling will have to be developed, but the basic probabilistic sampling design would remain the same for congruent sampling of all indicators.

New- Bathymetry

➢ *Recommend collecting bathymetry for the nearshore uplands, intertidal and shallow subtidal areas using a combination of aerial photography, LIDAR (both red laser for uplands and blue-green laser for water depths up to 60') and multi-beam SONAR.*

New- Synthesis

➢ *Recommend results from effectiveness monitoring from this effort and from other marine and estuarine protection, restoration and mitigation projects will be gathered, synthesized, and communicated.*

Links will be established with other watershed monitoring efforts to link upland, marine and estuarine efforts. If not done elsewhere as part of the CMS, these results must be coordinated for protocols, data management and designed to answer specific hypotheses (ISP 2002). This component most also be viewed as a part of an adaptive management system. It will permit the information to be used to test hypothesis, evaluate risks, make decisions, correct ongoing projects, and better design future projects.

Essential tools

Option A

- Underwater videography,
- Conventional quadrant and core sampling,
- GPS,
- GIS analysis,
- Computer modeling, and
- Data management- web portals.

Option B

- Underwater videography,
- Conventional quadrat and core sampling,
- GPS,
- Variety of sampling techniques,
- Lab analyses,
- GIS analysis,
- Computer modeling, and
- Data management- web portals.

New- Bathymetry

The nearshore, estuarine and riverine tidal landscape is one of relatively shallow waters that may occur in thin, steeply sloping strips along the shoreline or massive, flat areas at intertidal and subtidal elevations. Historically, these areas “fall between the cracks” of standardized mapping. Terrestrial areas are mapped using a number of remotely deployed aerial surveying instruments such as RADAR or LIDAR. Submerged areas are generally mapped using SONAR. The RADAR and LIDAR signals bounce off the surface of the water and ships equipped with SONAR cannot operate in shallow water. Therefore, this shallow water realm suffers from lack of a high-resolution base map onto which site-specific environmental information can be plotted. New technology, such as blue-green LIDAR has the capability of penetrating the water's surface allowing maps of the same detail as navigational charts and Digital Elevation Model maps.

New- Synthesis
- GIS analysis,
- Modeling, and
- Data management.

Identified agencies

Option A
- Washington Department of Natural Resources, and
- Puget Sound Nearshore Ecosystem Restoration Program (PSNERP).

Option B
- The DNR and the other monitoring programs carried out by member agencies of the Puget Sound Water Quality Action Team under the Puget Sound Ambient Monitoring Program (PSAMP). The PSAMP agencies have both the expertise and organizational structure to expand their efforts to carry out monitoring of Washington's entire marine and estuarine shoreline, although additional personnel and coordination will most certainly be needed. It will be necessary to add regional representation for the outer coast estuaries and the lower Columbia River to allow for maximum coordination with ongoing efforts in those regions,
- PSNERP,
- Olympic Coast National Marine Sanctuary,
- National Park Service- Olympic National Park,
- Lower Columbia River Estuary Program,
- NearPRISM at the University of Washington,
- Marine Resource Committees (MRC's) of the Northwest Straits Initiative, and
- Tribes and local governments will have significant data sets or site-specific inventory and monitoring data that will augment data collection.

New- Bathymetry
- PSNERP,
- USGS,
- University of Washington, and
- LIDAR Consortium.

New- Synthesis
- DNR,
- PSNERP,
- PSAMP agencies, and
- NearPRISM- University of Washington.

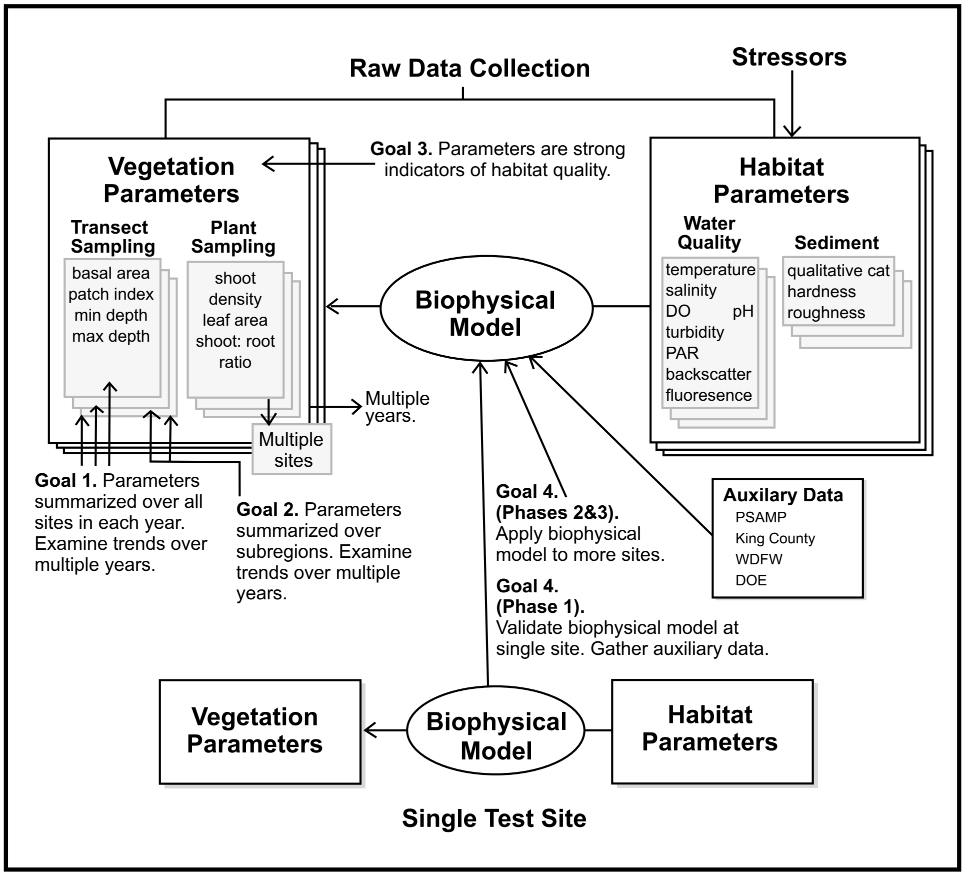
Information for analysis will flow from a variety of federal, state and local agencies, tribes, as well as tools for analysis from national and international studies.

Results will be communicated with a variety of decision making groups at all levels of government, tribes, NGO's, and citizens.

Recommended sampling protocols

Option A
The DNR's Nearshore Submerged Vegetation program component of PSAMP has already developed a statistical sampling design for status and trends of eelgrass in Puget Sound (Bailey 1998; Norris et al. 2002; DNR 2002). The ShoreZone Inventory (DNR 2000) provides a statewide baseline to design sampling for most of the parameters to be measured. Subsequent sampling of nearshore grids will ground truth that data set and inform trends. Macroinvertebrate sampling will follow the Shoreline Classification and Landscape Extrapolation (SCALE) protocol (Schoch and Dethier 1997, 1999a, 1999b). Eelgrass sampling procedures can be found in Figure 21.

Figure 21. Sampling scheme for eelgrass monitoring-Option A.



Option B

This option will build on existing protocols. Expanding the area and number of parameters to be measured is a relatively simple task. Water quality parameters measured in key indicators may address the status and trends information needed for water quality in nearshore areas.

New- Bathymetry

Rapidly changing technology makes this hard to define exactly, but pilot-scale mapping has defined feasibility and products.

New-Synthesis

This option will depend heavily on information being developed by the PSNERP and PSTRT. These include goals/objectives, performance measures, hypothesis testing of conceptual and quantitative models.

Performance benchmarks

Standards for “properly functioning condition” do not exist for riverine tidal, estuarine and nearshore habitats. Interim salmon recovery planning guidance is based upon the assumption that historical populations were viable over the long term under the historical habitat conditions.

➢ *Recommend the use of historical templates for estuarine and nearshore habitats for the major watershed units of the state is suggested as the initial performance benchmarks from which performance standards can be developed over time (PSTRT 2002).*

Conceptual model and quantitative modeling will over time allow better definition of performance measures (ACOE 2001; Simenstad and Cordell 2000). Yet to be fully defined is the relationship between programs aimed at ecosystem restoration and those for salmon recovery, although salon recovery efforts are no being couched in terms of necessary ecosystem processes and functions (ISP 2002).

Identified monitoring gaps/overlaps

There currently is a large gap in that nearshore bathymetry has not been done for most areas.

Quality assurance/Quality control

Quality assurance and quality control is in place for Option A. For Option B and Bathymetry, as details of the sampling design and protocol develop, a quality assurance/ quality control plan will be written specific to this monitoring program in accordance with guidance provided in Lombard and Kirchmer (2001). The model of using an expanded version of the existing PSAMP process and trained and qualified agency staff to collect and analyze data will be outlined in the plan. (Bailey et al.1998; Norris 2000; WDNR 2002; Schoch et al. 1997, 1999a, 1999b)

Risks

Options A and B build on existing, ongoing programs.

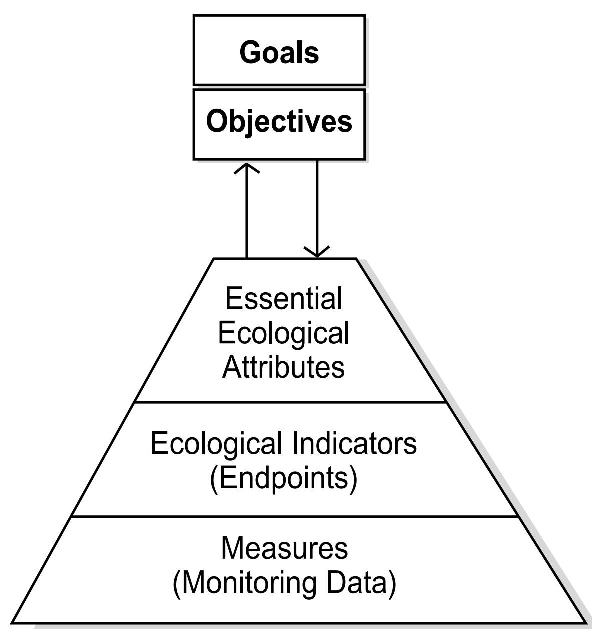
➢ *Recommend the development for a common base map upon which current conditions to be placed on and analyzed.*

This critical piece is not available at the needed scale and accuracy. Funding for this component is likely to highly cost-shared with federal and local governments.

The new synthesis component recognizes the importance of moving beyond a data gathering and reporting structure- that results from a wide variety of monitoring efforts need to be brought together, and analyzed in a framework that will allow adaptive management to occur- that not only do we need to increase our knowledge of the nearshore environment, but the knowledge needs to be used by decision makers in a positive feedback loop. Synthesis will allow cumulative impacts to be assessed over a broad temporal and spatial scale. It should be expected that the results be further used as feedback to the various source monitoring programs to refine their protocols.

The monitoring design outlined here recognizes limitations in our current understanding of population responses to habitat condition and in turn habitat condition to processes (ISP 2002; Bayley 2002). Unlike freshwater habitats, salmonids are not dominant throughout the year in marine nearshore, estuarine and riverine tidal areas. Rather, they are transitory and linked only to certain habitat components that are occupied by a large number of resident species. The complex interspecific interactions that occur in estuarine and nearshore waters may influence populations significantly more than changes in population that could be measured as a result of changes in habitat condition in those areas. Restoration efforts are likely to benefit many other species besides salmonids, including their prey base and their predators (Simenstad and Cordell 2000).

Figure 22. Conceptual approach for reporting on ecological condition (EPA Science Advisory Board 2002).



The goals and objectives of the monitoring program need to be clearly articulated before any meaningful program can be devised (NRC 1990; EPA Science Advisory Board 2002, see Figure 22). The goals are in turn predicated on environmental goals and ecosystem performance measures agreed upon by stakeholders, managers, and scientists. Monitoring will tell us whether we have met these goals and performance measures. And the results need to be linked to an adaptive management plan – thresholds and plans for action need to be agreed upon ahead of time. It is impossible to devise a meaningful monitoring strategy until these pieces are in place – otherwise we will be "documenting the demise– not effecting change".

The Puget Sound Nearshore Ecosystem Restoration Program (ACOE 2001) will devise a monitoring program based on a conceptual model of the nearshore ecosystem, agreed upon goals and performance measures. As this product becomes available, it must be used to further focus the monitoring strategy outlines in this document.

It is also important to consider the highly collaborative nature of nearshore monitoring. Because of the multi-jurisdictional and multi-agency milieu in the nearshore, there are many possibilities not only for collaboration, but for funding.

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I. Salmon Abundance, Productivity, Distribution and Diversity

Question 1: How are the annual abundance and productivity of salmon by species, ESU (Evolutionarily Significant Unit), and life stage changing over time?

Objective 1A: Measure status of the numbers of spawning salmon by stock in each Salmon Recovery Region; and trends. Evaluate whether numbers are improving.

Objective 1B: Measure status of the numbers of juvenile migrant salmon for selected index watersheds; and trends. Evaluate whether the numbers are improving.

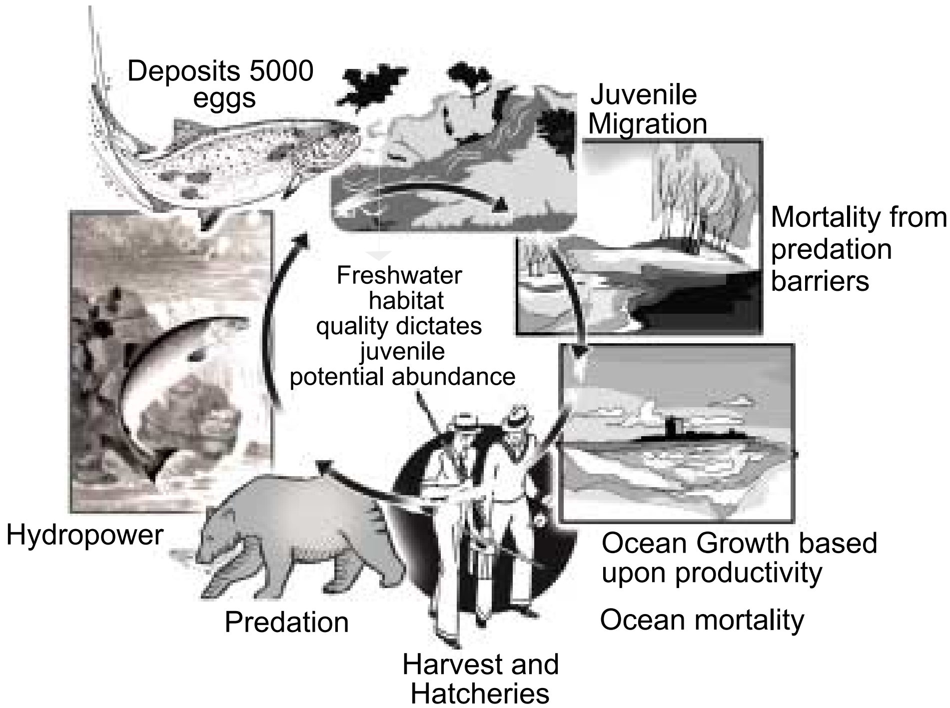
Objective 1C: Measure status of the number of resident juvenile cutthroat and bull trout for each stock; and trends. Evaluate whether the numbers are improving.

Objective 1D: Measure status of salmon productivity for selected watersheds, and trends.

For the various species of anadromous salmon, many factors contribute to survival at different life stages (i.e., female reproductive capacity, death rate of individuals due to environmental factors affecting food and shelter, and other mortality factors such as disease and predation). These factors are conceptually illustrated in Figure 23.

For example, an average chinook salmon female may deposit up to 5,000 fertilized eggs in the gravel of her natal stream. If we assume that the sex ratio is 50:50 and all 5,000 survived to spawn, they would produce 2,500 females. Their offspring would consist of 12,500,000 individuals. Therefore, this population will grow at an exponential rate of $2{,}500^N$ where N is the number of generations. However, we know that mortality factors keep this kind of growth from occurring. The average mortality from egg to fry stage is 85% (5,000 X .15= 750). Of the 750 that make it to the ocean, only 0.1% to 2% may survive the ocean to return as an adult. If we use the best-case scenario of 2%, then 750 X .02 = 15 returning adults. Of the 15 remaining, there would be 2 needed to replace the population and 13 that remain that could be used by predators, harvesters, or be lost by other mortality factors such as dams. If we use the worse case scenario recorded in recent years of 0.1% marine survival, then 750 X .001= .75 adults. There is no surplus and the species cannot replace itself even prior to harvest influences, additional predation, or other mortality. The surplus varies from species to species and year-to-year depending upon all of the environmental factors operating upon that particular generation (cohort) of salmon.

Figure 23. Factors affecting anadromous salmon life stages.



Therefore, for an understanding of the status of salmon recovery, it is crucial to determine the status and trends in the number of spawners, their total natural production of juveniles in freshwater, and the overall survival in the marine environment.

➢ *We recommend monitoring of spawner abundance for all species treated in the strategy and to use juvenile migrant trapping at selected locations to enumerate juvenile freshwater production for anadromous species.*

The above illustrated life history and mortality of a chinook salmon can be more formally represented in a series of formulas that reflect the overall complexity of addressing the factors limiting salmon abundance. The basic formulas are as follows:

$$N = R - Z$$

where N is total adult population returning to the river of origin. R is the total number of recruits produced from the spawning adults, and Z is the total mortality from all factors.

$$Z = M + F$$

M is the total natural mortality, F is the total fishing mortality (harvest).

$$M = FW + SW$$

FW is the freshwater natural mortality, SW is the marine natural mortality.

$$FW = HC + HY + PR$$

HC is the mortality associated with the habitat capacity and quality. As freshwater habitat quality improves, the overall mortality declines to optimal conditions.

HY is the mortality associated with the impacts of dams upon migration and rearing.

PR is the mortality associated with identified predation. This is often not discernible from habitat carrying capacity except when the predation is a result of abnormal conditions or has become a major factor, such as the predation caused by seals, sea lions, terns, and pike minnow.

$$SW = HC + PR$$

HC is the mortality associated with the marine habitat capacity and quality. HC is dependent upon large-scale ocean and climate conditions such as decadal oscillations, El Nino, etc.

PR is the mortality associated with identified predation. This is usually not able to be distinguished from the overall marine mortality but evidence indicates it is associated with climate and temperature as well. An illustration is the increased predation by jack mackerel on juvenile salmon during El Nino events.

As can be surmised from the above formulas, calculating salmon abundance and mortality is a complicated and often impossible task. Determining the cause of decline for a population and the effects of corrective actions with so many variables is also very difficult.

Spawners (Escapement)

Objective 1AL: Measure the status of the abundance of spawning salmon for each species by ESU and sub-basin; and the trends. Evaluate whether the numbers are improving.

Monitoring indicators

The number of salmon spawning in freshwater is a direct measure of the reproductive potential of the population and directly relates to the subsequent abundance of juvenile salmon produced. Fishery science has developed a relationship between the numbers of spawners and the ability of the habitat to produce offspring. The numbers of offspring produced must be at least enough to replace themselves in order to avoid decline, and ultimately, extinction.

Current monitoring activity

It should be noted that much of the available stock assessment data used to monitor and manage Washington's salmon populations has not been statistically evaluated. This situation occurs because most population statistics describing salmon populations are derived from multiple data sources, each with different and variable accuracies (or errors). Such population estimates, without associated variance estimates, are often not suitable for the most rigorous scientific studies, those that require the evaluation of statistical reliability of all study data.

However, the questions involved in salmon management and recovery programs are typically broader in scope and can be answered with some confidence using the available level of stock assessment data. It would be a mistake to disqualify monitoring data simply because they lack variance estimates. Each monitoring data set should be evaluated to determine if it could measure recovery. Some will clearly be inadequate, but many will confidently document the progress towards recovery.

The number of reproducing adults in a population is the single most important biological factor for salmon management, and this statistic is used for many purposes. The number of spawners determines the potential numbers of individuals that will make up future returns, is a measure of genetic health, can be used to assess risk to the population, and is an assessment of the effectiveness of fishery management. Without solid salmon escapement numbers fishery management is ineffective, and there can be no run size estimates or preseason forecasts. Because of this, tremendous effort is expended by WDFW and the co-managing Tribes to annually collect spawning ground counts for all salmon species. Collectively, WDFW conducts an average of over 6,000 miles of salmon spawner surveys each year, mostly on foot (also by boat and aircraft).

The following table summarizes the overall current number of salmon stocks identified by SaSI trout are monitored for spawner abundance, and includes a determination of whether the current monitoring is sufficient. Sufficiency is a subjective value judgment and is not based upon statistical criteria and precise estimates because there are few data available. As can be seen, the percentage of Chinook, coho, chum, pink, and sockeye stocks monitored by current programs is over 60% for five of nine species. Steelhead has significant gaps and bull trout, coastal cutthroat and west slope cutthroat abundance is not adequately sampled anywhere.

Table 20. Current statewide salmon spawner abundance monitoring.

Species	Number of stocks	Number monitored	Percent monitored	Adequate? Yes/No
Chinook*	107	99	93	Yes
Coho	89	56	63	Yes
Chum*	72	55	76	Yes
Pink	1	1	100	Yes
Sockeye*	9	8	89	Yes
Steelhead*	137	81	59	Maybe
Bull Trout*	80	21	26	No
Coastal Cutthroat	40	2	5	No
West Slope Cutthroat	Unknown	0	0	No
* Contains populations listed as threatened or endangered under the Endangered Species Act (ESA).				

Data source: Washington Department of Fish and Wildlife SaSI reports

Currently, spawner abundance is estimated using direct observation within specific index portions of streams. The current spawner surveys are not taken in a statistically valid manner across the ESU or SRR based upon random selection of sample sites or stocks. Rather they are a manifestation of the needs for managing harvest and constitute the most significant populations in terms of numbers and locations where harvest occurs. There has not been a scientifically sound sampling procedure to determine whether the stocks not measured annually behave in the same manner as the stocks measured. The best sampling procedures employed have been able to detect with 95% confidence an annual change of 20% in the number of chinook salmon redds. Because salmon stocks can behave very differently from other stocks nearby, it appears to be important to sample as many stocks as directly as possible. It is, however, very important that the WDFW and the tribes review their current approach and improve sampling procedures, quality control and protocols.

Work on current variances in chinook spawner abundance counts indicates that a random sample taken from Puget Sound would be able to detect a trend with 80% confidence within 3-5 years if at least 25 populations were sampled (Annette Hoffman, WDFW, personal communication). Although current sample sites are not random, exploring relationships to the other sites not sampled should provide additional confidence concerning the estimates.

Current monitoring activities are broken down by species in the following pages so that species for which data are lacking are evident. Each species is treated separately because sampling protocols, Quality Assurance/Quality Control, and data quality are variable from species to species.

Essential tools

Spawner surveys

Determining the presence and number of spawning salmon within specific index portions in most streams requires extensive effort using direct observation methods. Without these surveys, spawner abundance cannot be determined for most salmon species. Direct counts could be taken at dams or permanent fish traps.

Marked hatchery fish

The actual production of wild salmon in watersheds is difficult to determine when substantial numbers of hatchery salmon spawn in the same streams at the same time. Spawner abundance estimates showing good abundance of salmon may only be measuring abundance of hatchery fish and not the capacity of the habitat within the stream to produce wild salmon. Mass marking of hatchery steelhead began in 1980, and mass marking of hatchery coho and chinook salmon began in 1997. However, to date only part of the state and tribal hatchery production has been mass marked. There are already many streams where estimates are made of the contributions of natural and hatchery origin spawners, but until this tool or some other tool is fully implemented, data about wild salmon abundance in watersheds where mass marking has not occurred and where hatchery salmon are present may be less accurate and probably over estimate wild salmon abundance.

Spawner age

The ability to calculate production of returning adult salmon from any one juvenile out migration year is dependent upon knowledge about the age structure of adults returning after 1, 2, 3, or 4 years at sea. Without adequate age information, it is not possible to calculate production accurately.

Monitoring design

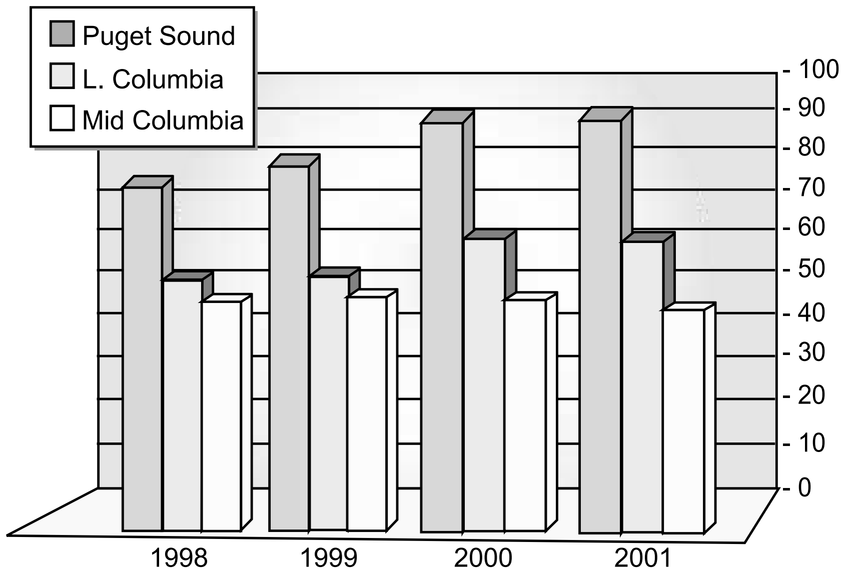
➢ ***It is recommended that the current approach to measuring spawner abundance as used by the WDFW and the Treaty Tribes be utilized to measure spawner abundance.***

This approach measures spawner abundance at established locations for each stock and then extrapolating the results for the entire watershed using various methods. Core data to estimate salmon abundance best relies on counting the number of adults on the spawning grounds. This is important because it measures the units of production or female spawners.

Spawner abundance could be collected for each stock within a SRR using a total count or census. This process would be expensive and may not be possible everywhere. Another method is to randomly select spawner abundance sites within each watershed and on an annual basis obtain a statistically valid representation of spawner densities within the sampled area. This approach is being used by the Oregon Department of Fish and Wildlife (ODFW) for coastal coho salmon using the Environmental Protection Agency's Environmental Monitoring and Assessment Program site selection protocol.

Data should be analyzed annually for the status of spawner abundance in each ESU, and the trends should be presented in a chart showing the spawner abundance of each of the index populations and another chart should show the cumulative escapement goal and the cumulative spawner abundance (escapement).

Figure 24. Sample presentation showing annual spawner abundance by region.



Another approach is to sample specific representative streams annually and extrapolate their trends in abundance to other nearby streams. This assumes that the nearby streams are under the same environmental influences and that salmon population will respond in a similar manner.

Continued spawning surveys

Spawner abundance information currently exists for most major stocks of salmon within the Salmon Recovery Regions except for bull trout and cutthroat trout. This information is useful for determining the status and the trends in the number of wild adult spawning salmon. Stocks not currently measured should be periodically using a random selection process to evaluate their relationships and trends compared to those measured annually.

➢ *It is recommended that current spawner abundance surveys be continued and current funding maintained in order to be able to evaluate the status of salmon populations.*

Mass marking hatchery fish

➢ *It is recommended that all hatchery salmon, with the exception of experimental groups, be marked as soon as possible.*

The actual production of wild salmon in a watershed cannot be determined when there are substantial numbers of unidentified hatchery salmon spawning in the stream at the same time. Spawner abundance estimates showing good abundance of spawning salmon may only be measuring hatchery abundance and not the capacity of the habitat within the stream to produce wild salmon. To date, only part of the state and tribal hatchery production has been mass marked. Until tools are available and implemented that allow accurate estimates of the relationships of habitat to fish production data about wild salmon abundance in watersheds where mass marking has not occurred and where hatchery salmon are present should be treated with caution.

Age analysis

➢ *It is recommended that current salmon age analysis programs be maintained and safeguarded.*

The ability to calculate production of adult salmon from any year of juvenile out migration is dependent upon knowledge about the various age groups that returned after 1, 2, 3, or 4 years at sea. Without adequate age information, it is not possible to calculate production accurately. This means that ongoing programs such as the WDFW aging laboratory that ages salmon by reading scales and otoliths are crucial for measuring salmon abundance accurately and should be adequately funded and maintained.

Genetic diversity

The WDFW currently operates a genetics laboratory that provides information about a wide variety of stocks both in Washington and in neighboring states. The genetics laboratory is a unique resource that should continue to be funded and encouraged in order to obtain the needed information about the genetic diversity of salmon. Current baseline information and the basis for determining "species" under the ESA are based strongly upon genetic characteristics of sampled populations. Current definitions of genetic diversity units (GDU), major ancestral lineages (MAL), and ESUs are based upon 30 years of protein allozyme allele information. Progress in newer genetic techniques has rendered protein allozyme analysis less useful, which has been replaced with mitochondrial and ribosomal DNA analysis. Fortunately, it is possible to reconstruct and extend much of the 30 years of baseline information collected for protein allozymes by sampling the DNA contained in scale samples taken in the past. To re-establish baselines for stocks would require 100 samples of tissue from each stock or discrete population.

Performance benchmarks

For harvest management purposes, spawning escapement goals are set by fishery co-managers for all major management unit stocks based upon the numbers of females needed to spawn to maintain the maximum sustainable surplus that can be harvested over time. For purposes of recovery under the ESA, Technical Recovery Teams established by NMFS are working with others to develop delisting criteria and recovery targets and goals. Performance benchmarks should be set based upon recognized escapement goals or recommendations of the Technical Recovery Teams.

Quality assurance/Quality control

➢ *It is recommended that the WDFW and the tribes develop formal written quality control procedures for testing the quality of spawner abundance information.*

Current data, with the exception of fish aging, has little or no quality control or quality analysis of data collection procedures. Data protocols are not formally identified and are not easily accessible to the public. Metadata are not identified for most databases. In some cases estimates of spawner abundance are based upon index area counts that are extrapolated to the entire stream as a ratio of a baseline year when a complete survey was conducted. Most of the baseline years were developed 10 or 20 years ago and have not been recently verified.

➢ *As a quality control measure, it is recommended that the WDFW and the tribes undertake a focused effort in the Skagit River for Chinook salmon.*

That effort would compare results from a new EMAP approach to monitoring spawner abundance of chinook in the Skagit River using a statistically valid random sampling design to compare spawner abundance estimates using current procedures.

➢ *It is recommended that a rotating panel approach be used to determine chinook spawner status so that we can be 90% confident that a change of 10% or more can be detected.*

This will allow an objective comparison of costs and accuracy using the two methodologies.

Risks

The following sections of this chapter discuss monitoring for each salmon species.

Chinook Salmon

Current monitoring activity

Table 21 shows the overwhelming majority of chinook SaSI stocks are currently monitored. No additional stocks need to be monitored for spawner abundance at this time.

Table 21. Current chinook spawner abundance monitoring.

Recovery Region	Number of stocks	Number monitored	Percent monitored	Adequate? Yes/No
Puget Sound*	29	27	93	Yes
Coastal	32	27	84	Yes
Lower Columbia*	20	20	100	Yes
Mid Columbia*	11	11	100	Yes
Upper Columbia*	12	12	100	Yes
Snake *	3	2	66	Yes
Northeast	0	0	0	NA
* Contains populations listed under the ESA..				

Data source: WDFW SaSI Reports

Estimates of measurement error and certainty

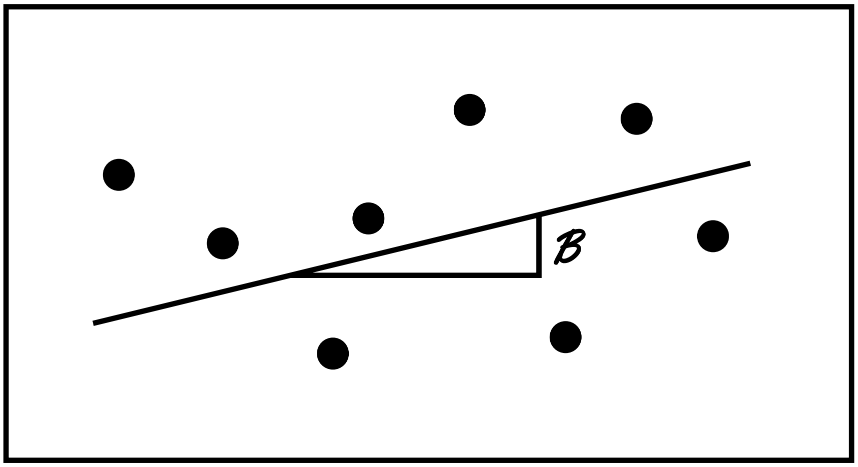
Spawner abundance in a region is defined to be the sum of all adult production in that region. Quantifying trends in total abundance in a region can be addressed with a regression of abundance with year. The ability of regression analyses to detect trends will depend on the number of years and the unexplained variance associated with the regression. The more unexplained variation there is, the more years will be required to detect a trend. Reducing the unexplained variation can be characterized as improving the quality of the data. Continuing the program over more years can be characterized as increasing the quantity of data. Therefore, designing an optimum strategy for monitoring regional abundance will be a compromise between the quality and quantity of the data (i.e., the cost of reducing the unexplained variation within a year and the costs associated with continuing the program over more years). This section develops the quantitative relationships between quantity and quality for monitoring abundance within a region and provides some guidelines to help decision makers optimize the ability of regressions to detect trends.

The utility of a monitoring program can be measured by its ability to detect trends. The ability to detect a trend is the power of the program. Statistically, power increases with both quantity and quality of data, but not necessarily at equal rates. Therefore, optimizing the utility of a monitoring program is equivalent to maximizing the power of the program within an allowable cost. To conduct this optimization, it is necessary to quantify the relationship between power and the quality and quantity of data.

Power of a linear regression

Consider an example where a trend is a linear function over time. A linear regression then describes the straight-line trend or slope (β) as increasing (β>0), decreasing (β<0), or stable (β=0). Figure 25 Conceptually illustrates an example of an increasing trend.

Figure 25. Linear regression with an increasing slope β.



The power of such a regression is defined to be the probability of concluding that a trend exists given that there actually is a trend. The greater the trend the easier it is to detect and therefore the greater the power. However, even a significant trend can be difficult to detect if there is a high degree of unexplained variation about that trend: the greater the degree of variation, the lesser the power.

The calculation of power is based on a test statistic, which in the case of a linear regression is:

$$\text{Test Statistic} = \frac{\text{Estimated Slope}}{\text{Standard Deviation Slope}}.$$

Under the null hypothesis where the slope is assumed to be 0, this test statistic can be expected to follow a central Student's T distribution with degrees of freedom determined by the number of data points in the regression ($df = n$-2). A central Student's T is centered at 0. Using the distribution under the null hypothesis, a rejection region is identified so that if the null hypothesis were true, it would be unlikely for the test statistic to fall into the rejection region. When the null hypothesis is not true, then the probability density function of the test statistic is no longer centered at 0. The greater the trend (the steeper the slope), the greater the absolute value of the test statistic, and therefore the more likely the test statistic will fall into the rejection region (which was defined under the null hypothesis). When there is a trend, the probability density function is not centered at 0, and the test statistic follows a noncentral Student's T distribution with $df = n$-2 and a noncentrality parameter that describes the degree of the trend relative to the expected uncertainty in the slope estimator. The greater the noncentrality parameter, the more likely the test statistic value will fall into the rejection region. Therefore, the power of the monitoring program can be understood by quantifying the relationship between the quality and quantity of data and the regression noncentrality parameter.

Mathematically,

$$Power = P\left(\mathrm{T}_{\delta,df} > t_{\alpha,df}\right)$$

where

- $T_{\delta,df}$ is a random variable distributed as a t-statistic with df degrees of freedom and non-centrality δ, and
- $t_{\alpha,df}$ is the α critical value of a central t-statistic with df degrees of freedom.

The noncentrality parameter, δ is the effect size of the regression slope relative to the variance in the slope estimator:

$$\delta = \left|\frac{\beta}{\sigma_\beta}\right| \qquad \text{(EQ. 1)}$$

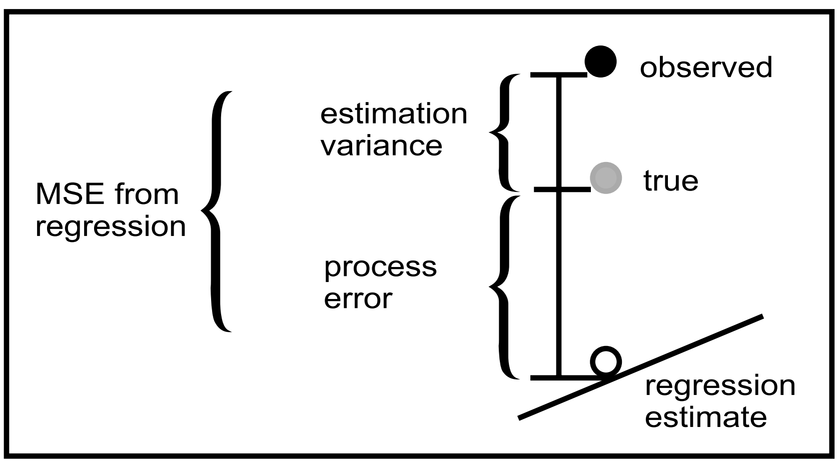
The noncentrality parameter increases either with a larger effect size (β) or smaller variance (σ_β). Letting the effect size be fixed, the noncentrality parameter can only be increased by decreasing the slope variance.

The variance of the regression slope is a function of the regression mean squared error (MSE) and the sum of squared errors produced by the years in the monitoring program.

$$\sigma_\beta^2 = \frac{MSE}{\sum_i (Y_i - \bar{Y})^2} \qquad \text{(EQ. 2)}$$

Increasing the number of years increases the denominator and therefore decreases the slope variance. Decreasing the regression MSE can also decrease the slope variance. The MSE is the sum of process error (PE) that cannot be affected and measurement error (ME) that can be affected by adjustments to sampling effort (MSE=PE+ME, see Figure 26). Thus, the variance of the regression estimate (EQ. 2) can be reduced by either decreasing the measurement error (increasing the data quality) or increasing the number of years (quantity) in the program.

Figure 26. Division of MSE into process and measurement error.



Substituting in *PE* and *ME* for *MSE* in EQ. 2 gives:

$$\sigma_\beta^2 = \frac{PE+ER}{\sum_i (Y_i - \bar{Y})^2} \qquad \text{(EQ. 3)}$$

Reduction of MSE through increasing data quality

Data quality is measured by the PE and the ME. The PE arises because fish behave stochastically, not deterministically. For example, even though an expected number of recruits per spawner might be 1.0, you would not expect exactly 1 recruit for every spawner. You would expect some variation about 1.0 due to the random nature of events, even if you could count all fish. This error is unexplainable and cannot be reduced. Therefore, for the purposes of this discussion, we will assume it is constant. On the other hand, ME is a description of how well abundance is measured in any year. ME can be decreased by monitoring more stocks within a region or by increasing the sampling on individual stocks. Reductions in measurement error require increased costs. If ME were small relative to PE, then there is little to gain in power by improving the precision by sampling more stocks or sampling stocks better. However, if ME wer êlarge relative to PE, then decreases in ME can substantially improve the regression estimator variance and lead to significant increases in power.

For a single ESU, let

N = *total number of stocks in the ESU,*

ρ_{ij} = *true escapement for the ith stock (i=1,...,n; n ≤ N) in year j (j=1,...,J),*

Π_j = *total escapement in year j (j=1,...,J),*

$$= \sum_{i=1}^{N} \rho_{ij}$$

τ_j^2 = *variance among the ρ_{ij} in year J (j=1,...,J) over the N stocks*

$$= \frac{\sum_{i=1}^{N}(\rho_{ij} - \bar{\rho}_j)^2}{N-1} \text{ where } \bar{\rho}_j = \frac{\sum_{i=1}^{N}\rho_{ij}}{N},$$

r_{ij} = *escapement estimate for the ith stock (i=1,...,n; n ≤ N) in year j (j=1,...,J),*

= *(ρ_{ij} + e_{ij}, where e_{ij} is the measurement error around ρ_{ij}, $e_{ij} \sim N(0, \sigma_{ij}^2)$, and*

R_j = *estimated total escapement in the ESU in year j (j=1,...,J)*

$$= N\bar{r}_j, \text{ where } \bar{r}_j = \frac{\sum_{i=1}^{n} r_{ij}}{n}.$$

For a given year, the variance of the estimated total escapement (the *ME*) is

$$V(R_j) = V(N\bar{r}_j)$$
$$= \left(\frac{N}{n}\right)^2 V\left(\sum_i r_{ij}\right)$$
$$= \left(\frac{N}{n}\right)^2 V\left(\sum_i \rho_{ij} + \sum_i \varepsilon_{ij}\right).$$

If the *ME* is independent among stocks within a year and independent of stock size, then the variance equation simplifies to:

$$V(R_j) = \left(\frac{N}{n}\right)^2 \left[V\left(\sum_i \rho_{ij}\right) + V\left(\sum_i \varepsilon_{ij}\right)\right]$$
$$= \left(\frac{N}{n}\right)^2 \left[\frac{n}{N}(N-n)\tau_j^2 + \sum_i \sigma_{ij}^2\right]$$
$$= \frac{N(N-n)}{n}\tau_j^2 + \left(\frac{N}{n}\right)^2 \sum_i \sigma_{ij}^2$$
$$= \frac{N(N-n)}{n}\tau_j^2 + \frac{N^2}{n}\bar{\sigma}_j^2 .$$

Since $\tau^2 j$ is unknown, it is helpful to rewrite the variance in terms of the empirical variance $S^2 j$. The empirical variance among the estimated escapements across stocks can be rewritten using the conditional variance formula:

$$V(r_{ij}) = V(E\lfloor r_{ij} \mid i \rfloor) + E(V\lfloor r_{ij} \mid i \rfloor)$$
$$= V(\rho_{ij}) + E(\sigma_{ij}^2)$$
$$= \tau_j^2 + \bar{\sigma}_j^2 .$$

Then

$$V(R_j) = \frac{N(N-n)}{n}\tau_j^2 + \frac{N^2}{n}\bar{\sigma}_j^2 .$$
$$= \frac{N(N-n)}{n}(S_j^2 - \bar{\sigma}_j^2) + \frac{N^2}{n}\bar{\sigma}_j^2$$
$$= \frac{N(N-n)}{n}S_j^2 + N\bar{\sigma}_j^2 .$$

The estimated variance is then:

$$\hat{V}(R_j) = \frac{N(N-n)}{n}\hat{S}_j^2 + \frac{N^2}{n}\hat{\sigma}_j^2 \quad \text{(EQ. 4)}$$

where

$$\hat{S}_j^2 = \frac{\sum_{i=1}^{n}(r_{ij} - \hat{\bar{r}}_j)^2}{n-1},$$
$$\frac{\sum_{i=1}^{n} r_{ij}}{n}, \text{ and}$$
$$\hat{\sigma}_j^2 = \frac{\sum_{i=1}^{n}\sigma_{ij}^2}{n}$$

Using data from Puget Sound chinook stocks and a percent standard error (PSE) of 0.4 (Hahn 2001), the ME is estimated to be about 77 million fish (Table 22):

$$V(R_j) = \frac{N(N-n)}{n} S_j^2 + N\bar{\sigma}_j^2$$
$$= \frac{30(30\text{-}27)}{27} 7{,}716{,}818 + 30(1{,}716{,}726)$$
$$= 77{,}224{,}506.$$

Table 22. Variance calculations based on an assumed constant PSE of 0.4.

SaSI chinook stock	Natural spawner estimate (2000)	w/in stock variance = (PSE*SpwnrEst)2
Cedar R. SM/FL	120	2304
Dosewallips SP/SM	29	135
Duckabush SM/FL	28	125
Dungeness SP/SM	128	2621
Elwha SM/FL	1959	614029
Green R.	6170	6091024
Hamma Hamma SM/FL	381	23226
Hoko FL	700	78400
Issaquah SM/FL (hatch. origin)	1668	445156
Lower Sauk SM	576	53084
Lower Skagit Main SM/FL	3262	1702503
N Lk Washington FL	227	8245
NF Nooksack FL	1242	246810
Nisqually	1253	251201
Puyallup FL	1193	227720
Samish/MS Nooksack FL	5250	4410000
SF Nooksack FL	283	12814
Skokomish SM/FL	843	113704
Skykomish	1427	325813
Snoqualmie	4665	3481956
Stilliguamish FL	158	3994
Stilliguamish SM	1464	342927
Suiattle SP	360	20736
Upper Cascade SP	625	62500
Upper Sauk SP	388	24087
Upper Skagit Main SM/FL	13092	27424074
White SP	1546	382419
Empirical Variance	7,716,818	
Average Variance		1716726

SM=summer; SP=spring; FL=fall.

Process error is that part of the regression *MSE* not accounted for my *ME*. Therefore, to estimate *PE*, we must first estimate *MSE*. A regression of total estimated abundance on year resulted in an overall estimated *MSE* of about 107 million fish.

Figure 27. Estimated total production.

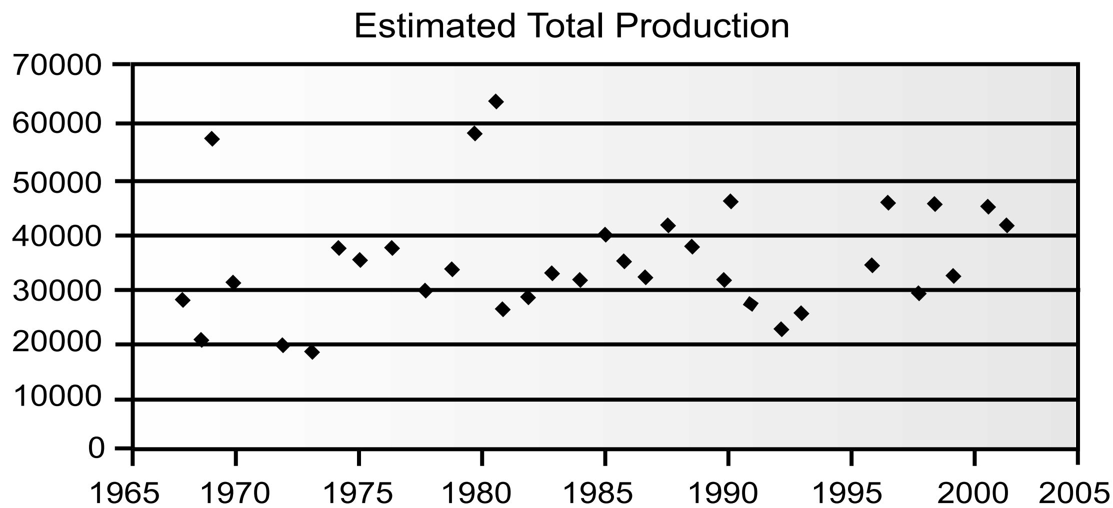


Table 23. ANOVA analysis.

ANOVA			
	df	SS	MS
Regression	1	28,855,681	28,855,681
Residual	32	3,420,200,640	106,881,270
Total	33	3,449,056,321	

Because the *MSE* is the sum of the process error and the measurement error, the estimated process error is approximately 30 million fish.

PE = MSE - ER

= 106,881,270 - 77,224,506

= 29,656,764

~ 30 million

Since under current sampling levels, the *ME* is approximately twice the *PE*, it is likely that optimizing power will involve some increases in sampling efforts.

Reduction of MSE through increasing data quantity

Data quantity corresponds to the number of years in the monitoring program. More years reduces the variance of the regression slope estimator because it increases the sum of squared errors (EQ 3). The sum of squared errors in years is independent of the particular start year. For example, the sum of squared errors for the years 1980-1985 is the same as for the years 2000-2005. The sum of squared errors increases monotonically with the number of years and will approach infinity. Table 24 shows how the number of years monitored impacts the variance of the regression slope estimator for 2 to 10 years. For example, with only two years of data the variance of the regression slope is inflated by a factor of 2 (divided by 0.5). With three years, the variance is reduced by half (divided by 2). The more years in the regression, the greater the denominator and the lesser the variability (σ_β), and thus the greater the power.

Table 24. Sum of squared errors in years as a function of the number of years.

# Years (i)	$\sum_i (Y_i - Y)^2$
2	0.5
3	2
4	5
5	10
6	17.5
7	28
8	42
9	60
10	82.5

Combining the information on *PE* and *ME* along with the sum of squared errors due to the number of years, the estimated regression slope variance is:

$$= \frac{30M + \frac{30(30-n)}{n} 7.7M + 30\,(1.7M)}{\sum_i (Y_i - Y)^2} \qquad \text{(EQ. 5)}$$

Using Equation 5, one can calculate the noncentrality parameter of the regression slope test statistic (EQ. 1) for a given effect size, number of stocks monitored and number of years in the monitoring program. That noncentrality parameter will yield a certain power of detection. By changing the number of stocks monitored and/or the number of years, one can find a combination that will yield a minimum of 80% power. The results are also a function of the *PSE* assumed in Table 24. Table 25 shows viable combinations of stocks (chosen at random from all stocks in the region) and numbers of years for different degrees of trend and different assumed *PSE's*.

Table 25. Number of years necessary to achieve at least 80% power given the effect size and the number of stocks monitored per year, assuming each stock was measured with a PSE of 40%.

Effect slope	# stocks/yr	# years
		PSE[7] = 0.4

3500/yr	30	>= 3
	25	>= 4
	10	>= 5

7 PSE is the percent standard error on the estimates of individual stock abundance.

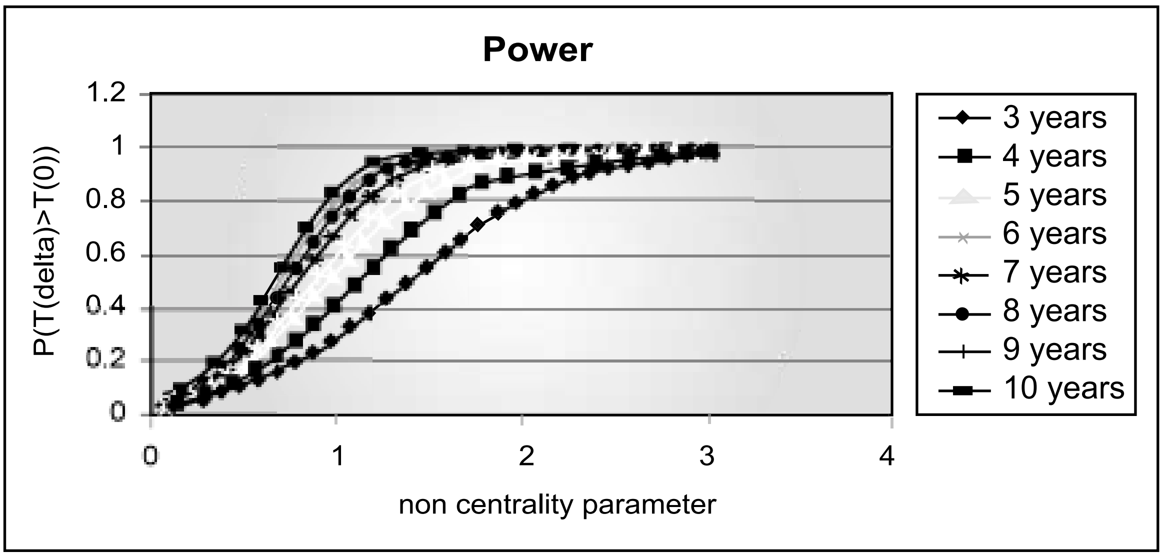
Table 25 Continued.

Effect slope	# stocks/yr	# years PSE[7] = 0.4
2000/yr	30	>= 3
	25	>= 4
	15	>= 5
	5	>= 6

7 PSE is the percent standard error on the estimates of individual stock abundance.

The above table shows the degree of measurement error relative to the estimated process error. If the trend were increasing or decreasing by 3500 fish per year and all 30 stocks were sampled, then it would take at least 3 years to achieve a power of 80%. If only 25 of the 30 stocks could be sampled, then at least 4 years would be required before a linear regression test would achieve a power of 80%.

Figure 28. A linear regression with an increasing slope B.



Starting with a level of desired power, say *p*% and a particular number of years (*NY*), one can determine the corresponding noncentrality value (δ).

Table 26. Relationship between number of years, power, and noncentrality.

Power	Number of years (N_Y)	Noncentrality (δ)
80%	3	3.3
	4	2.1
	5	1.7
90%	3	4.0
	4	2.5
	5	2.0

$$\delta = \left| \frac{\beta}{\sigma_\beta} \right|$$

(EQ. 1)

$$\sigma_\beta^2 = \frac{MSE}{\sum_i \left(Y_i - \bar{Y}\right)^2}$$

(EQ. 2)

$$\sigma_\beta^2 = \frac{PE+ER}{\sum_i \left(Y_i - \bar{Y}\right)^2}$$

(EQ. 3)

$$\hat{V}\left(R_j\right) = \frac{N\ (N-n)}{n}\hat{S}_j^2 + \frac{N^2}{n}\hat{\sigma}_j^2$$

(EQ. 4)

$$= \frac{30M + \frac{30(30-n)}{n}\ 7.7M + 30\ (1.7M)}{\sum_i \left(Y_i - Y\right)^2}$$

(EQ. 5)

Chinook Categories

The fishery co-managers have divided chinook stocks in Puget Sound into three categories in terms of how they should be prioritized for recovery under the ESA. These categories are:

1) Protect and recover Puget Sound chinook core populations. Core populations are genetically unique populations of chinook salmon that are indigenous to watersheds within Puget Sound. The highest priority is to maintain the genetic diversity and integrity of these stocks and to achieve abundance levels for long-term sustainability. Watersheds identified within Category 1 possess at least one indigenous stock (regardless of their distribution elsewhere), and the population is managed on a natural stock basis. Currently, all of these stocks are sampled annually for spawner abundance.

2) Reestablish natural spawning populations. For those watersheds that no longer have indigenous chinook populations, but where historical evidence indicates sustainable populations existed, management actions will be implemented to reestablish natural sustainable populations. This will require the selection of the most appropriate stock and the development of a management regime that will support natural spawning at sustainable levels. In these cases where the indigenous population has been extirpated, a hatchery stock of local origin can act as a surrogate brood source. Watersheds identified include Puyallup and Nisqually River stocks.

3) No chinook recovery required. In general, this category includes the smaller watersheds where chinook production is naturally limited and where coho, chum and cutthroat trout are the predominate salmonids. In many cases, chinook spawning in these watersheds is largely the result of hatchery strays. Stocks included here are Hood Canal summer/fall streams, South Sound tributary summer fall chinook, Issaquah Creek summer/fall chinook, and Nooksack fall chinook.

Overall, current sampling is adequate in the Puget Sound chinook because 100% of category 1 streams, 95% of category 2 streams and 95% of category 3 streams are sampled annually for spawners.

Identified agencies

The WDFW and the treaty tribes under US v Washington, and US v Oregon have been conducting spawner surveys for the identified streams. There are legal requirements under US v Washington and US v Oregon that require certain escapement goals to be met and that sharing of data and harvest occur between the tribes and the state. These activities should remain within the WDFW and the tribes. Additional information has been incorporated into SaSI from the Colville Tribe, NMFS, USFWS, and volunteer organizations.

Recommended sampling protocols

Spawner data are collected both as direct counts at dams and traps, and as indirect counts of relative abundance. In streams where direct counts are not available, spawner abundance is estimated from actual count data for index stream reaches, and is usually collected on an annual basis. These are usually calculated in terms of fish/mile or redds/mile. Indirect counts do not provide total escapements, but do provide relative trends in abundance.

In the past, sampling protocols have not been rigorously tested or documented. Future sampling should be conducted using the same degree of rigor for establishing protocols and precisions as described by Hahn (2001).

Performance benchmarks

For harvest management purposes, spawning escapement goals are set by fishery co-managers for all major management unit stocks based upon the numbers of females needed to spawn to maintain the maximum sustainable surplus that can be harvested over time. For purposes of recovery under the ESA, Technical Recovery Teams established by NMFS are working with others to develop delisting criteria and recovery targets and goals. Performance benchmarks should be set based upon recognized escapement goals or recommendations of the Technical Recovery Teams.

Identified monitoring gaps/overlaps

Some of category 2 and 3 stocks of chinook are not currently being monitored for spawner abundance. Better unbiased age composition data needs to be collected.

Quality assurance/Quality control

➢ *It is recommended that the WDFW and the tribes develop formal written quality control procedures for testing the quality of spawner abundance information.*

Current data, with the exception of fish aging, has little or no quality control or quality analysis of data collection procedures. Data protocols are not formally identified and are not easily accessible to the public. Metadata are not identified for most databases. In some cases estimates of spawner abundance are based upon index area counts that are extrapolated to the entire stream as a ratio of a baseline year when a complete survey was conducted. Most of the baseline years were developed 10 or 20 years ago and have not been recently verified.

➢ *As a quality control measure, it is recommended that the WDFW and the tribes undertake a focused effort in the Skagit River for Chinook salmon.*

That effort would compare results from a new EMAP approach to monitoring spawner abundance of chinook in the Skagit River using a statistically valid random sampling design to compare spawner abundance estimates using current procedures.

➢ *It is recommended that a rotating panel approach be used to determine chinook spawner status so that we can be 90% confident that a change of 10% or more can be detected.* This will allow an objective comparison of costs and accuracy using the two methodologies.

Risks

Risks associated with inaccurate spawner abundance information are high. Examples include:

- Potential over-harvest of stocks,
- Lack of ability to detect poor survival years,
- Inability to determine the effects of freshwater habitat and marine climate conditions upon the status of salmon,
- Inability to demonstrate which stocks are not at risk, making de-listing under the ESA highly unlikely, and
- Washington will be unable to show that funds expended on salmon recovery programs and projects have had a positive benefit.

Coho Salmon

Current monitoring activity

Washington coho salmon stocks are currently not listed under the Endangered species Act. A variety of methods are currently used for estimating coho spawner escapements in Washington. These include:

- Serial redd and/or live fish enumeration surveys,
- Mark-recapture methods, and
- Weir and dam passage counts.

Salmon escapements in Washington prior to the 1970s were typically monitored by one or two live and dead fish counts conducted annually, at or near the expected peak of spawning activity in fixed survey reaches, in selected streams thought to be representative of escapement to the streams in each area (Eagan 1978).

By the 1970s, the need to generate estimates of total escapement by region, across all major populations, to meet new fishery management mandates led to the adoption of new monitoring approaches. The primary method adopted was the use of serial live fish or redd count surveys in selected stream reaches that were expanded to basin total estimates of escapement using a variety of techniques (Flint 1984; Ames 1984). The serial redd count methodology is the preferred coho escapement estimation methodology for the coastal Washington and Strait of Juan de Fuca areas, and the serial live fish count method in most of the Puget Sound region (J. Haymes, WDFW, personal communication). Total natural coho escapement values in Washington are usually derived as point estimates, with no variance or confidence interval values.

Redd or fish count surveys are typically conducted at 7 to 10 day intervals over the course of the spawning season, in one or more fixed stream “index” reaches in selected stream basins. Redds and/or live and dead coho are enumerated in each index reach by the surveyor, along with other pertinent data, such as streamflow, water visibility, and estimated proportion of fish observed.

Redd-based escapement estimates for each index reach are typically derived by:

- Summing all the redds enumerated for the season in each index

Season-total redd estimates for the non-index stream reaches are derived by either a) conducting point count(s) of total visible redds and expanding the counts, or b) using redd density information from surveyed reaches.

Point redd counts are expanded to an estimate of season total redds for the reach by the formula:

- Redd count in supplemental reach s at time j * (season cumulative redds in index reach I)/(visible redds in index reach i at time j)

Data from representative or supplemental index reach(as) are used to estimate escapement in the non-surveyed reaches by the formula:

- Season total redds/mile value from a representative index or supplemental stream reach * linear length of un-surveyed reach.

Basin-total cumulative redd estimates are usually calculated as the sum of the season-total redds in the index reaches, and estimated season-total redds in non-index stream reaches. Cumulative redd values are typically converted to an adult equivalent escapement value by an expansion factor of two adults/redd (one male and one female) for the coastal Washington and Strait areas. The two adults/redd value is based on a study conducted by Chitwood and Parrack (1987), recommendations in Lestelle and Weller (2002), and professional judgment by WDFW and tribal biologists that this is an appropriate default value in the absence of site-specific information for the stream being monitored (J. Haymes, WDFW, personal communication).

Live fish count-based escapement estimates for a survey index are typically derived by:

(1) Connecting the live fish count observations collected through the season in each survey index on a two dimensional chart (date on horizontal axis, count values on vertical axis),

(2) Calculating the area described under the line, which is defined as the "area under the curve", or the "fish*days" value for the index, and

(3) Translating the fish*days value into an escapement value by use of a variety of approaches, which are described below.

Approaches used to estimate total escapement from serial live fish count fish*days data are dependent upon the species and/or watershed. The index escapement estimation procedure for chums and pinks in the southern Puget Sound, Hood Canal regions, and Lake Washington sockeye, is to divide the season-cumulative fish*days value for each index by an estimate of average survey life for the population (Ames 1984), which provides an estimate of season-total spawner abundance for the index. This is not a practical approach for estimating most coho spawning escapements, because:

(1) Coho tend to spawn throughout a large geographic portion of most watersheds, and the index areas only census a small portion of the total spawning population in each watershed,

(2) Counts in the index areas often include both local-spawning and transient fish, and

(3) "Survey life" for coho can be quite variable, depending on water temperature, streamflow, etc.

In the Puget Sound region season-cumulative fish*days values from index coho surveys (and for chum in large northern Puget Sound river basins) are typically expanded to basin-total estimates of escapement by the "base year" escapement estimation approach, described below:

> *Sum of cumulative fish days values for selected index reach(es)*$^{i \dots n}$ *for year* x, * *(base year*^{b} *basin total escapement estimate)/(sum of index fish*days in base year*^{b} *for selected index reach*$^{i \dots n}$*)*

Base year estimates of total basin escapement are commonly derived through mark-recapture or capture-recapture approaches. Mark-recapture or capture-recapture estimates of escapement are typically derived by marking coho captured near the river mouth using a fish trap or net gear, then using the tag recoveries at hatcheries and on natural spawning grounds to derive the estimate, or using capture ratios of returning adult coho coded wire tagged as juveniles in river mouth fisheries vs. upriver locations (hatcheries, other fish traps, or natural spawning ground locations). An overview of these approaches is provided in Cousens et al. (1982).

Mark-recapture approaches are commonly used for investigative projects that require estimates of escapement with higher precision and accuracy than is typically available with other approaches. These approaches are particularly suited for estimation of escapement in larger watersheds where direct census of a significant portion of the spawning population is difficult or impossible. A drawback of these approaches is that they often require significant manpower commitments for both the marking and recapture phases, to obtain adequate marking and tag recovery rates. This technique can significantly overestimate escapement if marks are missed during the recovery phase (D. Seiler, WDFW, personal communication). An example of the use of mark-recapture techniques for estimating escapement of a natural Washington coho spawning population (Skagit River) is described in Hayman (1987).

There are different strengths and biases associated with live fish counts vs. redd counts. Lestelle and Weller (2002) compared redd count vs. live fish*day estimate based estimates of coho escapement in two study streams in the Hood Canal and strait of Juan de Fuca areas, and observed that fish*day-based escapement estimates in the study streams were lower than redd based estimates at low escapement densities, and higher than redd based methods at higher escapements. Reasons attributed to this observation were that live coho were more difficult to completely census at low densities than redds, and complete redd census was relatively more difficult than live coho census at higher spawner densities due to redd superimposition. The tendency for visual live count surveys to observe fewer coho than the number actually present at higher spawner densities was also documented in an Oregon study on salmon survey observation error (Solazzi 1984).

A relatively new estimation methodology being used for some salmonid escapement monitoring programs in the Pacific Northwest region is the "Stratified Random Sample" (SRS) EMAP approach (Bocking et al. 1988; ODFW 1991; Jacobs and Cooney 1991; Jacobs and Nickelson 1998). This approach can reduce biases associated with fixed index escapement monitoring approaches, such as the propensity of fixed index areas to represent largely the higher density spawning areas in a stream basin, and the insensitivity of fixed indices to significant inter-annual changes in spawner distribution (Jacobs and Nickelson 1998). The SRS EMAP approach has some limitations. As an example, it is often not possible to select index locations on a truly random basis, due to stream access issues (J. Haymes, WDFW personal communication; Jacobs et al. 2001). Bocking et al. (1988) found the SRS EMAP approach offered some improvements over other escapement estimation approaches in regards to correcting the sampling biases associated with fixed survey indices, but the SRS EMAP method was also observed to be subject to some of the same problems that affected more traditional escapement monitoring approaches, particularly in regards to the conversion of the raw survey observations to total escapement estimates for the index reach or basin. Inter-annual and/or inter-index variance in fish residence time can cause errors in conversion of the fish*days values to index escapement estimates, as with any approach that depends on use of a fish*days or redd life value to convert serial fish or redd counts to a season-total estimate of fish or redds.

Also, even when index reaches were randomly selected, the reaches did not always appear to capture distribution of the spawners adequately, particularly in streams with a "patchy" spawner distribution. ODFW is currently conducting investigations into the accuracy and precision of the SRS EMAP methodology that they have been using to monitor and estimate coastal Oregon natural salmonid escapements since the 1980s (Jacobs et al 2001). In Washington, a modified version of the SRS EMAP approach, based on habitat stratified indices[8] is currently being used for coho escapement estimations in the Strait of Juan de Fuca region (R. Cooper, WDFW, personal communication).

Finally, the best estimates of escapement are usually obtained by weir or trap counts, at barriers that totally block upstream migration and force fish into a trap box or through a counting station. These types of estimates usually have little or no measurement error associated with them. This approach is used only opportunistically due to the expense, difficulty, and environmental consequences of constructing new barriers across streams.

8 *ODFW SRS surveys are stratified by estimated relative spawning density zones in the stream reaches.*

Table 27. Current coho spawner abundance monitoring.

Recovery Region	Number of stocks	Number monitored	Percent monitored	Adequate? Yes/No
Puget Sound	40	36	90	Yes
Coastal	32	20	56	Maybe
Lower Columbia	17	0	0	No
Mid Columbia	1	1	100	Yes
Upper Columbia	0	0	0	NA
Snake	0	0	0	NA
Northeast	0	0	0	NA

Data source: WDFW SaSI Reports

An overview of current survey index effort for the major North Puget Sound and Hood Canal natural coho escapement estimation units is as follows.

- The Hood Canal coho escapement estimation unit has 28 survey indices, totaling 23.6 linear miles of stream.
- The Snohomish River basin escapement estimation unit has 54 indices, totaling 54.0 linear miles of stream.
- The Stillaguamish River basin escapement unit includes 20 indices, totaling 10.7 linear miles of stream.
- The Skagit River basin has 18 indices, totaling approximately 12 linear miles of stream.

In some cases escapement estimation units are inclusive of a single SaSI stock (e.g., Skagit River), or in other cases contain multiple SaSI stocks (e.g., Hood Canal, Snohomish River). Numerous survey indices are also present in other smaller watersheds throughout Puget Sound. The annual escapement estimates generated from data collected in these indices are point estimates, with no variance values. Accuracy and precision of the estimates are largely unknown.

Escapement estimates with consistently high levels of accuracy and precision[9] are available for some stream basins in Puget Sound, through the use of weirs or traps operated by WDFW and other organizations. Permanent upstream/downstream counting weirs are operated by WDFW at Big Beef Creek (northeast Hood Canal, escapement counts available from mid 1970s to present, (D. Seiler, WDFW, personal communication), Deschutes River (deep South Sound, coho escapement counts available from 1960s to present, WDFW 1975), and Chambers Creek (South Sound)). In addition, the Puget Sound Energy company enumerates and mark-samples all upstream migrating salmonids at the Baker Lake trap-and-haul facility (Skagit River basin, north Puget Sound , coho counts are available from at least 1950 to present, Williams et al. 1965), and the WDFW SSHEAR division has operated an adult trap-and-haul facility at Sunset falls (S.F. Skykomish River, north Puget Sound, counts available from 1958 to present, Williams et al. 1965). All trapping sites listed above maintain sampling programs to identify the proportion of natural and hatchery origin coho returning to the stream basins above the traps. In addition, a variety of short-term adult rack

9 *Escapement estimates generated from weirs or traps are not always absolute estimates of escapement. High flows, staffing, and/or equipment problems may prevent weir operation through the entire run period, so some of fish passage past the trapping location may be estimated. In addition, wild and hatchery origin fish passage estimates are typically derived from tags or scales recovered in sub-sampling operations, so there are error parameters associated with the sub sampling expansions.*

or mark recapture studies over the years have provided partial or complete estimates of escapement in some smaller watersheds (e.g.; Harris Creek in the Snoqualmie basin, Flint 1984).

Terminal run size estimates for each of the major wild and hatchery fishery management units is available from 1963 brood year to present, and total run size estimates are available for the 1983-89 brood years. The terminal run size estimation process for Puget Sound coho was changed starting with the 1993 brood year, so estimates for the 1993 brood year to present are not directly compatible to those from previous years.

Estimates of measurement error and certainty

Variability in detecting coho spawner abundance was evaluated in Harris Creek. That study used stream indexing and a known count at a weir ranged from 40%-90% of the known run. Spawner index areas tended to underestimate the run.

Variance estimates can be calculated for total escapement estimates, but these estimates require consideration of several sources of uncertainty in the parameters used in the escapement estimates. These include:

1. Errors in fish or redd counts due to observer error (Jones et al. 1998),
2. Variance in residence life used for AUC based calculations (Perrin and Irvine 1990; Flint and Zillges 1980),
3. Missed tag recoveries in mark/recapture based estimates (Schwarz et al. 1993),
4. Estimates for escapement values based on subjective/professional judgment approaches, such as estimates of redd densities in non-surveyed reaches, and
5. Variance parameters associated with the base year estimates used for expanding index count data.

Given all these uncertainty parameters, many Washington coho escapement estimates are best thought of as relative escapement indicators, and not absolute estimates of escapement.

In regions with large hatchery programs, monitoring of hatchery straying into the natural escapements is a significant issue for assessing natural stock productivity, viability, and genetic issues. Natural coho spawning populations in the southern Puget Sound (Baranski 2001) and Columbia River regions (DeVore 1987; Ruggerone 1999) have been identified as having chronically high levels of hatchery origin coho in the natural spawning populations[10], and there are more localized situations of high hatchery straying into natural spawning populations elsewhere in Washington. This can be monitored by electronic, mark, and/or scale sampling of adults at weirs or fish traps, and sampling of carcasses on the spawning grounds.

The WDFW is not confident of the veracity of the current WDFW/Tribal escapement estimation methodologies for coho. Their juvenile production studies have often provided information contradictory to the parent escapement estimates that were generated by traditional visual survey methods in several stream basins in Washington. For example, juvenile production studies in the Skagit River basin, conducted in conjunction with mark-recapture based estimates of adult escapement by the Skagit Co-op Tribe and WDFW have strongly indicated the ‘live counts/base year’ based estimates of escapement in the Skagit basin were biased significantly low. Experimental spawner survey work conducted above the adult enumeration weirs

10 *This is a result of the hatchery production-oriented management objectives in these regions, which yield large returns of hatchery fish that often outnumber the natural populations in the region. Even smaller hatchery stray rates are numerically significant in comparison to the local natural population spawner abundances.*

by WDFW staff has indicated visual survey methods can be problematic even in smaller stream basins, often severely underestimating abundance of adult coho present in the stream (D. Seiler, WDFW, personal communication).

Although base years were sometimes calculated with 95% confidence intervals, the midpoint is usually used for the annual escapement calculations. There typically is no variance calculation conducted for the fish*days values for the year being censused. Significant problems with the base year escapement estimates are:

(1) Poor or non-existent documentation,

(2) The base year estimates are old (typically 1970s vintage), and

(3 The base year estimates were typically only done for one year, and therefore do not provide estimates for years with different hydrologic regimes (which will often affect distribution of coho spawners in the watershed, this is a significant issue for the estimation procedures using fixed survey indices).

Identified agencies

The WDFW and the Treaty Tribes under US v Washington, and US v Oregon have been conducting spawner surveys for coho salmon for the identified streams for 30 years. This activity should remain within the WDFW and the tribes. Additional information has been incorporated into SaSI from the NMFS, US Fish and Wildlife Service, and volunteer organizations.

Recommended sampling protocols

As discussed under current monitoring, a stream index system was developed for Puget Sound coho in 1951 as a means to estimate spawner abundance. These have been described by Egan (1982) and Flint (1984). Sampling protocols in the past for coho have not been rigorously tested or documented. The coho spawning abundance estimates are currently calculated by performing either live counts of spawning coho or counting redds throughout the index areas. The counts are then converted to a simple spawner curve and the area under the curve is calculated. For estimating total spawner abundance for specific areas, the abundance counts for various index areas are summed, averaged and converted into fish-days. The average value is then divided by the value for the spawner index areas for the base year for fish days and a ratio is established against the base year full spawning escapement estimate.

Coho spawner data is collected every year. There has been little quality control/quality analysis over the years to verify the validity of the counts. This would include verification that the current spawner index areas represent the true distribution of spawners, and whether the so-called “base year” estimate of total spawner abundance is an accurate reference point to extrapolate spawner abundance.

Future sampling should be conducted using the protocols similar to those described in Hahn (2001).

Surveys are conducted per WDFW stream survey manual protocols (Knudsen et al. 1987). Surveyors are trained by experienced survey staff.

Identified monitoring gaps/overlaps

Puget Sound

Given the uncertainties regarding the historical escapement and run size information for coho, and inadequate population data for several of the SaSI stocks in Puget Sound, improved stock assessment data is needed, both for monitoring of stock health/rebuilding, and to meet fishery management obligations.

Most of the current natural coho population escapement estimation procedures for the larger stream basins require use of a base year estimate of escapement to generate the escapement estimate from the index survey counts conducted each year. New base year estimates of escapement are needed to address shortcomings in the old base year estimates conducted in 1977 for the Skagit, Stillaguamish, and Snohomish basins (Don Hendrick, WDFW personal communication), and the derivation of current base year escapement estimates for many of the other stream basins in Puget Sound. Nooksack, Puyallup, Green, East Kitsap, Deep South Sound stocks are largely undocumented and are therefore of unknown veracity, and no confidence intervals are available for the values.

Stillaguamish/Snohomish

(1) A new mark-recapture-based escapement estimate is needed in the Stillaguamish River basin (highest priority), because the original one was highly suspect.

(2) A new tagging study escapement estimate is needed for the Snohomish River basin (second priority), because the original one, is 25 years old, and if there have been significant changes in average coho spawning distribution since the estimate was made, it would severely bias estimates of total escapement made in more recent years using the old base year estimate.

(3) Development of stock assessment tools for the 'Unknown' status SaSI Deer Cr. and Whidbey Island coho stocks, which would require annual adult and/or juvenile assessment activities that are not currently being done due to staff/funding limitations.

Skagit/Nooksack

(1) A stock assessment program incorporating escapement and/or juvenile data collection is needed for the 'Unknown status' Sumas/Chilliwack and North Puget Sound Tribes stocks. Work cannot currently be done due to staff/funding limitations.

(2) A functional base year estimate of natural escapement to the Nooksack is needed if the current index based escapement estimation system is to be continued.

Central Sound region

(1) New base year estimate of natural coho escapements are needed for Lake Washington and Green River, if current index based escapement estimation methodologies are to be continued. Current base year estimates are undocumented, and Lake Washington and Cedar stocks are currently rated as Depressed in SaSI.

South Sound region

(1) New base year estimates of escapement for Puyallup, and Deep South Sound, and East Kitsap tributaries are needed if current escapement estimation methodologies are to be continued. If this is done with tagging studies, $100,000 to $200,000 per escapement unit would be needed.

(2) Survey effort for Nisqually River and Deep South Sound tributaries needs to be increased. This would require 2 additional FTEs.

The above list would provide data that is needed for both SaSI stock monitoring and fishery management. The current management system is dependent on post-season estimates of escapement and terminal run size, for in-season terminal area fishery management modeling, and pre-season forecasting. If just SaSI stock assessment needs alone are considered, the current stock-specific population indicator of 'season cumulative index fish*days' that is currently annually available for many of the river basins may be adequate to monitor population trends for each stock. In all cases, no estimates of variance for any of the adult escapement estimation values are currently derived - further consultation with statistician(s) and possible modification of current monitoring programs may be required to meet confidence interval generation objectives.

Strait of Juan de Fuca

Functional escapement monitoring programs need to be developed for several of the SaSI coho stocks in the Strait of Juan de Fuca[11]. These stocks present some difficult assessment issues, due to environmental conditions and or basin size. Water visibility is a key problem in escapement assessment for these stocks; Dungeness and Elwha mainstems are glacial, Morse Cr. is often turbid, and the Lyre is intensely turbulent. Large hatchery populations are present in the Elwha and Dungeness, so methods of assessing the natural/hatchery component in natural spawning populations are also needed.

The current index redd count system may provide a reasonable annual indicator of relative stock abundance in most streams in the region, but the lack of absolute estimates of abundance for each stock makes assessing stock specific population health and genetic viability issues difficult. If stock-specific escapement estimates are needed, at a minimum peak redd count surveys would have to be done throughout much of the rest of each of the basin to provide data for deriving a complete escapement estimate, and variances of the estimates would be moderate to high with this approach.

Washington Coast

(1) Relevant population trend data is needed for Sooes/Waatch, Ozette, Raft, Quinault basin, Cook Creek, Moclips, and Copalis River coho stocks. The Sooes and Waatch Rivers are located on the Makah Indian Reservation, and stock assessment work for these basins falls under jurisdiction of the Makah Indian Tribe. The Raft and Quinault basin (in part) fall under jurisdiction of the Quinault Tribe.

(2) Validation experiments to compare current escapement estimation results against alternative estimation approaches are needed for at least one of the major watersheds, preferably for two or more years, to provide comparative results across years for the alternative approach(es), as well as between methodologies. The most likely alternative approach would use a mark-recapture study.

(3) Investigations into restructuring current escapement estimation procedures for deriving uncertainty parameters are needed. This would require significant staff time, and interaction with tribal biologists.

(4) Annual coded tagging of Sol Duc hatchery summer coho would improve accuracy of terminal run reconstructions for natural summer coho stock in Quilleyute basin. The hatchery stock is at much higher abundance than the natural stock (10:1 ratio or more in many years), and the current stock allocation system is based on adipose sampling, and weekly-stratified fixed proportional ratio estimator value that is based on analysis of a few years of summer coho CWT tagging in the early 1980s. Run timing overlap of summer and fall coho run in river fishery confounds just using adipose fin sampling as a natural stock contribution estimator (J. Haymes, WDFW, personal communication).

(5) More indicator stock programs would be useful for monitoring juvenile production and marine survival on the coast. Marine survival expectations are a raging annual debate during pre-season abundance forecasting processes. The co-managers currently use an expectation that marine survival for coho increases moving northward from Grays Harbor based on assumptions drawn from current population data (M. Gross, WDFW, personal communication), but no monitoring systems are in place to rigorously test this assumption.

11 Dungeness, Morse, Elwha, Lyre rivers.

Lower Columbia

Coho salmon production in this region has been a subject of several NMFS ESA reviews (Busby et al. 2001). The first, in 1991, was in direct response to a citizen petition specific to the status of natural coho in the Lower Columbia region. The 1994 ESA review of this ESU was conducted as part of a coast-wide review of coho status. The 1996 review re-examined the status of the proposed and candidate ESUs identified in the 1994 review. The 2001 review was conducted in response to a new citizen petition, specific to the status of Lower Columbia ESU coho. The geographic extent of the Lower Columbia River coho ESU has been modified though time, originally including Southwest Washington streams south of the Quinault, and Columbia basin tributaries from the mouth east to, but not including, the Klickitat River basin.

The 1991 and 1994 status reviews determined there were no remaining discrete natural populations in the region, and any listing was therefore not warranted. The 2001 review identified the presence of two remaining natural populations in the ESU (Sandy and Clackamas River basins, Oregon), and tentatively rated these populations as “at risk of extinction,” and restricted the ESU in scope to just the Columbia River basin downstream of the Klickitat River. A final listing determination for the ESU following the 2001 federal status review process has not yet been made.

Analysis of genetic samples from hatchery coho stocks in the region indicate lower Columbia coho are distinct from coastal populations (Busby et al. 2001), but there has been no significant analysis done of the natural spawning populations in the region to date.

This is largely done by use of live coho presence/absence and/or peak count surveys. Index data is historically very limited in geographic scope, with the exception of single year (1998 return year) ‘hatchery origin coho stray rate to natural spawning areas’ study (Ruggerone 1999) that provided survey coverage to a large area of the Lower Columbia basin.

No quantitative total natural escapement estimates are available for any of the natural coho spawning populations in the Lower Columbia. Preliminary input from WDFW staff indicates more traditional visual-based survey efforts (redd or live counts) are unlikely to provide quantitative escapement data in many stream basins in the region, so other methods (mark-recapture or weir approaches) will be required to achieve quantitative estimates. Due to the difficulty and expense of these types of estimation procedures, an “indicator stock” approach may be the best approach, where specific streams thought to be representative of the region are intensively sampled through weir or mark/recapture approaches. It is recommended escapement estimations be conducted on streams where juvenile production monitoring is ongoing or planned, in order to develop a production function (juvenile recruits/spawner) for some of the populations, as this data is important for identifying escapement/management objectives.

➢ *Traditional visual spawning survey work is still recommended, in part to help identify spawner distribution, identify presence of hatchery strays, etc.*

Quality assurance/Quality control

A variety of minor quality control measures have been taken to date. However, greater attention is needed in order to improve confidence in the data. The specifics have already been discussed under “Identified monitoring gaps/overlaps” above.

There are no standardized quantitative quality control procedures used to audit the performance of spawner surveyors, or to calibrate relative ability of surveyors to observe live fish and/or redds. Supervisors may conduct a variety of situation-specific reviews, using a variety of approaches. For example, if supervisor observes field information collected by a surveyor that is out of context with general expectations for a given stream index (e.g., species composition, number of fish and/or redds observed), further investigation is usually conducted to assess surveyor performance.

Puget Sound

Escapements for most of the major coho stocks in Puget Sound are generally derived by the use of serial live counts of coho in a group of fixed index reaches in each basin, expanded to basin-total estimates of escapement by the base year escapement approach described in the escapement overview section of the introduction. Base year escapement estimates were typically derived by mark-recapture studies in the larger river basins (e.g., Skagit, Stillaguamish, and Snohomish River basins (T. Flint, WDFW personal communication), and alternative methods for the smaller river basins or aggregate small stream regions (e.g., Green and Puyallup River basins, Hood Canal and East Kitsap aggregate escapement regions) (C. Baranski, WDFW personal communication).

Strait of Juan de Fuca

Natural coho escapement estimates have traditionally been calculated as a single aggregate value for the Strait of Juan de Fuca, based on annual serial live coho counts in a group of fixed index reaches, expanded by a base year estimate of escapement. Historical estimation approaches prior to 1998 were similar to those currently used in most of Puget Sound. Derivation of the base year estimate of escapement originally used for calculating total escapements was undocumented (J. Haymes, WDFW, personal communication). In 1998, the escapement methodology was switched to a modified Stratified Random Sample (SRS) approach, conceptually similar to that used in more recent years for coastal Oregon natural coho escapement estimations. The census methodology also switched from a mix of live fish and redd counts on different streams to redd counts, as it was felt that redd counts would be a more robust spawner abundance statistic than live fish counts in this region. Redd counts are multiplied by 2.0 adults/redd to derive escapement in the index reaches (R. Cooper, WDFW, personal communication). Because both the old and new escapement methodologies currently provide estimates of absolute escapement only for the aggregate, season-cumulative index redd values from indices in individual stocks (where available) are being used as the primary SaSI population trend indicator for most stocks.

Washington Coast

Season-cumulative redd counts are conducted in fixed index reaches. “Peak” redd counts are conducted in non-index areas, and expanded to season total redd construction estimates for these reaches. Surveys are conducted per WDFW stream survey manual protocols (Linth et al. 1990). New surveyors are trained by experienced survey staff. There is, however, no standardized, quantitative quality control system used to audit surveyor performance or calibrate relative ability of surveyors to observe live fish and/or redds. Supervisors may conduct situation-specific reviews of surveyor performance if significant abnormalities are noted in the field data. Variance estimates can be derived for redd based escapement estimates (Haymes et al. 1993), although this has not been done to date for any coho escapement estimates derived in this region. Hatchery/wild composition of natural escapements not typically derived due to inability to achieve adequate carcass recoveries on spawning grounds in the coastal region for mark sampling. Proportion of hatchery fish in natural escapement will vary across the region as a function of proximity to major hatchery production programs, and the number of returns from fry out-planting programs in some streams in the region.

Lower Columbia

Partial adult counts have been collected at Cedar Creek (N.F. Lewis tributary) since 1998 (D. Rawding, WDFW, personal communication).

Mid Columbia

Two SaSI coho stocks exist in the Mid-Columbia, and both are of unknown status (preliminary 2002 ratings). Since coho management in the Columbia Basin has been oriented primarily towards hatchery production for many years, natural coho production assessment activity has been limited in comparison to other parts of the state. Most upriver stock assessment was historically based on dam counts at mainstem Columbia dams (WDF 1965). Natural coho populations in the mid and upper Columbia region were considered extinct by the 1980s (Weitkamp et al. 1995).

In more recent years intensive coho stock reintroduction programs have been instituted, with extensive juvenile and adult monitoring programs (BPA 1999; Murdoch and Dunnigan 2002). The programs will provide the framework for monitoring natural coho production.

Redd and live fish counts – spawning ground sampling is generally not designed to provide total natural escapement estimates at this time, since most of returns are from experimental supplementation programs.

Dam passage counts – partial or total counts at fish ladders are used to provide estimates of adult fish passage up-river. Natural spawning ground population monitoring methods are under development.

Objectives are defined in reports such as:

(1) Mid Columbia Coho Reintroduction Feasibility Project, 1999. DOE/EA-1282. BPA, Portland, OR, and

(2) Feasibility and risks of coho reintroduction in Mid-Columbia River tributaries, 2000 Annual report. K. Murdock and J. Dunnigan, 2002. BPA, Portland, OR.

Chum Salmon

Current monitoring activity

The spawner counts are used to calculate estimates of total escapement for individual populations (stocks or stock aggregates) using a variety of methodologies. For Puget Sound chum salmon, 181 individual escapement estimates are produced each year, 154 for spawner counts and 27 at traps or hatcheries (Table 28). The quality of these estimates vary from very good to poor depending on factors such as:

- Viewing conditions in counting areas,
- Numbers of fish present,
- Percentage of spawners actually counted, and
- Availability of supporting escapement studies.

Table 28. Annual number of independent escapement estimates made for Puget Sound chum salmon populations.

Type of estimate

	Trap/Fishway	Spawner counts	Total
Chum Salmon			
Hatchery	26	0	26
Wild	1	154	155
Total	27	154	181

The coverage of chum salmon spawner abundance current monitoring is adequate statewide (Table 29).

Table 29. Current chum spawner abundance monitoring.

Recovery Region	Number of stocks	Number monitored	Percent monitored	Adequate? Yes/No
Puget Sound*	52	43	83	Yes
Coastal	17	8	47	No[1]
Lower Columbia*	3	3	100	Yes
Mid Columbia	0	0	0	NA
Upper Columbia	0	0	0	NA
Snake	0	0	0	NA
Northeast	0	0	0	NA

* Contains populations listed under the ESA.

1 Number monitored has been reduced from 11 to 8.

Data source: WDFW SaSI Report

Estimates of measurement error and certainty

Estimates of salmon escapement are derived from counts of fish made in a variety of ways. With Puget Sound chum salmon, however, the method used is almost exclusively through visual counting of spawners in streams. Multiple counts are normally made each season, and each count has its own unique error rate based on survey conditions. Once the seasonal counts are completed, they are converted into estimates of total escapement using a variety of methods (e.g., spawner curves, base year estimates), each of which has its own error rate. The multiple and variable sources of error associated with escapement estimates based on spawner counts have frustrated attempts in the past to derive associated variance estimates. This means that statistically reliable measurements of error have not been produced for most escapement estimates, and are not likely to be in the foreseeable future. This does not mean that the estimates are unusable, just that their error rates have not been statistically calculated.

Exceptions to the above situation would be when spawners are counted at traps or fishways, or their population size is estimated using a tagging study. Each of these approaches can provide escapement estimate that can be statistically evaluated. Puget Sound chum salmon, however, spawn low in watersheds and are often reluctant to pass through fishways. Locations where the escapement of a wild chum salmon population is routinely monitored at a trapping site are rare (e.g., Chambers Creek). There have been no chum salmon population estimates derived from tagging studies since the 1970s.

Identified agencies

The WDFW and Treaty Tribes under US v Washington have been conducting spawner surveys for chum salmon in identified streams. This activity should continue. Additional information has been incorporated into SaSI from the Colville Tribe, NMFS, USFWS, and volunteer organizations.

Recommended sampling protocols

Counts of adult salmon (or redds) made on spawning grounds and migrating fish passing through fishways and traps form the basic information used to estimate escapements. A standard set of index areas for Puget Sound salmon spawner counts was established in 1952. The number of these indexes has expanded over time to meet the need for more detailed management. Survey protocol is conducted according to Ames (1984).

To derive escapement numbers that would be useful to assess the impacts of fishery management, the spawner enumeration procedures emphasize standardized approaches so that resulting estimates will adequately measure the rate of change from year-to-year, if not absolute fish numbers.

Typically, a stream or index area is counted every seven to ten days throughout the duration of spawning. Particular emphasis is given to obtaining a count at or near peak spawner abundance. Data recorded include live and dead spawners for all species present, redds (if used for an estimate), and an estimate of the percent of fish or redds seen (visibility). The counts are recorded in field data books and are later transferred to data entry cards. At the end of each season, all counts are proofed to identify errors and omissions. A variety of methods are subsequently used to convert the counts into estimates of escapement (see Current monitoring activity).

Serial spawner counts are assembled for a specific run of salmon in a stream or index area. The counts are proofed to eliminate errors or non-representative counts. The data are entered into an electronic database, and are then used to construct escapement curves for the spawning populations to be estimated. The counts may, or may not, be adjusted for visibility. The area encompassed by the escapement curve is calculated, and the resulting value is the total spawner-days represented by the curve. At this point the method used can vary depending on the nature of the spawner counts, and the type of escapement estimate required. Most often, the total spawner-days are divided by the average number of day a spawner spends in the counting area, which provides an estimate of the total number of spawners. Another approach, used in large river systems, is to relate the spawner values for a number of index areas to one or more base years, when the total basin escapement was determined.

Sampling design

An average of approximately 1,000 miles of Puget Sound streams are surveyed each year to conduct chum salmon counts.

Visually counting salmon in the stream environment is subject to sources of error, primarily related to numbers of fish present and the environmental conditions at the time of observation. Because of this, it has been long recognized that achieving highly accurate escapement estimates from visual survey data was problematic.

Identified monitoring gaps/overlaps

➢ ***It is recommended that the current levels of chum salmon escapement estimation (for developing total return and brood return estimates) for use in resource management and recovery monitoring be maintained.*** *This is a core WDFW stock assessment function that is conducted annually by staff.*

➢ ***It is recommended that baseline chum salmon escapement studies be conducted on two large north Puget Sound river systems, the Skagit and Snohomish, to improve the accuracy of escapement estimates for these major production areas.***

Chum salmon cannot typically be counted effectively in large mainstem rivers, and survey counts are by necessity made in smaller tributary index streams. These index counts are expanded into total escapement estimates for the entire system by comparing spawner densities in the indexes to the densities that occurred on a year when a tagging study was conducted to estimate total escapement (a baseline study). Several chum salmon baseline studies were conducted in the mid-1970s, and are still used to estimate escapements. Over the years, however, spawner distributions within the systems have changed, and the current estimates are of questionable accuracy.

Mark-and-recapture population estimates were conducted in the Skagit River in 1976 and 1977. Since that time there has been a major shift in spawner distribution within the basin due mostly to changes in the release patterns of water from the dams on the upper Skagit. The current proportion of spawners in index areas to the total escapement differs considerably from the study years which violates a major assumption of the methodology and some drastic adjustments to the estimation calculations are required to compensate. In addition the two studies yield different results when used to generate later estimates. With the hindsight gained over the last 25 years, it appears that the 1976 study may have overestimated the escapement by a factor of as much as 50% which has resulted in the overestimation of all subsequent escapements.

The escapement of chum to the Snohomish has only been estimated by a mark/recapture study once, in 1977. The major known chum spawning areas in the Snohomish basin are the braids and side channels of the Skykomish River and in the larger Skykomish tributaries. Most of the index areas selected from the 1977 study were side channels.

These areas can be very unstable and most of those used as indices have changed substantially since 1977 which has necessitated some extensive adjustments to the escapement estimation methodology. There has also apparently been a dramatic increase in the number of chum spawning in Sultan River (tributary to Skykomish River) which the 1977-based estimates do not reflect. The 1977 study provided little data on the usage of the Snoqualmie and its tributaries by chum. As a result, that stock has continued to be rated as “unknown.” A basin-wide inventory of chum spawning in the Snohomish basin would considerably improve the quality of our escapement estimates as well as provide much needed information on the presence and distribution of chum in the Snoqualmie.

Quality assurance/Quality control

Manuals have been developed by the WDFW to instruct staff on the standardized counting and data recording methodologies for salmon spawning ground surveys. Maps of individual index reaches are also used to standardize areas surveyed. General survey techniques and data handling are discussed in Ames (1984).

Data are compiled by the various tribes and WDFW. These data are compiled for broad distribution through SaSI. The data are not easily comparable because some data are estimates of total escapement and others are estimates of spawners per mile. These data should be translated to a common protocol and approach. The quality of these data overall are good but the SaSI document should be updated and reported annually for key information components of adult spawners, juvenile abundance, and juvenile migrants. Annual chum salmon escapement estimates for major areas are provided in the Puget Sound Database Section of the WDFW Chum Salmon Web Page. These estimates can be used to determine escapement performance at the Evolutionarily Significant Unit level (an ESA population designation). Escapement estimates for many individual stocks will soon be provided on the WDFW Salmonid Stock Inventory Web Page. These data should be accessible via the state Web Portal for viewing and downloading using the identified structure under Part V in this document.

Pink Salmon

Current monitoring activity

Counts of adult pink salmon and redds are made on spawning grounds, and of migrating fish passing through fishways and traps. This basic information is used to estimate escapements. A standard set of index areas for Puget Sound pink salmon spawner counts was established in 1958 (WDFW et al. 1973). The number of these indexes has expanded over time to meet the need for more detailed management. Pink salmon are currently not listed in Washington under the ESA.

The spawner counts are used to calculate estimates of total escapement for individual populations (stocks or stock aggregates) using a variety of methodologies. For Puget Sound pink salmon, 22 individual escapement estimates are produced each year, 15 from spawner counts and seven at traps or hatcheries (Table 30). The quality of these estimates vary from very good to poor depending on factors such as: viewing conditions in counting areas, numbers of fish present, percentage of spawners actually counted, and availability of supporting escapement studies.

Table 30. Annual number of independent escapement estimates made for Puget Sound pink salmon populations.

Type of estimate

	Trap/Fishway	Spawner counts	Total
Pink salmon			
Hatchery	6	0	6
Wild	1	15	16
Total	7	15	22

Sampling design

See Sampling Design in the chum salmon discussion above.

Pink salmon spawner counts on Puget Sound streams annually average approximately 700 total survey miles for the stocks making up the odd-year returns, and about 30 miles for the even-year Snohomish stock.

Current monitoring of pink salmon spawner abundance is adequate (Table 31). No new monitoring is needed.

Table 31. Current pink salmon spawner abundance monitoring.

Recovery Region	Number of stocks	Number monitored	Percent monitored	Adequate? Yes/No
Puget Sound	15	14	93	Yes
Coastal	0	0	0	NA
Lower Columbia	0	0	0	NA
Mid Columbia	0	0	0	NA
Upper Columbia	0	0	0	NA
Snake	0	0	0	NA
Northeast	0	0	0	NA

Data source: WDFW SaSI Reports

Estimates of measurement error and certainty

See Estimates of measurement error and certainty in the chum salmon discussion above.

Mark recapture estimates of pink salmon spawner abundance are almost always an overestimate of the true number. The relative error for pink salmon at the 95% confidence level varied from 27 to 42%. Pink salmon populations using this technique will likely overestimate the population by more than 65%.

Identified agencies

The WDFW and the Treaty Tribes under US v Washington have been conducting spawner surveys for pinks salmon for the identified streams for 30 years. This activity should continue.

Recommended sampling protocols

Manuals have been developed by WDFW to instruct staff on the standardized counting and data recording methodologies for pink salmon spawning ground surveys. Maps of individual index reaches are also used to standardize areas surveyed (Hendrick 1984; Knunsen 1987; WDFW 1998). General survey techniques and data handling are discussed in Ames (1984).

Essential monitoring activities

The Puget Sound pink salmon stock assessment activities in the "Essential" category are the minimum elements for the measurement of salmon protection and rebuilding. These elements are currently a part of the WDFW salmon monitoring program, and are critical for both resource management and comprehensive monitoring. These activities must be maintained, or in some cases expanded, to provide the basic information necessary to make the decisions which will lead to the improvement of Puget Sound pink salmon populations.

Stock assessment support

The single highest priority for pink salmon is the re-establishment of the staff position(s) responsible for the assembly, maintenance, analysis of stock assessment monitoring data, and dissemination of information. As a result of budget reductions in recent years, WDFW's stock assessment support for pink salmon has been eliminated. If the positions remain unfilled, critical stock assessment data will not be assembled and analyzed, and resource management and comprehensive monitoring will suffer.

Spawner surveys

➢ ***It is recommended that the current levels of pink salmon spawning ground surveys both for resource management and monitoring be maintained.***

Number of spawners

➢ *It is recommended that the current levels of pink salmon escapement estimation (for developing total return and brood return estimates) for use in resource management and comprehensive monitoring be maintained.*

This is a core WDFW stock assessment function that is conducted annually. It is recommended that baseline pink salmon escapement studies be conducted in two large north Puget Sound river systems, the Skagit and Snohomish, to improve the accuracy of escapement estimates for these major production areas. Pink salmon often cannot be counted effectively in large mainstem rivers because of the large numbers of spawners in typical returns. The counts are expanded into total escapement estimates for the entire system by comparing spawner densities in indexes to the densities that occurred on a year when a tagging study was conducted to estimate total escapement (a baseline study).

Baseline studies should be updated. Pink salmon baseline studies were conducted in Puget Sound rivers from 1959 to 1963. These studies are still used as a basis for escapement estimation. Over the years, however, spawner distributions within the systems have changed, and the current estimates are of questionable accuracy. In the Skagit and

Snohomish basins, counts of live spawners were seldom recorded during the baseline studies and the only data available for comparison are the numbers of carcasses sampled. Since flow conditions can have a huge effect on the number of carcasses present, carcass counts are questionable indicators of spawner abundance and some major adjustments to the resulting estimates are often required.

➢ *It is recommended that the accuracy of baseline estimates be verified and recalibrated to reflect changes over time in fish distribution.*

The even-year run of pink salmon in the Snohomish system has been increasing steadily since monitoring began in 1980. Historical escapement estimates have been derived from mainstem counts of spawners and redds but the escapements have now reached a point where accurate total counts are difficult. These fish are highly desirable as a sport fish and a strong local interest in a fishery already exists. As the returns approach levels where harvests could occur, the need for a baseline escapement study is increasing.

Quality assurance/Quality control

The general methodologies for converting Puget Sound pink salmon spawner counts into escapement estimates are described in Ames (1984).

Data are compiled by the various tribes and WDFW. These data are compiled for broad distribution through SaSI. The data are not easily comparable because some data are estimates of total escapement and others are estimates of spawners per mile. These data should be translated to a common protocol and approach. The quality of these data overall are good but the SaSI document should be updated and reported annually for key information components of adult spawners, juvenile abundance, and juvenile migrants. These data should be accessible via the state Web Portal for viewing and downloading using the identified structure under Part V in this document.

Sockeye Salmon

Current monitoring activity

Coverage of spawner abundance monitoring across the state for sockeye salmon is adequate (Table 32). There is no need for additional spawner abundance monitoring.

Estimates of measurement error and certainty

Mark-recapture estimates of sockeye spawner abundance are almost always an overestimate of the true number. The relative error for sockeye at the 95% confidence level varied from 20 to 98%. Estimates using mark-recapture will likely overestimate the sockeye population by 35%.

Table 32. Current sockeye salmon spawner abundance monitoring.

Recovery Region	Number of stocks	Number monitored	Percent monitored	Adequate? Yes/No
Puget Sound	4	4	100	Yes
Coastal*	3	2	66	Yes
Lower Columbia	0	0	0	NA
Mid Columbia	1	1	100	Yes
Upper Columbia	1	1	100	Yes
Snake	0	0	0	NA
Northeast	0	0	0	NA

* Contains populations listed under the ESA (Ozette Lake).

Identified agencies

The WDFW and the treaty tribes under US v Washington have been conducting spawner survey for sockeye salmon for the identified streams. This activity should continue. Additional information has been incorporated into SaSI from the NMFS, USFWS, and volunteer organizations.

Recommended sampling protocols

The general methodologies used for converting Puget Sound sockeye salmon spawner counts into escapement estimates are described in Ames (1984).

Identified monitoring gaps/overlaps

Stock assessment support

A high priority for sockeye salmon recovery is adequate staffing so that assembly, maintenance, analysis of stock assessment monitoring data, and dissemination of information can be achieved.

Adequate staff, critical stock assessment data is not being assembled and analyzed, and resource management and recovery monitoring are suffering.

Spawner surveys

➢ ***It is recommended that the current levels of sockeye salmon spawning ground surveys both for resource management and monitoring be maintained.***

Number of spawners

➢ ***It is recommended that the current levels of sockeye salmon escapement estimation (for developing total return and brood return estimates) for use in resource management and comprehensive monitoring be maintained.***

This is a core WDFW stock assessment function that is conducted annually.

It is recommended that baseline sockeye salmon escapement studies be conducted in the Cedar River to improve the accuracy of escapement estimates for this major production area. Sockeye salmon in the Cedar River have changed their entry patterns and spawning duration, resulting in underestimates of actual escapements. The current method uses index counts, which are expanded into total escapement estimates for the entire system by comparing spawner densities in the indexes to the densities that occurred on timing data collected during past baseline studies. Sockeye salmon baseline studies were conducted on the Cedar River in the 1960s and 1970s, and are still used to estimate escapements. Over the years, however, spawner timing within the system has changed, and the current estimates are of questionable accuracy.

Quality assurance/Quality Control

The validity of sockeye salmon spawner counts is questionable because the number of observed spawners is never an absolute count. The identified agencies should develop highly systemized approaches to validating the accuracy of the data at locations where it is possible to count all fish entering the spawning area.

Data are compiled by the various tribes and WDFW. These data are compiled for broad distribution through SaSI. The data are not easily comparable because some data are estimates of total escapement and others are estimates of spawners per mile. These data should be translated to a common protocol and approach. The quality of these data overall are good but the SaSI document should be updated and reported annually for key information components of adult spawners, juvenile abundance, and juvenile migrants. These data will be accessible via the state Web Portal for viewing and downloading using the identified structure under Part V in this document.

Steelhead

Current monitoring activity

Spawner surveys are conducted for steelhead stocks throughout the state (Table 33). The most accurate estimates are conducted in Puget Sound and on the coast where tribal harvest is targeting returning spawners within the river. Flights and ground counts of redds are used predominantly because steelhead are secretive and often cannot be seen during spawning. This is especially true for winter steelhead where water clarity may be a problem due to winter freshets. At some locations, total counts can be obtained due to fish ladders and other counting stations. Well known locations include: the Ballard Locks, Skykomish River at Sunset Falls, Snow Creek, and the Kalama River at Kalama Falls.

Most steelhead spawner counts are indices of abundance and not true estimates of total escapement (spawner abundance).

Table 33. Current steelhead spawner abundance monitoring.

Recovery Region	Number of stocks	Number monitored	Percent monitored	Adequate? Yes/No
Puget Sound	54	32	59	Yes
Coastal	45	28	62	Yes
Lower Columbia*	24	15	62	NA
Mid Columbia*	6	1	17	No
Upper Columbia*	3	2	66	Yes
Snake	5	3	60	Yes
Northeast	0	0	0	NA
TOTAL	137	81	59	
* Contains populations listed under the ESA.				

Data source: WDFW SaSI Reports

Estimates of measurement error and certainty

Error and certainty have not been routinely estimated for steelhead spawner abundance. The results reported by Hahn et al. (2001) should be considered as the upper level of certainty and accuracy as most spawners are not as rigorously estimated. Estimates of spawner abundance are based on counting redds in selected index areas. Redd days are counted over time and the area under the curve calculated for the total spawning period. This number is then used to estimate spawners using an established ratio of redds per spawning female. Aerial counts of redds were made in the Stillaguamish, Skagit, Green, and Cedar Rivers with an observed coefficient of variation of 29.1% at the 95% confidence limit. Redd life estimates showed that they were 95% confident that they could detect a change of 60% or greater in the number of steelhead redds.

Identified agencies

The WDFW and the Treaty Tribes under US v Washington and US v Oregon have been conducting spawner survey for steelhead for the identified streams for a number of years. This activity should continue. Additional information has been incorporated into SaSI from tribes, NMFS, US Fish and Wildlife Service, and volunteer organizations.

Recommended sampling protocols
No protocol information has been provided by either the WDFW or the tribes.

Identified monitoring gaps/overlaps
No information has been provided.

Quality assurance/Quality control
The validity of steelhead spawner counts is questionable because the number of observed spawners is never an absolute count. The identified agencies should develop highly systemized approaches to validating the accuracy of the data at locations where it is possible to count all fish entering the spawning area.

Data are compiled by the various tribes and WDFW for broad distribution through SaSI. The data are not easily comparable because some data are estimates of total escapement and others are estimates of spawners per mile. These data should be translated to a common protocol and approach. The quality of these data are overall good but the SaSI document should be updated and reported annually for key information components of adult spawners, juvenile abundance, and juvenile migrants. These data currently are not accessible, but should be available via the state Web Portal for viewing and downloading using the identified structure under Part V in this document.

Bull Trout

Current monitoring activity
Bull trout have been listed under the Endangered Species Act by the U.S. Fish and Wildlife Service throughout its range in Washington. Current monitoring efforts are not adequate to determine the overall spawner abundance trends in bull trout populations within the Puget Sound, Coastal, and Northeast Recovery Regions (Table 34). Formalized monitoring programs for bull trout abundance rely primarily on adult redd counts. In most cases, index reaches for redd counts are used. When time permits, these redd counts are accompanied by counts of adults from spawner surveys and/or snorkel surveys.

Washington Coast
The coastal recovery region contains seven stocks. Stock assessment data are incomplete and sporadic. Adult spawner counts were conducted in the Hoh River (Brenkman and Meyer 1999) and again in the south fork Hoh in the fall of 2001 (Gross 2002). However, a formal program is not in place. The Olympic National Park conducts snorkel surveys on three index streams within the park boundary annually. Genetic samples have been collected for populations on the Hoh but have not been analyzed.

Puget Sound region
Twenty-two bull trout stocks are thought to exist in the Puget Sound Region but only four have data on stock status (WDFW 1998). Redd surveys are conducted on index reaches in the Snohomish and Skagit rivers. Periodic surveys are conducted in the Skykomish system as well. Stock assessment is based on out migrant information provided by Seiler et al. (2001). Sporadic snorkel surveys for adults are conducted in sections of the Dungeness and Graywolf systems.

Those data that are available may be capable of detecting change within their own watersheds, but are insufficient for the entire region.

Lower Columbia
Two bull trout stocks are thought to exist in this region: in the Lewis River and the Klickitat rivers (WDFW 1998). Ongoing monitoring in Swift Reservoir includes extensive redd counts and snorkel surveys. Tagging studies provide estimates of the adult population. Recently, a screw trap was placed on the Lewis River that will add to estimates of sub-adults in the population. Documentation for sampling methods is found in Leland and Hisata (2001).

Field investigations for bull trout have been conducted in the Wind, Big and Little White Salmon, and Klickitat river systems. To date, bull trout have only been observed in the upper Klickitat system within the Yakama Nation Reservation boundary. Details on these investigations are found in Thiesfeld et al. (2001).

Mid Columbia
A total of nine stocks have been identified in this region and reside in the Yakima River (WDFW 1998). Stock assessment data from this region is the best of any statewide. Redd count indices are available in seven of the nine stocks present. The survey protocol is documented in Brown (1992). While variances associated with estimates are not available, the estimates provide an index of stock status relative to previous years that is informative.

Upper Columbia
A total of 30 stocks have been identified in this region (WDFW 1998). Annual redd surveys are conducted on 13 of the 30 stocks but only six of those have enough data to make an assessment of stock status. Wenatchee National Forest (Ken McDonald, Wenatchee National Forest, personal communication) and USFWS personnel conduct most of these surveys, with some assistance from WDFW staff.

Redd counts are available for the Methow and Twisp rivers. Trap counts for this region provides the best estimate of juveniles and adults in the region (Seiler et al. 2001). A telemetry study on bull trout migration and habitat utilization was initiated by the USFWS in 2000, details available in Delavergne (1987).

Northeast
Bull trout data are sporadic in this region. Most of what is known comes from a Joint Stock Assessment Project by the Kalispel Tribe of Washington and WDFW. This study is funded by the Bonneville Power Administration and includes habitat assessment and resident fish stock status above Chief Joseph and Grand Coulee dams including the Pend Oreille system. See McLellan (2001) and Kalispel Tribe website at http://www.knrd.org/ for details.

Snake River
The Tucannon, Asotin and Wenaha are the three bull trout stocks recognized by the USFWS in this region. Under the USFWS recovery planning effort, the Walla Walla system is grouped with the Umatilla system in Oregon. However, for the purpose of this report we grouped Mill Creek with the Touchet River, tributaries to the Walla Walla.

Annual spawner and redd surveys are conducted in index areas of the Tucannon and Touchet rivers (Del Groat, USFS, Pomery, personal communication). and BPA project No_199405400. Go to http://www.cbfwf.org/2001/projects/199405400.htm for additional details).

Table 34. Current Bull Trout spawner abundance monitoring.

Recovery Region	Number of stocks	Number monitored	Percent monitored	Adequate? Yes/No
Puget Sound*	22	3	14	No
Coastal*	7	1	14	No
Lower Columbia*	1	1	100	Yes
Mid Columbia*	11	8	73	Yes
Upper Columbia*	30	6	20	No
Snake*	5	2	40	No
Northeast*	4	0	0	No
TOTAL	80	21	26	No

* Contains populations listed under the ESA.

Data source: WDFW SaSI Reports

Estimates of measurement error and certainty

Sources of error in counting bull trout redds include variations from year to year in the spawning areas used, timing of counts and observer variability. Inter-observer variability can range from 50-200% of the baseline estimate and the counting error can also range from 50 to 200%. Mark-recapture methods used by Byrne and Rawding (personal communication) at Swift Reservoir in Skamania County averaged +/- 24% over an 8-year study.

Monitoring design

The USFWS has identified the Columbia River and Puget Sound bull trout populations as two distinct population segments. Distinct population segments do not interbreed and are considered distinct and separate in terms of recovery efforts, genetics and other characteristics. They have also identified seven draft "recovery units" in Washington, with two other recovery units partially involving Washington. The recovery units identified by the USFWS are consistent with the units in the "Statewide Strategy to Recover Salmon."

Bull trout adult spawner information should continue to be collected for those index areas that have been established.

➢ *It is recommended that an EMAP stratified random sampling protocol be established using a stratified approach for known bull trout distribution to detect the status and the trends.*

See also the Resident Juvenile Abundance section of this report for more details.

➢ *It is recommended that adult abundance be estimated in terms of numbers of adults per square meter for each SRR by implementing a rotating panel design using the EMAP site selection process.*

This site selection process appears to have promise for application to Washington trout populations. It has been demonstrated to be effective in determining the status of Oregon coastal coho and Nevada red band trout. The EMAP utilizes a Geographic Information System (GIS) to select a spatially balanced sample of a population. The rotating panel design combines annual sampling at the same sites for trend detection with more extensive sampling over the distribution of the population for determining status. The rotating panel is designed to be able to determine the annual status of cutthroat and bull trout populations within the Salmon Recovery Regions, and be 90% confident that the abundance estimate is within 17% of the true abundance. The rotating panel is designed to sample all of western Washington and selected portions of eastern Washington where the distribution of bull trout and west slope cutthroat occurs.

It is proposed to tie these EMAP resident adult trout sites directly with the proposed EMAP habitat evaluation sites and water quality sites so that correlations can be drawn between trout abundance and habitat and water quality conditions and trends.

Identified agencies

The WDFW has been collecting the vast majority of the bull trout information. This activity should continue. Additional information has been incorporated into SaSI from the USFWS, and volunteer organizations.

Recommended sampling protocols

There are no sampling protocols widely used for bull trout in Washington. The USFWS is in the process of determining recommended protocols. Bonar et al. (1997) evaluated different methodologies and recommended the use of 20 randomly selected 100m sections to be snorkeled or electrofished to be 95% confident that bull trout densities are less than 0.6 fish/100m. These sample sites are selected within "patch" areas considered to be areas of bull trout presence based upon preliminary cursory surveys. Until a better protocol is identified, this protocol provides statistically valid information and should be used throughout Washington.

Most spawner abundance information for bull trout is in the form of redds observed per mile in specific index portions of streams.

Performance benchmarks

The USFWS has indicated that bull trout populations should, over a ten year period:

(1) Exhibit stable or increasing levels of abundance;

(2) Maintain or expand the current number of populations;

(3) Maintain and restore appropriate habitat conditions within a recovery unit; and

(4) Maintain bull trout diversity by providing for genetic exchange between local populations.

These parameters should be measured such that the USFWS can be certain (from a statistical sense) that the desired changes had occurred over a ten year period within a recovery unit. The recovery plans under development are expected to establish these benchmarks.

Identified monitoring gaps/overlaps

There is no statistically sound approach to measuring the abundance of adult bull trout now in use in Washington.

Quality assurance/Quality control

The validity of bull trout spawner counts is questionable because the number of spawners observed is never an absolute count. The WDFW and the USFWS should develop highly systemized approaches to validating the accuracy of the data at locations where it is possible to count all fish entering the spawning area.

Data are compiled by the WDFW. These data are compiled for broad distribution through SaSI. The data are not easily comparable because some data are estimates of total escapement and others are estimates of spawners per mile. These data should be translated to a common protocol and approach. The SaSI document should be updated and reported annually for key information components of adult spawners, juvenile abundance, and juvenile migrants. These data should be accessible via the state Web Portal for viewing and downloading using the identified structure under Part V in this document.

Coastal Cutthroat Trout

Current monitoring activity

Coastal cutthroat have been under review, but are currently not listed in Washington under the Endangered Species Act. Statewide monitoring of coastal cutthroat (CCT) spawner abundance is currently not adequate (Table 35). The Stillaguamish River in Puget Sound and the Kalama River in the Lower Columbia River are the only two sites in the state where a consistent approach to monitoring spawner abundance has occurred. Neither of these locations has applied statistical approaches to the data to determine their level of certainty in detecting changes in the population.

Table 35. Current coastal cutthroat spawner abundance monitoring.

Recovery Region	Number of stocks	Number monitored	Percent monitored	Adequate? Yes/No
Puget Sound	17	1	0	No
Coastal	12	0	0	No
Lower Columbia	11	1*	9	No
Total	40	2	5	No

*Only the Kalama River has trend data that are distinct from planted hatchery cutthroat.

Data are available sporadically through monitoring efforts for other salmon species. The most consistent monitoring efforts regarding stock status for CCT trout are incidental to trapping efforts directed at out-migrating juvenile salmon. This work is being conducted throughout much of the coastal cutthroat range in Washington and provides the best data for the assessment of stock status (Seiler et al. 2001).

This report will provide an assessment of available harvest information and monitoring efforts directed at adult and resident life history forms of CCT not reported by Seiler et al. (2001). This report should be considered only as a part of the total description of work surrounding CCT, and is limited to information within WDFW files.

Washington Coast

The Coastal Region is divided into the Southwest Coast (Grays Harbor and Willapa Bay), and the North Coast and contains a total of 12 stocks (SaSI 2000).

Southwest Coast

The Southwest CCT are comprised of stocks from Willapa Bay and Grays Harbor. The Weyerhaeuser Company conducted an extensive two-year sampling project on the Chehalis/ Grays Harbor and Willapa basins from 1994-95. Data collected on juvenile abundance and distribution indicates that CCT are widely distributed and abundant within the southwestern portion of the DPS (Hunter 2001).

Perhaps the best indication of the status of adult CCT is the increasing trend of repeat spawners . This trend was seen in both Grays Harbor (West Fork Hoquiam trap) and Willapa bay stocks.

There is no formalized monitoring program for CCT harvest in place at this time. Harvest information that is available is limited primarily to Grays Harbor stocks. That data indicates an increase of both catch per effort and size 1984 and 1999 (Hunter 2001).

North Coast

Sporadic stream surveys for juvenile CCT are available but there are no formalized monitoring programs in place. Genetic samples have been taken the past two years on several streams but have not yet been analyzed. No harvest data is available at this time.

Columbia River

A total of six stocks of CTT have been reported in the Columbia River (SaSI 2000). Field investigations targeted at resident juvenile cutthroat in the Columbia River tributaries were conducted between June and October of 2000 and 2001 (Mongillo and Hallock 2001). More than 130 sites were sampled in 2001 alone. Results from these investigations showed that CCT were widely distributed throughout Lower Columbia River tributaries both above and below anadromous zones and in areas they were expected to be found. Coastal cutthroat were not found above Bonneville Dam in Washington with the exception of a tributary to the White Salmon River. These investigations also showed that relative abundance data, CTT per square meter, and the percent of streams with CCT were similar to other systems that were found not warranted for listing by USFWS (Mongillo and Hallock 2001).

Additional field investigations as described above should be the priority for CTT in this region.

Creel surveys in the Lower Columbia continue to be directed towards salmon and steelhead fisheries and do not measure CCT fishing effort separately. Harvest of CCT is not allowed in the Lower Columbia.

Puget Sound

SaSI divides Puget Sound into four sub-regions: North Sound, South Sound, Hood Canal, and Strait of Juan de Fuca. A total of 17 CCT stocks are thought to exist among the four sub-regions. No directed monitoring program of CCT stocks or harvest is performed.

North and South Puget Sound

Outside of the data collected on juvenile CCT out migration (Seiler et al. 2001) the only other stock assessment data available comes from hook and line sampling on the Skagit, Stillaguamish, and Snohomish systems. Though harvest of CCT is allowed, there is no formalized harvest monitoring program in place at this time.

Hood Canal

Information on adult CCT abundance is available for Snow Creek, a tributary of Discovery Bay (Seiler et al. 2001). Additional downstream migrant trapping by the Hood Canal Salmon Enhancement Group is being conducted on the Tahuya and Dewatto drainages in Hood Canal.

CCT are limited to catch and release fishery and no formalized monitoring program for harvest is in place at this time.

Strait of Juan de Fuca

The WDFW collects baseline information on presence and absence of resident and anadromous CCT in middle and upper stream reaches in the Strait of Juan de Fuca. Up to 12 baited live traps are set throughout the middle and upper reaches of a stream. The following data are recorded: date and time traps are set and pulled, depth of water, instream cover, bank cover, overhead cover, water temperature, species caught, and total number. Longitude/latitude coordinates using a GPS are also recorded. Genetic samples were collected for all CCT captured.

Upstream and downstream CCT adult and smolt information is also available from Snow Creek (Seiler et al. 2001).

Olympic National Park has been conducting CCT redd surveys on Barnes Creek since 1989 and Boundary Creek and the Lyre River since 1994.

Though harvest of CCT is allowed, there is no formalized harvest monitoring program in place at this time.

Monitoring design

It is proposed to conduct estimates of adult CCT abundance in terms of numbers of adults per square meter for each SRR by implementing a rotating panel design using the Environmental Protection Agency's EMAP site selection process. (See also the Resident Juvenile Abundance section of this report for more detail.) This site selection process appears to have promise for application to Washington CCT populations. It has been demonstrated to be effective in determining the status of Oregon coastal coho and Nevada red band trout. The EMAP uses GIS to select a spatially balanced sample of a population. The rotating panel design combines annual sampling at the same sites for trend detection with more extensive sampling over the distribution of the population for determining status. The rotating panel is designed to be able to determine the annual status of cutthroat and bull trout populations within the Salmon Recovery Regions, and be 90% confident that the abundance estimate is within 17% of the true abundance. The rotating panel is designed to sample all of western Washington for CCT. It is recommended that approximately 25-50 sample locations be sampled per year within each SRR.

It is proposed to tie these EMAP resident trout sites directly with the proposed EMAP habitat evaluation sites and water quality sites so that correlations can be drawn between trout abundance and habitat and water quality conditions and trends.

Identified agencies

The WDFW have been conducting spawner surveys for CCT for some streams. This activity should continue.

Recommended sampling protocols

There are no identified sampling protocols established for CCT spawners. However, a commonly used approach involves electrofishing established stream reaches using multiple removal methods described by Zippin (1958) and others.

Performance benchmarks

Benchmarks should be developed that are consistent with management and conservation objectives for CCT.

Identified monitoring gaps/overlaps

There is no cohesive approach to monitoring the abundance of CCT spawners or their reproductive potential. The best information is available for the Coastal SRR. Where numbers of mature CCT appear to be increasing.

Quality assurance/Quality control

There are no quality assurance or quality control efforts for CCT now in place.

Data are compiled by the various tribes and WDFW. These data are compiled for broad distribution through SaSI. The data are not easily comparable because some are estimates of total escapement and others are estimates of spawners per mile. Data should be translated to a common protocol and approach. The quality of these data are overall good but SaSI should be updated and reported annually for key information components of adult spawners, juvenile abundance, and juvenile migrants. These data currently are not available, but should be accessible via the state Web Portal for viewing and downloading using the identified structure under Part V in this document.

West Slope Cutthroat Trout

Current monitoring activity

West slope cutthroat (WCT) are thought to be endemic in three river basins in Washington: the Stehekin River at the head of Lake Chelan, and the Methow and Pend Oreille rivers. Their distribution once covered 101 streams and two lakes. Through extensive stocking of hatchery fish from two state hatcheries, WCT are currently found in over 493 streams and 311 lakes (Williams 1998). The distribution described above includes 103 western Washington alpine lakes.

Stocks or local populations of WCT have not been identified in Washington and this species is currently not detailed in SaSI. In their status review of WCT the USFWS used the "6th field" Hydraulic Unit Code (HUC) as the smallest unit for analysis (USFWS 1999). Additionally, genetic evidence collected in the Pend Oreille River indicated that WCT from eight independent tributaries ("5th field" HUC) are significantly divergent from one another (Young et al. *in press*). Washington's WCT may be more protected from extinction today than the native populations were, though the latter had persisted for thousands of years (Williams 1998) due to the artificial extension of their range. West slope cutthroat abundance in their native range and throughout their current distribution indicates that the species is not endangered, and USFWS has found listing under the Endangered Species Act is not warranted. Washington's WCT are found within the Mid-Columbia, Upper Columbia, and Northeast regions. West slope cutthroat are not thought to be native in the Snake River and no observations of WCT have been recorded there.

While WDFW does not have formalized monitoring programs for WCT, limited observations and frequency of occurrence during surveys for other species indicate that WCT are fairly abundant throughout much of eastern Washington. There are no harvest statistics, or escapement numbers available at this time other than the Northeast region.

The Kalispel tribe of Washington and WDFW are in their second year of a joint stock assessment project in the Pend Oreille Basin. Habitat and fish stock assessment surveys are conducted in the main stem Pend Oreille River and nine tributaries. No harvest data are available (Lockwood et al. 2001).

Monitoring design

➢ ***It is recommended that estimates of adult cutthroat and bull trout abundance be conducted in terms of numbers of adults per square meter for each SRR by implementing a rotating panel design using the EMAP site selection process.***

See also the Resident Juvenile Abundance section of this report for more detail. This site selection process appears to have promise for application to Washington trout populations. It has been demonstrated to be effective in determining the status of Oregon coastal coho and Nevada red band trout. The EMAP uses GIS to select a spatially balanced sample of a population. The rotating panel design combines annual sampling at the same sites for trend detection with more extensive sampling over the distribution of the population for determining status. The rotating panel is designed to be able to determine the annual status of cutthroat and bull trout populations within the Salmon Recovery Regions and be 90% confident that the abundance estimate is within 17% of the true abundance. The rotating panel is designed to sample all of western Washington and selected portions of eastern Washington where the distribution of bull trout and WCT are known to occur.

➢ ***It is recommended that approximately 25-50 sample locations be sampled per year within each SRR.***

It is proposed to tie these EMAP resident trout sites directly with the proposed EMAP habitat evaluation sites and water quality sites so that correlations can be drawn between trout abundance and habitat and water quality conditions and trends.

Identified agencies

The WDFW and the Pend Oreille Tribe have been conducting spawner surveys for WCT for some streams. This activity should continue.

Recommended sampling protocols

There are no identified sampling protocols established for WCT spawners. However, a commonly used approach involves electrofishing established stream reaches using multiple removal methods described by Zippin (1958) and others.

Performance benchmarks

Benchmarks should be developed that are consistent with management and conservation objectives for WCT.

Identified monitoring gaps/overlaps

There is no cohesive approach to monitoring the abundance of WCT spawners or their reproductive potential.

Quality assurance/Quality control

There are no quality assurance or quality control activities now in place.

Juvenile Anadromous Salmon Abundance

Objective 1B: Measure the status of the numbers of juvenile migrant salmon in each federally recognized ESU; and the trends. Evaluate whether the numbers are improving. This objective pertains to juvenile anadromous salmon.

The Pacific salmon species are characterized by scientist as anadromous. This term essentially means that the species spends all or most of its adult life in the ocean, but spawns in freshwater. This is opposed to catadromous fish such as the American eel that spends most of its adult life in freshwater, but migrates to the Sargasso Sea in the Caribbean to spawn. Anadromous salmon species, once the eggs have hatched from the gravel in freshwater streams, spend varying amounts of time in freshwater before returning to the sea. The chum and pink salmon spend only a few months at most before migrating while the coho and chinook typically spend one year in freshwater, migrating to sea the spring following the one in which they were hatched. Steelhead and Sockeye are the most flexible in their freshwater residency with some individuals in a population migrating after one, two, three, and sometimes even four years in freshwater. During their residence in the stream, salmon are subjected to predation, and other mortality factors associated with the capacity of the stream to produce salmon. As the habitat improves, the stream is able to support more juveniles and therefore, more juveniles migrate to the sea to mature into an adult fish, Conversely, when habitat quality declines, the overall numbers of juvenile migrants is reduced. Salmon species that spend significant amounts of time in freshwater are more dependent upon good freshwater habitat than are those that migrate rapidly to the sea. Therefore, a stream that has good populations of chum and pink salmon may not have good populations of coho, chinook, or steelhead.

Monitoring indicators

Numbers of juvenile salmon (smolts) migrating to the sea by watershed.

Number of wild juvenile salmon migrating to the sea

Juvenile out-migrant abundance is the measure of freshwater production for anadromous salmon, which typically go to sea as smolts, but for some species can also out migrate as pre-smolts or fry. A later section of this report addresses juvenile resident salmon (trout) that do not out migrate to the ocean (Seiler 2001). The number of out migrants is dependent upon the numbers of fertilized eggs deposited by spawners and by freshwater mortality factors associated with predation, flow, and other in-stream, riparian, and watershed habitat factors. In recognition of this, natural coho and chinook escapement goals throughout this state are based on the projected smolt carrying capacity of each system.

Relating year-to-year differences in juvenile salmon production with parent spawner abundance, environmental conditions, and species interactions enables scientists to determine the factors that affect survival of salmon throughout their freshwater life stages. It is also expected that measuring changes in the number of wild juvenile salmon migrants over time will allow evaluation of the cumulative effectiveness of conservation-based harvest strategies, improved hatchery management, watershed-scale land management, and habitat improvement projects, on the production and productivity of freshwater life stages of salmon.

Current monitoring activity

Levels of monitoring for some species are low. The number of trapping sites/salmon stocks monitored should be increased so that monitoring occurs for at least 10% of the stocks within each SRR. In addition, chum and pink salmon production has largely been evaluated using catch as an index of freshwater production. Development of approaches to measure the freshwater production of these species should be explored by involved agencies.

Table 36. Current statewide salmon juvenile migrant abundance monitoring.

Species	Number of stocks	Number monitored[4]	Percent monitored	Adequate? Yes/No
Chinook	108	25	22	No
Coho	90	20	22	No
Chum[1]	72	6	8	Yes
Pink[1]	15	1	7	Yes
Sockeye[2]	9	3	33	Yes
Steelhead[1]	141	31	22	No
Bull Trout	80	21	26	No
Coastal Cutthroat[1, 3]	85	12	14	No
West Slope Cutthroat	Unknown	0	Unknown	No

1 *ODFW SRS surveys are stratified by estimated relative spawning density zones in the stream reaches.*

2 *Escapement estimates generated from weirs or traps are not always absolute estimates of escapement. High flows, staffing, and/or equipment problems may prevent weir operation through the entire run period, so some of fish passage past the trapping location may be estimated. In addition, wild and hatchery origin fish passage estimates are typically derived from tags or scales recovered in sub-sampling operations, so there are error parameters associated with the sub-sampling expansions.*

3 *This is a result of the hatchery production-oriented management objectives in these regions, which yield large returns of hatchery fish that often outnumber the natural populations in the region. Even smaller hatchery stray rates are numerically significant in comparison to the local natural population spawner abundances.*

4 *Dungeness, Morse, Elwha, Lyre rivers.*

Data source: WDFW SaSI Reports

Current monitoring activities are broken down by species in the following section to highlight circumstances for each species.

➢ ***It is recommended that production and productivity of identified index stocks be measured where trapping of juvenile migrant salmon is occurring.***

These locations may be representative of other nearby streams where trapping may not be feasible. Measurement of total production in terms of adults produced per adult spawner requires reconstruction of age class cohorts and calculations of total run size. To do this, information on juvenile migrant abundance, spawner abundance, marine survival, and age, sex ratios, and total harvest is needed. A vital component is the information derived from the current coast-wide coded wire-tagging program. These programs and their funding must be continued to answer questions concerning responses of salmon to improvements in freshwater. Total abundance of salmon cannot be estimated without adequate data.

Measuring the freshwater production of anadromous juvenile salmon is an extremely valuable tool for tracking stock status, and the best tool for evaluating habitat productivity. Concurrent collection of landscape-level habitat and environmental data enables determination of the effects of habitat and environmental changes on freshwater production within and between basins. However, even under the best circumstances, juvenile production monitoring is difficult and expensive. To be successful, a number of variables need to be considered and evaluated before monitoring can be undertaken, including the stream selection, flow pattern, spawning and rearing locations of targeted wild stocks, the location and operation of hatcheries, and other human uses of the river. In many watersheds, the requisite conditions do not exist for successful smolt monitoring. Therefore, it is unfeasible to make a measure of juvenile migrants for every system and all stocks in the state on an annual basis.

This CMS recommends two different measures of juvenile migrant abundance:

(1) Estimated freshwater production of wild salmon brood classes by species, and

(2) The use of catch from juvenile migrant traps as an index of freshwater production for wild salmon brood classes by species.

The estimate of freshwater production is, by far, the most valuable since it can be compared to spawner abundance to develop estimates of stock productivity, and can be used to compare the productivity of habitats between watersheds. The catch-based index of production only provides the ability to track year-to-year differences in production within watersheds. To provide the most benefits, long-term monitoring of wild juvenile anadromous salmon abundance should only be undertaken at locations where key species can be monitored by estimating total freshwater production.

While this approach limits the number of monitored stocks and species, it ensures that the data collected is of high quality and cost effective. As appropriate, inferences from data collected at these sites can be extended to other unmonitored stocks. In addition, freshwater production has historically been measured in many streams that are not currently being monitored. This work has provided a production baseline for selected species in a large number of watersheds statewide that, when coupled with changes in production found in monitored streams correlated with habitat and environmental changes, may enable estimation of production changes to the un-monitored streams as well.

The overall total numbers of stocks within the ESU and the total numbers of juvenile migrants within the ESU can be sampled in a design that would estimate an entire population within an ESU, if taken in a statistically sound manner. The design for measuring freshwater juvenile migrant production would be based upon a sample size to provide a 90% confidence limit that the trend in the data for sampled stocks are representative of the entire target population within an ESU. Ideally, the sample should be randomly selected from the ESU's stocks. However, many populations have been monitored for years, and taking advantage of those provides an important efficiency. It does mean, however, that stocks are selected on a non-random basis to some extent.

Essential tools

Juvenile migrant traps

Juvenile migrant trapping must be funded and increased in order to provide needed certainty for the recovery of wild salmon populations. There are various trapping techniques that are essential (e.g., smolt traps, seines) as described in the following situations for each species.

Performance benchmarks

No performance benchmarks have been established for wild juvenile migrant production within an ESU. The Technical Recovery Teams established by NMFS under the ESA may identify specific targets or levels for the various ESUs. In the meantime, performance benchmarks for juvenile migrants should reflect improving trends in juvenile out migrant production as evaluated over at least a ten-year period. Interpretation of trends over shorter periods may be complicated by inter-annual variation in climate (i.e., streamflow) or other factors.

Identified monitoring gaps/overlaps

Gaps and overlaps will be detailed for each species in the following sections. However, due to the complexities and associated costs of sampling juvenile anadromous salmon (smolts), the number of sampling sites is often inadequate.

Quality assurance/Quality control

The status of wild juvenile migrant production in each of the identified index watersheds within each SRR should be analyzed annually. Trends should be presented in charts showing the juvenile migrant production for each of the index populations and another chart should show the aggregate numbers of juvenile migrants for the SRR. Hypothetical examples are provided in Figure 29 and Figure 30.

A pilot watershed program is recommended to measure juvenile anadromous salmon to determine if usable trend information can be developed for chinook, coho, and steelhead from an EMAP design approach.

Figure 29. Sample presentation showing naturally produced juvenile coho migrants by year for index streams in the Puget Sound Salmon Recovery Region.

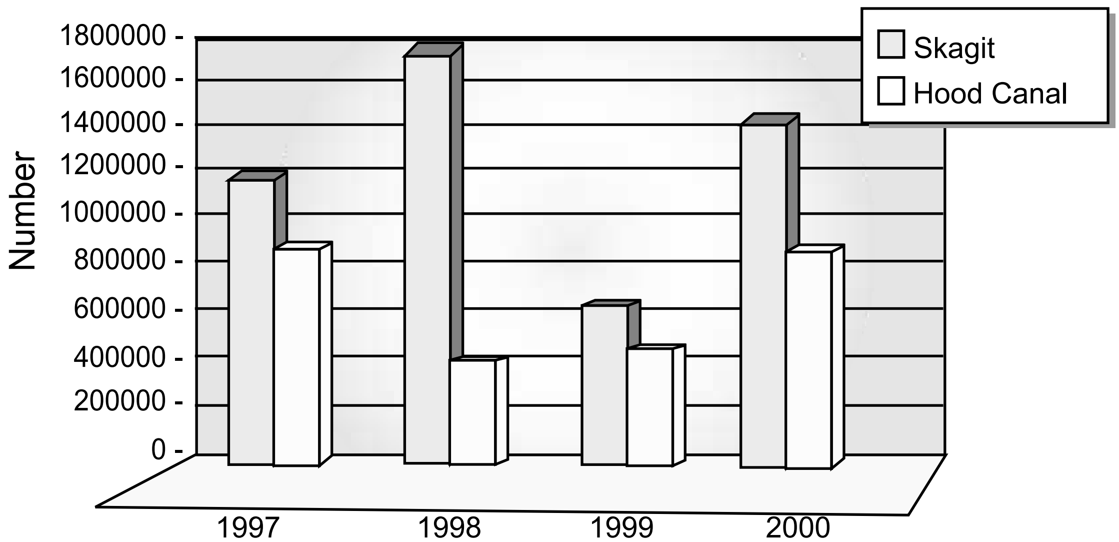
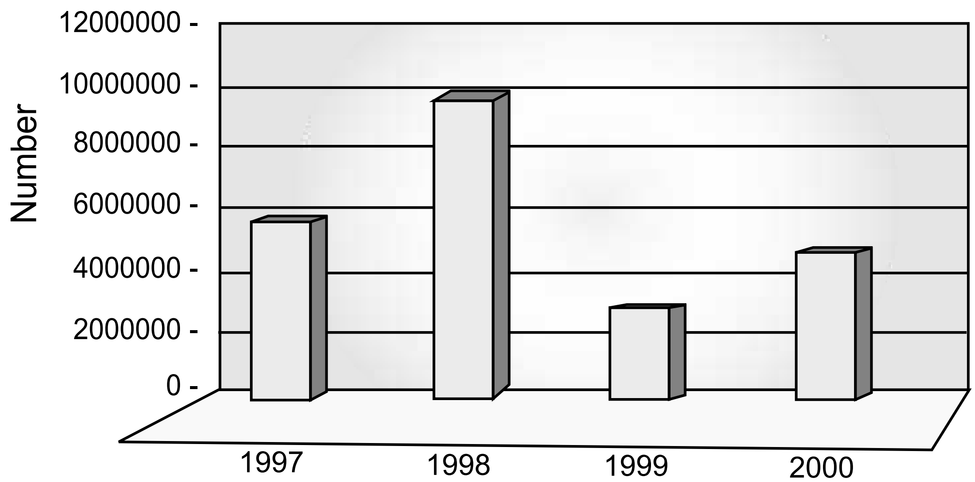


Figure 30. Sample presentation showing naturally produced juvenile coho migrants per year in the Puget Sound Recovery Region.



Performance benchmarks

Expressed as a performance benchmark, the average egg-to-migrant survival for age 0+ migrant chinook, chum, pink, and sockeye salmon improves by at least 20% from one 20-year period to the next.

Rationale:

(1) Inter-annual variation in juvenile migrant production is typically related to the effect of flow conditions on a cohort. The magnitude of these flow effects are related, among other things, to the condition of the habitat and the size of the spawning fish; neither of which is repaired year-to-year. Comparing juvenile migrant production over 10 or 20-year intervals better tests whether changes in the production relationship with flow has taken place.

(2) Healthy, complex habitat and watershed conditions, along with robust spawning populations, would be expected to better mitigate rainfall/stream flow effects on juvenile salmon production than poor quality, degraded habitat and watershed conditions. As watersheds, habitats, and fish population structure improves, inter-annual variability in juvenile migrant production should decrease.

(3) As the ability of the watershed, habitat, and population structure to mitigate the effects of peak runoff during incubation periods improves, so should average egg-to-migrant survival.

Juvenile Chinook Salmon

Current monitoring activity

Table 37 summarizes current naturally produced juvenile chinook migrant monitoring by recovery region. Juvenile chinook abundance is monitored in five rivers/streams in Puget Sound (Skagit, Bear Creek, Cedar, Green, and Deschutes). These operations provide for direct enumeration of 11 chinook stocks from which freshwater production estimates can be made. Some of these stocks are monitored in a conglomerate. For example, the Skagit River trap enumerates the aggregate abundance of six stocks (lower Skagit summer fall chinook, upper Skagit summer fall chinook, lower Sauk summer chinook, Suiattle spring chinook, upper Sauk spring chinook, and upper Cascade spring chinook) but cannot distinguish abundance for individual stocks.

Four traps and one seining operation are used to monitor six chinook stocks in the Lower Columbia River. All of these operations develop estimates of juvenile chinook production.

The Mid-Columbia has one trap on the Yakima River operated by the Yakama Indian Nation at Prosser Dam that enumerates the aggregate abundance of five stocks. In the Upper Columbia, chinook production estimates are currently available at one trap (Chiwawa).

In the Snake River there is one trap located on the Tucannon River, and it provides information about Tucannon spring and Snake fall chinook.

Trapping of the main stem of the Snake and Columbia rivers occurs at certain dams (Figure 31). These include Bonneville, John Day, and McNary Dams below the confluence of the Snake, Lower Monumental, Little Goose, and Lower Granite dams on the main stem of the Snake, and Rock Island dam on the upper Columbia River. There is also a new trap at Lewiston enumerating migrants from Idaho. These counts provide production indices for large combinations of stocks that rear above these dams; but they are of relatively little use in monitoring individual populations. Furthermore, inter-annual runoff patterns affect the distribution of juvenile salmon as they migrate past the dams, which if not accounted for, may bias production indices.

Table 37. Current naturally produced juvenile chinook migrant abundance monitoring excluding monitoring at Columbia and Snake River Dams.

Recovery Region	Number of stocks	Number monitored	Percent monitored	Adequate? Yes/No
Puget Sound	29	11	38	No
Coastal	32	0	0	No
Lower Columbia	22	6	27	Yes
Mid Columbia	9	5	56	Yes
Upper Columbia	13	1	8	No
Snake	3	2	66	Yes
Northeast	0	0	0	NA
Total	108	25	23	
Note: Monitoring was assumed adequate where 10% or more of the stocks within a recovery region were monitored.				

Data source: WDFW SaSI Reports

Figure 31. Map of Columbia-Snake river dams and trap sites.

Data source: Bonneville Power Administration Website

Identified agencies

The WDFW and Treaty Tribes under US v Washington and US v Oregon have been conducting juvenile chinook migrant trapping for the identified streams. The BPA, ACOE, and others have been involved in trapping migrants at Columbia and Snake river hydro-electric dams as part of long term evaluation of survival associated with operation of the FCRPS.

Recommended sampling protocols

Wild juvenile chinook migrant data are collected using various methods such as screw traps, inclined plane screen traps, weirs, and seines. Gate well or other trap types are used to monitor passage at mainstem dams. Screw traps and inclined-plane screen traps are most often used where production is to be measured for one to a few stocks within a single water-shed or sub-watershed. In general, production is estimated using these gear-types by:

(1) Estimating the catch per unit effort,

(2) Expanding the catch to account for periods when the trap was not fishing, and

(3) Dividing the expanded catch by the estimated catch rate, or trap efficiency (Seiler at al 2001).

The seining operation on the Lewis River uses a different approach. At this location, wild chinook migrants are seined in the lower river and coded-wire tagged. Returning adults are sampled in Lewis River sport fishery for the tags and the proportion of tagged returning adults of the same year class is multiplied by the number of tagged migrants to estimate total production. Using this approach, production is not estimated until all of the brood has returned to the river.

Production from multiple stocks is measured using dam counts on the main stem Columbia and Snake rivers. Chinook migrants are captured at main stem dams by trapping or by employing dam bypass facilities. The proportions of the migrants passing dams that are caught can vary depending on trap type and occurrence of spill. Capture rates can be highest when spill is not occurring and bypass systems are used to capture migrants. Capture rates can be low when spill occurs and/or when traps are used at dams that do not have bypass facilities. Sometimes hydro-acoustical methods are used to collect data used to estimate migration past dams based on the catch composition found in the trapping operation. Dam counts are generally considered indices of production due to these varying, and largely unknown, catch rates.

Identified monitoring gaps/overlaps

There are numerous streams where juvenile chinook migrant information is lacking. Because migrant traps cannot be used in all streams, it is important to sample a range of streams throughout the state.

➢ *It is recommended that more traps be used to fill gaps in knowledge about watershed freshwater production.*

➢ *It is recommended that funding and effort be increased to improve the accuracy and reduce the variance of estimates at existing sites.*

Quality assurance/Quality control

The accuracy of wild chinook juvenile migrant production estimates is discussed in Seiler et al. (2001) and other similar publications. Estimates of juvenile migrants are routinely compared against other kinds of trapping information where available, and against modeled predictions. The identified agencies should develop highly systemized approaches to validating the accuracy of chinook juvenile migrant trap data.

Data are compiled by various tribes and WDFW for broad distribution through SaSI. The SaSI document should be updated and reported annually for juvenile migrants. Information is also summarized in the Salmon Recovery Scorecard (Indicator A2). These data are currently not accessible, but should be available via the state Web Portal for viewing and downloading using the identified structure in Part V of this document.

Juvenile Coho Salmon

Smolts are the best measure of freshwater production for coho salmon (Seiler 2002). Total natural origin smolt out-migrations for several coho populations are measured annually by WDFW and tribal co-managers, through the use of a variety of trapping systems (Table 38). Permanent weir-type trapping systems used in some streams enumerate nearly 100% of the juveniles migrating past the sampling location, except during extreme high flow periods. Some of these traps also enumerate all or part of the upstream adult salmon passage via the same weir system. In larger or deeper stream channels that are not amenable to full channel width weirs, a portion of out-migrating juveniles are sampled through the use of screw or scoop traps. Season-total juvenile passage is estimated for these trapping systems by time and/or flow stratified mark-recapture studies.

Current monitoring activity

Table 38. Current coho salmon stock monitoring stations, and other ongoing juvenile monitoring activities.

Location	Region	Trapping system	Operator
Long-term monitoring			
Big Beef Cr.	Hood Canal	Upstream (adult) / downstream (juvenile) weir at mouth of Big Beef Cr. provides annual adult and juvenile passage monitoring for entire watershed.	WDFW Science Division
Snow Cr.	Strait of Juan de Fuca	Upstream / downstream weir, at mouth of Snow Cr. provides annual adult and juvenile passage monitoring for entire watershed.	WDFW Region 6
Deschutes R.	South Puget Sound (Deschutes R. basin)	Upstream / downstream weir, RM 0.2 on mainstem Deschutes R. provides annual adult and juvenile passage monitoring for entire watershed.	WDFW Science Division
Baker Lake	North Puget Sound (Skagit R. basin)	Upstream / downstream weir, at Baker Dam complex provides annual adult and juvenile passage monitoring for Baker lake watershed.	Puget Power. Juvenile fish marking is done by WDFW and/or Skagit Tribal Co-Op staff.
S.F. Skykomish R.	North Puget Sound (Snohomish R. basin)	Adult trap at Sunset Falls, S.F. Skykomish R. provides long term escapement monitoring (juvenile trapping was conducted at this location in late 1970s).	WDFW SHHEAR
Chehalis R.	Grays Harbor (Chehalis R. basin)	Scoop (juvenile downstream migrant) trap provides annual smolt production estimate for upper Chehalis basin.	WDFW Science Division

Location	Region	Trapping system	Operator
Elk Cr.	Grays Harbor (Chehalis R. basin)	Adult trap provides long term escapement monitoring for Elk Cr. Watershed.	WDFW Science Division and citizen co-op
Bingham Cr.	Grays Harbor (Chehalis R. basin)	Upstream / downstream weir at mouth of Bingham Cr. provides annual adult and juvenile passage monitoring for entire watershed.	WDFW Science Division
Cedar Cr. (Lewis R.)	Lower Columbia	Adult upstream and juvenile downstream trapping systems at mouth of Cedar Cr. (N.F. Lewis R. tributary) provides annual adult	WDFW Region 5
		and juvenile passage monitoring for entire watershed.	
Clearwater R.	North Coast	Screw (juvenile) trap in Lower Clearwater R. (Queets R. Tributary) provides juvenile passage monitoring for entire watershed.	Quinault Tribe
Sammamish R.	Lake Washington basin (central Puget Sound)	Screw trap in Sammamish R., located downstream of mouth of Bear Cr. provides juvenile passage monitoring for Bear Cr. and Lake Sammamish watersheds.	WDFW Science Division
White R.	Puyallup River basin (south Puget Sound)	Mud Mountain Dam adult trap provides annual upstream escapement monitoring.	Corps of Engineers and Puyallup Tribe operate adult trap.
		Juvenile screw trap operated in spring 2001.	Juvenile screw trap was operated by WDFW Science Dept., Puyallup Tribe may continue juvenile production study if funds can be found.
Other current monitoring			
Nooksack R.	North Puget Sound (Nooksack R. basin)	Screw trap – not currently conducting total coho smolt population estimates.	Nooksack Tribe
Snohomish R.	North Puget Sound (Snohomish R. basin)	Screw trap – not currently conducting total coho smolt population estimates.	Tulalip Tribe
South Sound independent tributaries	South Puget Sound on selected small tribs. in deep South Sound.	Juvenile screen traps	Squaxin Tribe

Location	Region	Trapping system	Operator
Strait of Juan de Fuca and Hood Canal	SJF/Hood Canal	Juvenile screen traps annually placed on several independent tributaries to SJF and Hood Canal.	Makah, Elwha, Jamestown tribes, WDFW Region 6 and Science Division.
Wenatchee R.	Mid-Columbia	Three screw traps: a) near town of Monitor on mainstem Wenatchee R., b) outlet of Lake Wenatchee, and c) Nason Cr. Partial adult counting conducted at Dryden diversion dam.	WDFW Region 3, Yakima Tribe
Yakima R.	Mid-Columbia	Upstream/downstream trapping systems (adults and juveniles) at irrigation dams at mainstem Yakima R.	Yakama Tribe, WDFW Region 3
Lower Columbia tributaries	Lower Columbia	Screw and/or screen traps on Germany, Mill, and Abernathy Cr. provided juvenile salmon production estimates in spring 2001 and 2002, are expected to be continued.	WDFW Science Division
Puyallup River (upstream of White River)	South Puget Sound (Puyallup R.).	Juvenile screw trap was operated in spring 2001 (might be continued in future if funding can be found).	Puyallup Tribe

Data source: WDFW Science Division

Wild coho production is monitored at nine locations in the Puget Sound, nine locations on the Washington coast, and four locations in the lower Columbia. Table 39 provides a summary of the number of coho stocks for which juvenile out migrants are monitored.

Table 39. Current coho juvenile migrant abundance monitoring.

Recovery	Number of Stocks	Number Monitored	Percent Monitored	Adequate? Yes/No
Puget Sound	40	9	23	Yes
Coastal	32	7	22	Yes
Lower Columbia	17	4	24	Yes
Mid Columbia	1	0	0	No
Upper Columbia	0	0	0	NA
Snake	0	0	0	NA
Northeast	0	0	0	NA
Total	90	20	22	No

Note: Monitoring was assumed adequate where 10% or more of the stocks within recovery regions were monitored. The value of monitoring the one stock (Klickitat coho) in the Mid Columbia Recovery Region is questionable since rearing is limited to only two miles of mainstem habitat plus tributaries and this stock comprises only a small percentage of the Southwest Washington/Lower Columbia coho ESU.

Data source: WDFW SaSI Reports

Puget Sound

Permanent juvenile migrant weirs, and temporary screw, scoop, and screen traps operated by WDFW and other organizations have provided estimates of coho smolt out migration with measured precision and accuracy for several watersheds and sub-watersheds in Puget Sound. The WDFW Science Division maintains permanent upstream/downstream migrant weirs on Big Beef Creek (1976 Biennial Year to present), and screw and/or scoop traps in the Skagit River (1988 Biennial Year to present), Deschutes River (1975 Biennial Year to present), and has worked cooperatively with Puget Sound Energy and the Skagit System Co-op at the Baker Lake juvenile out migrant trap (1989 to present). There have also been many other shorter-term juvenile coho production monitoring projects conducted in Puget Sound aimed at addressing specific research and/or management questions, and/or providing more general information on coho productivity. A partial listing of these projects includes:

(1) South Fork Skykomish trapping in the late 1970s (Seiler and Ackley 1984),

(2) Trapping of numerous small tributaries in western Washington in the late 1970s-1980s (Blankenship and Tivel 1980, Flint 1984, and Lenzi 1983),

(3) Stillaguamish trapping in the early 1980s (Seiler and Ackley 1984), and

(4) Juvenile coho trapping continues at several locations throughout Puget Sound, operated by state, tribal, and/or public co-op groups.

Coho out migrant estimates are point counts for screen trapping operations. Total, or near total trapping efficiency is typical. However, smolt estimates for time periods when traps are is not operational are typically made without variance estimates. Variance estimates are made for screw/scoop traps.

Strait of Juan de Fuca

Short-term coho juvenile out migrant monitoring has been conducted on many watersheds in the area over the years by both WDFW and tribal organizations. The WDFW sampling operations in recent years have been conducted per WDFW Science Department protocols. Out migrant estimates are point counts for screen trapping operations. Total or near total trapping efficiency is typical, smolt passage estimates for time periods traps are not operational are typically made without variance estimates.

Washington Coast

Long-term juvenile coho monitoring has been ongoing in the Queets and Chehalis rivers since the mid-1970s. Short-term juvenile out migrant monitoring has been conducted on many watersheds in the area over the years by both WDFW and Treaty tribes.

Lower Columbia

Juvenile out migrant monitoring has recently been conducted in Mill, Abernathy, and Germany Creeks, Cedar Creek (Lewis River), and the East Fork Lewis and the Wind rivers.

Mid Columbia

(1) Screw trap operation on mainstem Wenatchee River and Lake Wenatchee outlet, out migrant sampling at Yakima River and Columbia River mainstem dams.

(2) Density, distribution and presence/absence snorkel and electrofishing surveys for natural production and predation research.

(3) Mark/recapture studies to monitor out migration transit speed/predation losses, etc.

Estimates of measurement error and certainty

Trapping efficiency indicates that the coefficient of variance is approximately 5% and that we can be 95% confident that the traps can detect a 10% or greater change in the number of juvenile out migrating coho salmon.

Identified agencies

The WDFW and Treaty Tribes under US v Washington and US v Oregon have been conducting juvenile chinook migrant trapping for the identified streams. The BPA, ACOE, and others have been involved in trapping migrants at Columbia and Snake river hydroelectric dams as part of long term evaluation of survival associated with operation of the FCRPS.

Recommended sampling protocols

Wild juvenile coho production is measured using direct counts at permanent and temporary weirs, and using screw and inclined plane screen traps. Protocols vary somewhat depending upon the gear used. Weirs typically capture all migrating coho unless streamflow conditions compromise the weir's ability to do so. If this occurs, missed catch is estimated by interpolation or by the use of a capture efficiency estimate (Seiler et al.2000).

Protocols for the use of screw and inclined-plane screen traps are as described for chinook above. In general, trapping should follow the methods described in Seiler et al. (2001), Seber (1982), and Seiler (2001).

Identified monitoring gaps/overlaps

There are mainstem screw/screen traps currently in operation by the Stillaguamish, Snohomish, and tribes on those respective river basins. These traps are not currently providing estimates of total coho smolt production from the rivers due to operational limitations. Additional funding and/or staffing assistance from other sources may provide sufficient resources to gain annual total coho smolt estimates at these traps. This information would provide important information for assessing uncertainties with natural smolt production capabilities.

In addition to the Skagit smolt enumeration work already being conducted, there are mainstem screw/screen traps currently in operation by the Nooksack Tribe on the S.F. Nooksack River. This trap is not currently providing estimates of total coho smolt production from the river basin due to operational limitations. Additional funding and/or staffing assistance from other sources may provide sufficient resources to gain annual total coho smolt estimates at this trap. This information would provide important information for assessing uncertainties with natural smolt production capabilities.

Quality assurance/Quality control

There are no formal quality assurance and quality control guidelines or protocols in use for juvenile coho out migrant sampling. The accuracy of coho juvenile migrant counts and production estimates are discussed in Seiler et al. (2001), and other similar publications. Estimates of juvenile migrants are routinely compared against other kinds of trapping information where available, and against modeled predictions. Identified agencies should develop highly systemized approaches to validating the accuracy of juvenile coho trap data.

Coho data are compiled mainly by the WDFW. Juvenile migrant information is also collected by the Elwha, Makah, and Quinault tribes. These data are compiled for broad distribution through SaSI and are also summarized in the Salmon Recovery Scorecard (Indicator A2). The quality of these data varies from poor to excellent, depending on the trapping operation and project goals. The SaSI document should be updated and reported annually for juvenile migrants. These data and the forecasts should be accessible via the state Web Portal for viewing and downloading using the identified structure under Part V of this document.

Juvenile Chum, Pink, and Sockeye Salmon

In contrast to most other anadromous salmon, chum, pink and sockeye juveniles enter saltwater after only a short time in freshwater. This means that monitoring juvenile production for these species will require methods that differ greatly from other salmon.

Current monitoring activity

A system of index areas along Puget Sound marine shorelines was established in the early 1960s and has continue to date for the purpose of counting pink and chum salmon juveniles. These areas are generally a mile or more in length, and are located along shorelines thought to be within the migratory corridors used by the fry as they move seaward. Typically, the first pink and chum salmon fry seen each season are assembled into small discrete schools located in very shallow water near the water's edge. As the season progresses and the fish grow, they utilize increasingly deeper water and the schools become looser aggregations. At the end of the season, the fish have either emigrated from the area or are in water too deep to facilitate meaningful counts.

Various forms of these data have been utilized over the years to contribute to pre-season run size forecasting for harvest management of various components of the Puget Sound chum salmon return. Currently, marine fry data are incorporated into annual forecasts for the Nooksack, Skagit, Stillaguamish, and Snohomish chum runs. There are no other routine counts made of chum and pink juvenile populations (Table 40 and Table 41). Table 42 summarizes current sockeye juvenile migrant monitoring by recovery region. Some populations of chum and sockeye salmon are listed under the ESA, but there are no pink salmon listings.

Table 40. Current chum juvenile migrant abundance monitoring

Recovery Region	Number of Stocks	Number Monitored	Percent Monitored	Adequate? Yes/No
Puget Sound*[1]	52	6	12	No
Coastal	17	0	0	No
Lower Columbia*	3	0	0	No

Note: Wild juvenile chum abundance is not considered adequately monitored since the number of chum captured in downstream migrant traps represents an unquantified proportion of the total production.

* Contains populations listed under the ESA.

1 Chum abundance is measured using trap catch only.

Data source: WDFW SaSI Reports

Table 41. Current pink salmon juvenile migrant abundance monitoring

Recovery Region	Number of Stocks	Number Monitored	Percent Monitored	Adequate? Yes/No
Puget Sound[1]	15	2	13	No

Note: Wild juvenile pink abundance is not considered adequately monitored since the number of pink salmon captured in downstream migrant traps represents an unquantified proportion of the total production.

1 Pink abundance is measured using trap catch only.

Data source: WDFW SaSI Reports

Table 42. Current sockeye juvenile migrant abundance monitoring

Recovery Region	Number of Stocks	Number Monitored	Percent Monitored	Adequate? Yes/No
Puget Sound[1]	4	2	50	Yes
Coastal*	3	0	0	No
Lower Columbia	0	0	0	NA
Mid Columbia[2]	1	1	100	Yes
Upper Columbia	1	0	0	No

Note: Monitoring was assumed adequate where 10% or more of the stocks within a recovery region were monitored.
* Contains a population listed under the ESA

1 Sockeye fry (age 0+) production is measured for the Cedar River and Lake Washington Tribe stocks.
2 Sockeye smolt (age 1+) production is measured for the Wenatchee stock.

Data source: WDFW SaSI Reports

Juvenile pink salmon production is measured in the Skagit River using both a screw trap and an inclined-plane screen trap. Catch is currently used as an index of the actual production. Like chum salmon, an actual estimate of pink salmon production could be developed using the same approach used to estimate chinook production with this gear type. Estimation of total production is more easily accomplished with pink salmon, however, since their migration spans a longer period of time.

Sockeye fry abundance is measured using inclined-plane screen traps and screw traps in two tributaries of Lake Washington using the same approach used to estimate chinook abundance using this gear type. Since these measurements are made a year before the sockeye develop into a smolt, the monitoring program evaluates the impacts of stream flow and spawner density on the early life history stages.

Conversely, sockeye smolt production is measured in the Wenatchee system using a screw trap using the same approach described for chinook salmon using this gear. Monitoring at the smolt stage further integrates lake rearing along with early stream rearing to estimate production.

In addition to these trapping methods, sockeye smolt counts are also made at the mainstem Columbia and Snake River dams. However, estimating production at these sites face the same constraints as those described for chinook (i.e., large number of stocks and unknown variable capture rates).

Estimates of measurement error and certainty

Variance can be estimated for assessment of juvenile salmon abundance made with traps. If the marine fry count data were developed into a useable form, they would suffer from the same types of multiple and variable sources of error that are associated with escapement estimates based on spawner counts. This means that it is doubtful that statistically reliable measurements of error could be produced.

Maps and descriptions of the marine survey index areas have been developed. Since detailed analyses of the data have not been conducted, there are no protocols for producing abundance or other estimates.

Identified agencies

The WDFW and Treaty Tribes under US v. Washington have been conducting juvenile migrant trapping for chum, pink and sockeye in identified streams. This activity should continue.

Recommended sampling protocols

➢ *It is recommended that estimates of juvenile migrant abundance for pink and chum salmon be evaluated annually using beach index surveys in Puget Sound as in the past.*

Because pink and chum salmon migrate at such an early age to the sea, it is unfeasible to trap them in migrant traps. Past beach counts have provided a strong correlation with future adult abundance. However, it does not provide estimates of production within watersheds.

Visual counts are conducted on foot, or by boat, depending on the depth of water used by the fish. When pink and chum fry are present, beach seines are periodically used to determine relative species composition.

A vast amount of data has been collected over 40 years of marine fry counts. While there have been a number of attempts to use the data for forecasting, the entire body of data has never been rigorously analyzed statistically because of limits on available staff time.

Chum production is monitored using screw traps, inclined-plane screen traps, and in one case, a permanent weir. Estimating chum production is a difficult endeavor since the out migration occurs primarily in March when high stream flows coupled with a compressed migration timing distribution often compromises the estimation.

During its period of operation, the weir captures all migrating chum unless stream flow conditions compromise its ability to do so. However, since operation of the weir is currently oriented to the juvenile coho migration timing, it does not operate over the entire period of the chum migration. Extending the operation of the weir to include the entire chum migration period is not possible since stream flows during the March out migration often exceed the capabilities of the trap. Therefore, to estimate chum production at the weir site, the unsampled chum catch must be estimated by extrapolation using timing data from other locations.

Where screw traps and inclined-plane screen traps are used, chum catch is now used simply as an index of chum production. Although not currently done, total chum production estimates could be made using the same techniques as described for estimating chinook abundance using this gear type. However, production estimates would be compromised during periods in March when trapping is suspended as a result of high stream flow and debris load. As a result of the compressed nature of their out migration timing, a substantial and indeterminate proportion of the total migration could pass the trap during these periods. Furthermore, these traps are typically used on larger rivers where releases of unmarked hatchery chum salmon may occur. Accurately estimating naturally produced chum abundance in systems where hatchery and wild migrants cannot be visually separated is a difficult and expensive process. Therefore, estimating wild chum production in these systems should only be attempted where a critical need for the data exists.

Identified monitoring gaps/overlaps

None have been prioritized.

Quality assurance/Quality control

The accuracy of sockeye abundance estimates is similar to those described for chinook. Since chum and pink estimates are, at this time, primarily indices, their accuracy and suitability for monitoring are less than those for chinook, coho, and sockeye. The statistical properties of this indicator has largely been unexplored for chum and pink salmon.

The identified agencies should develop highly systemized approaches to refining this indicator for chum and pink salmon and for validating the accuracy of the resulting production estimates.

Data are compiled mainly by the WDFW and the Treaty Tribes for broad distribution through SaSI. The quality of data is adequate but the SaSI document should be updated and reported annually for juvenile migrants. These data and the forecasts should be accessible via the state Web Portal for viewing and downloading using the identified structure under Part V of this document.

Juvenile Steelhead Trout

There are two life history forms for this species; steelhead are the anadromous form, and rainbow trout are the resident form. This section pertains to the anadromous form (steelhead) only.

Current monitoring activity

Wild steelhead smolt production is monitored at 11 locations in Puget Sound, eight locations on the Washington Coast, 11 locations on the Lower Columbia, and one location on the Snake River (Table 43). Monitoring juvenile migrant steelhead is difficult because the migrants are such strong swimmers that, under less than ideal trapping conditions, many are able to avoid traps (e.g., screw and inclined-plane screen traps). Trapping efficiency is low and calibrating trapping efficiency has been difficult.

Table 43. Current steelhead juvenile migrant abundance monitoring.

Recovery Region	Number of Stocks	Number Monitored	Percent Monitored	Adequate? Yes/No
Puget Sound	53	11	21	Yes
Coastal	45	8	18	Yes
Lower Columbia	27	11	41	Yes
Mid Columbia	6	0	0	No
Upper Columbia	3	0	0	No
Snake	5	1	20	Yes
Northeast	0	0	0	NA
TOTAL	139	31	22	

Note: Monitoring was assumed adequate where 10% or more of the stocks within a recovery region were monitored.

* Four of the ten Puget Sound sites monitor steelhead production from eastern Hood Canal streams that are not part of a SaSI-recognized steelhead stock.

Data source: WDFW SaSI Reports

Estimates of measurement error and certainty

No estimates of measurement error or certainty have been provided.

Identified agencies

The WDFW and Treaty Tribes under US v Washington and US v Oregon conduct steelhead juvenile out migrant sampling. This activity should .

Recommended sampling protocols

Wild steelhead smolt production is monitored using screw traps or permanent weirs. When screw traps are used, capture rates may be size or condition-biased unless water velocities, flow configuration, and noise prevent steelhead smolts from detecting the presence of the trap prior to capture. At some sites, steelhead smolt production is estimated as was described for chinook using the same gear type. However, at other sites where direct trap efficiency estimates cannot be made, catch is sometimes used as an index of smolt production. Alternatively, capture rates for steelhead are indirectly developed by applying the ratio of steelhead-to-coho capture rates from other monitoring sites to the coho capture rate for the site where the steelhead capture rate estimate is to be made.

Where permanent weirs are used, wild steelhead smolt production is measured by direct count.

Identified monitoring gaps/overlaps

None have been provided.

Quality assurance/Quality control

There are no QA/QC standards or protocols currently in place for juvenile steelhead migrant monitoring. For many of the screw trap monitoring sites, the validity of steelhead smolt production estimates is questionable because the trapping efficiencies for steelhead are often indirectly calculated. These estimates rely on unverified assumptions as to how well the coho-to-steelhead trap efficiency ratios transfer between sites. The identified agencies should make a concerted effort to directly measure steelhead trap efficiency and/or to better validate the use of the steelhead-to-coho capture rate ratio.

Data are compiled by various tribes and by the WDFW for broad distribution through SaSI. The SaSI document should be updated and reported annually for juvenile migrants.. The information is also summarized in the Salmon Recovery Scorecard (Indicator A2). These data currently are not accessible, but should be available via the state Web Portal for viewing and downloading using the identified structure in Part V of this document.

Juvenile Bull Trout/Dolly Varden

Although Bull Trout are generally considered to be of the resident form, they also express anadromy. This section pertains to the anadromous form. Resident Bull Trout are treated in a later section of this report.

Current monitoring activity

Current monitoring efforts are not adequate to determine the overall juvenile migrant abundance trends in migrant Dolly Varden/bull trout populations within the Puget Sound and the Coast (Table 44). However, since most bull trout populations are not anadromous, trapping in eastern Washington is considered adequate for evaluating any out migration of bull trout to the sea

Table 44. Current Bull Trout/Dolly Varden juvenile migrant abundance monitoring.

Recovery Region	Number of Stocks	Number Monitored	Percent Monitored	Adequate? Yes/No
Puget Sound	22	6	27	No
Coastal	7	1	14	No
Lower Columbia	1	0	0	Yes
Mid Columbia	11	9	82	Yes
Upper Columbia	30	10	30	Yes
Snake	5	1	20	Yes
Northeast	4	0	0	Yes
TOTAL	80	21	26	No

Data source: WDFW SaSI Reports

Estimates of measurement error and certainty

None have been provided.

Identified agencies

The WDFW has been the major agency collecting bull trout information. This activity should continue. Additional information has been incorporated into SaSi from the USFWS and volunteer organizations.

Recommended sampling protocols

See chinook salmon.

Identified monitoring gaps/overlaps

None have been provided.

Quality assurance/Quality control

There are no QA/QC processes currently in use for monitoring of anadromous Dolly Varden or bull trout.

Data are compiled by the WDFW for broad distribution through the SaSI Bull Trout and Dolly Varden Appendix. The SaSI document should be updated and reported annually for key information components of adult spawners, juvenile abundance, and juvenile migrants. These data should be accessible via the state Web Portal for viewing and downloading using the identified structure under Part V of this document.

Juvenile Coastal Cutthroat Trout

There are both anadromous and resident forms of coastal cutthroat trout (CCT). This section pertains to the anadromous form; the resident form is treated in a subsequent section of this report.

Current monitoring activity

Coastal cutthroat trout smolt production is monitored at five locations in Puget Sound, four locations on the Washington Coast, and three locations on the Lower Columbia (Table 45). Monitoring juvenile migrants is difficult because migrants are strong swimmers and some can avoid traps (e.g., screw and inclined-plane screen traps). Typically small population sizes also hampers monitoring efforts for CCT. Trapping efficiency is low which makes calibrating trapping efficiency difficult.

Table 45. Current coastal cutthroat trout juvenile migrant abundance monitoring.

Recovery Region	Number of stocks	Number monitored	Percent monitored	Adequate? Yes/No
Puget Sound	15	5	33	Yes
Coastal	14	4	29	Yes
Lower Columbia	11	3	27	Yes
Mid Columbia	0	0	0	NA
Upper Columbia	0	0	0	NA
Snake	0	0	0	NA
Northeast	0	0	0	NA
TOTAL	40	12	30	Yes

Note: Monitoring was assumed adequate where 10% or more of the stocks within a recovery region were monitored. Two of the twelve Puget Sound migrant trap sites monitor Lake Washington cutthroat, however this population is not currently a SaSI-defined stock complex.

Data source: WDFW SaSI Reports

Estimates of measurement error and certainty

There are no estimates of error or certainly for juvenile CCT.

Identified agencies

The WDFW and the Treaty Tribes under US v Washington and US v Oregon have been the major entities collecting CCT information. This activity should remain within the WDFW and the tribes. Additional information has been incorporated into SaSI from the USFWS and volunteer organizations.

Recommended sampling protocols

Wild cutthroat smolt production is monitored using screw traps, inclined-plane screen traps, and permanent and temporary weirs. As with steelhead, measurements made using screw traps and inclined-plane screen traps may employ direct estimates of CCT capture rates or indirect estimates using data from other sites. In these cases, an unverified assumption is used that steelhead and CCT, being similar in size, are caught at similar rates. Accepting this assumption allows for the use of the steelhead-to-coho capture rate ratio described above (see steelhead). A third method of monitoring CCT using screw traps is to use catch as an index of smolt production.

When temporary or permanent weirs are used, CCT production is a direct count. As with other species, weir-based estimates may require interpolation of catch during periods when high stream flows compromise the weir's ability to capture all migrants.

At some sites, CCT migration timing is protracted well beyond the trapping period and is currently undefined which precludes extrapolating a total production estimate. Production estimates should be considered indices at these sites.

Identified monitoring gaps/overlaps

None have been provided.

Quality assurance/Quality control

There are no formal quality assurance or quality control standards or procedures developed for CCT. For some of the screw trap monitoring sites, the validity of CCT smolt production estimates is questionable because the trapping efficiencies for cutthroat are only indirectly calculated using steelhead trap efficiency data. These estimates rely on unverified assumptions as to how well steelhead capture rates apply to CCT smolts and how well the coho-to-steelhead trap efficiency ratios transfer between sites. The identified agencies should make a concerted effort to directly measure CCT trap efficiency and/or to better validate the use of the steelhead-to-coho capture rate ratio.

Data is compiled by various tribes and the WDFW. These data are compiled for broad distribution through SaSI and are summarized in the Salmon Recovery Scorecard. The SaSI document should be updated and reported annually for key information components of adult spawners, juvenile abundance, and juvenile migrants. These data should be accessible via the state Web Portal for viewing and downloading using the identified structure under Part V of this document.

Juvenile Resident Salmon Abundance

Objective 1C: Measure the status of the number of resident juvenile cutthroat and bull trout for each stock; and trends. Evaluate whether numbers are improving.

Monitoring indicators

Number of wild resident juvenile cutthroat and bull trout residing in Washington lakes and streams

Resident forms of bull trout and coastal cutthroat (CCT), and west slope cutthroat (WCT) are represented by multiple age classes of both mature and immature fish. Although this section specifically addresses juvenile resident trout, the strategy described here applies equally well to spawner abundance.

Strategy for measuring resident juvenile abundance

➢ *It is recommended that estimates of juvenile resident trout abundance be conducted in terms of numbers of juveniles per square meter for each SRR, by implementing a rotating panel design using the EMAP stratified random sampling site selection process.*

This site selection process appears to have promise for application to Washington resident trout populations. It has been demonstrated to be effective in determining the status of Oregon coastal coho and Nevada red band trout. The EMAP site selection process utilizes a GIS to select a spatially balanced sample of a population. The rotating panel design combines annual sampling at the same sites for trend detection with more extensive sampling over the distribution of the population for determining status. The rotating panel is designed to be able to determine the annual status of cutthroat and bull trout populations within the Salmon Recovery Regions and be 90% confident that the abundance estimate is within 17% of the true abundance.

The rotating panel is designed to sample all of western Washington for CCT and selected portions of eastern Washington where the distribution of bull trout and WCT are known to occur.

➢ *It is recommended that approximately 25-50 locations be sampled each year within each SRR.*

To optimize status estimates, the number of sample sites visited per year should be high. On the other hand, there is a need to repeat some sites each year in order to gain power to detect trends in the population over time.

➢ *A three-year rotation of the panels is recommended in order to obtain information in a timely manner.*

➢ *It is recommended that these EMAP sites be directly correlated with the proposed EMAP sites for habitat evaluation and water quality so that correlations can be drawn between trout abundance and habitat and water quality conditions and trends.*

Current monitoring activity

Considerable trout abundance and distribution information has been provided by various state, federal, and tribal biologists. However, there has not been a coordinated and statistically designed and valid approach to sample populations statewide that would provide reliable status and trend information.

Estimates of measurement error and certainty

There are no ongoing efforts to estimate measurement of error or certainty.

Essential tools

- EMAP site selection protocol

Randomized stream surveys must be conducted across the known distribution of bull trout, CCT and WCT trout in Washington.

Identified agencies

The WDFW has been the major agency collecting bull trout and cutthroat trout information. This activity should continue. Additional information has been incorporated into SaSI from the US Fish and Wildlife Service, tribes, universities, and volunteer organizations.

Recommended sampling protocols

Current sampling efforts are using a variety of sampling protocols. Recommended protocols for sampling of trout in sites selected using the EMAP protocol should be rigorous enough to provide useful abundance estimates. A commonly used approach involves electrofishing in sites using multiple removal methods (e.g., Zippin 1958). See also the section for Bull Trout spawners described earlier in this report.

Performance benchmarks

No performance targets have been established for wild juvenile resident juvenile production within ESUs or DPSs. The performance benchmark for juvenile resident trout should be an improving trend in juvenile production as measured by juvenile densities (fish/m2) evaluated over at least a 10-year period. Trends over shorter periods may be overly influenced by inter-annual changes in climate (i.e., streamflow).

Data should be analyzed annually for the status of wild juvenile trout production in each of the Salmon Recovery Regions, and the trends should be presented in charts showing juvenile trout production for each of the regions. Figure 32 and Figure 33 provide hypothetical examples. For bull trout, see the discussion of performance benchmarks in an earlier section of this document pertaining to spawners.

Figure 32. Sample presentation showing the annual status of naturally produced juvenile trout densities for a Recovery Region.

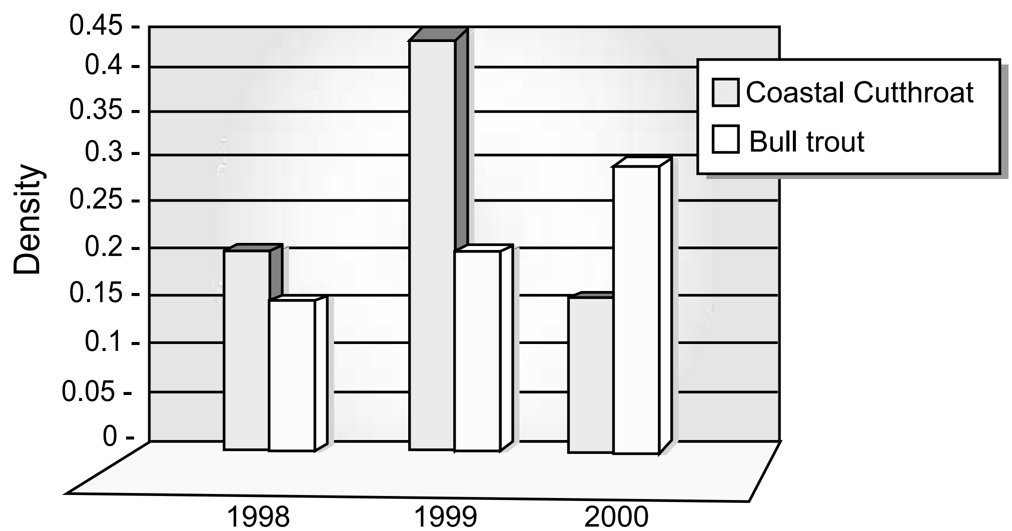
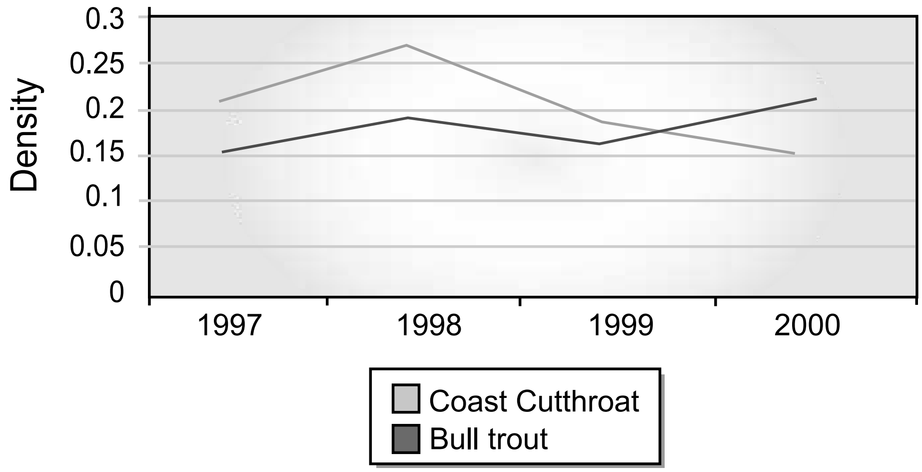


Figure 33. Sample presentation for trend in naturally produced juvenile trout for the Puget Sound Recovery Region.



Identified monitoring gaps/overlaps

No cohesive statistically relevant approach to measuring the abundance and distribution of resident juvenile CCT, WCT and bull trout.

Quality assurance/Quality control

There are no QA/QC procedures in place at this time.

Data are contained within individual reports and in the lake and stream database at WDFW and other agencies (e.g., USFS, USFWS).

Freshwater and Marine Productivity

Objective 1D: Measure status of salmon productivity for selected index watersheds; and trends.

Production

According to Ricker (1971)-, production is defined as the total elaboration of fish tissue during any time interval, including what is formed by individuals that do not survive. It may be measured in terms of net weight, dry weight, nitrogen content, or energy content. Production takes into consideration the overall changes in age class and weight of individual members of the population. Production estimates have not been used to compare changes in Washington salmon populations, although it was treated indirectly. We are not recommending using production as the measure of population viability, but it is attractive in that it takes into consideration the changes in fecundity associated with larger individuals in the population.

Productivity

According to McElhany et al. (2000), productivity is typically measured as the ratio between the number of recruits from a given brood year and the number of spawners in that brood year. Multiplying the number of spawners by this ratio yields the number of recruits. The growth rate of a population over time is the product of the productivities for each generation. Productivity in itself does not tell you whether the average size of the individual fish is changing or whether fecundity is changing over time.

Populations of salmon in Washington, in order to be viable, should produce sufficient offspring on the average to meet or exceed replacement needs (McElhany et al. 2000). This means that the spawner:spawner ratios or cohort-replacement ratios should be 1.0 or higher. Natural productivity is measured as the ratio of naturally produced spawners born in one brood year to the number of fish spawning in the natural habitat during that brood year. A viable population should not exhibit a trend of increasing contributions from naturally spawning hatchery fish.

Progress toward recovery for any given population within an ESU will be most accurately monitored by the trend in the total adult abundance, which tracks total production more accurately than individual components (e.g., spawning escapement and harvest). This is accomplished by reconstructing abundance of a given year class, just prior to the occurrence of fishing mortality using suitable representative hatchery and wild indicator groups. Cohort reconstruction comprises the sum of natural-origin spawning escapement, fishing and natural mortality.

$$\textit{Total run size} = M_F + M_N + E$$

where M_F is total fishing mortality, M_n is total natural marine mortality and E is spawning escapement.

Fishing mortality, including incidental mortality, is estimated from fishery recoveries of coded-wired tagged indicator stocks. Pre-terminal and terminal fishing rates (i.e., fishing mortality divided by total abundance) may be estimated separately. Escapement is expanded by these stock-specific fishing rates, and natural mortality factored in, to estimate 'unfished abundance.' It is not possible to make stock-specific estimates of all sources of sub-adult natural mortality, so standard rates are applied to each age-class. The ability to tag migrant salmon with coded wire tags is a crucial element of this indicator.

Monitoring indicators

Marine survival rates in terms of equivalent adults returning from the ocean to their native streams prior to harvest.

Marine survival rate is defined as the proportion of juvenile migrants leaving freshwater that survive to be harvested and/or spawn. It is a key indicator because non-fishing mortality during the marine phase varies substantially from year-to-year and directly affects adult salmon abundance. Extended periods of low marine survival can significantly reduce stock viability and status.

Accurately measuring the marine survival rate for a population or stock requires three data components:

(1) The annual number of juvenile out-migrants,

(2) The annual number of fish that are harvested, and

(3) The annual number of adults that return.

Fishing mortality estimated from coded wire tag recoveries

See Harvest Section (Part VII J) later in this report.

Adult spawner estimates from spawner counts

See Spawners (Escapement) (Part VII I) earlier in this report.

Age of spawners

The age at return is necessary in order to estimate total returns from any one cohort of juvenile out migrants. Aging of salmon currently relies upon the services of the aging laboratory operated by the WDFW.

Sex of spawners

The sex ratio of spawners is important to know in order to determine the total egg production potential.

Essential tools

Coded wire tagging program

The ability to mark individual hatchery salmon by imbedding a coded wire tag into their snout has allowed fishery managers to track the relative contribution of specific hatchery stocks originating from hatcheries located on various rivers along the Pacific Coast. This has in turn allowed total estimates of fishing mortality which were previously unavailable. By subtracting fishing mortality from the overall production of hatchery fish released, an estimate of their overall marine survival can be obtained.

Marked hatchery fish

The return of unmarked hatchery salmon to their hatcheries of origin cannot be determined when there are substantial numbers of wild salmon spawning in the stream at the same time. Mass marking of hatchery steelhead began in 1980, and mass marking of hatchery coho and chinook began in 1997. However, only part of the state and tribal hatchery production has been mass marked. Until this tool is fully implemented, marine survival rates for stocks that are not mass marked should be considered untrustworthy and probably erroneous.

Wild salmon index watersheds

The marine survival rates for wild salmon may differ from hatchery salmon. To measure wild salmon survival, specific sites are equipped with a counting weir so all naturally produced migrating juveniles and returning adults are enumerated. The naturally produced juvenile salmon must be coded-wire tagged to determine their relative contribution to various Pacific Coast fisheries.

Aging

Salmon ages are determined from scales and otoliths. The work of WDFW aging laboratory is crucial.

Monitoring design

A measure of the productivity of Washington salmon should be calculated at all locations where juvenile migrant traps provide estimates of the numbers of juvenile salmon migrating to the sea and where marine survival rate estimates are available to reconstruct salmon cohorts and estimate total run size.

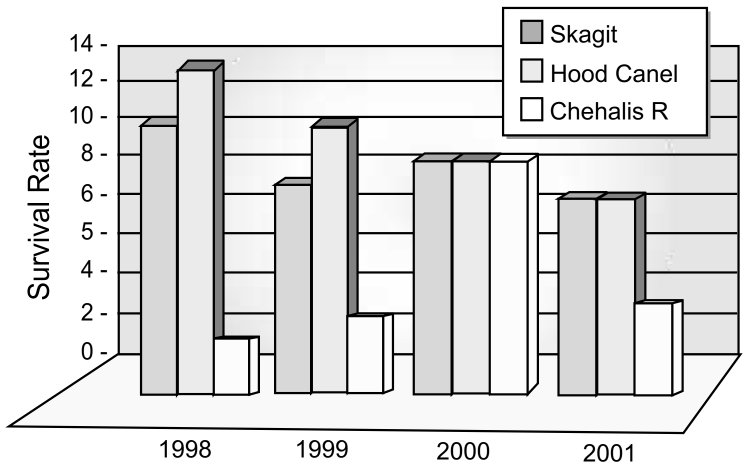
Performance benchmarks

The performance benchmark for productivity should be a ratio of 1.0 for adult:adult comparisons.

Marine survival

A chart of marine survival rates can be built for each anadromous species (Figure 34) that would reflect changes in marine survival and potentially identify shifts in productivity that would affect fisheries and other decisions.

Figure 34. Sample presentation of annual coho 3-year-old marine survival rate for three stocks.



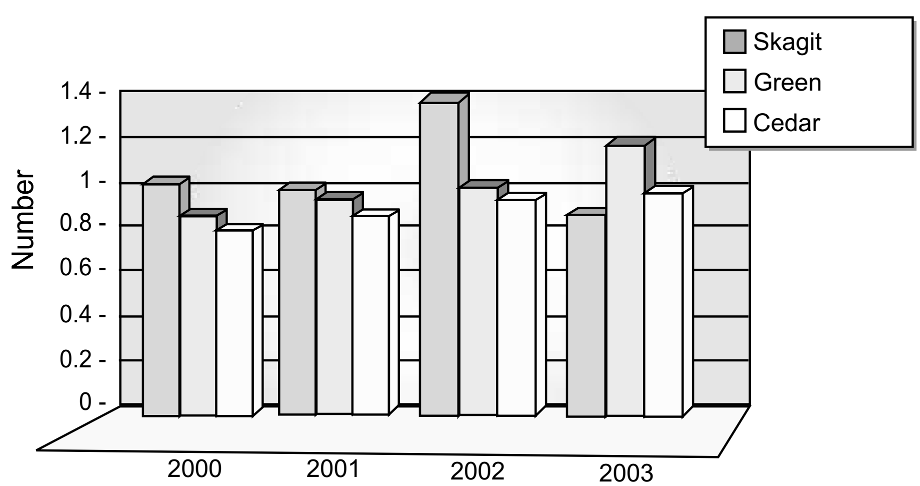
Identified monitoring gaps/overlaps

In the past, lack of funding and inability to measure all stocks on an annual basis has limited accurate estimates. Therefore, some “key” or “index” stocks have been used to model and predict salmon production. The index stocks are assumed to represent the behavior and characteristics of all other nearby natural populations. Harvest (including incidental) mortality is reconstructed from fishery recoveries, and added to estimated escapement. Natural mortality is assumed to be a fixed proportion of each age class.

The sum of escapement, harvest, and natural mortality is the adult abundance prior to any fishing mortality. Annual variation in sub-adult abundance reflects the broad spectrum of conditions that affect early marine survival. The Chinook Technical Committee of the Pacific Salmon Commission calculates the index for northern and southern Puget Sound chinook, using indicator stocks that have been consistently tagged since the mid-1980s. These indices may or may not reflect the marine survival of individual stocks that vary due to local conditions in their early marine environment.

Cohort reconstruction could be converted to adults per spawner ratios (Figure 35). These ratios should be expected to increase as overall productivity improves.

Figure 35. Sample presentation of annual numbers of adults produced per spawning pair for three stocks.



Chinook Salmon

Current monitoring activity

Due to low levels of fishing efforts, the use of selective fishing, and the lack of sampling/ catch accounting in some fisheries, the number of tagged fish that are harvested is often poorly estimated. Therefore, survival-to-return is another indicator that simply measures the proportion of juvenile migrants that return to the river. This indicator is measured with better accuracy and precision, but lacks the ability to distinguish between fishing and non-fishing mortality during marine life history phase. Marine survival of wild Puget Sound and coastal chinook is monitored by assuming a relationship to tagged hatchery indicator stocks. Therefore, whatever the return rate on tagged hatchery stocks is extrapolated to wild juvenile migrant numbers to estimate survival.

Coho Salmon

Marine survival

Marine survival rates for hatchery and wild coho stocks are commonly monitored through reliance on coded wire tagging programs, in which the tag recoveries can be used to measure total adult contribution to fisheries and escapement, and thus survival to adult. Much of current salmon forecasting in Washington is based on measured or predicted marine survival * measured or predicted smolt production in each harvest management unit. Marine survival rate data are very important for understanding the population dynamics of a stock for both management, and extinction risk modeling. The WDFW indicator stock programs currently provide most of the survival rate data available for natural Washington coho stocks.

Short and long term changes in marine survival can have a profound effect on coho population abundance and sustainability. The recent formal recognition of the presence long term regional and global atmospheric and oceanic condition trends, and their subsequent influences on salmon and other fish and wildlife population survival rates have been documented over short/intermediate (i.e., 10-20 year) time periods (Mysak 1986), and over much longer time periods (Finney et al. 2002). Within Puget Sound, marine survival rates for natural origin Puget Sound coho indicator stocks have declined from the 20-30% range in the early 1980s return year period down to 1-4% in the 1999 return year (Seiler 2002). Declines of this magnitude over an extended period can lead to the loss of population viability, particularly when combined with reductions in freshwater stock productivity, and/or continued harvest impacts that are not commensurate with the reduced stock productivity.

Coho marine survival rates for Puget Sound have been collected for many years at four locations where total spawners can be enumerated, and the total harvest can be estimated from coded wire tag recoveries. For some Puget Sound and coastal coho stocks, wild juvenile migrants are coded-wire tagged as they emigrate. Recoveries of these tags in fisheries and estimates of total escapement give direct estimates of marine survival.

Run size reconstruction

Adult run reconstructions for coho salmon attempt to account for most or all of adult production for a population or production region, at a particular geographic point and/ or time in their migration path. A run size reconstruction may be for the *terminal* area only (i.e., accounting only for adults that were caught in sport and commercial fisheries in marine waters near the stream mouth, catch within the stream, and spawning escapement). Alternatively, *total* run reconstructions attempt to account for *complete* adult production for each population, by adding together *all* population specific estimates of catch in all sport and commercial catches on the Pacific coast the population was harvested in, in all marine and fresh water fisheries, as well as escapement. Coded wire tag recoveries, genetic samples, escapement ratios, and/or other information are used to estimate stock contributions in each fishery. Estimates of non-landed mortality ("shaker" mortality and/or natural predation losses) are accounted for in selected situations.

Unbiased estimates of total adult coho abundance before fishery removals are difficult to derive, as they require stock or stock aggregate-specific estimates of both harvest and escapement, each with numerous error parameters, as discussed previously. Many Washington-origin coho are harvested in extensive "mixed stock" fisheries that occur in marine waters up and down the Pacific coast. These mixed stock fisheries harvest both hatchery and wild origin coho that originate from many regions, and require (often-problematic) sampling and analytical procedures to estimate catch contributions specific to each population/stock. Coho run size estimates are rarely made at the SaSI stock level, but instead are typically done at the management unit level, which usually consists of an aggregate of several SaSI stocks. As an example, the annual terminal run reconstruction for Snohomish River wild coho contains catch and escapement estimates for four SaSI stocks in aggregate.

Fishery catch estimates used in reconstructions often have several sources of potential error. A common problem is unreported, or erroneously reported or estimated catches. Fisheries do not always report all landings through official catch accounting channels (i.e., state, federal, or tribal commercial, ceremonial and subsistence (C&S), or sport fishery accounting and sampling systems). For example, the 1996 Area 9A commercial fishery coho landings officially reported to the WDFW fish ticket database totaled 1,027, whereas an alternative post-season estimate of catch later made by tribal fishery managers, to account for unreported catch in the terminal area fisheries was 2,500 (Beattie 1999). A 1999 report on Columbia River fisheries (WDFW and ODFW 1999) observed "since 1995, an increasing portion of Treaty Indian commercial landings have been sold to the general public and not licensed fish dealers because of low prices paid by dealers." In addition, tribal C&S and take-home catch estimates are made through a variety of often-indirect methods, and typically have unknown error rates. Sport catch estimates are based on punch card returns and/or direct census, with some limited error estimation (estimates of error in catch estimates are sometimes calculated for sport catch statistics, depending on available data).

Selective fisheries have introduced another complication to run size estimation procedures in recent years. Double Index Tag (DIT) groups are being used to attempt to determine catch-and-release mortality rates on un-ad marked, but coded wire tagged coho, and generate other management information. DIT tagging introduces a variety of complications to current fishery sampling and run reconstruction processes. New sources of sampling error are added to catch sampling processes from the need to electronically sample all retained fish for recovering tags from the un-ad marked portion of the coded wire tagged DIT releases (as opposed to the visual ad-clip sampling approaches used for all tagged coho used previously), and tag expansion procedures used to account for tagged coho contribution to fisheries have become more complex, with the increased number of tag groups representing each hatchery stock adding additional analytical issues.

Currently, run reconstructions for Washington-origin hatchery and wild coho populations are typically only annually estimated to terminal run size values. For stocks originating within Puget Sound, terminal run size estimates only include catches from "inside Puget Sound" marine fisheries, and in-river (freshwater) catches and escapements for each stock or stock aggregate. Terminal run size estimates for coastal coho populations tend to incorporate only in-river sport and commercial catches (and Grays Harbor and Willapa Bay fishery harvests for reconstructions of populations originating in those respective regions), and escapement estimates. Terminal run size estimates may represent anywhere from 20-100 percent of the total adult production for a management unit, depending on the extent of "pre-terminal" marine fishery interceptions in the Pacific Ocean for a given year. Terminal run size estimates for Puget Sound hatchery and wild coho populations were completed for the 1966-1995 return years using a standardized methodology. The terminal run size estimation methodology for Puget Sound coho was modified starting in the 1996 return year, adopting a new approach that incorporated annual sport catch estimates into the reconstruction, and annual coded winter tag recovery data to associate fishery catches to populations of origin (J. Haymes, WDFW personal communication).

Total run size estimates (including adult harvest in all fisheries along the Pacific coast) recently were completed for all Pacific coast coho salmon management units for the 1983 to 1988 brood years. This activity is not a common undertaking, due to significant inter-agency staff and time demands. The 1983-88 brood year estimation process took approximately 10 years, involving staff participation from WDFW, Northwest Indian Fisheries Commission, Treaty Tribes, and ODFW and Canadian Department of Fisheries and Oceans biologists.

An alternative approach for monitoring stock productivity and escapements is through the use of *indicator* populations expected to be representative of survival rates and harvest patterns of the natural and/or hatchery stocks in a region. Indicator populations are usually located in watersheds where both juvenile production and adult escapement for the population can be accurately monitored through upstream/downstream trapping at natural or man-made barriers. This approach requires a trade-off between collecting and using population information from many stocks at lower precision and accuracy vs. data collected from a limited number of populations at higher precision and accuracy. Indicator stock data can also be confounded by non-reporting or non-sampling of fisheries indicator stock origin fish are harvested in. The utility of the Big Beef Creek indicator stock program data has been compromised in recent years by systematic under-reporting and/or sampling of terminal commercial fishery catches, which has resulted in the indicator stock estimates of run size and marine survival being under-estimated (D. Seiler, WDFW personal communication).

Chum Salmon

Marine survival

Marine survival rates for Puget Sound chum salmon would be represented by a statistic such as the proportion of the total juveniles recruiting to saltwater that return to freshwater as adult fish. This would necessarily be a brood year statistic, calculating a value for each spawning population based on a cohort analysis of returning adults from that brood.

No marine survival estimates are produced for wild chum salmon because there are no estimates of total juvenile recruitment to marine waters. It should be noted that if the estimates of juvenile chum entering salt water were available, then freshwater survival rates could also be calculated, based on juveniles produced in freshwater per adult spawner.

Run size reconstruction

Estimates of annual run size are a primary management tool, and are produced each year for Puget Sound chum salmon using a process called "run-reconstruction." This process assembles catch and escapement data for each year's return into estimates of return for specific production units. There is typically a one-year lag in the availability of the most recent return years because of the time required to assemble, proof, and analyze the various data components.

To determine the numbers of salmon returning to specific production areas, fish that are harvested in mixed stock and terminal fisheries must be allocated to the streams from which they originated. Run reconstruction splits the harvests in each catch area into the numbers of fish that were likely contributed by the individual stocks or production units thought to be transiting the area. All estimated harvests for each stock or management unit are added to the escapement for that grouping to derive the estimated total return for each year.

There are three caveats relative to run size estimates that should be noted. First, the estimates are for “runs” of salmon. These runs are at a finer scale than NMFS’s ESU population designations, but often include more than one stock. The second caveat is that the estimates are not actual total run sizes. For Puget Sound chum salmon, the run size estimates are for the combined catch and escapement numbers for fish entering the Strait of Juan de Fuca (Washington waters only). They do not include catches in the ocean or Canadian waters, or sport catch in Puget Sound or river fisheries. While the chum salmon run size estimates are not all inclusive, they do represent a very high proportion of the total run size, and most are certainly indicative of annual run status. The final issue with run size estimates is that in regions with large hatchery chum salmon production (Hood Canal), the run-reconstruction estimates of wild chum run sizes are of questionable utility, because of an inability to distinguish hatchery and wild fish in catches.

Cohort analysis

Within the context of salmon recovery, cohort analysis is the method used to determine the total numbers of adult salmon of multiple age classes that return from a prior spawning in an individual season (brood year). This “brood return” estimate is routinely calculated for major wild populations of Puget Sound chum salmon, and is used to assess production and forecast future run sizes.

Brood return estimates for Puget Sound chum salmon are calculated from annual run size estimates (from run re-construction) and age composition data. For each chum salmon run, the estimated number of fish returning in a given year is multiplied by the proportions of age-3, age-4, and age-5 fish making up that return. The numbers of fish in each age class are then identified by their parent’s spawning year, or brood year (e.g., age-3 fish returning in 1999 were brood year 1996). When the three age classes making up each brood year have returned, the three return numbers are added to arrive at the total brood return. For example, the total 1996 brood return was the sum of the return of age-3 fish in 1999, age-4 fish in 2000, and age-5 fish in 2001.

Pink Salmon

Marine survival

Marine survival rates for Puget Sound pink salmon should be represented by a statistic such as the proportion of the total juveniles recruiting to saltwater that return to freshwater as adult fish. This would necessarily be a brood year statistic, calculating a value for each spawning population based on a cohort analysis of returning adults from that brood.

No marine survival estimates are produced for wild Puget Sound pink salmon because there are no estimates of total juvenile recruitment to marine waters. It should be noted that if the estimates of juvenile entering salt water were available, then freshwater survival rates could also be calculated, based on juveniles produced in freshwater per adult spawner.

Consistent approaches are used by the WDFW to conduct pink salmon run reconstruction. They have not, however, been documented in report form.

Run size reconstruction

Estimates of annual run size are a primary management tool, and are produced each year for Puget Sound pink salmon using a process called “run reconstruction.” This process assembles catch and escapement data for each year’s return into estimates of return for specific production units. There is typically a one-year lag in the availability of the most recent return years because of the time required to assemble, proof, and analyze the various data components.

Cohort analysis

Within the context of salmon recovery, cohort analysis is the method used to determine the total numbers of adult salmon of multiple age classes that return from a prior spawning in an individual season (brood year). Since Puget Sound pink salmon are uniformly of a single age at return (2 years), cohort analysis is not conducted.

Sockeye Salmon

Marine survival

Marine survival rates for sockeye salmon should be represented by a statistic such as the proportion of the total juveniles recruiting to saltwater that return to freshwater as adult fish. This would necessarily be a brood year statistic, calculating a value for each spawning population based on a cohort analysis of returning adults from that brood.

No marine survival estimates are currently produced for wild sockeye salmon because there are no estimates of total juvenile recruitment to marine waters. It should be noted that if the estimates of juvenile sockeye entering salt water were available, then freshwater survival rates could also be calculated, based on juveniles produced in freshwater per adult spawner.

Run size reconstruction

Estimates of annual run size are a primary management tool, and are produced each year for sockeye salmon using a process called “run reconstruction.” This process assembles catch and escapement data for each year’s return into estimates of return for specific production units. There is typically a one year lag in the availability of the most recent return years because of the time required to assemble, proof, and analyze the various data components.

Cohort analysis

Within the context of salmon recovery, cohort analysis is the method used to determine the total numbers of adult salmon of multiple age classes that return from a prior spawning in an individual season (brood year). This “brood return” estimate is routinely calculated for major wild populations of sockeye salmon, and is used to assess production and forecast future run sizes.

Steelhead/Rainbow Trout

No data.

Bull Trout

No data.

Coastal Cutthroat

No data.

West Slope Cutthroat Trout

No data.

Geographic Distribution

Question 2: What improvements are occurring in restoring the geographic distribution of salmon by ESU, species, and life stage to their historic range?

Objective 2A: Measure the geographic distribution of salmon in each federally identified ESU; and evaluate their trends. Determine whether their geographic ranges are improving.

Monitoring indicators

The presence or absence of spawning salmon by watershed and stream reach (spatial synchrony)
Wild salmon use the spawning habitat available to them to the extent that limiting factors allow. Such limiting factors include: migration barriers, total number of returning spawners, flow, temperature, pools, etc. By measuring the presence or absence of salmon spawners throughout their range, the overall trends in their reproductive potential and recolonization/ rebuilding can be tracked.

The presence or absence of rearing juvenile salmon.
Wild juvenile salmon use the rearing habitat available to them to the extent that limiting factors allow. Such limiting factors include: quality of in-stream habitat; riparian habitat, flow; temperature, sedimentation, food supply; etc. By measuring the presence or absence of juvenile salmon throughout their range, the overall trends in their production potential can be surmised.

Indicators:
- Presence/absence of juvenile and adult salmon.

Strategy for measuring geographic distribution of spawners by watershed and stream reach
The geographic distribution of spawners will be determined using current spawner survey techniques.

Strategy for measuring geographic distribution of juvenile salmon by watershed and stream reach
Nature Mapping is a tool for volunteers to measure biodiversity of the ecosystem by taking an inventory of the natural components, comparing this inventory to models based on known data.

➢ *It is recommended that volunteers be used to obtain information on the distribution of juvenile salmon.* The Nature Mapping Program can provide the delivery system for volunteer involvement in salmon recovery for the CMS.

The use of volunteers should be tested and phased. The first phase would consist of a pilot. During the pilot, volunteers will be addressing whether:
- The geographic distribution of salmonids has improved above barriers that have been removed, and
- Determining the number of stream miles where salmon are present.

Volunteers would be coordinated by organizations already in place such as “Streamkeepers” and “Long Live the Kings”. It is proposed that Nature Mapping train the coordinators of volunteer groups, who will then take responsibility to meet the quality control standards of this project that are developed by the Watershed Monitoring Council.

Essential tools

- Volunteers,
- Nature Mapping Website data entry address, and
- Training classes, manuals and support.

Recommended sampling protocols

Develop scientifically rigid standards and protocols with guidance from the IAC and associated agencies for data gathering that will:

- Focus on barriers removed for presence-absence salmon data collection. Volunteers can determine the navigability of the upper reaches for salmon and report presence-absence data.
- Focus on Type 3 and 4 stream reaches.
- Prioritize watersheds and streams to focus volunteer attention.

Performance benchmarks

- Volunteer groups monitor one fifth of the barriers removed per annum on a rotational basis.
- All targeted watersheds have trained volunteer groups reporting Level 2 data.
- At least 20 new groups report presence absence data per year.
- At least 20 new sites are added to the data base per year.

Quality assurance/Quality control

➢ *It is recommended that training programs be conducted for volunteers in the proper ways to gather and report data.*

The WDFW and ECY should:

- Identify watersheds with a number of years of coordinated volunteer activity. Target those groups for training and certification as data collectors.
- Maintain data quality by reviewing all data, work with data providers and users to ensure mistakes are identified and corrected. Create programmed automatic analyses and feedback of data being contributed.
- Coordinate, train and certify each participating group for competency in reporting adult and juvenile salmon and in use of protocols.
- Require a QAPP (Quality Assurance Project Plan) from each group to be checked by a coordinator and available through a website.
- Certification of volunteers will include a self reporting of ability and training from Level 1 (novice) through Level 4 (professional). Criteria for reporting by level will be established. In Level 2 certification, volunteers will have received training and their data will have value to monitoring entities (e.g., Watershed Monitoring Council).

Salmon Diversity

Question 3: Are the unique life history characteristics of salmon within an ESU changing over time due to human activities?

Objective 3A: Determine the status of genetic and other diversity characteristics of salmon in each federally identified ESU in Washington; and the trends. Evaluate whether they are improving.

Summary recommendations

Genetic diversity

The WDFW currently operates a genetics laboratory that provides information about a wide variety of fish stocks both in Washington and in neighboring states. The laboratory's work with salmon populations is supported both by State of Washington funds and external contracted dollars while its work with fish in neighboring states is entirely funded as contracted services to external agencies, tribes, and other entities. The laboratory is an important resource that should continue to be supported and funded by State of Washington funds in order to continue to obtain needed information about the genetic diversity and status of salmon populations in Washington.

Current baseline information and the basis for determining "species" under the ESA are based strongly on genetic and other biological characteristics of sampled populations. Existing definitions of genetic diversity units (GDUs), major ancestral lineages (MALs), and ESUs rely heavily on 20 years of accumulated genetic information (mostly allozyme data). Advances in genetic research have led to newer, more powerful and non-lethal methodologies based on DNA analysis, which the laboratory is also now employing. Because DNA studies are generally more informative than allozyme studies, they can be accomplished with tissue samples obtained non-lethally, and they are cost-competitive, there are compelling reasons to switch from allozyme to DNA methodologies. While such a transition will involve the expense of analyzing DNA markers in all relevant samples, it is possible to avoid the cost of re-collecting samples from many populations that were analyzed in the past by utilizing WDFW's archive of tissue and/or scale samples to accomplish much of the needed DNA analysis.

➢ *It is recommended that the necessary DNA analysis (and associated field collections, where necessary) to achieve a comprehensive understanding of the genetic characteristics and interrelationships of Washington's salmon stocks be implemented in phases, with the first phase focused on ESA-listed species.*

Other measures of diversity

➢ *It is recommended that other measures of diversity (e.g., life history, timing, age) be collected with existing staff using existing methods.*

Monitoring indicators

Age composition, migration and spawn timing overlap among sympatric populations

Identifying and understanding the effects of quantitative genetic changes in salmon populations are important to salmon recovery. Because quantitative traits are inheritable, non-random fishing mortality and other human impacts can cause changes in fish population genetics (traits such as spawn timing, age composition, and migration timing). While spawn timing, age composition, and migration timing clearly have a genetic (quantitative genetic) component, they also have an environmental component.

Performance Target: Historic data have been collected on the sex ratio, spawn timing, and migration timing of adult salmon. A performance target could be established based upon a standard deviation around the historic means for each parameter.

Morphologic and meristic traits of wild salmon populations

Identifying and understanding the effects of quantitative genetic changes in salmon populations is important to salmon recovery. Because quantitative traits are inheritable, non-random fishing mortality and other human impacts can lead to genetically based changes in fish populations in traits such as body shape and size of salmon.

Performance Target: Historic data have been collected on the size of adult salmon. A performance target could be established based upon a standard deviation around the historic mean size.

Population size (census and genetically effective).

As populations get smaller, the risk of extinction due to environmental and other events increases. Furthermore, small populations are at risk of loss of both local adaptation and genetic diversity due to random genetic events (e.g., genetic drift). Smaller and less diverse populations are presumed to be less able to accommodate changes in their environment. Monitoring the census size of meta-populations of salmon within an ESU (via stream surveys and other approaches) can provide a key indicator of the overall health of the species. Similarly, estimating the effective population size (Ne) for salmon stocks provides additional (and more direct) information regarding the likelihood of random genetic changes in these fundamental units of reproduction. Effective population size can be statistically estimated from at least two types of genetic data.

Performance Target: The historic census size of populations of salmon within specified ESUs is known for some stocks but unknown for others. A possible performance target is the historic variance around the mean census size for populations of wild salmon (where this is known). In contrast, there is basically no existing information regarding current or historic effective population sizes for salmon stocks in Washington. Therefore, performance targets for N_e would be limited to estimating current levels and monitoring populations to look for future changes.

Genetic diversity, heterozygosity integrity, within- and among- key natural populations

The local adaptations of populations to different conditions provide a source of genetic diversity for the entire species (WDFW 1997). Since an ESU is a species under the ESA, this indicator will be applied to each ESU. Salmon ESUs are typically composed of multiple sub-populations or stocks, each one significantly different from the others. The different traits found in different stocks may be important for survival under a certain set of conditions. Overall, this genetic diversity promotes the survival of the entire species (ESU), even though some part of it may be lost via local extinction. It is, therefore, important to maintain and/or restore historic levels of genetic diversity within and among key natural populations within an ESU.

Straying of populations into other streams (gene flow – introgression)

Salmon species are a collection of interacting populations, and some consider the aggregate to be a meta-population. Such collections of populations are typically interrelated to one another by shared ancestry, usually occur in the same geographic region, and interact to some degree via gene flow. There are no reliable data on the straying rates among wild salmon populations. Tag recoveries of hatchery salmon provide information as to the degree that it could occur. Natural straying is difficult to measure directly, and it would require a significant investment in funds and research for specific populations over an extended period of time to achieve. Because genetic data can be used to estimate genetic differences among populations, researchers have used it to infer the degree of reproductive isolation or, alternatively, the level of gene flow among populations. However, any given genetic difference between two populations could result from:

(1) Evolutionary divergence since the two populations shared a common gene pool, without any gene flow;

(2) Increased genetic similarity of two ancestrally divergent (historically unrelated) populations due to recent gene flow; or

(3 Evolutionary divergence in the face of limited gene flow between the populations.

Because it is generally not possible to be sure which of these scenarios applies in a given situation, using genetic differences to infer rates of gene flow is difficult and risky. Nevertheless, this is a common genetic approach and its application may shed light on the degree to which this phenomenon affects salmon recovery.

Strategy for measuring diversity

Ongoing investigations of genetic diversity should continue to be funded with an emphasis on DNA characterizations of high-priority salmon populations. The WDFW Genetics Laboratory has both the technical capability and the proven ability to accomplish the needed genetic analyses. The lab currently collects and analyzes genetic information for a wide variety of salmon stocks in Washington (and in neighboring states). The laboratory provides important information for fish and wildlife resource management and conservation and it should play a large role in evaluating and monitoring salmon recovery. The laboratory has successfully added DNA analysis capabilities to its activities and has gained experience and expertise in a range of genetic investigations relevant to salmon recovery monitoring, including:

(1) Assessing the genetic characteristics and diversity of stocks (populations),

(2) Documenting cases of hybridization and genetic introgression that can diminish diversity and alter the character and productivity of stocks,

(3) Estimating stock contributions to mixed-stock fisheries, assigning individuals from mixtures to their most likely stock-of-origin,

(4) Screening prospective adult broodstock to avoid genetic “contamination” of recognized stocks, and

(5) Evaluating the relative reproductive success of hatchery vs. natural origin adults in both natural and hatchery environments.

Because genetic principles and data play a major role in determining “species” under the ESA, genetic evaluation and monitoring should be central elements of salmon recovery monitoring. The obvious starting point for such genetic evaluation and monitoring is to develop robust and comprehensive baseline data sets that characterize existing salmon stocks throughout Washington.

➢ *It is recommended that DNA baseline analysis be implemented in phases with the first phase focused on ESA-listed species.*

Other measures of diversity

➢ *It is recommended that other measures of diversity be collected with existing staff using existing methods.*

Current monitoring activity

Age composition

Chum Salmon – Chum salmon have a variable maturity schedule, typically returning to spawn at ages of 3-, 4-, and 5-years. Because of this, it is necessary to collect age composition data from returning fish each year for use in cohort analysis (see Cohort analysis above), to determine brood year returns for each spawning year. Brood returns are used to calculate survival rates, which are one of the three primary measurements of stock status and recovery.

Chum salmon are sampled from fish landed by commercial and Tribal fishers. Specific management areas are sampled during management periods, and age, sex, and length data are collected from a predetermined number of chum salmon randomly selected from the landed fish. Sample size is typically 200 fish per week per management area. Several scales from each fish sampled are placed on a gummed card along with associated data. Impressions of the scale samples are subsequently pressed into acetate sheets, and the age of each fish is determined by "reading" the magnified scale impression.

The age composition of returning chum salmon can generally be used to measure the recovery of a salmon stock in two circumstances. The first, and most important, use is as a principle component of cohort analysis. Stock survival rates are calculated from run size and age compositions, and changes in stock survivals would not be measurable without adequate age data. The second would be if ages have been skewed by human interventions (most likely through fishery selection) to the point that stock fitness and performance is affected. In those cases where age compositions have shown a substantial shift from historic values, and there is no observed natural environmental cause, returning the stock to the normal age structure would be a measure of recovery.

Age composition data can be analyzed for change over time, and associated variances can be estimated. Age composition data used in cohort analysis is less likely to support statistical evaluation (see Cohort analysis).

There is a caveat associated with the current age sampling program: the resulting estimates represent the age compositions of the fisheries sampled, and are not necessarily representative of total run size. The ages of those fish that survive fisheries are likely somewhat different than the harvested fish because of selection in the fisheries. It would be desirable to collect separate age data for both harvested fish and spawners; however, staff and fiscal restraints have always precluded the more difficult spawning ground sampling.

Pink Salmon – Pink salmon have a single age at maturity: 2 years. Because of this, it is unnecessary to collect age composition data from returning fish.

Sockeye Salmon – Sockeye salmon have a variable maturity schedule, typically returning to spawn at ages of 3-, 4-, and 5-years. Because of this, it is necessary to collect age composition data from returning fish each year for use in cohort analysis (see Cohort analysis), to determine brood year returns for each spawning year. Brood returns are used to calculate survival rates, which are one of the three primary measurements of stock status and recovery.

Sampling Design – Scales are collected from sockeye post-spawners in the Cedar River and at the Baker artificial spawning beaches. In the case of the Cedar River age samples, sampling is not currently conducted as a part of a long term effort to identify the overall age structure of the population so conclusions reached from the data must be carefully evaluated.

Morphologic traits

Chum Salmon – The management of chum salmon requires the collection of scales from returning adult chum salmon for age determinations (see Age composition). As a part of the standard scale sampling routine, the lengths and sexes of all sampled fish are recorded. Chum salmon are sampled from fish landed by commercial and Tribal fishers, and at several hatcheries. Specific management areas are sampled during management periods, and age, sex, and length data are collected from a predetermined number of chum salmon randomly selected from the landed fish. Sample size is typically 200 fish per week per management area. The length of each fish sampled is measured to the nearest millimeter, and sex of the fish is noted and recorded on the scale sampling card. There is a specific set of protocols for the scheduling, location, and number of samples for chum salmon age, length, and sex ratio sampling. Additionally, commercial and sport salmon sampling protocols are documented. Length and sex data can be analyzed for change over time, and associated variances can be estimated.

Pink Salmon – Because there are no scale collections from returning Puget Sound pink salmon, there is no routine collection of lengths and sexes. If length and sex data were to be collected, they could be analyzed for change over time, and associated variances could be estimated. However, if major shifts in adult size occur, the measurement of recovery in response to a return to normal size would be an improvement in the stock's survival rate. Survival statistics are influenced by a large number of often changing factors, and past experience has shown that only those impacts with a very large affect on survival can measured with statistical certainty. The size of returning adults, although important, is unlikely to be among those survival factors that can be measured with certainty.

Sockeye Salmon – Information on the morphologic traits of wild salmon is seldom collected in a systematic manner. Some studies have been conducted that detail specific morphologic traits at certain locations.

The management of Puget Sound sockeye salmon requires the collection of scales from returning adult sockeye salmon for age determinations (see Age composition). As a part of the standard scale sampling routine, the lengths and sexes of all sampled fish are recorded.

Steelhead Trout – No data provided

Bull Trout/Dolly Varden – No data provided

Coastal Cutthroat Trout – No data provided

Migration timing

Chum Salmon – The traditional method of measuring the return of maturing adults to nearshore waters is through the analysis of fishery catch information. Unfortunately there are a variety of reasons why catch data are not suitable to directly monitor recovery. Nearly all chum fisheries operate in areas where mixed stocks are present, and it is generally not possible to identify the presence of individual stocks. Fishery catches seldom represent the overall migration timing, because their timing and duration are often limited to a fraction of the overall run timing by management factors such as: available harvest numbers, concerns for other stocks or species, or intent to focus on hatchery stocks. And finally, in some circumstances, no fisheries occur because there are no surplus fish for harvest.

The freshwater entry timing of wild adults is typically measured where fish are trapped and enumerated. For chum salmon, the only continuously monitored trap sites are: Snow and Salmon Creeks in Discovery Bay (summer chum); Big Beef Creek (summer and fall chum); Lilliwaup Creek (summer chum) and Union River (summer chum) in Hood Canal; and Chambers Creek in south Puget Sound (winter chum).

Consistent approaches are utilized by the WDFW to conduct salmon trapping operations. They have not, however, been documented in report form.

Migration timing as a measurement of recovery would only be of interest if normal timing had been severely altered by human intervention. This does not seem to be the case with any of the above referenced stocks. However, if major shifts in migration timing do occur, the measurement of recovery in response to a return to normal migration timing would be an improvement in the stock's survival rate. Survival statistics are influenced by a large number of often changing factors, and past experience has shown that only those impacts with a very large affect on survival can measured with statistical certainty. Timing of migration, although important, is unlikely to be among those survival factors that can be measured with certainty.

Pink Salmon – Migration timing can represent any point in salmon life history including:

(1) Juvenile out migration,

(2) Sub-adult migration in the ocean,

(3) The return of maturing adults to nearshore waters, and

(4) The freshwater entry of adults.

For the purposes of recovery monitoring, the last to life stages (3 & 4 above) are the most pertinent.

The traditional method of measuring the return of maturing adults to nearshore waters is through the analysis of fishery catch information. Unfortunately there are a variety of reasons why catch data are not suitable to directly monitor recovery. Nearly all Puget Sound pink fisheries operate in areas where mixed stocks are present, and it is generally not possible to identify the presence of individual stocks. Fishery catches seldom represent the overall migration timing, because their timing and duration are often limited to a fraction of the overall run timing by management factors such as: available harvest numbers, concerns for other stocks or species, or intent to focus on hatchery stocks. And finally, in some circumstances, no fisheries occur because there are no surplus fish for harvest.

The freshwater entry timing of wild adults is typically measured where fish are trapped and enumerated. For Puget Sound pink salmon, the only continuously monitored trap site is at Sunset Falls on the South Fork Skykomish River.

Sockeye Salmon – Migration timing can represent any point in salmon life history including:

(1) Juvenile out migration,

(2) Sub-adult migration in the ocean,

(3) The return of maturing adults to nearshore waters, and

(4) The freshwater entry of adults.

For the purposes of recovery monitoring, the last to life stages are the most pertinent.

The traditional method of measuring the return of maturing adults to nearshore waters is through the analysis of fishery catch information. Unfortunately there are a variety of reasons why catch data are not suitable to directly monitor recovery. Nearly all Puget Sound sockeye fisheries operate in areas where mixed stocks are present, and it is generally not possible to identify the presence of individual stocks. Fishery catches seldom represent the overall migration timing, because their timing and duration are often limited to a fraction of the overall run timing by management factors such as: available harvest numbers, concerns for other stocks or species, or intent to focus on hatchery stocks. And finally, in some circumstances, no fisheries occur because there are no surplus fish for harvest.

The freshwater entry timing of wild adults is typically measured where fish are trapped and enumerated. For Puget Sound sockeye salmon, the continuously monitored trap sites include: Baker River (Skagit system), and the Lake Washington Ship Canal (Ballard Locks).

Spawn timing

Chum Salmon – Timing information is not routinely calculated for each Puget Sound chum stock, but rather, is assembled for individual stocks when needed (e.g., timing of Hood Canal summer chum was developed for recovery planning).

Serial spawner counts are conducted each year in a large number of streams and index areas. The timing of live spawner abundance (expressed as percent complete) can be calculated from the escapement curves generated from spawner counts.

Since 1998, the WDFW computer program that is used to develop spawner curves and escapement estimates, also automatically produces and electronically stores a table of timing values represented by the curve. This timing information is slightly different from spawn timing because it reflects the timing of live fish presence in the area surveyed, which includes pre- and post-spawning fish.

There are no written protocols for developing run timing estimates. The automatic computer generation of spawning timing estimates is a standardized approach. It is, however, applied to every set of spawner counts regardless of the quality of the data. The proper use of this timing information requires that each data set be examined to identify those where the individual counts were sufficient in number of surveys and temporal distribution of counts through the season to adequately represent actual timing.

Shifts in timing based on serial spawners counts can be measured with statistical certainty; i.e., variance can be estimated from inter-annual timing data. However, the measurement of recovery in response to a return to normal spawning timing would be an improvement in the stock's survival rate. Survival statistics are influenced by a large number of often changing factors, and past experience has shown that only those impacts with a very large affect on survival can be detected with statistical certainty. Timing of spawning, although important, is unlikely to be among those survival factors that can be measured with certainty.

Pink Salmon – The specific season during which salmon stocks spawn is the result of selective pressures, exerted by environmental and human influences, which ultimately contribute to the overall survival of the stock. Each salmon stock faces a unique set of factors limiting their production, and have adapted their timing of spawning to optimize their survival.

Timing information is not routinely calculated for each Puget Sound pink stock, but rather, is assembled for individual stocks when needed (e.g., timing of Dungeness summer and fall pink stocks was developed for recovery planning).

Sockeye Salmon – The specific season during which salmon stocks spawn is the result of selective pressures, exerted by environmental and human influences, which ultimately contribute to the overall survival of the stock. Each salmon stock faces a unique set of factors limiting their production, and has adapted its timing of spawning to optimize its survival.

Timing information is not routinely calculated for each sockeye stock, but rather is assembled for individual stocks when needed (e.g., timing of Hood Canal summer sockeye was developed for recovery planning).

Census and effective population size

Population abundance (census population size) of wild fish is estimated annually for many stocks. The overall population size can be calculated for areas where adequate spawning counts have been constructed.

However, because many adults may not contribute any offspring to the next generation and the numbers of progeny from successful spawners can vary widely from family to family, the genetic characteristics of populations are influenced more by the effective population size (N_e; a theoretical number related to the numbers and proportions of successfully reproducing males and females in a population) than by the adult census size. The N_e of a natural population can be estimated from genetic data (especially data collected over time for the same population) and it can be more-or-less directly measured by pedigree reconstruction analysis using data from DNA-based investigations specifically designed to investigate this attribute of populations.

Two measurements of population size that are used to consider extinction risk are total population size (N) and effective population size (N_e). Total population size is the number of spawners cumulated over a number of years equivalent to one generation (typically between 3.5 and 3.8 years for sockeye salmon, depending on stock). The effective population is a lower value that provides an estimate of the number of spawners that represent successful reproduction and considers such factors as: sex ratios, pre-spawning mortality, fertility rates, etc. Effective population size is equivalent to the total population size times a factor representing the ratio between effective and total population size. There has been much scientific discussion about the relationship of the total population size to the realized effective population size (N_e/N). Pacific salmon effective population size has been variously estimated to be from 10% to 25% of total population size. Allendorf et al. (1997) assumed a N_e/N value of 20% for wild Pacific salmon populations (R. Waples, NMFS, personal communication).

Chum Salmon – Effective population size is not routinely calculated for chum salmon stocks, because most are healthy and currently have effective population sizes far in excess of the point at which risk of extinction or of genetic damage would be a concern. However, this statistic can be easily calculated for any populations for which reliable escapement estimates exist. Effective population sizes are calculated for one depressed group of chum stocks, the summer chum salmon of Hood Canal and the Strait of Juan de Fuca. In a State/Tribal recovery plan for these fish, the Summer Chum Salmon Conservation Initiative (SCSCI; Ames et al. 2000), effective population size is determined for each stock as a measure of extinction risk. The estimated effective population sizes for Hood Canal and Strait of Juan de Fuca summer chum salmon are provided on the WDFW web site in the SCSCI and the subsequent Annual Report (Ames et al. 2000, WDFW and PNPTT 2002). Effective population sizes are not calculated or reported for other Puget Sound chum salmon stocks.

Pink Salmon – Calculate for all Critical and Depressed status stocks. This is a core WDFW stock assessment function that is conducted annually by the Statewide Species Management Programs. The calculation of pink salmon effective population sizes is an activity performed by the Fish and Wildlife Biologist 3 position described above under Stock Assessment Support.

Effective population size is not routinely calculated for Puget Sound pink salmon stocks, because most are healthy and currently have effective population sizes far in excess of the point at which risk of extinction or of genetic damage would be a concern. However, this statistic can be easily calculated for any populations for which reliable escapement estimates exist.

Sockeye Salmon – Effective population size is not routinely calculated for sockeye salmon stocks, because most are healthy and currently have effective population sizes far in excess of the point at which risk of extinction or of genetic damage would be a concern. However, this statistic can be easily calculated for any populations for which reliable escapement estimates exist.

Steelhead Trout – No data provided.

Bull Trout/Dolly Varden – No data provided.

Coastal Cutthroat Trout – No data provided.

Straying

The return of small numbers of adult salmon to spawning areas other than their natal streams (called "straying"), is a normal part of the biology of Pacific salmon. At natural levels which are typically low, such straying undoubtedly is a means of both range expansion and of population replacement to offset naturally occurring local population extinctions. It may also be an important natural protection against inbreeding. Potential problems occur when straying becomes excessive, which can threaten the overall genetic integrity of a native population and negate the benefits of local adaptation. Excessive straying is most commonly the result of human intervention through the artificial enhancement (hatchery programs) of one or more populations and/or anthropogenic habitat alterations. This can greatly increase the stray rate of fish from the enhanced population into adjacent wild populations or among natural populations in an altered environment. The introduction of non-local stocks of salmon into a hatchery program can tremendously exacerbate the problem.

Chum Salmon – Puget Sound chum salmon spawning stocks are not routinely monitored for the presence of fish from other populations. An exception would be the monitoring and evaluation procedures incorporated into the SCSCI (Ames et al. 2000). This state/tribal recovery plan for Hood Canal and Strait of Juan de Fuca summer chum stocks includes protocols for the measurement of the numbers of hatchery produced summer chum salmon straying into wild fish only streams from the supplementation program. Summer chum fry from the supplementation program are marked to distinguish between them and natural-origin fish upon return as adults in fisheries, at hatchery racks, and on the spawning grounds. For the supplementation program on Big Quilcene River, all fry have been adipose-fin-clipped beginning with brood year 1997. For all other supplementation programs, the otoliths of summer chum salmon embryos are thermally mass-marked prior to release. Examination of otoliths recovered from spawned adults and/or for presence/absence of adipose fins provides the necessary information to separate the number of supplementation (hatchery) fish from the number of naturally spawning fish and assists in determining the contribution of the supplementation program to the total summer chum population. In addition, adipose-fin-clipping and otolith-marking make it possible to determine the level of straying of supplementation program-origin fish to other drainages.

Pink Salmon – Puget Sound pink salmon spawning stocks are not routinely monitored for the presence of fish from other populations.

Sockeye Salmon – Puget Sound sockeye salmon spawning stocks are not routinely monitored for the presence of fish from other populations.

Steelhead Trout – No data provided.

Bull Trout/Dolly Varden – No data provided

Coastal Cutthroat Trout – No data provided

Genetic diversity

Genetic variability is an important characteristic of species, with diversity among individuals and among populations being key contributors to genetic vigor, ecological fitness, and evolutionary potential. Furthermore, because many genetic traits are not directly affected by environmental conditions, they can be useful and powerful markers of populations and species and their interpretation is straightforward and uncompromised by potential environmental effects. The WDFW Genetics Laboratory is equipped to collect and analyze such data and has a 17-year history of contributing to our understanding of the character and interrelationships of Washington's salmon populations. While the laboratory has a substantial program of such genetic studies, many projects are funded by outside agencies (not state dollars), and thus are directed at regional or other needs and not directed at specific state salmon recovery information needs. To the extent that many of these externally funded studies contribute to our understanding of Washington's salmon populations they can provide useful information for monitoring and evaluating salmon recovery. However, it is essential that a directed genetic salmon recovery monitoring and evaluation program be established and supported by dedicated state funds to ensure that the program is both comprehensive and successful.

Diversity of salmon populations can be categorized in many ways. In dealing with ESU issues, the NMFS uses the ESU whereas the USFWS uses the term Distinct Population Segment. WDFW has used genetic data to identify two levels of population groups based on genetic (and other) characteristics. A genetic diversity unit (GDU; Busack and Marshall 1995) is a group of genetically similar stocks that is genetically distinct from other such groups. The stocks typically exhibit similar life histories and occupy ecologically, geographically, and geologically similar habitats. A GDU may consist of a single stock or of many stocks. A major ancestral lineage (MAL) is a group of one or more genetic diversity units whose shared genetic characteristics suggest a distant common ancestry, and substantial reproductive isolation from other MALs. Some of these groups are likely the result of colonization and diversification preceding the last period of glaciations. Washington's salmon species are described below in the context of GDUs and MALs.

Chinook Salmon – Genetic diversity of 58 chinook stocks throughout the state was evaluated by WDFW in 1995 using 42 enzyme-encoding loci. The data were collected and analyzed using accepted protocols for electrophoretic analysis. Five genetic diversity units were identified within Puget Sound chinook belonging to one MAL. Six GDUs were identified for the coast and the Strait of Juan de Fuca belonging to one MAL. For the Columbia River, ten GDUs were identified belonging to two MALs. Other biological diversity characteristics were also evaluated in the study.

No formal approach to measuring the status or trends in the changes in the diversity or heterozygosity of GDUs has been developed or implemented.

Coho Salmon – Genetic (allozyme or DNA analysis), phenotypic (body form and/or differences), or life history data (unique run timing, ocean distribution, etc.) are typically the most desirable data for identifying stock structure. Unfortunately, most coho stocks in the 1992 and 2002 SaSI reviews were identified on the basis of geographic isolation criteria only. This was due to limitations in the available genetic data. No significant phenotypic differences has observed between Washington coho stocks to date, and most Washington coho populations currently in existence do not have strong life history variations below the regional level.

Allozyme (electrophoretic) based analyses for coho conducted to date have not had sufficient resolving power at the stock level, due to the limited amount of variation observed at protein electrophoretic loci in this species (Wehrhahn and Powell 1987; Bartley et al. 1992). Genetic stock identification capabilities for coho are rapidly improving with the advent of DNA based genetic analysis technologies, which are providing the ability to achieve finer levels of population discrimination than previously (Beachman et al. 2001). Numerous tissue samples for Washington coho are already collected and available for DNA analysis, but only limited DNA sample processing has been conducted to date for Washington origin coho samples, due to the significant financial commitment needed to conduct these types of analyses. The cost is typically 40-60 dollars to analyze each individual sample, "baseline" development for each stock commonly requires 100 samples (J. Shaklee, WDFW, personal communication), and there is significant post-sample-processing data analysis required to make use of the data. There is also the continuing need to collect more samples from more stocks, as smaller populations often require several years of field sampling to achieve sample goals.

Coho Salmon – No comprehensive, state-wide genetic characterization of coho salmon stocks in Washington has been completed to date.

Pink Salmon – Genetic diversity of Washington pink salmon was evaluated by WDFW in 1995 using 28 enzyme-encoding loci. The data were collected and analyzed using accepted protocols for electrophoretic analysis. Fifteen stocks were recognized. Eight genetic diversity units were identified within Puget Sound odd year pinks belonging to MAL 1. One GDU was identified for even year pinks for MAL 2. Other diversity characteristics were also evaluated in the study.

Chum Salmon – Genetic diversity of Washington chum stocks was evaluated by WDFW in 1995 using 39 variable enzyme encoding. The data were collected and analyzed using accepted protocols for electrophoretic analysis. Seven genetic diversity units were identified for inner Puget Sound chum belonging to MAL 1. Two GDUs were identified for chum in Hood Canal, Discovery Bay, and Sequim Bay for MAL 2. Five GDUs were identified for the Strait of Juan de Fuca, Washington coast, and Columbia River and they comprised MAL 3.

Sockeye Salmon – Genetic diversity of sockeye was evaluated throughout the state in 1996 using 29 enzyme-encoding loci and 19 collections from nine locations. The data were collected by NMFS using accepted protocols for electrophoretic analysis and analyzed by WDFW. Nine genetic diversity units were identified for Washington sockeye. Four GDUs were identified for Puget Sound, three for the coast, and two for the Columbia River. No MALs were identified.

Steelhead Trout – The genetic characteristics of a large number of Washington steelhead populations have been documented by WDFW staff and preliminary Genetic Diversity Units have been identified for this species. While there is not a formal steelhead GDU report, the genetic basis (allozyme data) for it already exists in the form of four WDFW reports (Leider et al. 1994, 1995; Phelps et al. 1994, 1997).

Bull Trout/Dolly Varden – No comprehensive, state-wide genetic characterization of bull trout or Dolly Varden stocks in Washington has been completed to date, although the WDFW Genetics Lab and other labs in the region have conducted genetic analysis of selected populations that has revealed substantial genetic divergence among local populations. The WDFW intends to conduct a thorough characterization of population structure in these species once suitable DNA markers are developed.

Coastal Cutthroat Trout – WDFW reviewed genetic (allozyme and microsatellite DNA data) and other data for approximately 47 collections of Washington coastal cutthroat trout (collected by WDFW, NMFS, and others) and concluded that there was evidence for at least 40 stock complexes (Blakley et al. 2000).

Estimates of measurement error and certainty

Genetic data are often subjected to a series of well-defined statistical tests of specific hypotheses to investigate fundamental aspects of the data themselves and of population structure. Additionally, such data are usually analyzed by both subjective and rigorous statistical methods to identify patterns in the data and interrelationships among samples. Many of these statistical tests calculate the precision of the resulting estimates, thereby providing an indication of estimation error and uncertainty. Wherever appropriate, suitable statistical tests of the genetic data will be performed to assure the validity of the resulting conclusions.

Identified agencies

The WDFW, Treaty Tribes, NMFS, USFWS are participating agencies.

Recommended sampling protocols

Genetic investigations of population structure are typically based on collections of 50-100 individuals sampled from each potential or assumed population in a manner so that the entire collection is obtained with regard to both geographic and temporal heterogeneity on the scale that could affect population structure. This approach will be continued in the proposed monitoring and evaluation of salmon recovery, with temporally repeated collections representing an important component of the analysis to detect and document observed changes through time and evaluate their significance.

Performance benchmarks

The historic genetic diversity of salmon populations is not known and cannot be used as a performance target. We strongly recommend that the current genetic character and diversity of salmon stocks be documented by DNA analysis and then used as a benchmark to evaluate future changes.

Identified monitoring gaps/overlaps

There is a need to collect DNA information for most salmon stocks.

Quality assurance/Quality control

The WDFW Genetics Lab and other cooperating genetics laboratories in the region have been involved in ongoing data collection and analysis coordination and standardization efforts to ensure data quality and comparability among labs for over 17 years (for allozyme based studies). In addition to the specific quality assurance or quality control procedures implemented in the laboratory, there are many generally accepted procedures and approaches (Shaklee and Phelps 1990; White and Shaklee 1991). Recommended aspects of data quality assurance and quality control include:

(1) Where possible, selecting specific genetic markers so as to maximize data comparability and standardization in the region by screening loci that are also being used by other labs;

(2) Developing and using DNA allele binning procedures that maximize reliability, precision, and inter-lab comparability; and

(3) Double-scoring of all electropherograms.

Where feasible, sample sizes will be collected and analyzed to achieve a suitable level of precision and collections will be stratified by location and date to be as representative of the target populations as possible.

Data will be located at the WDFW Genetics Laboratory in Olympia. Summaries of many data sets will be available in written laboratory or agency reports and/or via peer-reviewed technical publications.

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J. Harvest

Question 7: What is the impact of harvest upon the recovery rate of wild salmon populations?

Objective 7A: Measure the salmon harvest rates and total numbers of harvested salmon for the stocks in each federally identified ESU; and determine the trends.

Objective 7B: Determine whether harvest restrictions have been implemented as required under the ESA 4(d) rules. (implementation monitoring)

Objective 7C: Determine whether harvest restrictions have been effective in allowing enough salmon to spawn. (effectiveness monitoring)

Objective 7D: Determine whether harvest is age, size, or sex selective, to the detriment of natural production. (validation monitoring)

Objective 7E: Measure the status and the trends in illegal salmon harvest.

Monitoring indicators

Total harvest

The total harvest is the mortality associated with targeted and non-targeted fisheries. Total harvest can rarely be directly calculated except where commercial fisheries require the completion of harvest information at the time the fish are sold. In most cases involving sport harvest, the total must be calculated using extrapolations developed from sampling participants in the fishery. Harvest by itself is not an indicator, but is necessary, along with spawner abundance to assess harvest.

Total fishing effort

The total fishing effort is the total amount of time expended in catching fish within a specific fishery. It can be measured in terms of hours, days, vessel trips, or other standard unit of measurement. Total effort expended is a necessary statistic for calculating total catch when a complete census of catch is unfeasible.

Age composition

Age composition of fish caught and harvested is important in reconstructing the different run components for any one year's juvenile salmon migration. For example, a steelhead may return to the river after spending either one, two, or three years in the ocean. Out of any one year class of out migrant smolts, approximately 15% may return after one year, 60% after two years, and 25% after three years at sea.

Annual targeted harvest rate

The annual targeted harvest rate is the rate of harvest that is projected to occur within the fisheries that year. Harvest rates should not exceed the rate that will ensure that there are sufficient salmon returning to meet the needs for adequate spawners to fully "seed" the rivers of origin. In mixed stock fisheries, this becomes a major problem where there may be 10 stocks involved and some of the stocks are more abundant than others and can sustain a higher harvest rate. Less abundant stocks are then subjected to harvest rates that are greater than their ability to maintain adequate seeding of the river of origin. For mixed stock fisheries managed by harvest rates, mixed stock fishery impacts are modeled using the best available data, to assure that needs of least abundant stocks are met. This harvest strategy does not provide "full seeding" of habitat; it provides optimum productivity.

Length and weight

Length and weight information are important indicators of fish caught and harvested in that it determines the overall potential fecundity of the females, and the poundage landed. This information can also be used to determine if the fishing gear is selective for size and how this might impact the overall reproductive success of the population when returning to the river of origin. Selectivity is measured by comparing age, size, and sex composition of catch with spawner escapement.

Sex
Determining the sex of fish caught and harvested provides information on the fecundity of the population and potential selection by sex in fisheries.

Background

Total fishing mortality (harvest) is calculated by summing all of the harvest that occurs in each fishery that impacts the stock of concern. For any one stock, total mortality (F_T) is calculated using the basic formula: $F_T = F_1 + F_2 + F_3 + Fn$ where Fn is the total number of fisheries that intercept the stock of concern. Models have been developed that create formulas for each stock and generate the harvest impacts upon each stock when a fishery is proposed. The models also predict unlanded harvest resulting from net dropout mortality, hooking mortality and other incidental mortality factors.

Harvest quotas for Washington's coho and chinook fisheries are modeled for the following:

(1) Canadian fisheries for the West coast of Vancouver Island commercial troll, Area 20 net fisheries, Georgia Strait sport and troll,

(2) U.S. fisheries south of Cape Falcon as a conglomerate, and

(3) Washington fisheries for Tribal and non-Tribal ocean commercial troll, ocean sport fisheries for areas 1-4; Columbia River buoy 10; treaty Strait of Juan de Fuca troll, Puget Sound sport for areas 5-13; and numerous terminal fisheries at the mouths of rivers.

Harvest quotas for chinook fisheries in Puget Sound and along the coast are modeled using exploitation rates for the following indicator stocks:

- Skagit summer/fall; Stillaguamish summer/fall; Snohomish summer/fall; Nooksack early; Skagit spring; White River spring; Nooksack natural and hatchery summer/fall; Tulalip summer/fall; Hood canal natural and hatchery summer/fall aggregate; Mid Hood Canal natural; Skokomish natural; Juan de Fuca natural and hatchery summer/fall; Lake Washington summer/fall; Green River summer/fall; Puyallup summer/fall; Nisqually summer/fall; Misc. Area 10 and 10E summer/fall; Carr Inlet summer/fall; Chambers Bay summer/fall; McAllister Creek summer/fall; and Deschutes and 13D-K summer/fall.

Columbia River chinook stocks are managed through a quota for the following indicator stocks:

- Bonneville pool hatchery tule; upriver bright fall chinook; lower river hatchery tule; lower river wild; Bonneville upriver bright fall chinook; Priest upriver bright fall chinook; Lower river bright fall chinook; and Snake River fall chinook.

Harvest quotas for coho fisheries in Puget Sound and along the coast are modeled for the following indicator stocks:

- Skagit wild; Stillaguamish wild; Snohomish wild; Hood Canal wild; Juan de Fuca wild; South Sound wild; Nooksack wild; Quillayute fall wild; Hoh wild; Queets wild; Grays Harbor wild.

Columbia River coho stocks are managed through a quota for the following indicator stocks:

- Upriver coho and lower river marked coho.

Strategy for Measuring Salmon Harvest Rates and Total Numbers of Harvested Salmon

Salmon Sport Fishery

The procedures for estimating salmon and steelhead sport harvest are based upon sound statistical sampling practices and fairly robust protocols and quality control procedures. Whereas coastal cutthroat and resident trout sport harvest estimates are much more difficult to accurately determine because the effort is so dispersed and difficult to monitor. They are not considered robust or statistically sound.

➢ *It is recommended that the current level of salmon and steelhead monitoring be maintained.*

Harvest sharing under U.S. v Washington, and U.S. v Oregon court decisions require accurate and timely information about the location and amount harvested in order to meet allocation goals, quotas, and other harvest guidelines. The current structure is adequate for determining the annual status of harvest and the trends as it relates to monitoring the impacts of harvest upon salmon recovery. Current Internet data access should be improved to include all salmon species harvested by sport fishers.

Although a sport fishery drop out rate is modeled into the sport harvest mortality quota, current harvest estimates may be underestimating sport harvest mortality. As a quality control measure, more information should be collected concerning the mortality rate of naturally produced salmon caught and released associated with selective fisheries targeting marked hatchery fish.

Commercial Harvest

The current commercial sampling and fish ticket system are adequate for estimating harvest throughout the state. Net drop out mortality is modeled into harvest quota estimates. However, estimates of commercial mortality may be low because mortality due to drop out from commercial gear has not been adequately documented in order to determine the true mortality rate for naturally produced salmon populations impacted by commercial harvests. As a quality control measure, it is recommended that improved estimates of drop out rate from commercial harvests be developed. The fish ticket system should be periodically assessed and modified to enable accurate accounting of all catch, particularly as marketing has diversified (e.g., direct retail sales and sales of eggs). Studies should also include sub-legal and legal encounter rates and shaker mortality for troll fisheries, release mortality from seine gear, marine mammals, and pre-spawning mortality.

Harvest Rate Management

Harvest (exploitation) rate management was implemented because it lessens the risk of over harvest of the less abundant stocks.

➢ *It is recommended that post-season assessments be used as a tool for periodic updating of harvest objectives to reflect changing productivity of stocks.*

Quality control should be maintained by providing an annual comparison of harvest rates proposed versus harvest rates achieved and these compared to current escapement goals to track either upward or downward trends in spawner abundance.

In Season Updates

A problem associated with managing harvest is the risk that predicted acceptable harvest levels (based upon pre-season forecasts of run size) are erroneous and that over harvest will occur but be undetected.

➢ *It is recommended that the WDFW and the treaty tribes implement "in season" run size updates similar to those conducted in the fisheries in Alaska and elsewhere in order to reduce risks of over* *harvest. In-season updates are most useful near the terminal areas.*

Current monitoring activity

Setting harvest levels for salmon in Washington is a very complex process that entails actions by the following entities:

(1) Pacific Salmon Commission, which sets allowable harvest levels between Canada and the United States,

(2) Pacific Fishery Management Council (PFMC), which sets harvest allocations among the three coastal states of California, Oregon, and Washington,

(3) North of Falcon, which sets allocations within Washington territorial waters between the State and the treaty Indian tribes having fishing rights described under the U.S. v Washington (Boldt) and U.S. v Oregon (Belloni) decisions, and

(4) Columbia River Compact, which sets harvest levels in fishery management zones 1-6 of the Columbia River.

Pacific Salmon Treaty

Every year, fishery experts from Alaska, Canada, Washington, and Oregon prepare estimates of the total numbers of salmon expected to return to the native rivers from each country and state. Provisions of the treaty outline the sharing formulas between the parties and the total allowable catch. Total allowable catch is modeled using various computer programs depending upon the species. Convention water fisheries (areas 4B, 5, 6C, 6, 7, and 7A) targeting sockeye and pink, salmon are regulated by the Fraser Panel of the Pacific Salmon Commission. This group sets weekly allocations to each country depending upon continual run size updates for various stocks of sockeye and pink salmon entering the Fraser River. The updates are based upon racial analysis and catch per unit of effort in test fisheries, as well as spawning ground counts and sonar counts taken at the mouth of the Fraser River. State and tribal allocations are balanced in season as the fishery progresses. Chinook and coho salmon are allocated between Canada and the U.S. based upon modeled abundance over time and break points in harvest levels.

Chum fisheries are managed according to the forecast abundance of Puget Sound fall chum stocks. Chum fisheries in Catch Areas 6/7/7A are managed on in-season assessments of Southern British Columbia chum abundance.

When salmon abundance is lower due to climate conditions, the harvest allocations are lowered. Their application to chinook management is designed to specifically account for the unpredictability of recruitment, and is done to avoid over harvest. The allocations and abundance information is dependent upon a coastwide Coded Wire Tag (CWT) program that allows the tracking of where fish are caught. Nearly all CWT data are derived from hatchery fish. A basic assumption that may not be true is that the behavior of hatchery and wild salmon are identical and that one can be used to predict the other. The other weakness in this approach is the fact that productivity models are essentially averages over a number of years and as a result have a tendency to over estimate harvestable surplus in poor years and under estimate harvestable surplus in years with ideal freshwater and marine survival conditions. There is a need, therefore, to continue to evaluate the relationships between hatchery stocks and wild stocks when CWT hatchery fish are used as indicators of wild salmon survival.

Pacific Fishery Management Council

The PFMC is one of eight such councils established under the Magnuson-Stevens Fishery Conservation and Management Act as a means of enforcing conservation practices and resolving allocation issues of marine fisheries between the states of California, Oregon, and Washington. The PFMC meets periodically throughout the year to hear testimony from experts on the status of various stocks of marine fishes including Pacific salmon, to hear public testimony, and to set the allocations for specific geographic areas along the coast.

The two areas of most interest to Washington are the areas north of Cape Falcon, and south of Cape Falcon to Point Arego. The PFMC exerts jurisdiction over recreational and commercial salmon harvest in Washington catch areas 1-4. Oversight of overfishing has been recently more constrained under the Magnuson-Stevens Act for stocks that comprise 5% of harvest in those catch areas. The PFMC consists of the States of California, Oregon, Washington, and Idaho and has authority over the fisheries in the Pacific Ocean seaward of such states. The PFMC consists of 14 voting members, including eight appointed by the U.S. Secretary of Commerce (Secretary) in accordance with subsection (b)(2) of the Magnuson-Stevens Act (at least one of whom shall be appointed from each such state), and including one appointed from an Indian tribe with federally recognized fishing rights from California, Oregon, Washington, or Idaho in accordance with subsection (b)(5) of the Magnuson-Stevens Act.

The PFMC has produced a Pacific Coast Salmon Fishery Management Plan which must be approved by NMFS under the requirements of the ESA. A series of Biological Opinions have been issued by NMFS concerning ocean fisheries implemented under the plan and the associated 4(d) rules.

North of Falcon

Federal court decisions under U.S. v Washington and U.S. v Oregon have required that up to half of the harvestable salmon be allocated to tribal fisheries. The status and harvestable numbers of salmon have been established on a river by river and run by run basis based upon the specific ceded areas of each treaty tribe and their usual and accustomed fishing areas. Because these allocation issues involve intra-tribal negotiations as well as negotiations between the state and the various tribes, a process was needed to avoid protracted litigation and to bring fisheries management out of the courtroom. As a result, the North of Falcon process was created.

Each year state, federal, and tribal fishery managers gather to plan the Northwest's recreational and commercial salmon fisheries. This pre-season planning process involves a series of public meetings between federal, state, tribal and industry representatives and other concerned citizens. Based upon those meetings, allocations are made to non-Indian sport and commercial fisheries, and tribal fisheries within Puget Sound, Grays Harbor, Willapa Bay, the Columbia River and all tributary fisheries. Fisheries are predicted using the Fishery Resource Assessment Model for coho and chinook.

The North of Falcon planning process coincides with the March and April meetings of the PFMC. Agreements are reached between the state, tribal, and federal managers as to the sharing formulas and days of fishing allowed to harvest up to 50% of the harvestable numbers of salmon.

Columbia River Compact

The Columbia River Compact (Compact) is charged by congressional and statutory authority to adopt seasons and rules for Columbia River commercial fisheries. In recent years, the Compact has consisted of the Oregon and Washington agency directors, or their delegates, acting on behalf of the Oregon Fish and Wildlife Commission and the Washington Fish and Wildlife Commission. In addition, the Columbia River treaty tribes have authority to regulate treaty Indian fisheries.

When addressing commercial seasons for salmon, steelhead, and sturgeon, the Compact must consider the effect of the commercial fishery on escapement, treaty rights, and sport fisheries, as well as the impacts on species listed under the ESA. Although the Compact has no authority to adopt sport fishing seasons or rules, it is an inherent responsibility of the Compact to address the allocation of limited resources among users. This responsibility has become increasingly demanding in recent years.

The Columbia River has been divided into 6 fishing zones for the purposes of management. Zones 1-5 are located between the mouth of the Columbia and Bonneville Dam, and they are the areas utilized by non-Indian commercial fishers. Zone 6 consists of the area between Bonneville Dam and McNary Dam, and is open only to tribal fisheries.

The Compact has established a Technical Advisory Committee (TAC) to provide run size forecasts, in-season updates, and analysis of harvest information for consideration by the Compact. TAC members include representatives from the Treaty tribes, ODFW, WDFW, Idaho Fish and Game, NMFS and the U.S. Fish and Wildlife Service. Their findings are published as joint staff reports.

After allowable harvest levels are established in the above mentioned processes, commercial and sport fisheries are monitored to estimate harvest rates. Sport harvest is monitored using two major methods, creel census and catch record cards. Creel census is conducted in three areas:

- Ocean,
- Puget Sound, and
- Columbia River.

Ocean Creel Census

Monitoring indicators

Total sampled harvest, total sampled effort, number of CWTs, length and weight, age composition of harvest, and sex of harvested fish.

Current monitoring activity

Creel census is used for ocean salmon fishing along the Washington coast and in the Strait of Juan de Fuca for estimating sport harvest of chinook, coho, pink salmon, and any incidental steelhead harvest. The ocean along the coast and throughout Puget Sound and the Strait of Juan de Fuca has been divided into 13 catch areas so that sport harvest can be categorized into geographic areas for purposes of controlling harvest and tracking allocations. Dockside samplers are posted throughout the open areas and during the sport fishing season to interview individual fishers and commercial charter boats as they arrive at the pier with their catch. Estimates of the total fishing effort and total catch are made each week and the tally is reported to the PFMC. This process continues until the quota has been reached for each coastal catch area with a quota system monitored by the PFMC (catch areas 1-4b).

Essential tools

The CWT creel census sampling program has provided the ability to mark individual hatchery salmon by imbedding a CWT into their snout has allowed fishery managers to track the relative contribution of specific hatchery stocks originating from hatcheries located on various rivers throughout all of the fisheries of the Pacific coast. This has in turn allowed total estimates of fishing mortality which was previously never available. By subtracting fishing mortality from the overall production of hatchery fish released, an estimate of their overall marine survival can be obtained.

The models that have been developed to predict total harvest can also be considered essential tools.

Monitoring design

Sampling has been designed to create in season and post season estimates with a coefficient of variation of 5% or less. An annual “Operating Plan” (WDFW 2002a) is available that details the goals, objectives, and overall approach to sampling. The dockside sampling scheme is designed to sample at an overall rate of no less than 20% of the total effort. At least 20% of the catch of chinook and coho are examined using electronic detection devices for detecting CWTs. Scales are collected from a minimum of 120 chinook per stratum in the sport fisheries for age determinations.

Estimates of measurement error and certainty

Although Lai et al. (1991) described the formulas and the procedures for using a FORTRAN program to address statistical issues, there is no real discussion of the certainty level sought in the surveys and the overall target variance. It is believed to be a 95% certainty that the true catch and effort is within 5% of the calculated estimate.

Identified agencies

The WDFW, in cooperation with the PFMC, hires a temporary crew each year to conduct dockside monitoring.

Recommended sampling protocols

Sampling protocols are found in WDFW (2001). The procedures for calculating total harvest and total effort are found in Lai et al. (1991).

Performance benchmarks

Annual quotas are established by the PFMC based upon the allowable share of harvestable salmon and non-targeted impacts to listed species.

Identified monitoring gaps/overlaps

Current monitoring is sufficient for controlling harvest in the ocean. However, current technology does not allow monitoring of the impacts of harvest by each wild salmon population or distinct population segment. Therefore, clumping of populations based upon indicator stocks remains the norm. Genetic evaluations using DNA hold promise for future harvest evaluations that can be much more definitive than present.

Quality assurance/Quality control

There are some quality control measures built into the sampling protocols such as checking to be sure certain numbers or letters are legible. Supervisors periodically check the creel checkers to be sure they are completing forms in the proper manner and are actually interviewing anglers. This procedure is not randomized and formalized. Data are located in the WDFW.

Risks

Because ocean fisheries are a mixture of numerous strong and weak stocks returning to multiple streams of varying size, there is a great risk of over harvesting some populations in order to harvest more robust hatchery or wild stocks.

Puget Sound Creel Census

Monitoring indicators

Total sampled harvest, total sampled effort, number of CWTs, length and weight, age composition, CWT, and sex of harvested fish.

Current monitoring activity

The main objective of the Puget Sound creel census is to provide auxiliary data for the catch record card system; species composition to estimate sport harvest by species and catch per unit of effort (salmon per angler trip) to estimate total effort. The data are stratified by catch area, and time for Catch Areas 4B, 5, 6, 7, 7A, 8, 9, 10, 11, 12, and 13.

Essential tools

Creel census and sport catch record card system.

Monitoring design

Sampling has been designed to create in-season and post season estimates with a coefficient of variation of 5% or less. An annual “Operating Plan” (WDFW 2002b) is available that details the goals, objectives, and overall approach to sampling. The dockside sampling scheme is designed to sample at an overall rate of no less than 20% of the total effort. At least 20% of the harvest of chinook and coho are examined using electronic detection devices for detecting CWTs. Scales are collected from a minimum of 120 fish per stratum in the sport fisheries for age determination.

Estimates of Measurement error and certainty

Although Lai et al. (1991) described the formulas and the procedures for using a FORTRAN program to address statistical issues, there is no real discussion of the certainty level sought in the surveys and the overall target variance. It is believed to be a 95% certainty that the true catch and effort is within 5% of the calculated estimate.

Identified agencies

The WDFW, in cooperation with the PFMC, hires a temporary crew each year to conduct dockside monitoring.

Recommended sampling protocols

Sampling protocols are found in WDFW (2001). The procedures for calculating total harvest and total effort are found in Lai et al. (1991).

Performance benchmarks

The harvest sharing agreements established during the North of Falcon process are used as performance benchmarks. These are either used as actual quotas, or converted into days of fishing effort based upon past performances of the fishery in achieving a daily total harvest.

Identified monitoring gaps/overlaps

There are often not enough monitoring activities in place to adequately capture the true harvest in real time with confidence.

Quality assurance/Quality control

There are some quality control measures built into the sampling protocols such as checking to be sure certain numbers or letters are legible. Supervisors periodically check the creel checkers to be sure they are completing forms in the proper manner and are actually interviewing anglers. This procedure is not randomized and formalized. Data are located in the WDFW sport harvest database and are also exported to the RECFIN database administered by the Pacific States Marine Fisheries Commission and can be accessed through their website.

Risks

Because Puget Sound fisheries are a mixture of numerous strong and weak stocks returning to multiple streams of varying size both in Washington and in British Columbia, Canada, there are risks, if insufficiently monitored, of over harvesting some populations in order to harvest more robust hatchery or wild stocks.

Columbia River Creel Census

Sampling design and protocols can be found in various summaries produced by the managing entities. The most recent description can be found in Johnson et al. (in press).

Monitoring indicators

Total sampled harvest, total sampled effort, number of CWTs, length and weight, age composition, and sex of harvested fish.

Current monitoring activity

The Columbia River creel census is conducted through funding provided by the Bonneville Power Administration and provided to the Pacific States Marine Fisheries Commission. The Commission in turn subcontracts to the Oregon and Washington departments of Fish and Wildlife to provide temporary personnel to interview the public. It includes sport harvest in Buoy 10 and in the sport fisheries in the Lower Columbia River and upstream pools (Areas 1-6).

Essential tools

Creel census and CWT programs.

Monitoring design

Sampling has been designed to create in-season and post season estimates with coefficients of variation of 5% or less. An annual “Operating Plan” (WDFW 2002) is developed by the WDFW and is available that details the goals, objectives, and overall approach to sampling. The dockside sampling scheme is designed to sample at an overall rate of no less than 20% of the total effort. At least 20% of the catch of chinook and coho are examined using electronic detection devices for detecting CWTs. Scales are collected from a minimum of 120 fish per stratum in the sport fisheries for age determinations.

Estimates of measurement error and certainty

Although Lai et al. (1991) described the formulas and the procedures for using a FORTRAN program to address statistical issues, there is no real discussion of the certainty level sought in the surveys and the overall target variance. It is believed to be a 95% certainty that the true catch and effort is within 5% of the calculated estimate.

Identified agencies

The WDFW, in cooperation with the PFMC, hires a temporary crew each year to conduct dockside monitoring.

Recommended sampling protocols

Sampling protocols are found in WDFW (2001). The procedures for calculating total harvest and total effort are found in Lai et al. (1991).

Performance benchmarks

Escapement goals have been established for chinook and steelhead for lower Columbia and upper Columbia River tributaries and as conglomerates passing upstream of selected dams. Harvest quotas are set for the Columbia River as part of sharing agreements between the Columbia River treaty tribes and the states of Washington, Oregon, and Idaho in order to meet these escapement goals. The NMFS sets allowable incidental take levels for listed species for treaty Tribes and non-treaty fishers. Escapement goals and recovery goals have not been set for various rivers and stocks.

Identified monitoring gaps/overlaps

Because escapement and recovery goals have not been set for many tributaries, we cannot address harvest on a population by population approach.

Quality control/Quality analysis

There are some quality control measures built into the sampling protocols such as checking to be sure certain numbers or letters are legible. Supervisors periodically check the creel checkers to be sure they are completing forms in the proper manner and are actually interviewing anglers. This procedure is not randomized and formalized. Data are located in the WDFW.

Risks

Because Columbia River fisheries are a mixture of numerous strong and weak stocks returning to multiple streams of varying size both in Washington, Oregon, and Idaho, there are risks, if insufficiently monitored, of over harvesting some populations in order to harvest more robust hatchery or wild stocks.

Catch Record Cards

Monitoring indicators

Number of fish recorded caught, location, date, species caught.

Current monitoring activity

Catch Record Cards (CRC) are issued automatically by computer to all Washington sport fishers targeting salmon, sturgeon, halibut, Dungeness crab, or steelhead. The CRC must, under state law, be completed after catching a salmon, sturgeon, halibut, crab, or steelhead. The CRC contains information about the species caught, the marine catch area or stream, date, and the person catching the fish.

The CRCs are required to be turned in at the end of the fishing year (March 31). They are processed by hand using data entry operators to record the information into a database. However, only 46-66% of the CRCs issued have been returned to the WDFW annually. In order to be able to extrapolate the total catch, sources of bias and error in CRCs returned must be detected and known.

Essential tools
Sport catch record card system, including data entry and analysis.

Monitoring design
Each CRC is uniquely identified by a sequential number. These numbers are randomly sampled to identify the year's sample population. For salmon, the sample rate is 4%. The average harvest per CRC within these samples represents an unbiased estimate of the true harvest per card for all CRCs issued, if 100% of the corresponding CRCs are returned. Reminder letters are used to improve the non-response rate. Prior to 2000, the CRCs were issued separately for each species and the sample sizes and variances were calculated separately. In 2000, the WDFW consolidated the CRCs into one document to improve customer service. This action altered the overall sampling design.

Estimates of measurement error and certainty
If a 100% return of these CRCs is not achieved, and, if average harvest per CRC is different for the group of anglers not returning their CRCs, then, a non-response bias is introduced. The tendency of unsuccessful anglers not to return their CRC has introduced a non-response bias requiring correction in the estimate of total salmon sport harvest. The precision of estimates depends largely on the size of the harvest estimates. Generally, larger estimates are more precise. There is a significant relationship between the harvest estimate and the coefficient of variation calculated using the random sample group variance (r= -0.54 and Spearman's p= -0.90 both significant at the 99% level) (Conrad and Alexandersdottir 1993). Coefficient of variation has varied between 5% and 40% depending upon the catch area and the size of harvest.

Identified agencies
The WDFW calculates the CRC harvest annually.

Recommended sampling protocols
Sampling protocols are found in Hahn (1997), Conrad and Alexandersdottir (1993), and Alexandersdottir et al. (1994). However, there is a need to publish revised protocols instituted since the separate CRCs for salmon steelhead, halibut, sturgeon, and Dungeness crab were combined in 2000.

Performance benchmarks
Performance is measured by the return rate for CRCs, and is compared to historic return rates.

Identified monitoring gaps/overlaps
None identified.

Quality assurance/Quality control
Annual random samples of the CRCs insures that the CRC return bias is recalibrated annually. Data are published annually and are available through the WDFW website.

Risks
If the CRC monitoring system is inaccurate, harvest would be significantly under- or overestimated.

Commercial Harvest

The commercial harvest of salmon authorized under the PFMC and North of Falcon processes are monitored in a manner similar to sport harvest.

Commercial Buyer Sampling

Monitoring indicators
Name of the licensed fisher, location, fisher type, date caught, species, and catch weight.

Current monitoring activity
The WDFW and the treaty tribes work cooperatively to report commercial harvests from their respective fisheries. The fish buyers are required by state law to complete and mail to the WDFW a commercial fish ticket for each commercial salmon caught detailing the name of the licensed fisher, location, fisher

type, date caught, species, weight, etc. so that a proper accounting of salmon harvest can occur. The information is entered into the computerized commercial fish ticket system (LIFT) where totals are maintained for each species, catch area and gear type.

Essential tools
Commercial fish samplers, and LIFT.

Monitoring design
Commercial landings are sampled for CWTs, length, weight, age, sex, and other characteristics. The goal is to sample 20% of the catch of coho and chinook per catch area per week. All chinook and coho of the 20% sample are checked for CWTs. The 20% sample is randomly taken usually by sampling all fish within a tote, truckload, vessel, or some other unit chosen that has pre-selected the fish to be sampled. The overall methodology can be found in WDFW and NWIFC (2001).

Estimates of measurement error and certainty
The fish ticket method is required by state and tribal regulations. It is assumed that 100% of the commercial landings are known through the LIFT system. No estimates of non-compliance are available for reporting commercial harvest. The precision of the 20% commercial sampling for CWTs and other information is not reported.

Identified agencies
The WDFW and the Treaty Tribes sample commercial harvest annually and report it through the LIFT system.

Recommended sampling protocols
Sampling protocols are found in WDFW and NWIFC (2001).

Performance benchmarks
The performance benchmark has been established by policy as being able to sample 20% of the total landed commercial harvest.

Identified monitoring gaps/overlaps
There is a need to adapt LIFT to accurately account for direct marketing, egg sales, and other recent changes in sales of salmon and salmon products.

Quality assurance/Quality control
There are no written quality control procedures, but the sampling manual provides cautionary information about specific areas of data quality. The information is entered into the LIFT system, where totals are maintained for each catch area and gear type.

Risks
If LIFT is inaccurate, significantly underestimated harvest could be occurring within Washington.

Ocean Commercial Troll Sampling

The objectives of the ocean troll sampling program are to collect information from commercial fishers receiving tickets during the non-treaty and treaty fishery to track harvest and keep the fishery within the limits of its chinook and coho quotas set by the PFMC for ocean areas. The WDFW samples non-treaty troll fishers, and the Quinault, Hoh, Quilleute, and Makah tribes track the commercial harvest of tribal troll fishers. The WDFW samples so that 20% of all troll fishers are sampled at dockside. The methods are similar to those reported for the ocean sport catch above.

Puget Sound Commercial Sampling
The objectives of the Puget Sound sampling program are to collect information from commercial fishers receiving tickets during the non-treaty and treaty Fraser Panel sockeye, pink, and chum fisheries to track harvest and keep the fishery within the limits of its quotas set by the Fraser Panel of the Pacific Salmon Commission for the control area of the Fraser Panel in both Canada and the United States. The WDFW samples non-treaty gill net, purse seine, and reef net fishers and the tribes track the commercial harvest of tribal fishers. The

WDFW samples so that 20% of all fishers from each gear type are sampled at dockside. The methods are similar to those reported for the ocean sport catch above.

Columbia River Commercial Sampling

The objectives of the Columbia River commercial sampling program are to collect information from commercial fish receiving tickets during the non-treaty and treaty spring and fall fisheries for chinook, coho, and steelhead, and to track harvest and keep the fishery within the limits of its quotas set by the Columbia River Compact and the Pacific Fisheries Management Council. The WDFW and the ODFW sample non-treaty gillnet fishers and the tribes track the commercial harvest of tribal fishers. The WDFW and ODFW sample so that 20% of all fishers are sampled at dockside. The methods are similar to those reported for the ocean sport catch above.

Objective 7B: Determine whether harvest restrictions have been implemented as required under the ESA 4(d) rules (implementation monitoring).

Although this implementation-related objective is listed here, it is under the purview of the United States government acting through the NMFS for anadromous salmon species, and the U.S. Fish and Wildlife Service for non-anadromous species such as bull trout and cutthroat trout. Only these federal agencies can officially make determinations under the ESA whether 4(d) rules have been implemented as required. However, the citizens of Washington should also be aware of whether the WDFW and tribes have restricted harvest to the extent necessary to meet ESA standards. Annual reporting under the State Agency Action Plan and Scorecard through a web portal should be made available to all citizens.

Strategy for Determining Whether Harvest Restrictions Have Been Effective

Objective 7C: Determine whether harvest restrictions have been effective in allowing enough salmon to spawn (effectiveness monitoring).

Coho and chinook

Most current coho and chinook harvest management goals were established to meet fishery management objectives on the management unit scale. They often incorporate several stocks in each management unit in an aggregate. Fishery harvests have historically had moderate to high effects on coho escapement and abundance throughout the Pacific coast region. Even before the rise of "industrial-scale" commercial and sport salmon fisheries in the late 1800s, tribal fishermen significantly harvested salmon in many estuaries and rivers for both subsistence and economic purposes (Wilkenson and Conner 1983; WDF et al. 1973).

With the arrival of post-subsistence fishery technologies, exploitation rates (total number of adults harvested, divided by total adult run size before harvest) on all salmon species climbed rapidly, reaching as high as 80% or more for some stocks by the 1980s (based on review of CWT data recovery data from PSMFC tag recovery database, Portland, OR).

Harvest management goals for most major natural Washington coho populations throughout the mid to late 20th century have revolved around meeting fixed minimum natural escapement goals, or escapement ranges for each of the major coho stocks, or stock aggregates. These goals were intended to provide maximal long-term adult harvests from each of the stocks. The Puget Sound Salmon Management Plan (PSSMP 1985) provided this objective:

> *"For primary management units returning to natural spawning areas, the escapement goal shall be the maximum sustained harvest level."*

Maximum sustainable harvest was defined in the PSSMP as:
"The maximum number of fish of a management unit that can be harvested on a sustained basis, measured as the number of fish that would enter freshwater to spawn in the absence of fishing after accounting for natural mortality. The MSH is intended to mean maximum sustained harvest to Washington fisheries."

A byproduct of this management approach was "weak stock management." During the annual PFMC pre-season management process, any ocean fisheries that were identified as expected to impact production from (managed) stocks predicted to be below escapement goals had to be restricted or eliminated.

The co-managers, after struggling annually with the coho and chinook fishery planning problems caused by weak stock management through the 1970s-to-1990s time period, developed a new management strategy called the Comprehensive Coho Management Plan (CCMP) in the 1990s time period (Comprehensive Coho Workgroup 1998). The goal statement of the Comprehensive Coho Management Plan is:

> *"Develop and implement improved coho management approaches that support the maintenance and restoration of wild stocks in a manner that reflects the region's fisheries objectives (resource protection, allocation, and harvest stabilization), production constraints, and production opportunities."*

The CCMP and chinook processes subsequently derived new stock-specific management objectives. These new management objectives include:

(1) Identification of minimum escapement levels for each stock needed for stock sustainability (NOT MSY). Derivation of these levels attempted to consider population production and management uncertainty. No directed harvest on a stock is allowed below this level, and

(2) Establishment of tiered stock-specific exploitation (harvest) rate objectives for populations above the minimum escapement level goals. The tiered rates are intended to provide maximal long term fishery benefits from each stock or stock aggregate, which is defined in this process as a balance between long term productivity, and achievement of more stable fisheries from year to year: *"…a fixed harvest rate policy may provide greater long term catches than a fixed escapement policy while minimizing inter-annual variability in fishing seasons… (CCMP)"*

The combination of tiered exploitation rate and escapement range objectives is expected to provide more fishery planning flexibility than the previous fixed escapement goal management system. Some of the biggest benefits of this system will be:

(1) The fishery planning process is not as (tightly) tied to the (often flawed) preseason forecasts, since management goals for each population are set more for an expectation of an abundance range than a point estimate of abundance, and

(2) Post season assessment of management can be more based on examination of the observed exploitation of indicator stocks, than post-season estimates of total run size for the major fishery management units (which are also often quite flawed, due to the run reconstruction problems discussed earlier).

This approach is not without its skeptics. There is a risk that utilizing harvest rates rather than managing to a strict escapement goal will provide too much leeway when making harvest and allocation decisions. Harvest rate management is dependent upon having accurate estimates of the ongoing allowable harvest rate, which is based upon marine survival estimates. If marine survival is fluctuating, harvest rates may be set too high for some years and wild stocks would be at higher risk.

Steelhead

Wild steelhead harvest is managed differently than the salmon in that state law prohibits commercial harvesting of steelhead by non treaty citizens. As a result, harvest is managed by estimating the expected run size returning to the river to spawn. Since very few steelhead are taken in ocean fisheries, harvest is managed for in-river sport and tribal commercial fisheries. Once the total run size is estimated, the number needed to meet the escapement goal is subtracted from the total and the remaining surplus is divided equally between the tribes and the non Indian sport fisheries. Allocations are agreed to at North of Falcon and formalized in annual fisheries plans, Each side is provided an opportunity to harvest their fair share of the wild and hatchery steelhead. Effectiveness of harvest allocations are evaluated by reviewing spawning ground estimates post season. For steelhead fisheries, there are no mutually agreed upon in-season updates considered statistically valid at this time.

Cutthroat Trout

Cutthroat trout harvest is managed using bag limits and minimum size limits to ensure that adults (as determined by a minimum size at maturity) have an opportunity to spawn at least once. This strategy is detailed in "A Basic Fishery Management Strategy for Resident and Anadromous Trout in the Stream Habitats of the State of Washington" (WDG 1984).

Bull Trout
In recent years no bull trout harvest has been allowed under provisions of the ESA. Bull trout harvest in the past was managed using bag limits and minimum size limits to ensure that adults had an opportunity to spawn at least once. This strategy is detailed in "A Basic Fishery Management Strategy for Resident and Anadromous Trout in the Stream Habitats of the State of Washington" (WDG 1984).

Essential tools

Coded Wire Tag — The Coded Wire Tag (CWT) sampling program has provided the ability to mark individual hatchery salmon. A CWT is a small piece of metal imbedded into snouts of fish. This has allowed fishery managers to track the relative contribution of specific stocks originating from hatcheries located on various rivers throughout the Pacific coast. This has in turn allowed estimation of total fishing mortality which was previously unavailable. By subtracting fishing mortality from the overall production of hatchery fish released, their overall marine survival can be estimated.

Spawning Surveys — Ultimately monitoring the number of fish returning to spawn is the true measure of the effectiveness of harvest restrictions. Was the escapement goal met? If not, harvest restrictions were not effective in meeting the established benchmarks and targets.

Monitoring design

There is no established design for effectiveness monitoring of salmon and trout harvest restrictions statewide. There has been discussion for a number of years about holding post season evaluation meetings to discuss and report on the effectiveness of harvest strategies. These evaluation meetings have not been implemented, and there is no reporting mechanism that reveals how effective the WDFW and the tribes were in meeting the goals.

Identified agencies

The WDFW and treaty tribes in cooperation with the NMFS, USFWS, and US Forest Service, Bureau of Land Management, and other federal agencies.

Recommended sampling protocols

None provided.

Performance benchmarks

The performance benchmarks for all species of salmon should be the escapement goal (number of spawners needed to meet the production potential of the freshwater habitat). The NMFS Technical Review Teams are in the process of recommending recommended spawner abundance ranges as new ESA targets for measuring state and tribal success in meeting spawner recovery targets.

Identified monitoring gaps/overlaps

There is a huge gap in the sophistication and expenditures used to monitor the effectiveness of salmon compared to resident trout harvest statewide. Monitoring harvest in lakes is well documented because the harvest is directed mostly at hatchery produced trout, and they can be easily observed when fishers return to a public boat ramp, etc. However, monitoring harvest of resident wild trout in streams is difficult because fishers are thinly scattered over a large geographic area. Effectiveness of wild trout harvest regulations has been evaluated by comparing the presence of adult trout of spawning age in the population post harvest. By setting the minimum size limit of trout above the average minimum size of trout when they first spawn, the assumption is that there is adequate seeding of the watershed prior to harvest. This management approach has worked well in many places, but does not work where harvest regulations are ignored or where hooking mortality represents a significant loss to fish caught and released prior to their first opportunity to spawn.

Quality assurance/Quality control

None provided.

Risks

The basic management philosophy and approach of both salmon management and trout management is intended to be conservative. However, without effectiveness monitoring we will be unable to document the adequacy of our efforts to manage harvest within the necessary bounds and limitations placed upon it by the productivity of the habitat and the overall need for wild spawning salmon on the spawning grounds. Therefore, the risk is that we cannot justify having the fisheries at all and ultimately the conclusion that harvest is the reason that salmon runs are declining.

Under most situations, listing of a species under the ESA leads to closure of all harvest opportunities, especially harvest targeting the listed species. However, the NMFS has chosen to allow harvest under the 4(d) rule. Allowable harvests are currently set by NMFS so as not to "substantially impede" recovery. "Substantial" has not been defined quantitatively. This policy received criticism from the Salmon Recovery Science review Panel in their report to the NMFS, August 2001. Since the NMFS has provided directed harvest opportunities to tribal and non tribal fishers on listed species, it is even more important to monitor and report on the effectiveness of the harvest rules and restrictions.

Recommendations

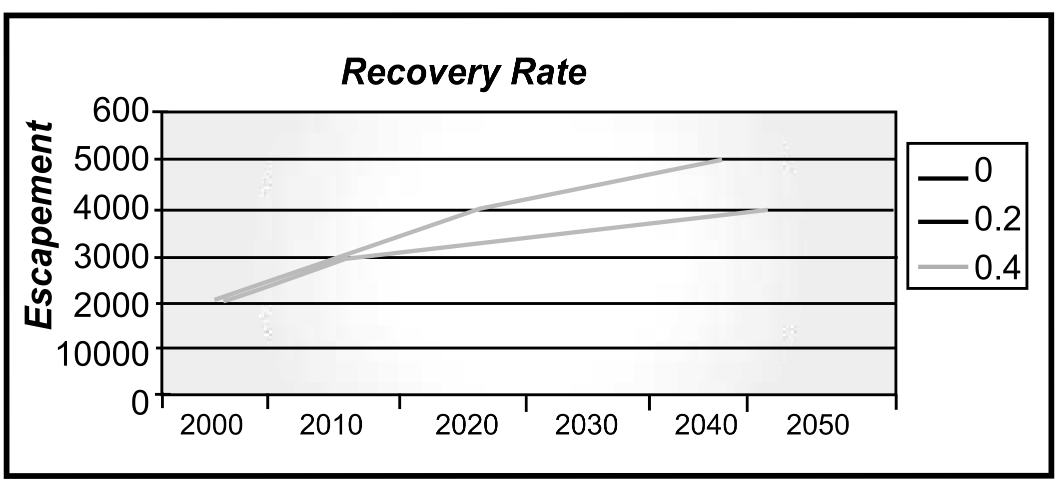
- *It is recommended that post season analysis be performed for all salmon and steelhead fisheries to determine whether the spawner escapement goals have been met.*

The current North of Falcon process is sufficient in forecasting run sizes, modeling expected harvests, escapements and exploitation rates. However, there is no formal "post hoc" analysis to determine if the goals were actually attained. This analysis should be available for public access via the Internet.

- *It is recommended that a risk analysis evaluation be designed and implemented to estimate the length of time for recovery of each salmon ESU, based upon variable harvest rates, and a no harvest rate option.*

This would clarify the time (years) needed for recovery based upon harvest restrictions that allow varying numbers of fish to the spawning grounds (Figure 36), all else being equal.

Figure 36. Hypothetical illustration of recovery rate estimated for variable harvest levels.



Validation Monitoring of Harvest Age, Size, and Sex Selectivity

Objective 7D: Determine whether harvest is age, size, or sex selective, to the detriment of natural production (validation monitoring).

Monitoring indicators

Fish harvest may select for a specific size, age, sex, or other characteristic of fish by virtue of fishing gear type, time and location fished. Traits that are selective in fisheries are not distributed in future populations. The following are monitoring indicators for Objective 7D:

- Size of spawners vs size of fish harvested,
- Age of spawners vs age of fish harvested, and
- Sex ratio of spawners vs sex ratio of fish harvested.

Current monitoring activity

The WDFW and the Treaty Tribes are currently measuring spawner abundance and harvest information that could be used to compare the results of size, age, and sex ratios between escapement, commercial fish sampled, and creel checks.

Essential tools

Spawner surveys, sport and commercial harvest sampling.

Monitoring design

None identified. No monitoring design has been developed. This is a major need for future monitoring.

Identified agencies

The WDFW, Treaty Tribes, NMFS, and USFWS are participating agencies.

Recommended sampling protocols

None identified.

Performance benchmarks

Historic information concerning size, age, and sex ratios may be able to be used as benchmarks of performance.

Identified monitoring gaps/overlaps

Current sampling efforts are not adequate to measure fishery selectivity. A status review was conducted by the NMFS for chinook salmon and coho salmon when they were being evaluated under the listing process. Currently there is no scheduled periodic evaluation of the results of data collected. A specific methodology and a theoretical approach are needed.

Quality assurance/Quality control

None identified.

Risks

Insufficient evaluation could result in lack of corrective actions to reduce or eliminate major changes in harvest to benefit natural production of wild salmon populations. Harvest opportunities and economic benefits may be reduced if we are unable to validate the efficacy of conservative harvest approaches that avoid adverse impacts to natural production.

Strategy for Measuring Impact of Illegal Harvest on Production

Objective 7E: Measure the status and the trends in illegal salmon harvest.

The vast majority of sport and commercial fishers conscientiously comply with laws designed to manage the taking of salmon in a manner that protects and restores wild stocks. However, there is a significant amount of illegal harvest that is outside the monitoring and reporting structures outlined under Objective 7A. The following are monitoring indicators for this objective:

- Number of sport and commercial fishers contacted by enforcement officers,
- Number of sport and commercial fishers violating season, bag limit, size limit, and other laws governing taking of salmon, and
- Number of salmon by species taken by violators.

➢ *It is recommended that the WDFW and the tribes develop sampling procedures that measure the compliance rate among sport and commercial fishers and estimates the number of salmon by species taken by violators.*

The sampling procedures should be based upon randomized statistically valid approaches to encountering both commercial and sport fishers such that we can be 90% confident that the compliance rates and numbers of salmon taken by violators is within 10% of the true value.

➢ *It is also recommended that the CWT system be evaluated to determine if the rate of return of CWTs in illegal harvests can be estimated and extrapolated to estimate the total number of illegally harvested salmon.*

Current monitoring activity

The WDFW, the U.S. Coast Guard, NMFS, USFWS, county sheriffs, Washington State Patrol, U.S. Forest Service, Tribes, and others assist in the enforcement of fishing laws in Washington. The WDFW officers hold federal USFWS and NMFS commissions, and have jurisdiction over federal violations, the most important of which are the ESA and the Lacey Act. Officers work joint patrols and coordinate with these agencies and the U.S. Coast Guard.

Data reflect that 83% of a WDFW officer's time is devoted to natural resource law compliance – fish and shellfish; wildlife, both hunted and non-hunted; and habitat protection (HPA, FPA, litter, etc.). The remaining 17% is made up of: compliance with other laws; police powers and boating safety; problem wildlife management (13% of time); public safety; crop and property damage; and nuisance wildlife. In the early 1980s there was one officer per 23,000 citizens; now it is approximately one officer per 35,000 citizens.

Because officers are few, they must maximize the efficiency of their time by concentrating on areas where known violators congregate or where violations are most likely to occur. This economy of effort is necessary to address the greatest poaching threats, but is not random and does not generate statistically valid information that can be used for estimating total impacts from harvest, especially in a statistically unbiased way.

Salmon Selective Fisheries

Currently the WDFW samples harvest landings at ocean ports for species, presence of marks, and other parameters described under Objective 7A. The incidence of unmarked fish in fisheries where only marked fish may be legally retained are recorded. The sampling regime and estimation procedures are described under Current

Sport Fish Monitoring in this chapter and result in a precise number with statistical significance. This information is compared to the incidence of violations recorded by enforcement officers. The incidence of violation reported by enforcement officers is not random and has no associated precision estimate. It is assumed that enforcement officers tend to check individuals in a manner biased toward violators, whereas dock samplers would have data biased toward those complying with laws. The combined total of these two estimates is assumed to represent a fairly accurate estimated of compliance.

Essential tools

Adequate number of trained enforcement personnel, and an adequate sampling design and analysis framework.

Monitoring design

There are two common design approaches to measuring illegal harvest:

(1) The most common approach is to measure the number of violators in a subsample of the population of fishers and then extrapolate the findings to the total population of fishers in a typical mark-recapture approach, and

(2) The second approach is to mark a segment of the population with a tag, radio beacon, etc., and trace the fate of the marked animals in the population using a mark-recapture approach.

The fisher encounter approach (#1)has been used most in Washington, but without the scientific rigor necessary for statistically valid results. Recently, the WDFW conducted a study of the compliance rate of fishers in releasing externally unmarked wild salmon. Results showed compliance rates in the 90 percentile for many fisheries. However, no precision estimates were provided.

Estimates of measurement error and certainty

There currently are few estimates of error or certainty for statistics involving fishing violations. Precision estimates should be built into future monitoring.

Identified agencies

The WDFW and the Treaty Tribes, with assistance from the U.S. Coast Guard, NMFS and the USFWS, enforce commercial and sport harvest annually and channel the information through their respective agencies.

Recommended sampling protocols

With the exception of dock sampling that monitors compliance with selective fisheries, there are no written sampling protocols for sampling fisher compliance. Protocols should be developed after careful consideration and review of compliance work done by other states or agencies.

Performance benchmarks

Statistically valid sampling of compliance in the various fisheries should be conducted to establish a baseline for measuring future progress. Target goals can then be established which should consider:

- Value of the resource – Are the fish Endangered? How many fish are in the populations or stock?
- Cost of improved performance – Is the area easily enforced? How much time and effort will be needed to obtain the new target goal for compliance?
- Public awareness – has the public been made aware of the rules governing the fishery?
- Appropriate penalties – Are the penalties for violation adequate to assist in deterring other potential violators if the probability of arrest is increased?

Quality assurance/Quality control

There are currently no written quality control procedures. Quality assurance and quality control procedures should be developed and formalized in writing as the protocols and sampling approach is completed.
The information is entered into WDFW's violator system but is not readily accessible. Selective fishery compliance is reported annually in joint reports from Oregon and WDFW to the PFMC.

Risks

If compliance is not monitored, we will be unable to account for illegal harvest mortality. This may lead to direct impacts on the status of wild stocks. It may also greatly confound ability to reconstruct run sizes, and inhibit attainment of management and recovery goals.

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K. Hatcheries

Question 6: *What are the trends in effects of hatchery production on the survival and productivity of wild salmon populations within each ESU?*

Objective 6A: Determine whether state hatcheries are in compliance with established Best Management Practices (BMPs).

Objective 6B: Determine whether hatchery BMPs have been effective in reducing or eliminating the adverse effects of hatchery fish upon wild salmon productivity and production within each ESU.

Hatcheries have been in existence in Washington for over 100 years. The Washington Department of Fish and Wildlife (WDFW) manages 90 facilities and also works with 250 cooperative fish rearing projects, and 40 regional fisheries enhancement group projects. In addition, the Washington treaty tribes operate another 35 facilities and the U.S. Fish and Wildlife Service operates 12 others. All together, 340 million fish are planted annually into Washington state waters. Hatcheries provide many beneficial services including commercial and recreational fishing, supplementation of depressed natural stocks, mitigation for lost habitat, and research. However, evidence has indicated that improperly operated and implemented hatchery programs can be a major factor contributing to the decline of natural populations of salmon. It is important for recovery of wild salmon populations that the use of hatchery salmon be carefully monitored, evaluated, and reported on a consistent basis.

Compliance of Hatcheries with Best Management Practices

Objective 6A: Determine whether state hatcheries are in compliance with established Best Management Practices (BMPs).

Monitoring indicators

Hatchery stock identification

All hatchery fish should be mass marked in some way to distinguish them from naturally produced fish. The exception to this is where the intent of the hatchery program is to help restore the natural population. In this case, not marking these fish protects them from harvest. Spawning ground surveys conducted in key areas provide the necessary data to determine the hatchery/wild composition during spawning. Too many hatchery fish on the spawning grounds interbreeding with naturally produced fish or out-competing them for spawning areas may adversely affect the genetic makeup of the natural population. (See also Salmon Diversity.)

Compliance with Hatchery and Genetic Management Plans

Each hatchery is to have a completed Hatchery and Genetic Management Plan (HGMP) as a means of implementing hatchery best management practices as detailed in Policy 6 of Washington Fish and Wildlife Commission's Wild Salmonid Policy, and requirements of NMFS under the ESA.

Compliance with broodstock selection criteria

The proper mix of hatchery and wild fish in the hatchery broodstock is important to prevent genetic divergence of the hatchery stock from the affected natural population, to prevent the over utilization of wild fish in the hatchery population to the detriment of the natural population (broodstock mining), and to minimize potential domestication effects. Mass marking hatchery fish will allow them to be differentiated from wild fish when they return to the hatchery as adults allowing for greater accuracy in meeting the broodstock management goals.

Compliance with Disease Control Policy
Implementation of proper disease control measures is an indication of proper hatchery management and a means of reducing the impacts of disease upon both the cost efficiencies of hatcheries and wild populations of salmon. Evaluation of the Disease Control Policy indicator would mean that each hatchery, cooperative project and Regional Fisheries Enhancement Group project would be evaluated to determine their compliance with the "Salmonid Disease Control Policy of the Fisheries Co-Managers of Washington State."

State and federally compliant screening and fish passage
All fish hatchery intakes, dams and weirs, on waterways which have anadromous or resident salmon, should operate in such a way so as not to impede, injure, impinge or kill those fish. Improperly designed and/or maintained hatchery intakes, fish ladders and weirs may hinder the perpetuation or recovery of wild salmon in the vicinity of the hatchery structures. Structures which are designed and built to the most current state and federal standards, and which are operated and maintained in the manner in which they were designed will assure that such structures do not impede salmon perpetuation or recovery.

State and federally compliant hatchery pollution abatement
The WDFW hatcheries, including co-ops, should be operated in such a manner as to not exceed state and federal water quality discharge standards. Improperly designed and/or maintained hatcheries and /or pollution abatement system discharges may adversely impact the rearing environment of salmon in the stream downstream of the discharge location hatchery. Pollution abatement systems which are designed and constructed to the most current state and federal standards, and which are operated and maintained in the manner in which they were designed, will ensure that the hatchery water discharge meets the water quality standards for the receiving water body.

Recommended strategy
Because monitoring hatchery operations is not environmental monitoring per se, the best strategy for monitoring whether hatcheries are reducing their impacts on wild salmon production would be focused around monitoring the efforts underway to mitigate the inherent adverse operational impacts of hatcheries upon wild fish. These adverse impacts include:

- Mis-identification of hatchery fish as wild fish both in the ocean and in rivers and streams;
- Blocking access to spawning areas and killing or delaying downstream migrant juveniles;
- Creating adverse genetic impacts upon wild stocks by either breeding or introducing hatchery stocks that are genetically dissimilar to wild stocks;
- Contributing to disease within wild populations either through increasing the incidence of already existing diseases or the introduction of new diseases such as whirling disease and infectious hematopoietic necrosis; and
- Contributing to the degradation of watershed health through hatchery discharges that violate water quality requirements under the Clean Water Act.

Procedures have been detailed in numerous publications about how these adverse impacts can be reduced. As a result, criteria have been established to ensure that the best practices are being used. These criteria are proposed for use as indicators of progress made by hatcheries in reducing their adverse operational impacts on salmon recovery.

➢ *We recommend ranking state hatcheries for their overall compliance with the identified indicators by developing a scoring system.*

Providing hatchery stock identification
The CMS supports the current strategy to externally mark all production hatcheries where salmon are released for harvest. The strategy is based upon the premise that externally marking hatchery salmon will have three major benefits to salmon recovery.

First, it will allow estimates of the true annual productivity of a watershed because the true adult spawners to adult recruits produced ratio can be determined. This will improve monitoring information and increase the certainty that the status and trends of wild populations of salmon are known. It will allow for more accurate estimates of gene introgression between hatchery and wild spawners.

Second, it will allow for maximum harvest pressure on hatchery stocks while minimizing harvest pressure on wild stocks through selective harvest strategies in sport and commercial fisheries. This will reduce the numbers of hatchery salmon that escape the fishery and enter streams to spawn. This will reduce crossbreeding with wild salmon and will reduce competition for spawning areas

Third, hatchery and wild adults migrating through fishways and dams can be enumerated and distinguished, providing for more accurate migration information and inter-dam mortality estimates. Those hatcheries where marking has occurred would receive a higher score than those areas where marking has not occurred.

Hatchery and Genetic Management Plans
The CMS proposes to score hatcheries for their compliance with the HGMP.

Complying with the Disease Control Policy
The CMS proposes to score hatcheries for their compliance with the Disease Control Policy.

Providing compliant screening and passage
A statewide, comprehensive, on-site inventory and evaluation of all hatchery facilities for compliance with current state and federal intake and fish passage standards should be performed. Hatcheries would receive a score for the degree of compliance with screening and passage requirements.

Hatchery pollution abatement
A statewide, comprehensive, on-site inventory and evaluation of all hatchery pollution abatement for compliance with current state and federal standards should be performed. Hatcheries would receive a score for the degree of compliance with pollution abatement requirements. Hatcheries should be scheduled to have wastewater treatment systems evaluated and/or installed in order to meet CWA criteria.

Current monitoring activity

Hatchery stock identification
External marking of steelhead, cutthroat, coho and chinook at WDFW hatcheries is underway. Hatchery steelhead and cutthroat have been externally marked by removing the adipose fin statewide since 1986. Yearling coho externally marked releases from WDFW facilities were begun in 1996. Marked adult coho have been returning to WDFW hatchery facilities and spawning grounds since 1999. State, federal and local funding has been secured to continue these efforts.

Efforts have been underway since 1998 to externally mark chinook in Puget Sound. State, Federal and Tribal agreement is required to conduct external marking in Puget Sound. To date, agreements between WDFW, USFWS, and most tribes have resulted in mass marking approximately 77% of the Puget Sound chinook. Discussions between WDFW, USFWS, and the remaining tribes are continuing.

External marking at WDFW coastal hatchery facilities has been limited to coho, steelhead and Soleduck spring chinook. Lack of agreement with Canada concerning electronic detection of coded-wire tags is preventing chinook mass marking at coastal facilities. The intent is to eventually externally mark all chinook intended for harvest purposes.

In the lower Columbia River, coho are being marked. Spring chinook marking is continuing downstream of the Klickitat River.

Although both Oregon and Washington have requested it, federal and Tribal facilities on the Columbia River have not marked their hatchery production.

External marking programs for pink, chum, and sockeye are not currently being conducted. These species are released from hatcheries at sizes too small to utilize the adipose fin clip as a mass mark. New technology will be needed to effectively mass mark these species. There is no hatchery production of bull trout in Washington.

Hatchery and Genetic Management Plans
The NMFS requires an HGMP for each hatchery program that could potentially affect listed species. Current efforts at development have been focused in Puget Sound and the Columbia River. WDFW staff have developed and submitted draft HGMPs for all Puget Sound hatchery programs. Pending discussions with tribes and NMFS, existing HGMPs will be modified and submitted in their final form. Once approved by NMFS, these become the ESA authorization for continued hatchery production. This process was nearly completed in 2002; final approvals from NMFS are pending.

In the Columbia and Snake River basins, many hatchery programs already have ESA coverage under a Section 10 permit application (which is essentially an HGMP). Before the existing permits expire, HGMPs will be developed for these programs. The HGMP development will be funded by BPA for approximately 40 Mitchell Act and BPA funded programs. The HGMP development has begun for these facilities and is targeted for completion by September 2003. Funding for completing the remaining HGMPs will be acquired from the various Public Utility Districts charged with hatchery production in those areas.

Broodstock selection criteria
Broodstock selection criteria have been established for hatchery programs used to restore natural populations or hatchery programs propagating listed species. Mass marking of hatchery fish will provide the tool needed to differentiate hatchery fish from naturally produced fish at hatchery racks.

Disease Control Policy
The Disease Control Policy of the fishery co-managers of Washington State was developed in 1991.

Screening and fish passage
All state funded, Mitchell Act and PUD hatchery facilities have been inventoried for intake and passage related problems at various times in the past. The efforts were sometimes specific to a particular region, funding entity or ESU.

Hatchery pollution abatement
There has been no statewide, comprehensive, on-site inventory and evaluation of all hatchery facilities for compliance with current state and federal discharge standards and benchmarks.

The permitted facilities collect water discharge samples to measure various parameters each month and report the results on a discharge monitoring report. That report is submitted quarterly to the Washington Department of Ecology. Data are entered into a spreadsheet and violations, or the number of times that a facility exceeds the permit limits, are tracked.

There are substantial records of hatchery discharges, which can be used to monitor trends and compare with current standards for compliance.

Performance benchmarks

Mass external marking

All WDFW hatcheries have externally mass marked all steelhead, cutthroat, coho and chinook, except where the intent of the hatchery program is to help restore the natural population.

Hatchery and Genetic Management Plans

All WDFW hatcheries operate under an HGMP approved by NMFS.

Hatchery broodstock selection

The Hatchery Scientific Review Group has recommended 10-20% as the appropriate level of naturally produced fish in hatchery broodstock.

Disease Control Policy

All WDFW hatcheries are in compliance with the Disease Control Policy.

Fish screening and passage

All WDFW hatcheries have proper fish screening and passage devices.

Hatchery pollution abatement

Compliance with National Pollution Discharge Elimination System permits issued under the authority of the state and the Federal Clean Water Act discharge standards. The WDFW facilities and co-ops have required pollution abatement systems, or some form of treatment that meets the Department of Ecology's approval under their BMPs and All Known Available and Reasonable Treatment, as agreed to verbally with Ecology.

Analysis and outcomes

It is recommended that an overall evaluation process should be developed that scores each hatchery for the identified indicators. This will allow comparisons between hatcheries and SRRs. The results of the analysis should be available through the web portal and should be evaluated by the action agencies for corrections and adaptations.

External mass marking

Mass marking data should be analyzed annually. Trends in percentage of salmon effectively mass marked should be examined and depleted by species and ESU.

Broodstock selection criteria

Hatchery/wild composition data should be evaluated annually statewide and for each SRR. Outcomes should include charts displaying the percent of hatchery and the wild stocks, and another displaying the proportion of hatchery/wild mix in the hatchery broodstock for each hatchery by SRR.

Disease Control Policy

Fish health data at hatchery facilities should be evaluated annually and summarized for occurrences of diseases consistent with the Disease Control Policy.

Screening and fish passage

Facilities where screening and passage are not adequate should be evaluated annually to assess the need for corrective measures. Evaluation procedures could include:

(1) Prioritization of facilities,

(2) On site inspection and evaluation of facilities,

(3) Identification of structured needs,

(4) Project design and scope,

(5) Cost benefit analysis,

(6) Capital funding requests from affected funding sources,

(7) Implementation of infrastructure changes, and

(8) Tracking of implementation progress to completion.

Note: Fish passage above intakes, dams or weirs may be contrary to BMPs at individual hatcheries. This may be due to fish health or other reasons. These facilities will be identified, on a case-by-case basis, and excluded from consideration after consultation with the proper entities.

Pollution abatement

An annual evaluation should occur of facilities that are not in compliance with pollution abatement needs. Evaluation procedures could include:

(1) On-site inspection and evaluation using existing ECY and CWA standards,

(2) Review of historic hatchery discharge records,

(3) Categorization of hatchery structured needs,

(4) Developing design, scope of work, and implementation cost estimates and cost benefit analysis,

(5) Prioritization of hatcheries for project implementation,

(6) Development of capital funding requests,

(7) Implementation of changes, and

(8) Tracking implementation progress to completion.

Essential tools

Mass external marking

(1) Tribal Agreements – By federal court order, agreements must be reached with the affected tribes before mass marking at hatchery facilities can begin.

(2) Infrastructure – Because of the large volume of fish to be mass marked, adequate staff and equipment must be made available. This is particularly important in the spring when mass marking of over 100 million fingerling chinook must be accomplished in approximately 2 months.

(3) Marking Technology – The ability to mark millions of salmon in a short time has only been recently possible due to technological advances, funding of the Bonneville Power Administration, and efforts both in the private and government sectors. The technology to mark salmon externally and to detect coded wire tags without killing the fish are major breakthroughs that should be built upon and improved in the coming years.

Hatchery and Genetic Management Plans

None identified.

Broodstock selection criteria

Externally marked hatchery fish.

Disease Control Policy

The WDFW Fish Pathology Laboratory and the USFWS Olympia Fish Health Center are essential tools in monitoring prevalence of disease in both hatchery and wild populations. The facilities should continue to be funded.

Screening and fish passage

None identified.

Pollution abatement

None identified.

Estimates of measurement error and certainty

Hatchery stock identification

Estimates of sampling error and certainty could easily be calculated from the information obtained from the sampling protocol. However, there does not appear to be any formal requirement to do so. It is recommended that precision standards be implemented for mass marking.

Hatchery and Genetic Management Plans
Measures of certainty and error do not apply to this category.

Broodstock selection criteria
Measures of certainty and error do not apply to this category.

Disease Control Policy
Measures of certainty and error do not apply to this category.

Screening and fish passage
Measures of certainty and error do not apply to this category.

Pollution abatement
Measures of certainty and error do not apply to this category.

Recommended sampling protocols

Prior to release, 500 to 1000 fish from each group of mass marked fish should be sampled for adequate fin clips. The criteria for “good” and “bad” clips have been documented by Thompson and Blankenship (1997) based on studies analyzing fin regeneration.

All sampling will involve on-site evaluation and measurements of intake and passage facilities. The standard for evaluation of compliance shall be current state and federal criteria, or whichever standard supercedes. In the case of compliance for ESA, NMFS has agreed that a trained WDFW employee may act as an agent for the NMFS and recommend certification, for compliance with ESA, intake and passage structures at WDFW hatcheries.

Hatchery and Genetic Management Plans
None have been identified.

Broodstock selection criteria
None have been identified.

Disease Control Policy
None have been identified.

Screening and fish passage
None have been identified.

Pollution abatement
All discharge samples are collected on-site per a prescribed monitoring protocol and schedule. The total suspended solids samples are sent to WDFW for analysis. Where required, discharge monitoring forms are submitted to WDFW and Ecology. The standard for evaluation of compliance shall be current state and federal water quality criteria, or whichever standard supercedes. A professional engineer shall do on-site evaluations of facility upgrade(s) need(s).

Identified agencies

The WDFW (including volunteer cooperators and Regional Fisheries Enhancement Groups), USFWS, and Puget Sound tribes, Ecology, NMFS, and local PUDs.

Quality assurance/Quality control

Mass external marking
There are two levels of measurement to evaluate the quality of mass marking:

(1) Did a particular group of fish get mass marked and what percentage of the total groups does this represent?

(2) When a group of fish does get mass marked, what percentage of those fish were successfully marked? Current mass marking utilizes the adipose fin clip. During the mass marking process, the fish are checked periodically for the adequacy of the fin clip. At the completion of the marking this percentage is documented. Each group of fish are then re-sampled for adequate fin clips prior to release. This re-sampling is necessary because fins may regenerate and some fish may have been missed in the initial mass making process especially if they came from a large pond where a pond seine was used to divide the pond.

Hatchery and Genetic Management Plans
Hatchery and Genetic Management Plans require approval by NMFS; quality assurance is a condition of that approval.

Broodstock selection criteria
None have been identified.

Disease Control Policy
None have been identified.

Screening and fish passage
None have been identified.

Pollution abatement
Discharge monitoring is subject to human error, changes in weather conditions and other variables. Seasonal irregularities, usually caused by flooding events, can lead to anomalies. Samplers have different reporting techniques that have caused variation in the reporting of data. A consistent statewide approach and adequate training are needed.

Data locations and data quality

Mass external marking
The WDFW mass marking data is located in the Hatcheries Division in Olympia. Tribal data is located at the NWIFC in Olympia, or with the individual tribes.

Hatchery and Genetic Management Plans
Data related to WDFW's Hatchery and Genetic Management Plans are located in the Science Division of the Fish Program in Olympia. Quality of the HGMPs has varied and they will be rewritten and updated pending new information and results from research projects until they meet NMFS's standards.

Broodstock selection criteria
Data are located in the Hatcheries Division in Olympia. Tribal data are located at the NWIFC in Olympia, or with the individual tribes.

Disease Control Policy
Data are located in the Hatcheries Division in Olympia. Tribal data are located at the NWIFC in Olympia, or with the individual tribes.

Screening and fish passage
Data collected will be located in the Engineering and Hatcheries Divisions of WDFW. The NMFS will locate similar data for federal facilities. Where applicable, both NMFS and WDFW will locate data pertinent to ESA certification in appropriate agency divisions.

Pollution abatement
Data collected will be located in the Engineering and Hatcheries Divisions of WDFW. NMFS will locate similar data for federal facilities. Where applicable, both NMFS and WDFW will locate data pertinent to ESA certification in appropriate agency divisions.

Effect of Hatchery Fish on Wild Salmon

Objective 6B: Determine whether hatchery BMPs have been effective in reducing or eliminating the adverse effects of hatchery fish upon wild salmon productivity and production within each ESU.

Monitoring indicators

Genetic drift, introgression, and effective population size for key hatchery stocks
Local adaptations of populations to different conditions provide a source of genetic diversity for the entire species (see also Salmon Diversity). A species is made up of a variety of sub-populations, each are different. These differences allow the various sub-populations to survive subject to certain conditions. This, coupled with the ability to adapt to different conditions, allows the entire species to survive. It is therefore, important to maintain the genetic diversity within and among natural populations.

For these reasons, the genetic influence of hatchery fish on natural populations is important to monitor. Periodically sampling the genetic makeup of the key natural populations and the hatchery stocks through DNA or allozyme analysis will be necessary to monitor diversity (see Salmon Diversity). Existing allozyme and DNA baselines are a useful basis for measuring gross changes in heterozygosity (diversity) for some species.

Reproductive success of hatchery fish in the wild

The reproductive success of hatchery fish in the wild can have a direct affect on the genetic makeup and production dynamics of the natural population. Obviously the more successful the hatchery fish are at reproducing, the greater the potential impact. The contribution of hatchery fish to natural production increases, so in turn does the need to account for naturally produced offspring of hatchery fish in run reconstruction escapement estimation, and harvest management.

Disease incidence in hatchery and wild populations

Little is known about the incidence of disease in wild fish populations. Mortality from disease outbreaks reduces the number of fish in the affected population. Implementation and compliance with fish health monitoring protocols can reduce the spread and amplification of pathogens from hatchery fish to wild fish.

Predation by hatchery fish on wild populations or hatchery fish used for recovery

Little is known about the effects of hatchery salmon preying on wild salmonids. Due to the large size of the hatchery program in Washington, there may be significant mortality of wild salmon due to predation by hatchery salmon.

Current monitoring activity

Genetic drift and reproductive success

There has been an interest in obtaining information on the impacts of hatchery fish on wild fish since the early 1970s. As a result, funding was provided to monitor the effects of selected hatchery strains of salmon and steelhead on wild populations. The project having perhaps the longest continuous monitoring on this subject is the WDFW Kalama River steelhead studies. This work began in 1975 by measuring the impact of Skamania hatchery summer steelhead upon Kalama River wild summer run steelhead through the use of a genetic marker. The study followed the impacts of releasing four consecutive years of genetically marked hatchery steelhead. They were followed through their release, return, spawning in the wild, and the return of their offspring as adults back to the river. Monitoring showed that offspring of hatchery parents were 1/3 as likely to survive to adult as the offspring of wild parents. This information, coupled with studies conducted with Oregon hatchery steelhead and coho provided initial scientific information on differences in reproductive success associated with the hatchery environment. Ongoing WDFW monitoring includes:

- Evaluation of the effects of supplementation on wild stocks of steelhead and chinook in the Tucannon, Methow, and Wenatchee rivers,

- Monitoring the reproductive behavior of hatchery and wild origin spawners in a spawning channel and evaluating the reproductive success of hatchery and wild crosses in Yakima River spring and fall chinook, and coho,

- Evaluating ecological impacts of hatchery salmon on natural salmon populations in the Yakima River, and measuring genetic changes caused by adaptation to the hatchery environment, and

- Similar studies are underway at Forks Creek, Minter Creek, and the Deschutes River.

Disease incidence in wild populations

The state has not tracked disease in wild populations of salmon in a planned approach or with statistical certainty or power. Occasional sampling is conducted to obtain specific information. Most monitoring has been in conjunction with determining the disease risk to fish hatcheries where wild fish are present upstream of the water intake to the hatchery. Incidence of IHN has been documented in wild populations in steelhead, coho, chinook, and sockeye/kokanee in various waters throughout the state. Evidence is strong that IHN did not exist in steelhead in the Columbia River in significant amounts or possibly not at all until the eruption of Mt. St Helens in 1980 caused massive straying of both hatchery and wild fish throughout the lower Columbia River. In the ensuing years, major epidemics of IHN produced by fish spawning upstream of the hatchery, forced the destruction of hatchery fish at Cowlitz, Skamania, and Beaver Creek hatcheries. Other potential diseases in wild populations can be traced to contaminated effluents and escapees from both anadromous and non-anadromous hatchery programs.

The USFWS maintains a monitoring database called the "National Wild Fish Health Survey." Its purpose is to determine the presence of certain aquatic pathogens and the location and species of wild fish populations that may harbor them. The impetus for this survey was the introduction of whirling disease into North America from Europe. Wild fish are sampled with the assistance of state and tribal partners in order to determine the presence and distribution of fish pathogens across the United States at a level designed to detect a minimum assumed presence level of 5%.

For example in FY 98, the Olympia Fish Health Center collected 1,174 wild fish of 8 species from 6 sites in Oregon and 13 sites in the State of Washington. Major cooperators included the National Marine Fisheries Service, Washington Department of Fish and Wildlife, Yakama Nation, and the Makah Tribe. The causative agents of enteric redmouth *(Yersinia ruckeri)* and vibrosis *(Vibro anquillarum)* were the only pathogens detected and those were at low levels in the affected populations. Both pathogens were detected in populations at the mouth of the Duwamish River, a highly urbanized river near Seattle, Washington.

Predation by hatchery fish on wild populations

The effects of predation by hatchery fish on wild populations has never been adequately demonstrated. Studies have shown that hatchery steelhead migrants approximately 22cm in length can predate upon juvenile salmon and trout. Dolly Varden and sea-run cutthroat are known to migrate with salmon and to predate heavily on salmon eggs and fry. Early in the 20th century rewards were given for Dolly Varden carcasses as a method for improving salmon production. These characteristics have been documented in food habit studies and direct observations. Research has not established whether this predation has a significant impact on the overall production or productivity of a watershed. There are no ongoing long-term monitoring strategies attempting to monitor the impact of predation by hatchery reared salmon upon wild salmon in Washington.

Recommended strategy

Monitoring design

- *It is recommended that the effectiveness of hatchery programs in reducing gene drift and reproductive success in wild fish be monitored indirectly over time by comparing the observed gene drift in each identified wild population (stock) with the observed changes in the genetic composition of hatchery stocks directly affecting those same populations of wild salmon.*

- *It is further recommended that selected research projects continue to be funded both through the universities and through selected state and federal research monitoring projects.*

The evaluation of changes in loss of genetic fitness and its relationship to hatchery programs can only be demonstrated after investing significant money and time in the outcome.

- ➢ *It is recommended that Washington State rely upon and support the USFWS National Fish Health Survey program as the method for sampling wild populations of salmon and trout on a random basis across the state so that changes in the incidence of disease organisms can be detected and tracked.*

More studies are needed to explore the effects of predation by hatchery fish upon wild salmon and trout. However, we are not recommending a monitoring strategy for hatchery predation at this time.

- ➢ *It is recommended that geneticists within the WDFW, NMFS, USFWS, universities, and tribes should evaluate the genetic fingerprint of hatchery salmon and trout and wild salmon and trout every five years to look for statistically significant changes.*

These evaluations should be available through written reports and could be expressed in terms of % change in allele frequencies or some other easily understood media.

Prevalence of disease organisms in wild trout and salmon could be expressed in terms of incidence of occurrence for major diseases of concern.

Performance benchmarks

Performance benchmarks of wild populations and hatchery populations can be determined relative to baseline information already collected. The baseline information can be used as benchmarks to compare future changes in heterozygosity both in the wild and hatchery origin fish.

Incidence of disease in wild populations can be compared using initial survey information as a benchmark for future comparisons.

There are no benchmarks for comparing predation of hatchery fish upon wild salmon and trout.

Analysis and outcomes

Geneticists within the WDFW, NMFS, USFWS, universities, and tribes should evaluate the genetic fingerprint of hatchery salmon and trout and wild salmon and trout every 5 years to look for statistically significant changes. These evaluations should be available through written reports and could be expressed in terms of % change in allele frequencies or some other easily understood media (see Salmon Diversity).

Prevalence of disease organisms in wild trout and salmon could be expressed in terms of incidence of occurrence for major diseases of concern.

There are no specific recommendations for expressing hatchery predation issues.

Essential tools

In order to evaluate the impacts of hatchery fish upon wild populations, genetics laboratory is an essential tool where protein allozymes and DNA analysis can occur.

Investment in long term (ten or more years) research is crucial in order to answer some of the major questions about genetic changes that can occur in wild populations as a result of hatchery interactions.

Fish health facilities are essential for evaluating fish pathogens. Washington State is fortunate to have the Olympia Fish Health Center of the USFWS and also the pathology laboratory of the WDFW where bacteria, viruses, and parasites can be identified and evaluated.

Estimates of measurement error and certainty

Ongoing genetic studies employ statistical sampling methods. A description can be found in the experimental design and reports produced by these studies. See Salmon Diversity section.

Information concerning error and certainty for the national fish health survey can be obtained from the National Fish Health Center located in West Virginia.

Recommended sampling protocols

Sampling protocols for genetic studies and population estimates are documented in the Fish Abundance Chapter.

Sampling protocols for the National Fish Health Survey Program can be obtained from the National Fish Health Center.

Identified agencies

The WDFW, USFWS, NMFS, and Treaty Tribes are participating agencies.

Quality assurance/Quality control

A Quality Assurance (QA) Project Plan should be developed by each entity conducting monitoring. The QA Project Plan will describe the objectives of the study and the procedures to be followed to achieve those objectives. The preparation of a QA Project Plan helps focus and guide the planning process and promotes communication among those who contribute to the study. The completed plan is a guide to those who carry out the study and forms the basis for written reports on the outcome. Quality assurance for sample survey designs should include a patterned revisit to sites both within the index period of a given year and revisits to sites across years to evaluation the different components of variation. Lombard and Kirchmer (2001) present detailed guidance on the preparation of QA Project Plans. They describe 14 elements to be addressed in the plan and it provides supporting information and examples relevant to the content of each element.

Data locations and data quality

Data concerning genetic studies in Washington can be obtained from the WDFW genetics laboratory.

Data from the National Fish Health Survey Program can be obtained from the National Fish Health Center.

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L. Predation and Competition

Question 5: In the context of other sources of natural and human-caused mortality, is predation by avian, marine mammal, or other aquatic species inhibiting the recovery of salmon within each ESU?

Objective 5A: Measure the status and trends in the rate of consumption of Threatened and Endangered salmon by marine mammals.

Objective 5B: Measure the status and trends in marine mammal populations in Washington State.

Objective 5C: Determine the status and trends of the Caspian tern populations at the mouth of the Columbia River and elsewhere in Washington. Determine whether the predation rates previously measured are still valid.

Objective 5D: Measure the status and trends in Northern pikeminnow (previously 'squawfish') populations in the reservoirs of the Columbia River.

Objective 5E: Determine whether northern pikeminnow control measures have been effective in reducing predation on salmon juveniles to target levels.

Objective 5F: Measure the status of selected invasive species that effect salmon abundance and recovery.

Marine Mammals

Monitoring indicators

For Objectives 5A and 5B, the hypothesis is that marine mammals contribute significantly to the mortality of juvenile and adult migrating salmon. Given the best estimates of local or general marine mammal abundance, salmon recovery monitoring should be able to establish the proportion of adult salmon of a given population management unit that marine mammals are removing.

Current monitoring activity

California sea lions

Most of the following information has been taken from NMFS websites and various publications cited here. California sea lion population sizes, which occur from the offshore islands of Mexico north to Vancouver Island, British Columbia, have increased substantially this century. Following passage of the Marine Mammal Protection Act (MMPA) in 1972, the California sea lion population off the West Coast of the U.S. increased at an average annual rate of over five percent.

Although the population is now very large and may be greater than any time for which records are available, there is no evidence that it has reached its optimal sustainable population level, which is the management goal mandated by the MMPA. In other words, the population will likely increase until natural conditions limit additional growth. These limiting factors are usually associated with food supply, disease, breeding areas, or predation. There are no estimates as to the optimal level and currently no plans exist to limit population levels through intervention.

Currently, the California sea lion population off the West Coast of the U.S. is estimated at between 167,000 and 188,000 individuals. In the last 15 years, counts of

California sea lions at Everett, Washington (in Puget Sound) have increased from 108 in 1979 (Everitt et al. 1980) to 1,113 sea lions in 1995 (NMFS 1996; Brown et al. 1995; Riemer 1996). They are present in Washington waters primarily during the non-breeding season (September to May) and are concentrated in Puget Sound, particularly near Everett, WA. Counts of sea lions hauled-out in the Everett area are used as an index of the number of sea lions in the inland waters (Strait of Juan de Fuca/San Juan Islands, Hood Canal, Puget Sound). Preliminary analysis of mark-recapture data collected in 1995 indicates that counts at Everett may represent only 50-55% of the animals in the inland waters (NMFS-AFSC unpubl. data). Counts of sea lions in the inland waters of Washington averaged 300-500 animals from 1986 to 1994, and then peaked in 1995 at more than 1,100. Approximately 200-500 California sea lions have been observed during surveys in the 1990s on the offshore rocks and islands on the outer coast of Washington. The majority of these animals are found in the more northern portion of the coast. Sea lions are now also reported far upstream in rivers such as the Nisqually and Chehalis rivers.

Harbor seals

The Pacific harbor seal is found along the West Coast of North America from Asuncion Island, off Baja California, northward into Alaska. Harbor seals are the most abundant pinniped in Washington. They are present year-round and pupping occurs in all three West Coast states.

Harbor seal populations have increased dramatically since the MMPA was passed in 1972. Recent preliminary analyses underway by NMFS indicate that at least one harbor seal population, the Washington/ Oregon coastal stock, may be at the Optimum Sustainable Population level. The status for the other harbor seal stocks is uncertain (similar to the California sea lion population status).

In Washington, numbers of harbor seals increased by 7.7 per cent annually since the 1970s and are estimated at over 35,000. There are 319 harbor seal haul-out sites in Washington.

A coordinated state and federal coastwide program to study and monitor the effects of expanding populations of Pacific harbor seals and California sea lions began in August 1998. The program focuses on five areas:

- Pinniped effects on depressed salmon,
- Pinniped conflicts with commercial and recreational fisheries,
- Non-lethal methods to mitigate pinniped conflicts with people and other resources,
- Pinniped population assessments, and
- Other coastal ecosystem pinniped impacts.

The Northwest Region of the National Marine Fisheries Service issued a $720,000 cooperative agreement with the Pacific States Marine Fisheries Commission for studies in the states, and utilized $480,000 for NMFS studies. Subjects include pinniped populations, pinniped predation on salmon in several systems, and fishery interactions with the salmon troll fishery and the southern California charter boat fishery. The areas of pinniped-salmon predation studies include the lower Columbia River, Willamette Falls, Rogue River, Alsea Bay, Ozette River, Hood Canal, Duamish River, Ballard Locks, Klamath River, Scott Creek and San Lorenzo River. Preliminary results from several of the studies were produced in April 1999.

Some seals move seasonally from one area to another in response to locally abundant prey species such as eulachon in the Columbia River (Beach et al. 1985) or sockeye salmon in the Fraser River (Olesiuk 1993). Most information on harbor seal abundance in Washington is based on surveys conducted during the pupping season, which occurs in May/June on the coast and July/August in the inland waters. The major exception is two studies on abundance and movements of harbor seals in the Columbia River and adjacent estuaries (Grays Harbor, Willapa Bay, Tillamook Bay) in 1980-82 and 1991-94 (Beach et al. 1985; Brown et al. 1995). Many of the seals, which pup and breed in the coastal estuaries of Washington and Oregon in summer feed in the Columbia River in spring and fall (when salmon are present) and in winter (when eulachon are abundant).

Riemer and Brown (1996) recently reanalyzed harbor seal food habits samples collected in the Columbia River in 1980-82 (Beach et al. 1985) using salmon bones, gill rakers, and teeth, as well as otoliths, for prey identification. Using these additional hard parts increased the occurrence of salmon in all samples for both California sea lions and harbor seals. There are uncertainties concerning the appropriateness of relating the occurrence of hard parts from prey species to the actual occurrence of the prey species in the diet because it is not known if identifiable hard parts occur in the same proportion in food habits samples as they do in the actual diet. Those studies indicate that 15-20% of harbor seal diet consists of salmon at the mouth of the Columbia River.

Essential tools

No essential tools have been identified.

Monitoring design

➢ *It is recommended that the federal government, through the NMFS, should continue to monitor the status and trends in the sea lion and harbor seal populations within Washington State.*

New studies are needed to estimate the actual numbers of salmon consumed for the Puget Sound, the coast, and the Columbia River. The current federal expenditures to monitor predation by seals and sea lions of 1.1 million dollars annually should be maintained or increased to allow for these monitoring needs.

Identified agencies

National Marine Fisheries Service and the Washington Department of Fish and Wildlife.

Recommended sampling protocols

No protocols have been identified. Protocols would be tailored to the specific study question and related design.

Performance benchmarks

The current population benchmark is considered to be “optimum” population level. The actual number is not known, but must be inferred when population growth curves reaches an asymptote. At that point, mortality would equal recruitment.

Identified monitoring gaps/overlaps

There currently is not sufficient information on the predation rate of harbor seals and sea lions on salmon species. The collection and analysis of scat samples for analysis of CWTs and the extrapolation of this information to the overall predation rate has not been validated.

Quality assurance/Quality control

None have been identified.

Risks

Inability to understand this source of salmon mortality means that attempts to estimate total mortality for many salmon populations will be incomplete. Run reconstructions, harvest models, and understanding how well our recovery efforts are working.

Caspian Terns

Objective 5C: Determine the status and trends of the Caspian tern populations at the mouth of the Columbia River and elsewhere in Washington. Determine whether the predation rates previously measured are still valid.

Monitoring indicators

The NMFS has established information that Caspian terns are significant predators of migrating juvenile salmon, and that the growth of nesting colonies in areas where salmon are in need of recovery is not compatible with recovery. In order for this indicator to be used, measures of total tern population and the incidence of juvenile salmon in the diet must be determined.

Figure 37. Caspian Tern

Current monitoring activity

According to information provided from the NOAA website at the Northwest Fisheries Science Center, bird numbers in the Columbia River estuary have increased from a few hundred nesting pairs of cormorants in 1984, to 6,400 pairs of cormorants, 9,400 pairs of terns and 10,000 pairs of large gulls in 1997. Estimates for 1998 indicate continuing increases in fish-eating birds. The islands where most nesting occurs were created when the U.S. Army Corps of Engineers deposited dredged material from the river's navigation channel. The first two years of a five-year research project on bird predators indicates that the Rice Island Caspian tern colony may have consumed as many as 20 million juvenile fish in 1997. Cormorant and gull colonies are believed to have consumed a similar magnitude of juvenile salmon. Tag recoveries and other evidence suggest that as much as 40 percent of some salmon migrations may be consumed by birds. Overall that the annual losses due to Caspian tern predation range from 7.5 to 15.2 million migrants.

Diet analysis indicated that juvenile salmon were an important part of the diet of fish-eating colonial water birds in the Columbia River estuary. Caspian terns appeared to be most dependent on salmon (ca. 75% of the diet), followed by double-crested cormorants (ca. 24% of the diet), and glaucous-winged/western gull hybrids (ca. 11% of the diet). The large California and ring-billed gull *(Laws californicus and L. delawarensis)* colonies up-river relied less on juvenile salmon as a food source compared to fish-eating waterbirds in the estuary, perhaps due to measures implemented at Columbia River dams to reduce bird predation.

Juvenile salmon were especially prevalent in the diets of fish-eating water birds in the Columbia River estuary during May. Steelhead smolts were most prevalent in Caspian tern diets during early May, followed by coho smolts in late May to early June, and then chinook smolts in late June to late July.

Over 2,000 salmon smolt PIT tags were found on the Rice Island Caspian tern colony by visually searching, and we estimated that over 30,000 PIT tags have been deposited there over the last nine years. The recovered PIT tags indicate that steelhead smolts were consumed in greater proportion to availability than other salmon species, and that juvenile salmon of hatchery origin were consumed in greater proportion to availability than wild smolts.

Federal and state agencies have formed a Caspian Tern Work Group to identify the immediate and long-term options to reduce bird impacts and develop a lower Columbia River tern management and research strategy.

Based on recommendations from seabird researchers, the ACOE has planted vegetation on Rice Island to discourage Caspian terns from nesting on the island (terns prefer barren nesting sites) and is encouraging the terns to nest on East Sand Island, thirty miles downriver where young fish may be less vulnerable to birds. The Corps planted winter wheat on most of the nesting areas on Rice Island. A single acre was left unplanted to allow 500-1000 pairs of terns to continue nesting as a control group for researchers to compare the birds' habits.

The annual cost to monitor bird populations at the mouth of the Columbia River is estimated to be $204,000/yr. Funding has been provided by BPC through the NWPPC.

Essential tools

None have been identified.

Monitoring design

Current monitoring should continue to determine if the actions taken to constrain Caspian tern breeding have been effective, and to validate the reduction in mortality of migrant salmon as a result.

Identified agencies

U.S. Fish and Wildlife Service, Washington Department of Fish and Wildlife, Northwest Power Planning Council, U.S. Army Corps of Engineers, Oregon State University, Oregon Department of Fish and Wildlife.

Recommended sampling protocols

None have been identified.

Performance benchmarks

Caspian terns are found throughout the globe with confirmed occurrences in Britain, Denmark, Switzerland, Africa, China, Australia, Canada, United States, India, and elsewhere. The U.S. Fish and Wildlife Service monitors the population levels of Caspian terns nationally. There do not appear to be any established target population levels for these terns and they do not appear as a priority species.

Identified monitoring gaps/overlaps

Tern status and trends do not appear to be known nationally.

Quality assurance/Quality control

None have been identified.

Risks

None have been identified. (See Marine Mammals.)

Northern Pikeminnow

Objective 5D: Measure the status and trends in northern pikeminnow populations in the reservoirs of the Columbia River.

Objective 5E: Determine whether northern pikeminnow control measures have been effective in reducing predation on salmon juveniles to target levels.

Monitoring indicators

Pikeminnow abundance and size.

Current monitoring activity

There is a Northern Pikeminnow Management Program in the mainstem Columbia and Snake rivers whose goal is to reduce the impact of northern pikeminnow predation on juvenile salmon and steelhead.

There is also a harvest fisheries project, "Sport Reward System", whose objective is to demonstrate the feasibility of sustained harvest of northern pikeminnow, and to maximize the benefit to anadromous fish while allowing a viable population of northern pikeminnow to exist in the Columbia and Snake rivers.

The working hypothesis is that a sustained northern pikeminnow harvest rate of 10-20 percent will lead to a restructuring of the age and size classes of northern pikeminnow, which will result in a reduction in mortality of juvenile salmon due to predation, by 50 percent or more within 10 years.

An evaluation of the effectiveness of fisheries (beginning with test fisheries in the John Day Reservoir) was implemented in Columbia River Basin in 1990 to test whether sport reward fisheries could be effective in:

(1) Reducing northern pikeminnow numbers,

(2) Altering northern pikeminnow population structure, and

(3) Reducing predation on juvenile salmon by northern pikeminnow.

In the Columbia and Snake rivers, it is currently estimated that 200 million emigrating smolts are produced. Of these, it has been estimated that approximately 16 million were consumed by northern pikeminnow prior to implementation of the NPMP. For the sake of argument, assume that total mortality of downstream migrants through the system in 1998 were 111 to 119 million juvenile salmon, including approximately 7.5 to 15.2 million due to Caspian tern predation. Thus, in the absence of the NPMP, northern pikeminnow predation would have accounted for approximately 13.7 -14.7 percent of total system wide mortality. These calculations assume a total smolt production of 200 million fish, total system mortality of 115 million, and that mortality due to northern pikeminnow was 16 million before the NPMP was implemented. Thus, if fisheries resulted in reduction of the total northern pikeminnow predation to approximately 50 percent of its original value, approximately 5 million smolts might be saved annually, substantially less than 50 percent of the original 16 million.

Essential tools

The NPMP is an essential tool for monitoring harvest of northern pikeminnow. Without this type of system, there is little incentive to harvest them because they are not considered edible by most fishers.

Monitoring design

As part of the NPMP, monitoring activities should continue to evaluate the status and trends of northern pikeminnow populations and should continue to evaluate the effectiveness of the program in reducing the mortality of migrant salmon due to predation.

Identified agencies

The Bonneville Power Administration, Oregon Department of Fish and Wildlife, WDFW are participating agencies.

Recommended sampling protocols

Sampling protocols have been identified in numerous publications of the WDFW, BPA, and Oregon Department of Fish and Wildlife.

Performance benchmarks

The performance benchmark has been established to reduce predation levels by 50% over ten years by maintaining a targeted exploitation rate of 10-20% on adult northern pikeminnow.

Identified monitoring gaps/overlaps

None have been identified.

Quality assurance/Quality control

There have been annual estimates made of the exploitation rate to insure that the benchmark is being reached. There have been federal audits of the program to track expenditures and the quality of the reward program.

Risks

There are risks that the original estimates of pikeminnow program benefits to downstream migrant salmon were not accurate. (See also Marine Mammals.)

Invasive Species

Objective 5F: Measure the status of selected invasive species that effect salmon abundance and recovery.

Monitoring indicators

Presence or absence of the invasive species.

Current Monitoring Activity

The Ecological Society of America contends that the introduction of non-native species of various taxa is considered to be the second greatest threat to global biodiversity, just behind habitat destruction. Non-native species can and have caused dramatic changes to many of the earth's ecosystems. The traditional sources of food for native species can suddenly be replaced by new species that alter the food chain at all tropic levels. Invasive species are estimated to be responsible for the listing of approximately 40% of the species on the Endangered species list.

Washington State has responded to the threat of aquatic invasive species by establishing an Aquatic Nuisance Species (ANS) Committee (RCW 77.60.130), hiring an ANS Coordinator, implementing a ballast management program (RCW 77.120.), creating a classification and screening program to regulate the intentional release of nonnative animal species (SSB 6553), and establishing a program to encourage recreational boaters to clean plants and animals from their boats.

Over 60 species of nonnative species are already present in Washington's marine waters. Current monitoring is conducted through periodic surveys. There is no structured assessment of the status and trends in overall abundance of invasive species, and no direct studies are underway on the effects of invasive species on salmon populations or upon other watershed health indicators. The University of Washington and the Washington Department of Natural Resources have coordinated several surveys to look for the presence of marine nonnative species. The United States Coast Guard is funding a survey of nonnative species in the Columbia River and results should be available in 2003.

Fish

Food habit studies have implicated other nonnative predatory fish as probable factors in reducing juvenile salmon abundance in the Columbia-Snake rivers and other lakes and reservoirs where they reside. These species are nearly all fishes transplanted to the Pacific Northwest from the Mississippi drainage and include largemouth and smallmouth black bass, channel catfish, brown bullhead, and walleye. These species are normally found in low gradient rivers of the east and central U.S. and in lakes, ponds, and reservoirs. Their presence in the west over the past 100 years is tied to habitats that can support their life histories. They have become a problem to juvenile salmon and trout mostly as a result of the creation of hydroelectric impoundments where the quiet waters allow reproduction and growth and where migrant salmon and trout are susceptible to predation as they pass through the reservoir and after passing over dams or through turbines.

In June of 2002, NOAA published a technical memorandum (NMFS 2002) entitled Review of Potential Impacts of Atlantic Salmon Culture on Puget Sound Chinook Salmon and Hood Canal Summer-Run Chum Salmon Evolutionarily Significant Units. This paper found that the level of risk from Atlantic salmon was not significant, however the issue is hotly debated, and many questions remain. Atlantic salmon are non-native and prohibited in Alaska, while their production is encouraged in British Columbia. WDFW is in the process of increasing the regulatory control of Atlantic salmon farms in Washington waters. Juvenile Atlantic salmon have been found in over 70 rivers in British Columbia, suggesting natural reproduction. A snorkel survey will be conducted in the summer of 2003 by WDFW to look for the presence of juvenile Atlantic salmon in selected rivers in Washington.

Invertebrates

Zebra mussels have been invading east coast and Mississippi drainages where they have caused extensive damage to native fauna. The small mussels tend to create massive colonies where their filtration systems remove most of the plankton from the water, and out compete native mollusks for space and food. In addition, fish species have been affected due to lack of sufficient planktonic foods for juvenile life stages. Sampling occurs in 30 Washington lakes twice per year by taking a timed plankton tow and then examining the sample for zebra mussel veligers. The lakes are not randomly selected, but are considered high recreational use lakes that have the highest probability of being infested with zebra mussels. This sampling has been ongoing for two years.

Green crabs and mitten crabs have recently been introduced into West Coast waters and are moving northward. Green crabs have been detected in Willapa Bay and Grays Harbor. It is not known how they might interact with juvenile salmon in the marine environment.

Occurrence of mitten crabs is currently monitored in the Columbia River by Portland State University through periodic installation of trapping stations.

Exotic plants

A number of exotic aquatic plants have been introduced to Washington and they are also considered factors in reducing the survival of native salmon and trout. These include *Spartina* (cord grass), which has taken over large areas of Willapa Bay, and reduces the area where juvenile salmon can feed and rear. An extensive eradication program has been funded by the USFWS that is underway in Willapa Bay.

Purple loosestrife has created a similar crowding problem in freshwater areas of the state where waterways have become congested with vegetation and no longer provide feeding and rearing areas for juvenile salmon and trout.

The WDFW, the USFWS, Washington Department of Agriculture, Washington Department of Natural Resources, and the NMFS have been monitoring the status of these exotics, and are implementing a coordinated eradication program.

Essential tools

None identified.

Monitoring design

The impact of nonnative aquatic species on native salmon populations is not well understood, and should receive additional research funds. The gains made by implementing salmon recovery programs could be reduced or eliminated by the impact of an invasive species. For example, non-native aquatic invasive plants in the Columbia River may serve as cover for non-native and native predatory fishes causing higher predation on juvenile salmon. Non-native plants may cause a loss of habitat and increased mortality by displacement. The ANS Committee should work with others to identify priority monitoring projects, and assist in the implementation of projects to mitigate invasive species impacts on salmon populations.

➢ *It is recommended that monitoring for zebra mussels continue through an expanded sampling program that would sample the 700 lakes statewide that have public access boat launches.*

A probabilistic sampling design may be appropriate where some lakes with likelihood of high infestation are sampled every year and other lakes are sampled periodically on a more random basis. The sample sizes should be selected so that we can be 90% confident that the presence of zebra mussels in Washington lakes can be detected within 3 years.

Surveys of presence/absence of Atlantic salmon should be planned and funded on an ongoing basis in order to determine their status and distribution in Washington.

Identified agencies
The WDFW, and USFWS are participating agencies.

Recommended sampling protocols
None identified.

Performance benchmarks
None identified.

Identified monitoring gaps/overlaps
There currently is no structured monitoring program in existence in Washington to track the status of invasive species other than zebra mussels. The WDFW attempts to monitor selected locations as time permits with a limited staff.

Quality assurance/Quality control
None identified.

Risks
The risks are huge in terms of both biological impacts to native flora and fauna, and also in terms of economic impacts to the state involved in attempting to control their population growth and impact to drinking water, industrial uses, and watershed health and associated salmon recovery.

Preventing the unintentional introduction of nonnative species, and evaluating intentional introductions, prior to importation or release, is the most cost effective and environmentally responsible way to reduce the risk and impact of invasive species on our native salmon populations. Our state is fortunate not to have the zebra mussel and other highly invasive species that could significantly impact salmon recovery. Prevention programs, though widely recognized as effective, are hard to fund. It is often easier to fund control programs after a new introduction than it is to fund prevention programs and avoid the impact. A coordinated effort should be initiated to increase funding for invasive species programs that can reduce the risk of unexpected impacts to salmon recovery.

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Part VIII

Question 17: What are overall impacts of human activities on freshwater habitat and landscape processes as they relate to watershed health and salmon recovery?

Question 21: Are habitat improvement projects effective?

Objective 21B: Determine whether habitat improvement projects are effective in increasing the number of salmon produced.

This part of the CMS pertains to monitoring that is intended to address how management and habitat restoration project activities, and their cumulative effects, specifically affect fish production. As is discussed in greater detail below, validation monitoring (or as termed here, intensive monitoring) is the only way this can be achieved (ISP 2002). Status and trends, effectiveness, and implementation monitoring are not able to determine causal relationships between management activities and fish production. Compared to other types of monitoring, intensive or validation monitoring requires the greatest extent of scientific rigor and integration in monitoring design development and analysis of results.

The goals, questions and objectives listed in Part II encompass a broad array of monitoring needs across a large range of spatial and temporal scales. The objectives fall into three categories:

(1) Status and trends of fish populations, habitat, and water quality/quantity indicators – The basic objective is to estimate indicators of fish populations, generally at the ESU scale, and to track indicators of habitat, water quality, water quantity, and other factors that impact wild fish and watershed health. Estimates of fish abundance, productivity, distribution, and diversity are the ultimate measures of the effectiveness of salmon recovery efforts as they account for the net effect of natural events and management actions.

(2) Effectiveness of small-scale projects – Much restoration/enhancement work consists of individual small-scale projects with site-specific objectives for habitat, water and fish. To efficiently allocate resources it is critical to know whether such projects have attained their immediate objectives within reasonable time frames.

(3) Effectiveness of programs that conduct, promote, or regulate, activities meant to protect or restore habitat, water quality or fish – There are numerous efforts at local, state, and federal levels meant to aid salmon recovery. Monitoring of these is needed to determine:

   a. Are the programs being funded and implemented as prescribed?
   b. Are they producing the intended on-the-ground effects? and
   c. Are these efforts adequate to recover salmon?

An integrated approach to answering these questions is needed for the efficient allocation of resources. The different types of monitoring associated with these three questions are described in Part III. This Part of the CMS focuses on question (c) above – addressing the relationships of actions in terms of how they affect salmon and lead to their recovery (cause-effect monitoring). Some answers should be relatively straightforward to obtain and are associated with activities performed by individual agencies.

Determining effectiveness of habitat protection and restoration projects may be assessed by measuring characteristics that will be enhanced before and after implementation at appropriate temporal scales. Deciding appropriate temporal scales should be based on the type and rate of change expected. For example, riparian planting efforts could include monitoring of: seedling survival (any time after planting); increase in stream shading (at least five or more years after planting); and increase in large woody debris (LWD) recruitment (decades after planting).

Similarly, many status and trends questions are conceptually straightforward. Steps include identifying the population and geographic area of interest (within logistical constraints), designing and implementing a plan to obtain unbiased population estimates. Determining the effectiveness of entire, multi-faceted programs on salmon and salmon recovery is much more complex and challenging.

Regardless, inferences must be made from improvements in habitat, water quality, water quantity and their influences on salmon abundance, productivity, distribution, and diversity. This requires more than the evaluation of small-scale projects and programs and the repeated monitoring of population status for trends. It requires sound management experiments in the context of an intensive, needs-driven validation monitoring program to investigate the cause-effect relationships between the factors that state and federal policies can manipulate and salmon populations, to understand the effects of management actions on highly variable salmon populations at multiple scales.

Clearly, one of the most important needs identified by Congress and the Washington State Legislature is to determine the extent to which the major expenditures authorized for habitat restoration projects and other recovery activities improve watershed health and increase salmon production. To meet this need, the common theme of intensive monitoring is to develop an understanding of the linkages between management actions and the salmon resource.

The framework in Part III that outlines monitoring types can accommodate the broad spatial and temporal scales of monitoring needs and facilitate the integration of results across monitoring scales. Integration occurs within each type of monitoring:

(1) Extensive (status and trends) monitoring – Integration of the results of the status and trend monitoring across the different resource groups (fish, habitat, and water quality/quantity) requires close coordination in the sampling designs (spatial scale, how and when the data are collected, etc.) and interpretation of the results. This is essential to effectiveness monitoring.

(2) Project effectiveness monitoring – Effectiveness monitoring answers the question – were the objectives of a specific action met? Each study design depends upon the specific action taken and the anticipated benefits. For example, a single riparian planting on a river will have no immediate measurable effect on fish populations, but the shade and LWD potential could be significant. However, removal of a single fish passage barrier could have a substantial impact on local fish populations. The integration of the results of individual projects could support evaluation of specific programs or whole classes of restoration projects if the indicators monitored were tailored to the program or class of projects being addressed.

(3) Intensive (validation) monitoring – This is the only type of monitoring that can reliably validate and discern how changes in habitat, water quality and quantity, and management actions affect salmon production. It is the focus of this part of the CMS. Also termed validation monitoring (noted above) is complementary to monitoring of status and trends, and effectiveness monitoring. The more complex the monitoring question, the more complex the monitoring design and implementation will be. Intensive monitoring is technically very challenging. It has a large potential for benefiting from partnerships, cost efficiencies, and economies of scale.

Intensive cause-effect monitoring as outlined here is similar to “Tier 3” of the monitoring framework identified by the Federal Caucus (NMFS 2000), and in other draft Columbia River planning guidance.

Monitoring indicators

Monitoring indicators and metrics will depend upon the specific questions addressed and associated experimental design needs.

Current monitoring activity

With few exceptions, examples of current intensive cause-effect monitoring do not exist. In the last biennium, Ecology and WDFW jointly monitored water quality and fish populations in five "index" watersheds. In that effort, Ecology monitored water quality, quantity, temperature, and benthic invertebrate variables in five streams (Summers 2001), and WDFW monitored smolt production. The ultimate goal was to perform integrated analyses that would clarify relationships between water quality factors and smolt production.

Monitoring design

➢ *The CMS recommends establishment of "Intensively Monitored Watersheds" (IMWs) where monitoring is designed to address key questions in a disciplined scientific manner.*

The intensive monitoring strategies of the Forests and Fish Monitoring Design Team (MDT 2002) provide a strong first step that the overall strategy can build upon. The MDT is a key technical group focused on monitoring design issues for implementation under the Forests and Fish Agreement.

The spatial scale at which intensive monitoring is conducted depends upon the specific question asked and the experimental design approach. For example, responses in a single channel segment to the application of a localized management action can be adequately addressed at a very small scale. However, most of the more pertinent questions regarding the effects of management actions require evaluations at much larger spatial scales. This is especially true when attempting to evaluate a biological response of migratory species such as salmon. An area large enough to encompass the full range of habitats required for the salmon to complete freshwater rearing is the smallest experimental unit at which a comprehensive evaluation the effects of management actions on these fish can be conducted. Selecting this relatively large area provides the opportunity to evaluate biological effects of management actions at hierarchical spatial scales ranging from the reach, sub-watershed, and watershed scales as identified by experimental designs addressing key questions.

The IMWs can help focus evaluations of cause-effect for habitat restoration projects where reliable answers can be obtained. Because salmon species have a life history that encompasses up to five years for the completion of one generation, and live in highly variable environments, it may take a long time (two or three generations) to detect a statistically credible trend. Also, because there is significant variation from year to year in salmon numbers, it is often difficult to detect a change in overall abundance above the normal annual fluctuations (signal to noise).

Sampling locations

Due to differing mandates and objectives, coordinated measurements of fish, habitat, and water have not occurred in a single watershed. Intensive monitoring requires a high level of coordination. For example, to have any hope of detecting changes in the number of salmon produced by various kinds of habitat projects or programs, the total juvenile migrant production and productivity of the watershed must be measured along with the total population of adults spawning. Watershed size and expected effects from projects are important design considerations. For example, where habitat restoration projects are involved, the size of the area monitored must be large enough so that the projected effect of the action will be detectable.

In working with Salmon Recovery Region organizations, state agencies, the Forests and Fish Monitoring Design Team and other partners, IMWs will be identified where carefully planned experiments with appropriate controls and treatments can be designed and implemented. To date regional recovery organizations have identified several candidate IMWs: the Kalama, Coweeman and Cispus rivers and Arkansas Creek in the Lower Columbia Region; and the Wenatchee River in the Upper Columbia Region.

In these candidate IMWs, it is feasible to intensively monitor freshwater habitat, water quality, instream flows, resident juvenile salmon, migrant juvenile salmon, and adult escapement of multiple species. The candidates in the Lower Columbia were identified using the following considerations:

(1) They would have adequate size so that restoration efforts would affect a significant portion of total stream length.

(2) Control reaches and/or sub-watersheds that have similar habitat and productive potential to the treated locations are available so that the response to restoration actions can be measured.

(3) Adult spawner returns and smolt are now monitored (or could feasibly be monitored).

(4) Baseline data on existing habitat conditions, restoration actions, and fish productivity would be beneficial.

(5) Salmon within control and treatment "watersheds" experience similar outside influences such as hatchery inputs and fish harvest rates to minimize variation.

(6) Habitat restoration and/or protection funding through the Lower Columbia Fish Recovery Board or other agencies has been expended that could provide measurable biological response in both the short and long term.

(7) The watershed provides habitat for priority salmon and steelhead stocks.

(8) Opportunities exist to gain data on the effectiveness of specific types of habitat restoration projects. Priorities for data collection include restoration of access including culvert barrier removal and floodplain restoration, and instream or riparian restoration projects.

(9) There is the potential and public support for maintaining a control watershed where restoration does not occur.

(10) Preferred watersheds represent a variety of land uses.

(11) There are existing and/or proposed data collection and monitoring efforts, such as Forests and Fish, storm water, and other local and regional monitoring efforts.

Guidance on experimental design

Much of what follows below is similar to the content in Part III. However, in contrast to systematic surveys over space and time that provide information on status and trends, experimental designs address cause-effect questions.

The ability to draw inferences from intensively monitored controlled experiments depends on framing hypotheses as clearly as possible, defining controls and/or references clearly, and collecting the data in a manner having the least possible uncertainty.

An example principal hypothesis is: recovery action X will make fish response of life stage Y higher in area Z. In this case, "fish response" reflects fish characteristics, such as abundance, productivity, and diversity. A specific application is: use of agricultural diversion screens has increased the numbers of salmon yearlings in river Z. How much action is needed to test these hypotheses and to have confidence in the answer obtained? Alternatively, how much uncertainty can we tolerate?

To illustrate, how critical is it to detect a 5% change in a population within a 4-year period, 19 times out of 20? If that power of resolution is critically needed, then a corresponding level of effort can be calculated and applied, and its associated cost can be determined. These issues pertain to statistical power analysis, which involves knowing four critical things:

(1) Sample size (if measurements can only be taken for four years, how many sites/projects need to be monitored?)

(2) Confidence (can we afford to be wrong one time in 20? Can we tolerate being wrong half the time? Most of the time?)

(3) Variability in the data (what is the reliability of the measurements we are making?)

(4) Effect size (what difference do we need to see? ±5%? ±50? ±150%?)

All four of these parameters are interdependent: specifying any three of them affects the fourth. In reality, some parameters will be set by available resources, variability of the population, and other factors which will be out of the control of the parties conducting the monitoring.

If features of the analytical process are viewed as statistical planning tools, then both policy and science need to influence this process at different points to affect the implemented monitoring plan. For example, if it is going to take 125 years to see a small effect size (e.g., 5%) that may have been specified, the cost is likely to be prohibitive. On the other hand, if being "wrong" in population abundance monitoring is equivalent to extinction of the salmon we are trying to monitor, are we willing to be "wrong" half the time (i.e., confidence of 0.5)?

Articulation of a testable hypothesis will involve identifying biological effects of the management action and appropriate controls. The hypothesis should also identify the geographic area of influence of the action. Details of specific experimental design choices are presented in MacDonald et al. (1991) and Conquest and Ralph (1998).

General experimental design planning guidance questions

A significant challenge in providing guidance for planning of controlled experiments is balancing the different levels of technical expertise of those conducting the monitoring with the diversity of demands of monitoring to be performed across the range of management actions implemented and the environments that salmon occupy. Crafting a "cookbook" of specific monitoring plans that contains recipes for every management action in each habitat type across the state is prohibitively difficult. Outlined here is an approach that if followed, will result in custom-made adequate monitoring plans. Importantly, this will generate data that is useful both within the context of individual recovery actions, and also in the context of broader (i.e., regional, cross-regional) comparisons within classes of recovery actions.

Those developing appropriate cause-effect monitoring plans should address the technical questions below. These are questions of a generic nature that all proposals for monitoring need to address. Other more specific scientific questions emerge from other chapters of this document, wherein evaluation of the causal relationships between management/recovery actions and fish responses is intended. If these questions were collectively answered adequately, you would have a high degree of confidence that the proposed monitoring plan would produce useful results. It is particularly important to evaluate the sources of uncertainty in proposed plans to maximize the probability that data from various plans can be usefully compared, and classes of recovery management actions identified.

Generic scientific questions that address issues common to all actions

(1) What is the scientific question that is framed by the recovery management action?

(2) What is the hypothesis to be tested? (If the hypothesis is explicit it is easier to evaluate the choice of controls and indicators.)

(3) What are the controls?

(4) What is being measured?

(5) Are measures primary or correlated indicators, and how does the measurement being made relate to the specific question?

(6) What are the connection between what is being measured and the biological result that is desired? This is another way of defining the assumptions implicit in the choice of monitoring strategies-for example, are you measuring actual fish numbers, or a surrogate figure such as carcasses or redds?

(7) Explicitly, what are the assumptions of the monitoring plan?

(8) What is the spatial area of effect of the recovery management action? Is the extent of the area incorporated into the monitoring plan? How? If not, why?

Variability:

(1) What is the measurement error of the technique used to make the measurement?

(2) What is the net accuracy of the measurement technique, sampling design, and experimental design?

(3) What is the net precision/variability of the measurement technique, sampling design, and experimental design?

(4) To what degree is the data collected spatially explicit?

(5) What level of statistical power is desired? In other words, what level of biological response (fish numbers, growth rate, diversity, etc.) is desired, and, given the obtainable accuracy and precision of our measurements, how long must one monitor to obtain this level of result?

Effect size:

(1) How have estimates of historic fish densities or possible carrying capacity been addressed?

(2) Does the program monitor year-round, seasonally, or just for a few weeks in a particular season(s)?

(3) If it is presumed that the action is expected to result in $\mu>0.0$, what value of μ is required? Is this answer based on biology, or based on politics? Was this value arbitrarily determined?

(4) Do you know beforehand how precise you need to be about estimating μ?

(5) What technique was used to calculate μ? Why was that technique chosen?

Sample size:

(1) How does the duration of the monitoring correlate with the generation period of the salmonids affected by the recovery management action?

(2) What technique was used to determine sample size?

Confidence:

(1) What level of confidence is being used?

(2) How was this value derived?

(3) What are the implications or consequences of being wrong?

Fish ecology questions:

(1) What is the fish response to the management recovery action?

(2) What species and life stages use the affected area?

(3) What is the change in salmonid egg-fry survival with the action?

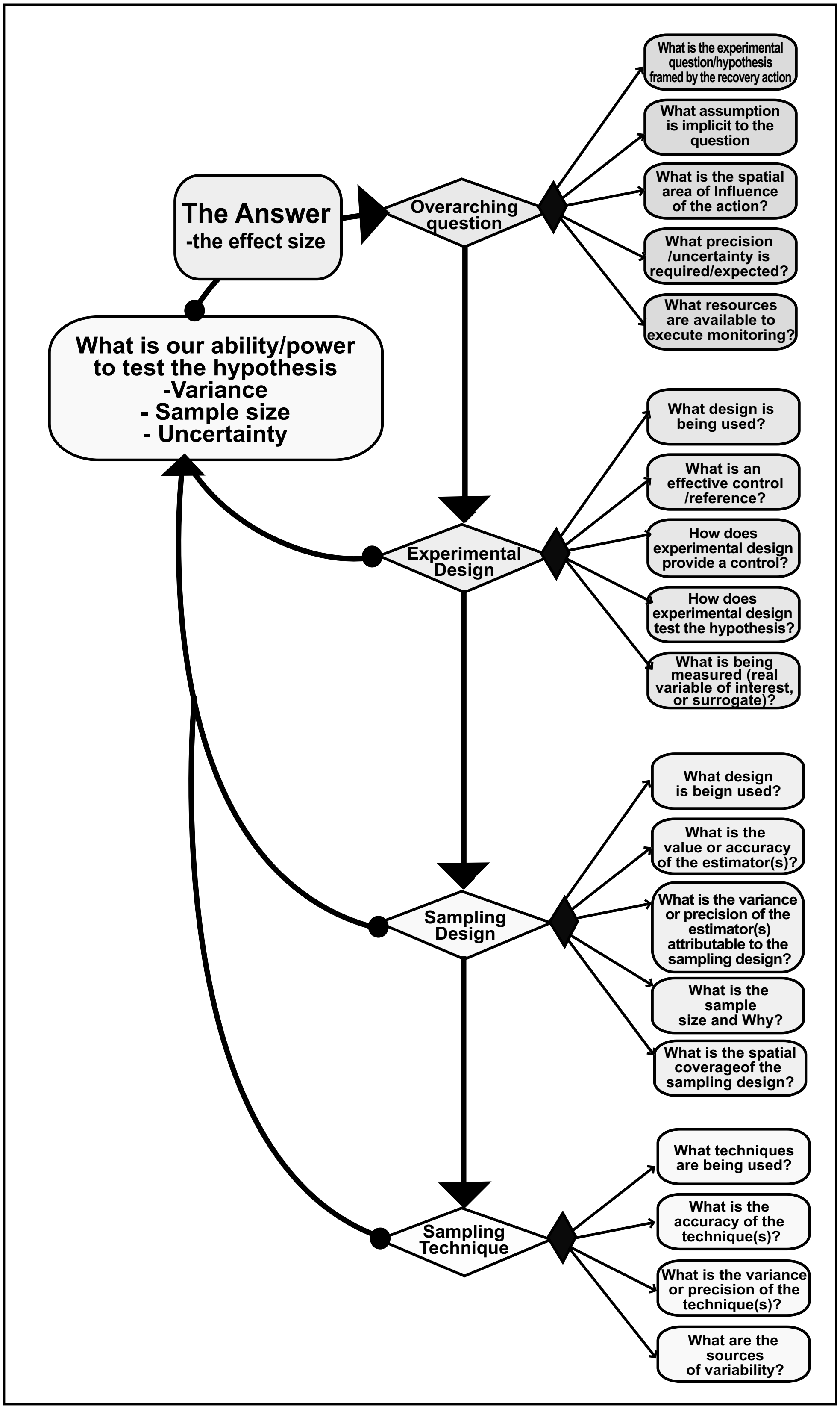
(4) What is the change in salmonid fry-smolt survival with the action?

(5) Are there changes in juvenile salmonid density with the action?

(6) Which life-history change shows the largest response to the action?

(7) Are there changes in non-salmonid densities with the action?

Figure 38.


The Answer
-the effect size
What is our ability/power
to test the hypothesis
-Variance
- Sample size
- Uncertainty
Overarching
question
What is the experimental
question/hypothesis
framed by the recovery action
What assumption
is implicit to the
question
What is the spatial
area of Influence
of the action?
What precision
/uncertainty is
required/expected?
What resources
are available to
execute monitoring?
Experimental
Design
What design is
being used?
What is an
effective control
/reference?
How does
experimental design
provide a control?
How does
experimental design
test the hypothesis?
What is being
measured (real
variable of interest,
or surrogate)?
Sampling
Design
What design
is beign used?
What is the
value or accuracy
of the estimator(s)?
What is the variance
or precision of the
estimator(s)
attributable to the
sampling design?
What is the
sample
size and Why?
What is the spatial
coverageof the
sampling design?
Sampling
Technique
What techniques
are being used?
What is the
accuracy of the
technique(s)?
What is the variance
or precision of the
technique(s)?
What are the
sources
of variability?

Identified agencies

Participating agencies include the WDFW, Ecology, representatives of the Forests and Fish Monitoring Design Team, Salmon Recovery Regional organizations, and efforts of the Northwest Power Planning Council.

Recommended sampling protocols

Recommended sampling protocols are dependent upon the indicators chosen for the experimental design.

Performance benchmarks

Performance benchmarks will be identified based on the experimental design, project needs and required time frames. The design would include controls to compare with treatments in order to account for alternative explanations in data interpretation.

Quality assurance/Quality control

Quality Assurance (QA) Plans will be developed for studies in IMWs. QA Plans will be experimental design and implementation plans that describe the monitoring objectives, procedures, and tasks. The preparation of a QA Plan helps focus and guide the planning process and promotes communication among participants. The completed plan will serve as a guide to monitoring entities and will form the basis for written reports. Lombard and Kirchmer (2001) present detailed guidance on the preparation of QA Plans.

Consistent with the QA Plan, involved parties will develop appropriate frameworks for coordinated and integrated analyses and reporting of results. Data from each IMW will be compiled and key characteristics will be summarized. Results will be statistically analyzed as means and variances and will be graphically expressed at appropriate scales. Annual progress reports will be prepared.

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Glossary of Terms

Part IX

Abundance
Number of fish (juveniles, out-migrants, adults).

Adaptive management
A specific management approach for the planning, implementation, and scientific evaluation of actions whereby the knowledge gained from monitoring those actions is used in future management decisions.

Ambient monitoring
The measurement of environmental variables (limiting factors) over specific periods of time to detect changes in habitat, water quality, or fish production.

Anadromous fish
Species that are hatched in freshwater, migrate to and mature in saltwater, and return to freshwater to spawn.

Assessment
Technical tools to describe conditions, and analyze problems and causal relationships (e.g., watershed assessment).

Baseline monitoring
Monitoring which describes conditions or status at a specific point in time. A baseline may be defined as a historical or other reference condition at a particular time.

Beneficial use
Use of water for domestic, stock watering, industrial, commercial, agriculture, irrigation, hydroelectric power production, mining, fish and wildlife maintenance and enhancement, recreational and thermal power production, and preservation of environmental and aesthetic values, and all other uses compatible with the enjoyment of the public waters of the state.

Bycatch
The harvest and retention of species other than those targeted in specific fisheries.

Catch
T

Compliance monitoring
Monitoring to determine whether a specific environmental standard, regulation, or law is met.

Data portal
A web-based interface that provides common access to a variety of distributed data, information, and tools.

Ecological interactions
Interactions within and between species in ecological factors (e.g., predation, competition) that cause changes in salmon abundance and watershed health.

Effectiveness monitoring
Monitoring to determine whether the management practices employed by a project or management action met its stated objectives.

ESA
Endangered Species Act.

Escapement
Those fish that have survived all fisheries and make up a spawning population.

Evolutionarily Significant Unit (ESU)
A population or group of populations of salmon that:

- is substantially reproductively isolated from other populations, and

- contributes substantially to the evolutionary legacy of the biological species (This concept is used by NMFS in its administration of the ESA for anadromous salmon populations).

Exotic species
A non-native species.

Glossary of Terms

Exploitation rates
The proportion of a returning run or total population of salmon harvested by fisheries.

Genetic diversity
All of the genetic variation within a particular group. The genetic diversity of a species includes both genetic differences between individuals in a breeding population (within-stock diversity) and genetic differences among different breeding populations (among-stock diversity).

Goal
A broad statement describing a desired future condition or achievement without identified specifics. The establishment of a goal implies sustained effort and energy directed to it over a longer period of time.

A target toward which effort is expended. Broad-based activities developed to support and realize organization management missions and visions[12].

Habitat
The physical, chemical, and biological features of an area that supplies food, water, shelter and space necessary for a particular species' existence.

Habitat-forming processes
Physical agents of landscape formation and maintenance (i.e., natural rates of delivery of water, sediment, heat, organic materials, nutrients, and other dissolved materials).

Harvest
To subdue a fish (salmon) by means of hook and line, net, trap, or other gear such that the fish is in the control of the person catching the fish. Depending upon the regulations, a person may be required to release all fish or selectively release only those fish of a specific species or that have an identifiable external mark. See also Harvest.

Hydrograph
A graph showing the variations in depth or discharge of water in a stream over a specified time: flow over time. Generally expressed as cubic feet per second over a specified time period.

Hypothesis
A tentative assertion based on reasonable synthesis of information about conditions in the environment, assumed, but not positively known. The basis for science and the scientific method, a hypothesis poses the question that is to be tested and measured through repetitive trials, which eventually leads to verification or rejection of the hypothesis.

Implementation monitoring
Monitoring to determine whether an activity was performed and/or completed as planned.

Incidental harvest
See Bycatch.

Indicator
Indicators measure progress toward water quality goals, milestones, and objectives. Indicators provide information on environmental and ecosystem quality or give reliable evidence of trends in quality.

Instream flow
A stream flow level adopted as a regulation and used for regulating water rights.

Limiting factors[13]
Conditions that limit the ability of habitat to fully sustain populations of salmon.

Outputs
Quantified information that permits evaluation and comparison relative to goals, objectives, standards, and past results.

Objective
A specific statement of a desired short-term condition or achievement. Includes measur-

12 Washington State Quality Award Program
13 RCW 77.85.010 Salmon Recovery

able end results to be accomplished within specific time limits. The "How and When" for achieving a goal.[14]

Outcomes
Refers to the results of human activities intended to lead to environmental improvement. When linked to performance measures (i.e., "outcome-based performance measures"), refers to an evaluation of performance based on real results or consequences.

Native species
A species of fish indigenous to Washington State.

Nearshore marine area
Includes intertidal estuarine and marine areas, and tidally influenced areas of rivers and streams.

Nuisance species
Non-native species that out-compete, prey upon or bring diseases or parasites to economically and ecologically valuable indigenous species, often adversely changing the ecosystem in the process.

Productivity
A measure of the capacity of a biological system. The efficiency with which a biological system converts energy into growth and production. Can be expressed as the number of smolts produced.

Properly functioning condition
State of the physical, chemical, and biological aspects of watershed ecosystems that sustain healthy salmon populations. Properly functioning condition generally defines a range of values for several measurable criteria rather than specific, absolute values.

Performance measures
Quantifiable indicators that document change in a specific condition or attribute in order to measure or evaluate progress toward goals and objectives. Can be defined as change, targets, or benchmarks.

Population
See Stock.

Protocols
Methodological specifications for the design and implementation of scientific sampling and surveys, and handling of resulting data. May also pertain to analysis.

Quality Assurance (QA)
Quality assurance is the planned and systematic demonstration that fulfills requirements for quality and reliability. In the case of monitoring, that the data collected meet standards of reliability and credibility for their intended purpose.

Quality Control (QC)
The routine application of statistical procedures to evaluate and control the accuracy of measured data.

Reach
A defined section of a river or stream channel.

Recovery
The process by which the decline of an endangered or threatened species is stopped or reversed, and threats neutralized so that its survival in the wild can be ensured. The goal of the ESA is the recovery of listed species to levels where protection under the ESA is no longer necessary.

Reference areas
Areas that have been least affected by human activities such as roads, urbanization, agricultural activity, and forest management.

Region
Salmon recovery region as defined in Washington's "Statewide Strategy to Recover Salmon: Extinction is Not an Option" (1999).

14 Washington State Quality Award Program

Salmon
All salmon, steelhead, trout, and char native to Washington State.

Scientific certainty
The statistical properties of data on a parameter in terms of the sample size variance and confidence that the results of the hypothesis being tested or the trend being examined are an accurate representation of the facts.

Smolt
A juvenile salmonid that is undergoing the physiological change to migrate from fresh to salt water.

Spatial distribution
Geographic distribution of fish.

Statistical power[15]
The ability of an analysis to detect a signal or pattern in a highly variable system. The probability that an analysis can detect a statistically significant trend in a given parameter.

Stock
Fish spawning in a particular lake or stream(s) at a particular season, which to a substantial degree do not interbreed with any group spawning in a different place at the same time, or in the same place at a different time.

Strategy
An approach to reaching an objective.

Survey or status monitoring
An inventory of conditions in a defined geographic area summarized for a particular time.

Task
Specific, definable activities to perform an assigned piece of work, often finished in a certain time, can be studied, quantified, and analyzed.

Trend monitoring
Used to track the variability and change of a particular parameter over a period of time as needed to meet objectives, on either a short or long time frame.

Validation monitoring (model verification)
Monitoring to measure and explore cause and effect relationships and the dynamics of cumulative effects. Attempts to verify the validity of assumptions and predictions formulated through effectiveness monitoring and modeling.

Water Resource Inventory Area (WRIA)
Sixty two areas designated by the State of Washington to delineate watershed boundaries within the state for management purposes.

Watershed
The area of land that water flows across or under on its way to a river, lake, or ocean. Includes all surface water and adjacent estuaries and marine areas. A legal framework for watershed boundaries is provided through Washington's designation of Water Resource Inventory Areas (see Water Resource Inventory Area).

Watershed health
The environmental conditions needed for the protection and propagation of native aquatic life and the support of recreational uses of surface waters. Includes water quality, river/stream flows, fish tissue contaminant levels, and relevant landscape features.

15 Gibbs, J.P. 1998. "Monitoring Populations of Plants and Animals". Bioscience.

Appendix 1. Summary of Comments from the Independent Science Panel

Summary of Key Independent Science Panel Comments and Responses

This is a project staff summary highlighting key recommendations formally made by the Independent Science Panel (ISP) on various drafts of Comprehensive Monitoring Strategy and Action Plan documents. It also summarizes changes made to the Strategy and Action Plan documents in response to those ISP recommendations. Specific editorial comments made by

1. October 10, 2001 ISP recommendations on the Comprehensive Monitoring Strategy Goals and Objectives

	ISP Recommendation	Response
1	Questions still need to be identified	Monitoring questions are identified in the Strategy.
2	Address monitoring types in organization of goals and objectives	Monitoring types are identified in the goals and objectives of the Strategy.
3	Address factors outside Washington expressly	Some outside factors are now included. Ocean conditions and climate are identified separately in the Strategy, whereas multistate/ international fish harvest aspects are embedded more generally in the harvest section.
4	Include ecological interactions	Priority predation and competition issues are included in the Strategy.
5	Include instream habitat	Instream habitat is included in the Strategy.
6	Include effects of hydropower	A section on hydropower is included in the Strategy.
7	Discriminate goals for monitoring in general vs. monitoring goals that will be addressed by the project	The Strategy identifies comprehensive monitoring, and the Action Plan identifies those parts (or parts of parts) that will be recommended for the first monitoring action plan.
8	Define ambiguous terms	The Strategy defines terms in a glossary.
9	Modify each goal to include "in terms of scientific certainty"	Strategy goals include "in terms of scientific certainty"
10	Where now combined, separate objectives for measurement, analyses, and interpretation. Provide policy direction to maintain rigor and accountability at each step.	As noted for #2 above, objectives focus on status and trends, effectiveness or validation monitoring. Measurement, analyses, interpretation, and reporting functions will be managed via implementation of the governance process.

2. December 5, 2001 ISP recommendations on the Comprehensive Monitoring Strategy Working Outline (v2.4)

	ISP Recommendation	Response
1	Reorganize goals and objectives hierarchically	Some changes to goals and objectives were made to make them more hierarchical.
2	Choose levels of certainty consistent with expected biological impact or change, and properties (e.g., natural variation) of the data	MOC chose target levels of statistical certainty based on available analysis and documentation. Technical analyses of certainty (e.g., confidence, power, precision) for some indicators were completed by technical teams, but not for other indicators due to lack (or inaccessibility) of applicable data and analytical capacity. Data on expected biological impacts were not identified. Refinements to certainty targets will be reviewed and revised as appropriate as more information is available.
3	Refine tiering framework and expand Tier 3 and show its linkages to Tier 2	The framework is described in more detail in the Strategy. The concepts of status and trends, effectiveness, and validation (intensive) monitoring were used instead of the similar federal tiering concepts. Linkages between intensive monitoring (explains relationships; similar to Tier 3) and status and trend monitoring (describes trend but doesn't explain what causes it; combines Tiers 1 and 2) were clarified.
4	Choose indicators by identifying the most important short and long-term questions, and relationships to model used to answer the question(s)	Monitoring questions and overarching policy decisions were identified and prioritized. Modeling approaches were not developed by technical teams. Technical teams generally identified indicators that were the most directly relevant, supported the broadest range of questions, were cost-effective to monitor, and produced information in the shortest timeframe.
5	Monitoring and sampling protocols are not yet included	Protocols for some aspects are included in the Strategy. On an interim basis, the Strategy designates EMAP sampling protocols for water and physical habitat. Further work is needed on fish protocols and on finalizing habitat protocols.
6	Quality control/quality assurance are not yet included	Specific quality control/quality assurance project plans will be created by parties to various actions. These will clarify commitments, expectations, timelines, analyses, and reporting expectations, which in some cases involve cooperation of multiple parties.The proposed governance structure and information sharing activities will also address quality issues.
7	Make all data available	The Strategy and Action Plan includes a web portal for data access and sharing.
8	Develop and include a monitoring prioritization scheme to ensure the most important monitoring issues and activities will be performed	The Action Plan identifies criteria to prioritize actions. The governance structure will address prioritization on an ongoing basis.
9	Decision-making - adaptive management are not yet included	A section of the Strategy addresses adaptive management and governance.

3. April 9, 2002 ISP recommendations on the Comprehensive Monitoring Strategy (dated 3/29/02)

	ISP Recommendation	Response
1	Reorganize to be more consistent with the *Statewide Strategy to Recover Salmon (SSRS)*	Organization of products better reflects that of the SSRS.
2	Evaluate health of salmon at the population level and salmon habitat and watershed health at the regional level	The Strategy outlines an approach to monitor most salmon populations/stocks over time (SaSI) within regions, and this will also enable regional characterization. The Strategy includes an approach to monitor status and trends of habitat indicators at the watershed and/or regional level, and water at the ecoregion scale.
3	Prioritize and phase-in elements and actions, based on what a comprehensive strategy would include	The Action Plan was developed after information on current monitoring was obtained and summarized, and after the comprehensive strategy was drafted. Prioritization criteria for the Action Plan priorities are included.
4	Clarify that what is "adequate," is not the same as what is comprehensive	The Strategy characterizes what a comprehensive approach would include, whereas the Action Plan represents what would be adequate given available funding and resources.
5	Clarify monitoring definitions (page 1)	See response to October 10, 2001 ISP recommendation #8. Definitions have been revised for clarity in the Strategy, and a Glossary is included.
6	Clarify intent and approach mentioned to monitor cumulative effects for water quality (p. 2); explain why phasing is necessary	Clarification of long term trend monitoring of water quality has been bolstered in the Strategy. Phasing was to include toxics, but such are no longer included in the sampling design.
7	Trends in peak flows may be less tractable and useful than monitoring of mean annual runoff and low flows (p. 3)	Indicators representing mean annual runoff and low flows are included in addition to peak flows.
8	Bolster marine nearshore (p. 3)	Material on nearshore marine/estuaries has been bolstered in the Strategy.
9	Hydropower monitoring should not be limited to implementation monitoring (p. 6)	Agree. The hydropower section draws upon information from various monitoring types and synthesizes it to provide a general indication of patterns in trends operation of "fish friendly" hydropower systems.
10	Cause-and-effect monitoring is needed on issues and areas besides private forest lands (p. 7)	In the Strategy, cause-and-effect monitoring is identified in the section pertaining to "Intensively Monitored Watersheds" and in sections other than private forest lands.
11	There may be limits to how much integration of data can occur, please qualify (p. 7)	The data chapter of the Strategy outlines where needed data currently exist, and where opportunities to integrate and develop key interfaces may occur.
12	Include scheme for how conflicts between phasing criteria will be resolved (p. 8)	Criteria for prioritizing actions in the Action Plan are included.

4. July 17, 2002 ISP recommendations on the Comprehensive Monitoring Strategy Summary (dated 6/20/02) and matrices

	ISP Recommendation	Response
1	Include further internal technical review to improve consistencies and completeness	Further technical, policy, and public review work was performed and assistance from technical writers/ editors was applied.
2	Adaptive management still needs to be included	An adaptive management and governance section has been included.
3	Improve integration across monitoring types, in analysis and interpretation, within and across Hs	The Strategy includes the indicators of the Salmon Recovery Scorecard, a balanced and integrated approach to tracking environmental changes and implementation activities over time. Integration has been further clarified in a section on Intensively Monitored Watersheds (IMWs), and under the subheading "Analysis, Interpretation, and Outcomes." In addition to cross-H integration accomplished in IMWs, an integrated approach to status and trend monitoring of habitat, water, and resident fish is included. Completion of watershed plans and regional recovery plans will eventually provide focused frameworks for integrated monitoring across Hs in the context of local goals and objectives for watersheds and salmon recovery.
4	Clarify criteria and rationale for prioritization	Criteria for prioritization of items are included in the Action Plan.
5	Monitoring types are unbalanced; validation monitoring needs to be increased	A section on "Intensively Monitored Watersheds" (IMWs), is included in the Strategy. IMWs are where priority validation monitoring will be performed. The level of effort devoted to this and other types of monitoring are policy and budgetary decisions.

5. September 13, 2002 ISP recommendations on the Comprehensive Monitoring Strategy (Volume III, version 6, 8/21/02) and draft Action Plan (9/4/02)

	ISP Recommendation	Response
1	Identify timeframe and process for completing missing or inadequately developed critical elements (i.e., some statistical designs, protocols, data quality control/assurance, performance measures)	The Strategy and Action Plan will recommend that those priorities in need of additional work or development would fall under the purview of the "Monitoring Council" or its equivalent.
2	In cases where the full complement of monitoring types (implementation, status & trend, effectiveness, validation) is not present, identify uncertainties that may be introduced	To the extent practicable, such uncertainties will be identified in the Strategy document.
3	Compare descriptions of the monitoring programs to the stated objectives to identify and address gaps	To the extent practicable, and where they match priorities, gaps are identified and addressed as part of the Strategy. However, as in #1 above, analysis of remaining priority gaps will fall under the purview of the "Monitoring Council" or its equivalent.
4	Include validation of indicators or indices associated with performance measures	To the extent that they are not already included, it will be recommended that issues associated with validation of indicators or indices will fall under the purview of the "Monitoring Council" or its equivalent.
5	Bolster validation monitoring	The levels of attention in the Strategy and effort in the Action Plan devoted to this and other types of monitoring reflect policy and budgetary considerations. Further work on matters associated with validation monitoring will fall under the purview of the "Monitoring Council"or its equivalent.
6	Clarify the strategy for how information from different impacts (Hs) will be analyzed, evaluated and integrated	See response to July 17 ISP recommendation #3. Further work on this recommendation will be performed by the proposed "Monitoring Council" or its equivalent.
7	Incorporate hierarchical, decision-analysis tools	Further work on decision tools will considered by the proposed "Monitoring Council" or its equivalent as noted in the Adaptive Management/Governance section.
8	Once the most important issues or impacts are identified, the actions in the draft Action Plan should be compared with Table 1 to identify gaps and actions	A comparison of the Strategy (see ISP Table 1) with the Action Plan elements is outlined in the Action Plan.
9	Many editorial suggestions to improve consistency and clarity of presentation	Each of these suggestions were considered, and many of them were incorporated in the Strategy.

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Appendix 2. Integrated Status and Trends Monitoring Considerations and Overview of Associated Experimental Design

The purpose of this appendix is to clarify and expand the discussion about various aspects of integrated status and trends monitoring as recommended in the Comprehensive Monitoring Strategy and the Action Plan. This appendix does not address experimental design considerations for effectiveness or validation monitoring; those are briefly outlined in Part VIII of the monitoring strategy.

In the context of the monitoring strategy and Action Plan, integrated status and trend monitoring involves physical habitat, components of water quality, and resident trout. Status and trend monitoring of other aspects (e.g., anadromous fish) is also recommended, but integration would not be a sampling design feature in the same way as described here. Integrated status and trend monitoring is referenced in various sections of the monitoring strategy (see Part VII – physical habitat (B), water quality (G), and resident trout (I) sections). Because of the fundamental need and broad interest in improving physical habitat monitoring in the state, this appendix emphasizes specifics associated with physical habitat monitoring.

Context

Much of the environmental restoration we do involves manipulation of the physical attributes of aquatic ecosystems. Our assumption is that enhancing the physical environment will lead to improvements in the water quality and biotic components. Key questions that we ask from measurement and description of physical conditions in streams are:

(1) Which variables show favorable change as a result of management decisions, and

(2) How long will it take to detect any measurable change in the physical environment that results in enhanced biological conditions?

One of the first steps necessary for identifying appropriate physical habitat variables used in a monitoring program is to consider what role they play at a landscape scale and whether change can be measured in stream "subpopulations" during a single year or at all streams over time. Detecting temporal change requires revisiting sites within and between years. Such site revisits factor out site-to-site variability in the same manner as experimental designs use pairing to factor out subject-to-subject differences that evaluate "treatment" effects (Phil Larsen, personal communication).

Detecting change within sub-populations of streams can be useful when we expect to see changes in some stream types. For example, headwater or high gradient streams may change quickly in response to wood and sediment loading. The receiving reaches in the lower watershed may not reveal change using the same indicators appropriate for headwater streams. Reducing the landscape to areas with similar characteristics identifies fragments at which select habitat variables can detect change over time. The size of these fragments at which habitat variables can detect change varies. Individual variables are identified within appropriate landscape classifications so that the "signal" of change is larger than the "noise" or variability inherent of environmental information.

Integrated Monitoring

The monitoring strategy includes characterization of all stream ecosystem elements. The inclusive approach in monitoring is important for making effective decisions by targeting multiple ecosystem elements for restoration and protection. Many natural linkages exist between habitat/water quality and the influence on the biotic community. These natural linkages between the physical and chemical setting of streams and response in biotic communities reveal sources of degradation and suggest more effective restoration strategies.

Identifying Natural Associations Between Habitat, Water and Fish (Biota)

Stream ecosystems are unique for their aggregation of physical, chemical, and biological characteristics. Elements that comprise the stream ecosystem interact with others to form unique dynamics that enhance or diminish the ability for species to survive. Channel and riparian features form or modify habitat that provide living space for stream species. Chemical conditions modify the surface water environment and can create a barrier or act as a passable conduit to drainage areas with preferred habitat.

Indicators measured at landscape level, reach level or site-specific level can be especially effective at explaining why stream biota reside in some settings and not others. Exploratory data analysis is used to identify which indicators are appropriate for use at each of the spatial scales and are verified by their strength of correlation. The relationships between physical/chemical attributes of the stream setting and the response biota (like salmon) must be able to address objectives for the monitoring program. An example for a linkage between physical and biological elements might be the availability of spawning habitat for chinook salmon *(Oncorhynchus tshawytscha)* and the number of returning spawners as measured by the number of redds counted. Another common linkage in stream ecosystems is the relationship between substrate variety and the number of benthic macroinvertebrate (aquatic insect) species inhabiting an area (Hayslip and Herger 2001). Generally, greater habitat variety opens broader niche space for a greater number of species to occupy. This promotes constancy in biomass as food source for various life stages of vertebrates that would take advantage of stream reaches.

Evaluating Status of Natural Resources

Probabilistic sampling designs attempt to characterize stream and river miles over a hierarchy of spatial scales by collecting information from representative portions of the total population. This way, the condition of each environmental element (habitat, water quality, biology) can be summarized by extrapolation throughout the entire spatial area included in the sampling universe (e.g., ecoregion, salmon recovery region, WRIA). Statements about condition based on total river miles with poor, fair, or good conditions within a region is useful for making decisions about where to focus restoration effort (Merritt et al. 1999). Another useful approach in summarizing condition of streams throughout a region is by focusing on extent of biological distributions. For example, knowledge of the extent of bull trout *(Salvelinus malma)* distribution in regions throughout the state would have important implications for analyses of: (1) recovery measures, and (2) economic benefits and risks. Monitoring over time also provides understanding about how climatic influences and human activity affects the distribution of a species within regions.

Describing the status of stream resources is the first step in using monitoring information effectively. The second step involves using the linkages identified between physical/chemical and biological elements to identify causal mechanisms for degradation of streams. Recording the location of landscape or riparian characteristics that could pose a risk to natural stream biological conditions is useful for categorizing urgency for restoration/protection management decisions. Presentation of this information could include color-coded maps where streams within an "Ecoregion" or "Salmon Recovery Region" are identified according to the level of risk from current and future human activity that results in degradation to stream resources. This risk-analysis diagram could look different for each species, based on their need for environmental stream conditions that optimize survival.

Summarizing Environmental Changes and Inter-relationships

Fragments of the landscape can respond in different ways to human activities that are close enough to alter stream condition and function. Classification variables are important to consider here for their ability to further compartmentalize the types of landscape settings in which streams flow through and experience predictable physical or chemical alterations. One of the classification variables that account for land uses typical of spatial areas are ecoregions. By using ecoregions as the highest level of spatial categorization, we find that a dominant human activity usually has the greatest influence on stream resources. For instance, the Columbia Basin ecoregion is dominated by agricultural activity and the Cascades ecoregion is dominated by forest practice activity. Some agricultural practices near streams can lead to increased stream bank failures, riparian vegetation removal, introduction of pesticides/herbicides and many other types of factors with adverse effects on aquatic life. Similarly, some forest practices can lead to increased sediment input to the stream, riparian vegetation loss, and herbicide inputs with cumulative impacts to the downstream "response" reaches eventually becoming severely degraded as desirable habitat for aquatic life.

Classification strategies further refine the "risk analysis" approach in viewing the stream network throughout a watershed or region. This refinement allows for greater applicability of the monitoring information that extends to local governments who may consider the ramifications of zoning designations near aquatic resources. Initial monitoring efforts that summarize resource condition and then provide information about causal factors provides a great deal of information that feeds back into the decision-making process (Whittier et al. 2002). Continued status monitoring over time leads to trend and correlative analyses that can evaluate: (1) climatic influences (which can be quantitatively accounted for as a factor that influences variability in observations of various landscape factors between years), and (2) can inform attempts to identify positive and negative land use practices that influence stream conditions and fish populations. Finer levels of spatial classification of the landscape increases the applicability for use of the monitoring data at local levels.

Implications for Predictive Models

An eventual product from monitoring over large spatial scales and from the variety of stream settings is an ability to assemble predictive models. Environmental models that predict the potential for specific stream settings can be used to define goals for management. The data for establishing predictive models require monitoring over a reasonable amount of space and time. The basis for deriving predictive models is a careful examination of the relationships between physical, chemical, and biological elements of stream ecosystems and the ability to use surrogate independent measures like substrate composition, water temperature, and ecoregion to predict the type of salmon species that are normally associated with a mix of these characteristics.

The distribution of salmon species can be described through probability-based monitoring designs (EMAP), and the associated physical and chemical variables collected along at the same sites can be used to mathematically search for useful and reliable patterns. The biota (e.g., salmon) follow preferred environmental gradients, often several gradients simultaneously, that are included in a predictive model. It is easier to visualize this example by thinking about a typical distribution of a salmon species across a portion of the landscape and then by acknowledging that each stream setting where this species is found has one or more consistent physical or chemical characteristics. These consistencies are the basis for predicting what we should expect for extent of salmon distribution and for condition of a population. Each successive step of the comprehensive monitoring program provides information that can be used at different hierarchical scales of management: for example, multi-state (Federal), multi-ecoregion (State), and multi-watershed (County or Municipality).

Classification Variables and How They Work

Classification variables for identifying landscape areas with continuous characteristics have been identified in the comprehensive monitoring strategy as "Landscape Forming Processes." These classification variables are spatial descriptors that can be immediately obvious like the difference between the Cascade Range and the Columbia Basin. Others may be directed more toward function/dynamics of specific stream settings as defined by stream order or channel type. The classification variables can be arranged in a descending order based on the number of physical habitat characteristics that define them. Ecoregions are the largest level of landscape classifications and are defined by landform, soils, potential natural vegetation, and land use (Omernik and Gallant 1986). Next may be Valley Segment Type (Cupp 1989), followed by Channel Classification (Montgomery and Buffington 1993).

One of the desired products from classifying the landscape using these variables is to reduce the amount of variability inherent in physical measurements by appropriately limiting the size of landscape fragment in which it is analyzed. Some variables, like substrate size classes, can be measured from several streams throughout an ecoregion and have results with variances as large as the mean of any one substrate size class. If the ecoregion is part of a hierarchical classification that also includes: valley segment type, stream order, and channel classification, then the mean of a particular substrate size has a much smaller variance. Creating a classification tree for appropriately describing important physical habitat variables should consider the influence of stream dynamics. Limiting the size of the variance for individual physical habitat measurements has greater utility for use as an indicator of change.

Hierarchical Structure of Classification Variables and their Relationship to Individual Habitat Variables

Spatial Variation

Physical habitat variables can describe large areas of the landscape or a small portion of a stream reach. Measurements made at smaller spatial scales tend to be highly variable over the length of a reach and especially among several streams. As previously stated, classification variables play a large role in effectively using stream channel measurements to record current conditions and determine when change occurs. One of the first combinations of classifications variables that have been used to identify landscape fragments are ecoregions and then "stream order" (Phil Larsen, personal communication). Ecoregions combine several important large-scale characteristics into immediately recognizable areas that exhibit obvious continuity in human activity, topography, climate, vegetation, and soil/geology. Stream order considers hydrological characteristics and the resulting in-stream dynamics. Aggregating stream information based on a "hierarchical tree," for example, by using ecoregions and stream order will generate habitat condition summaries for landscape fragments that have a signal (among stream variation) that exceeds noise (variability from repeat visits to a stream). The larger the signal compared to noise in a data set, the easier it is to detect significant change.

Physical variables that describe larger portions of the landscape can be measured through remote sensing. These descriptions include naturally occurring features like soil/geology type, vegetation patterns, topography, and land use. Landscape features that can be altered by human activity and represent a potential impact to aquatic ecosystems can be remote sensed. Altered landscape features degrade aquatic ecosystems and can originate from landslides, high road densities in a watershed, extent of impervious surfaces, destruction of wetlands, and land uses that change the hydrologic characteristics surrounding a stream. Quantification of these features within an area of influence (e.g., sub-basin or watershed) for each stream observation serve as diagnostic elements and help determine the appropriate restoration decision once severity of degradation at a stream reach is measured. Besides diagnosis of degradation at the smaller reach-level scale, these impacts can be quantified over larger portions of a landscape to determine how extensive human impacts have become. Landscape-level characterization for these types of degradation can be recorded over time to provide some notion of how the aggregate of management decisions is performing.

Temporal Variation

The rate of change in physical habitat conditions is variable. In some instances, physical habitat conditions change over long periods of time (months, years, or decades). Indicators for such characteristics include riparian condition (trees take many years to grow and provide effective shading and contribute large wood to streams) or aggregation of woody debris (dependent on major flood events). Other variables such as substrate size distribution respond instantaneously to changes in the hydrologic regime and results are typically highly variable in stream reach characterization or among several streams within a landscape classification.

The utility of variables that can be measured for change over short or long time periods depends on the management question asked and the appropriate association between restoration action and expected ecosystem response. If the majority of streams in a set shows that a large proportion have been degraded from riparian vegetation disturbance, then restoration recommendations would likely include re-vegetation and restrictions on human activities that increased this type of occurrence. We would expect that a noticeable effect on stream ecosystem integrity might not be detectable for ten or more years. In another example, eroding soils reaching a stream channel may be filling living space for resident biota. A decision may be made to create a physical barrier that would slow or stop the soils from continually eroding and allow the stream current to transport excess soils away from this reach. We may see an improvement in ecosystem integrity in as short a time period as one year. These examples illustrate how the size of a disturbance in a stream accumulates over time and that depending on severity of the impact, our ability to detect change using current knowledge can take time.

How Habitat Variables Respond to Different Human Disturbance Gradients

Physical habitat variables can be categorized as to their ability to detect an actual trend (signal) amidst substantial variation (noise). The signal from degradation is useful when variability about the mean for a habitat condition described from a set of streams is small enough that a significant change is detectable from one time period to the next. However, this change due to degradation must be larger than the noise, or the variation stemming from repeat visits from a set of streams, so that the signal-to-noise ratio is sufficiently large for trend detection (Kaufmann et al. 1999).

Human disturbance affects the physical integrity of stream ecosystems in a variety of ways. First, human disturbance can either be a severe event or can be subtle and build up over a longer time period. Human disturbances that are large can appear as an immediate impact to a stream channel (i.e., land slide). Second, degradation due to human activity that slowly introduces pollutants (physical or chemical) over time accumulate in the stream channel and are not detectable for much longer time periods (e.g., riparian removable and subsequent stream bank erosion).

Primary considerations for identifying appropriate physical habitat variables that detect human disturbance and monitor for change are:

(1) The severity of the impact,

(2) The dynamics of the degradation (does it accumulate over time?), and

(3) The ability for a physical habitat variable to detect various types of impacts (high signal-to-noise ratio).

Often, the appropriate physical variables that satisfy these requirements for use as an indicator have something to do with the resulting changes from the degradation and the extent of the degradation. If woody debris is an integral component of a stream setting, quantification is relatively simple, having numerous units to count and categorize within a reach. If a catastrophic flood removes most of the debris, then a significant change is detectable. If woody debris is not that common in certain stream reaches and floods add or remove small quantities of wood, the change from original status often results in high variability among repeated reach measurements (noise). This is just one example where physical habitat variables must be chosen with a focus on important characteristics of stream settings, especially those that are integral to ecosystem integrity.

Physical Habitat Variables and Biological Response

Using the response to make decisions regarding restoration effort

The goal for monitoring associated with the Comprehensive Monitoring Strategy is to provide information that guides management decisions for restoration of aquatic ecosystems, including salmon (see Part IV). One of the most important aspects regarding habitat monitoring and restoration is to focus on the endpoint, aquatic life. In the case of the Comprehensive Monitoring Strategy we are striving to improve "watershed health" with an emphasis on "salmon recovery." Aquatic life sees the stream environment for its needs to survive. Sometimes, individuals from stream populations choose poorly in their struggle to survive. However, many individuals are successful in satisfying needs for survival and will seek out microhabitats that optimize their chances.

To focus on salmon recovery, we need to begin asking what critical elements are in need of restoration for salmon inhabiting a stream reach. Next, we must ask how to facilitate these changes at a stream reach level by modifying our activity at a larger landscape scale. The answers to these questions will help us identify the appropriate variables that indicate how effective our decision-making has been.

The decision-making process based on monitoring program results is an iterative process that is modified over time to achieve optimal results toward our goal of restoration. The Comprehensive Monitoring Strategy has laid out critical elements of a monitoring plan that includes data gathering from a variety of sources, coupled with integrated analysis and reporting. The management decisions we make are simply facilitating a more hospitable physical and chemical environment in which aquatic life can survive. The test of management effectiveness is based on the condition of aquatic life (i.e., salmon, amphibians, aquatic invertebrates). This treatment/response approach assists in refining our ability to manage aquatic resources. We have the opportunity to build on existing efforts and to introduce new technology and knowledge into our monitoring programs for the improvement of aquatic life that inhabit our rivers and streams.

Overview of the Recommended Experimental Design for Integrated Status and Trends Monitoring

The recommended experimental design is intended to meet the demands of integrated status and trends monitoring consistent with the complexities inherent in the discussion above. The design is very flexible, and can be adapted to meet different statistical criteria, geographic priorities, and fiscal constraints. The design is graphically depicted in Figure 39.

The design calls for two categories of sampling that will produce results at WRIA, Salmon Recovery Region, and ecoregion scales. The two categories are:

(1) Water Resource Inventory Area (WRIA)

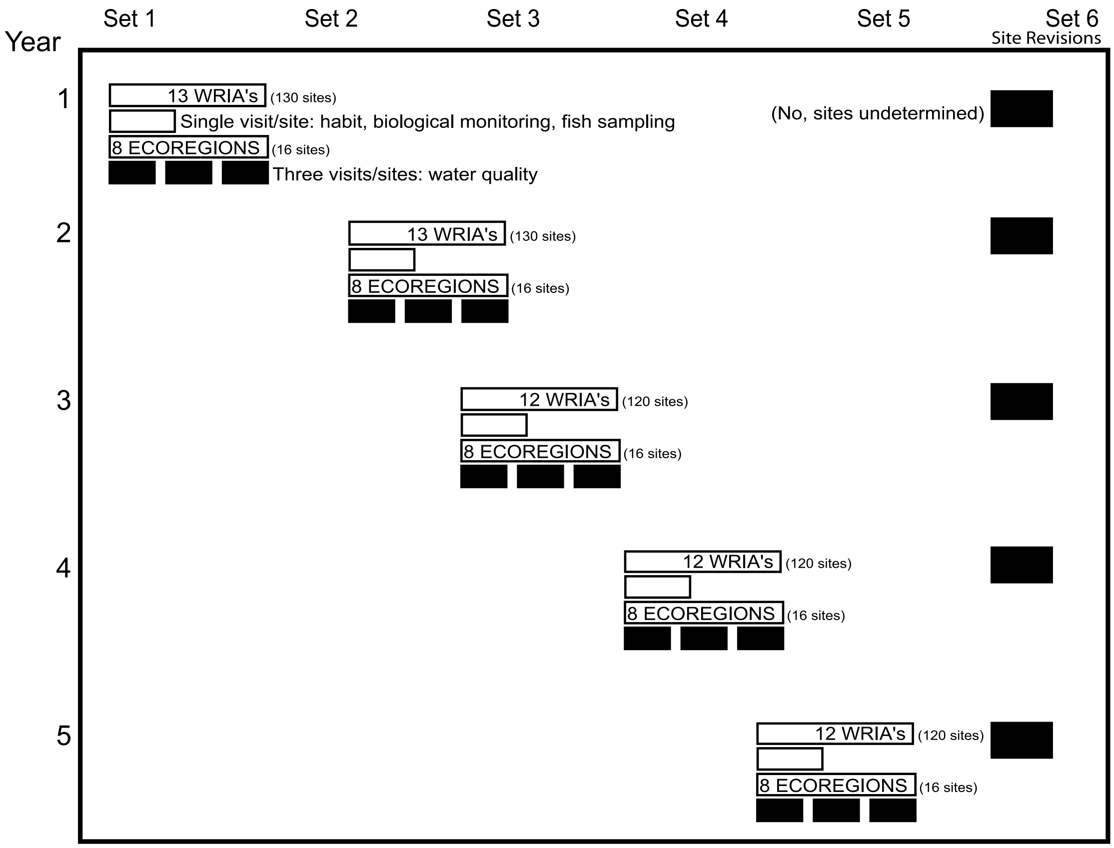
(2) Ecoregion.

Specific WRIAs within Salmon Recovery Regions will be identified for sampling each year. All WRIAs within Salmon Recovery Regions across the state will have been sampled once in each five-year sampling cycle. Five sets of WRIAs (multiple WRIAs) will be identified. Various types of environmental information will be monitored within these sets of WRIAs, including physical habitat, biota (benthic macroinvertebrates), and fish assemblages. Ten sites will be visited within each WRIA within each set each year. A total of 120 to 130 site visits will occur in each set within each year in a five-year period. All 62 WRIAs will have been visited following the completion of each five-year sampling cycle (all WRIAs statewide resulting in a total of 620 visits). The WRIA monitoring component requires a single site visit to gather the environmental information described above.

A second type of environmental monitoring will complement the WRIA sampling. It focuses on water quality variables with site selection that is ecoregion-based. Two sites will be selected within each of the eight ecoregions in Washington State. This will result in an annual total of 16 site visits per set statewide. Over the five-year sampling cycle, 80 sites will have been visited that describe water quality conditions. The ecoregion monitoring component differs from the WRIA strategy in that three site visits are made at each of the 16 locations per set as indicated in Figure 39 below.

Additional information is collected from one WRIA-based site chosen randomly and from one ecoregion-based site chosen randomly. These two additional sites allow for evaluations of quality assurance and detection of sources of error in the sampling program.

Figure 39.



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Montgomery, D.R. and J.M. Buffington. 1993. Channel Classification, Prediction of Channel Response, and Assessment of Channel Conditions. Timber, Fish, and Wildlife Agreement: SHAMW Committee. TFW-SH10-93-002. 84p.

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Appendix 3. Management Plans Recognized By The Federal Energy Regulatory Commission

Management Plans recognized by the Federal Energy Regulatory Commission that affect Washington State:

Oregon Plans

Bureau of Land Management. 1987. Spokane resource area management plan. Department of the Interior, Spokane, OR.

Bureau of Land Management. 1990. Resource assessment of the Grande Ronde River. Department of the Interior, Baker, OR.

Bureau of Land Management. 1992. South Fork of the Walla Walla River area plan amendment. Department of the Interior, Vale, OR.

Washington Plans

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Forest Service. 1988. Land and Resource Management Plan for the Colville National Forest. Department of Agriculture, Colville, WA.

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Forest Service. 1990. Olympic National Forest land and resource management plan. Department of Agriculture, Olympia, WA.

Forest Service. 1990. Wenatchee National Forest land and resource management plan. Department of Agriculture, Wenatchee, WA.

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Washington State Department of Community Development. Office of Archaeology and Historic Preservation. 1987. A resource protection planning process identification of prehistoric archaeological resources in the lower Columbia study unit. Olympia, WA.

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Appendix 4. Glossary of Acronyms

ACOE Army Corps of Engineers

ALEA Aquatic Lands Enhancement Account

ANS Aquatic Nuisance Species

AREMP Aquatic and Riparian Effectiveness Monitoring Program

BEF Bonneville Environmental Foundation

BMP Best Management Practice

BPA Bonneville Power Administration

CBFWA Columbia Basin Fish and Wildlife Authority

CC Conservation Commission

CCT Coastal Cutthroat Trout

CFR Code of Federal Regulations

CI Confidence Intervals

CMER Cooperative Monitoring, Evaluation and Research

CMS Comprehensive Monitoring Strategy

CRC Catch Record Card

CREP Conservation Reserve Enhancement Program

CTED Community Trade and Economic Development

CV Coefficients of Variation

CWA Clean Water Act

CWP Clean Water Program

CWT Coded Wire Tag

DDG Data Development Group

DFC Desired Future Condition

DIS Department of Information Services

DIT Double Index Tag

DNA Deoxyribo Nucleic Acid

DNR Department of Natural Resources

DOE Department of Energy

DOH Department of Health

DPS Distinct Population Segment

DSM Decision Support Model

ECY Department of Ecology

EDT Ecosystem Diagnosis and Treatment

EMAP Environmental Monitoring and Assessment Program

EPA Environmental Protection Agency

ESA Endangered Species Act

ESHB Engrossed Substitute House Bill

ESRI Environmental database

ESU Evolutionary Significant Unit

FCRPS Federal Columbia River Power System

FERC Federal Energy Regulatory Commission

FFA Forests and Fish Agreement

FGDC Federal Geographic Data Council

FPA Forest Practices Act

FY Fiscal Year

GDU Genetic Diversity Units

GIS Geographic Information System

GSRO Governor's Salmon Recovery Office

HCP Habitat Conservation Plan

HGMP Hatchery and Genetic Management Plan

HPA Hydraulic Project Approval

HUC Hydrological Unit Code

IAC Interagency Committee for Outdoor Recreation

IFIM Instream Flow Incremental Method

IHN Internal Hematopoeitic Necrosis – a disease virus highly contagious in salmon

IMW Intensively Monitored Watershed

ISAB Independent Science Advisory Board

ISB	Information Services Board
ISP	Independent Science Panel
ISRP	Independent Science Review Panel
ITFM	Intergovernmental Task Force on Monitoring
JNRC	Joint Natural Resources Cabinet
LEAG	Lead Entity Advisory Group
LFA	Limiting Factors Analysis
LIFT	Commercial Fish Ticket System
LSC	Legislative Steering Committee
LWD	Large Woody Debris
MAL	Major Ancestral Lineages
MDT	Monitoring Design Team
MLLW	Mean Lower Low Water
MMPA	Marine Mammal Protection Act
MOA	Memorandum of Agreement
MOC	Monitoring Oversight Committee
NA	Not applicable
NEPPS	National Environmental Performance Partnership System
NFP	Northwest Forest Plan
NGO	Non Governmental Organization
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPMP	Northern Pikeminnow Management Program
NSSP	National Shellfish Sanitation Program
NWIFC	Northwest Indian Fisheries Commission
NWPPC	Northwest Power Planning Council
ODFW	Oregon Department of Fish and Wildlife
OESF	Olympic Experimental State Forest
OFM	Office of Financial Management
OWEB	Oregon Watershed Enhancement Board
PDO	Pacific Decadel Oscillation
PFH	Properly Functioning Habitat
PFP	Properly Functioning Population
PFMC	Pacific Fishery Management Council
PIBO	PACFISH/INFISH
PRISM	Project Information System
PSAMP	Puget Sound Ambient Monitoring Program
PSAT	Puget Sound Action Team
PSNERP	Puget Sound Nearshore Ecosystem Restoration Program
PSTRT	Puget Sound Technical Recovery Team
PSWQMP	Puget Sound Water Quality Management Plan
PUD	Public Utility District
QA	Quality Assurance
PHABSIM	Physical Habitat Simulation
RAINS	Environmental database
RCS	Riparian Conservation Strategy
RCW	Revised Code of Washington
RMZ	Riparian Management Zone
RP	Reference point
SASSI	Salmon and Steelhead Stock Inventory
SaSI (SASSI)	Salmonid Stock Inventory
SCALE	Shoreline Classification and Landscape Extrapolation

SCSCI	Summer Chum Salmon Conservation Initiative
SE	Standard error
SEA	State EPA Agreement
SOS	Save Our Wild Salmon
SRS	Stratified Random Sample
SRFB	Salmon Recovery Funding Board
SRR	Salmon Recovery Region
SSB	Substitute Senate Bill
SSHEAR	Salmonid Screening, Habitat Enhancement and Restoration
SSHIAP	Salmon and Steelhead Habitat Information and Assessment Project
SSRS	Statewide Salmon Recovery Strategy
SWIM	Salmon and Watershed Information Management
TAC	Technical Advisory Committee
TBD	To be determined
TFW	Timber, Fish, and Wildlife
TMDL	Total Maximum Daily Load
UEPRS	Uniform Environmental Project Reporting System
USDA	United States Department of Agriculture
USFS	United States Forest Service
USGS	United States Geological Survey
USFWS	United States Fish and Wildlife Service
UW	University of Washington
WAC	Washington Administrative Code
WAGIC	Washington Environmental Monitoring and Assessment
WAU	Watershed Administrative Unit
WCT	Westslope Cutthroat Trout
WDF	Department of Fisheries
WDFW	Washington Department of Fish and Wildlife
WDG	Department of Game
WMC	Watershed Monitoring Council
WQI	Water Quality Index
WRIA	Water Resource Inventory Area
WSDA	Washington State Department of Agriculture
WSDOT	Washington State Department of Transportation
WUA	Weighted Useable Area

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