NOAA FISHERIES SERVICE - NORTHWEST REGION

Guidance For Monitoring Recovery of Salmon and Steelhead

Listed Under the Federal Endangered Species Act (Idaho, Oregon, and Washington)

Bruce A. Crawford & Scott Rumsey

D_R_A_F_T

Monday, April 27, 2009

[This document is under review and may contain future changes or additional information.]

Guidance to salmon recovery partners concerning prioritizing monitoring efforts to address the viability of salmon populations and the associated threats and factors involved in listing certain Evolutionarily Significant Units and Distinct Population Groups under the federal Endangered Species Act.

EXECUTIVE SUMMARY

This guidance document is designed to better assist those involved with salmon recovery in understanding the recovery monitoring needs and the associated level of certainty at the regional, local, and project level. The recommendations included are for federal and state agencies, Indian tribes, local governments and watershed organizations participating within each *evolutionarily significant unit* (ESU) and *distinct population segment* (DPS) which are actively developing recovery plan monitoring programs, or are modifying existing monitoring. It is our intention that these recommendations will be considered as the desired level of monitoring to be conducted and will provide a consistency across ESU domains. Recommendations include monitoring that addresses all of the *viable salmonid population* (VSP) criteria and the listing factors and threats. Following are specific NOAA Fisheries Service recommendations for monitoring, data collection, and reporting ESA information. This document is not intended as a step by step process to de-list a species.

RECOMMENDATIONS FOR DATA COLLECTION EVALUATION AND REPORTING

1. The regional environmental databases should be coordinated such that a common set of metadata and common data dictionaries are used to track information so that it can be readily reported to NOAA Fisheries Service and shared among the participants (page 19).
2. The natural resource agencies and tribes should develop automated internal infrastructure to assess and evaluate their data such that all methods and calculations are transparent and repeatable to all interested parties (page 20).
3. All recovery entities should include elements of the *Pacific Coast Salmon Recovery Fund* (PCSRF) database dictionary for tracking implemented projects within their databases and or/ adequate data mapping of projects to be able to provide data to the PCSRF database when NOAA is conducting a status review (page 21).
4. The regional salmon recovery partners should build a distributed data system that can communicate between various agencies and tribes involved in natural resources and report to the public progress in salmon recovery (page23).
5. The agencies and tribes sampling habitat, water quality, and fish VSP criteria should coordinate their sampling programs to fit within an integrated master sample program for the domain or tri-state region (page 25).

RECOMMENDATIONS FOR MONITORING VSP STATUS/TRENDS

VSP Adult Spawner Abundance

6. Incorporate a robust unbiased adult spawner abundance sampling design that has known precision and accuracy. (page37).
7. Monitor ratio of marked hatchery salmon and steelhead with an external adipose clip to unmarked natural origin fish in all adult spawner surveys (page 38).

8. Agencies and tribes, as a first step to improved data quality, should calculate the average coefficient of variation for all adult natural origin spawner databases for ESA populations and provide that information to all interested parties (page 39).
9. Agencies and tribes should strive to have adult spawner data with a c*oefficient of variation* (CV) on average of 15% or less for all ESA populations (page 39).
10. Agencies and tribes should conduct a power analysis for each natural population monitored within an ESU to determine the power of the data to detect a significant change in abundance and to provide that information to all interested parties (page 40).
11. Agencies and tribes should utilize the protocols published in the American Fisheries Society Salmonid Field Protocols Handbook whenever possible in order to standardize methodologies across the region in evaluating population abundance (page40).

VSP Productivity

12. Agencies and tribes should develop at least 12 brood years of accurate spawner information as derived from cohort analysis in order that NOAA Fisheries can use the geometric mean of recruits per spawner to develop strong productivity estimates (page 431).
13. Agencies and tribes should obtain estimates of juvenile migrants for at least one significant population for each *major population group* (MPG) within an ESU or *distinct population segment* (DPS) (page 44).
    a. The goal for all populations monitored for juvenile migrant is to have salmon data with a CV on average of 15% or less and steelhead data with a CV on average of 30% or less. (page44).
    b. A power analysis for each juvenile migrant population being monitored within an ESU should be conducted to determine the power of the data to detect a significant change in abundance and to provide that information to all interested parties.

VSP Spatial Distribution

14. Determine spatial distribution of listed Chinook, coho, and steelhead with the ability to detect a change in distribution of ± 15% with 80% certainty. (Page 47).

VSP Species Diversity

15. As a short term strategy, utilize species distribution information and spawn timing, age distribution, fecundity, and sex ratios to determine status/trend in species diversity of natural populations (page 49).
16. As a long term strategy, develop a baseline of DNA microsatellite markers based on *single nucleotide polymorphism* (SNPs), allozyme and DNA genotypes and phenotypes for each population within each MPG and ESU (page 49).

RECOMMENDATIONS FOR MONITORING LISTING FACTORS AND THREATS

Threats Due To Loss of Habitat

17. Implement a randomized geospatially referenced tessellated habitat status/trend monitoring program incorporating on the ground protocols coupled with remote sensing of land use and land cover. Coordinate and correlate habitat status/trend monitoring with fish in and fish out monitoring wherever possible (page 52).
18. USEPA, state agencies, and local governments should monitor storm water and cropland runoff for status/trends of concentrations of toxics and identify their sources (page 55).
19. To the extent possible all regional and local restoration efforts should be capable of being reported and correlated with habitat limiting factors as defined in the PCSRF data dictionary so that the cumulative effects of restoration actions can be tracked and given proper credit by population, MPG, and ESU/DPS (page 55).
20. Reach scale effectiveness monitoring should be conducted for various habitat improvement categories using a *Before and After Control Impact* (BACI) design whenever possible. Recovery entities should coordinate their monitoring to reduce costs and improve sample size (page 57).
21. Implement at least one *intensively monitored watershed* (IMW) for each domain and address different limiting factors by coordinating IMW sites and designs across the Pacific Northwest utilizing a BACI design wherever possible (page 58).
22. For maximum ability to detect change and to avoid poorly designed studies that cannot detect change, IMWs should have a power analysis completed early in the project to determine the amount of the watershed required to be treated in order to detect a 30-50% change in fish response (page 59).

Threat Due To Hydropower Production

23. Monitor all hydropower facilities for status/trends of survival impacts to upstream migrating adults and downstream migrating juvenile salmon and steelhead (Page 61).

Threats Due To Overutilization (Harvest)

24. Manage exploitation rates and total catch in coast wide fisheries and terminal fisheries for TRT identified natural populations phasing out the use of all hatchery-natural stock aggregates by 2020 (page 66).
25. Cohort reconstructions for natural populations should be made available to the science community within one year of the return of all age classes in the cohort (page 66).
26. The PNW states and tribes should recalibrate the FRAM model to reflect harvest management of natural populations (page 67).
27. Initiate snapshot sampling programs in the various coastal fisheries to capture the distribution of the TRT population within the specific fisheries in preparation for a coast wide annual coordinated approach to monitoring harvest status/trends by 2020. (page 68).

28. The states and tribes should be able to demonstrate that there was a greater than 90% compliance with adopted fishery regulations designed to minimize incidental take of listed species (page 69).
29. Allowable incidental harvest rates identified for coastwise, in river, and terminal fisheries should be modeled annually to determine their effectiveness in providing for ESU population spawner escapement goals in terms of years to recovery and jeopardy (page 69).

Threats Due to Disease and Predation

30. In order to determine the extent of the threat from aquatic invasive species, the status of existing invasive species should be compiled for each ESU/DPS and watershed assessments for those species known to affect salmon and steelhead should be conducted (page 75).

Threats Due To Inadequacy of Regulatory Actions

31. Implement a recovery plan tracking system that will be capable of recording whether local and state agencies have implemented regulatory actions proposed in recovery plans (page 77).
32. Develop a randomized sampling program to test whether permits issued under local and state regulatory actions designed to protect riparian and instream habitat are in compliance and that the provisions have been enforced. Compliance rate should be equal to or greater than 90% (page 78).

Threats Due To Hatchery Production

33. The states and tribes should be able to determine annually the percent hatchery origin spawners (PHOS) and natural origin spawners (PNOS) for each population changes of ± 5% with 80% certainty and determine the trend toward reaching HGMP targets. (page 82).
34. The proportion of natural influence (PNI) for primary populations within the ESU for supplementation programs should be calculated periodically. (page 82).
35. A Hatchery and Genetic Management Plan (HGMP) must be developed for each hatchery and submitted to NOAA Fisheries Service for approval and to determine whether they are complete (page 84).
36. Documentation should be available that demonstrates that Hatchery and Genetic Management Plans have been implemented and to what extent (page 84).
37. Every hatchery program should monitor and record the practices and protocols it follows and be ready to report this information on an annual basis (page 85).
38. Every hatchery should monitor the spatial and temporal distribution of juvenile fish released from the program (page 85).
39. Implement effectiveness monitoring recommended by the Ad Hoc Supplementation Monitoring and Evaluation Workgroup by developing a large scale treatment/reference design to evaluate long term trends in the abundance and productivity of supplemented populations. This strategy should be incorporated into each ESU and DPS containing supplementation hatcheries and should be coordinated across broader geographic scales such as the recovery domains, Columbia River and Puget Sound basins (page 85).

40. The genotype and phenotype of every hatchery brood stock program should be monitored periodically to determine effectiveness of maintaining the integrated or isolated stock goals of the hatchery product (page 86).
41. Assess effectiveness of actions taken to address threats to NOF due to hatchery operations (page 88).

Threats Due To Natural Causes

42. The states and tribes can assist in monitoring the effects of changes in climate upon salmon and steelhead populations by monitoring changes in stream flow, temperature, and their effects upon freshwater survival at all life stages (page 92)

ACKNOWLEDGEMENTS

To Be Completed In The Final Draft

CONTENTS

LIST OF TABLES

LIST OF FIGURES

1.0 INTRODUCTION

This guidance document is designed to better assist those involved with Endangered Species Act salmon recovery in understanding the recovery monitoring needs at the regional, local, and project level and the levels of certainty that may be needed.

The recommendations included are for federal and state agencies, Indian tribes, local governments and watershed organizations participating within each *evolutionarily significant unit* (ESU) and *distinct population segment* (DPS) which are actively developing recovery plan monitoring programs, or are modifying existing monitoring. It is our intention that these recommendations will be considered as the desired level of monitoring to be conducted and will provide a level of consistency across ESU domains.

Recommendations include monitoring that addresses all of the VSP criteria and the listing factors and threats. Although this document is focused on listed species, the guidance can be applied to other populations that currently are not listed. The unlisted species could benefit from monitoring that will reveal their status/trends and any management actions underway to reduce their limiting factors and threats.

NOAA's National Marine Fisheries Service (NOAA Fisheries Service) has previously provided three documents detailing the need for various kinds of information for determining the status of salmon and steelhead listed under the Endangered Species Act of 1973(ESA).

- Viable salmonid populations were described in *NOAA Technical Memorandum NOAA FISHERIES-NWFSC-42* (McElhany, 2000).
- Additional guidance mainly directed toward habitat restoration monitoring has been given to the states and tribes through the Pacific Coastal Salmon Recovery Fund *"Performance Goals, Measures, and Reporting Framework* (NOAA Fisheries Service, December 2006)*"*, and
- *The initial framework for developing monitoring is described in "Adaptive Management for ESA-Listed Salmon and Steelhead Recovery: Decision Framework and Monitoring Guidance"* (NOAA Fisheries Service , May 2007).

The ESA requires that NOAA Fisheries Service shall conduct, at least once every five years; a review of all species included in the ESA list and determine on the basis of such review whether any such species should—

- be removed from such list;
- be changed in status from an endangered species to a threatened species; or
- be changed in status from a threatened species to an endangered species.

In addition, section 4(g) requires that once a species has been de-listed that monitoring must be conducted in cooperation with the states for at least five years to ascertain the de-listing action.

The next salmon species review is 2010. This document is offered to assist in bringing together a regional monitoring strategy and guidance that will assist in obtaining the monitoring information in the most cost effective way for the region.

There are many acronyms and terms that may be unfamiliar to the reader. Appendix 1 contains a list of acronyms and definitions to assist the reader.

2.0 WHAT INFORMATIO IS NEEDED FOR DE-LISTING OR DOWN-LISTING A SPECIES?

This question is central to the efforts of local salmon recovery entities, states, tribes, and other federal agencies and tribes as they work together to restore salmon and steelhead to our streams.

The following diagram (Figure 1) is taken from the *Decision Framework and Monitoring Guidance* (NOAA Fisheries Service , May 2007)and illustrates the combination of VSP criteria and listing factors to be monitored and how implementation (compliance), effectiveness monitoring, status/trends and researching critical uncertainties work together to provide necessary information for determining listing status and for adaptive management.

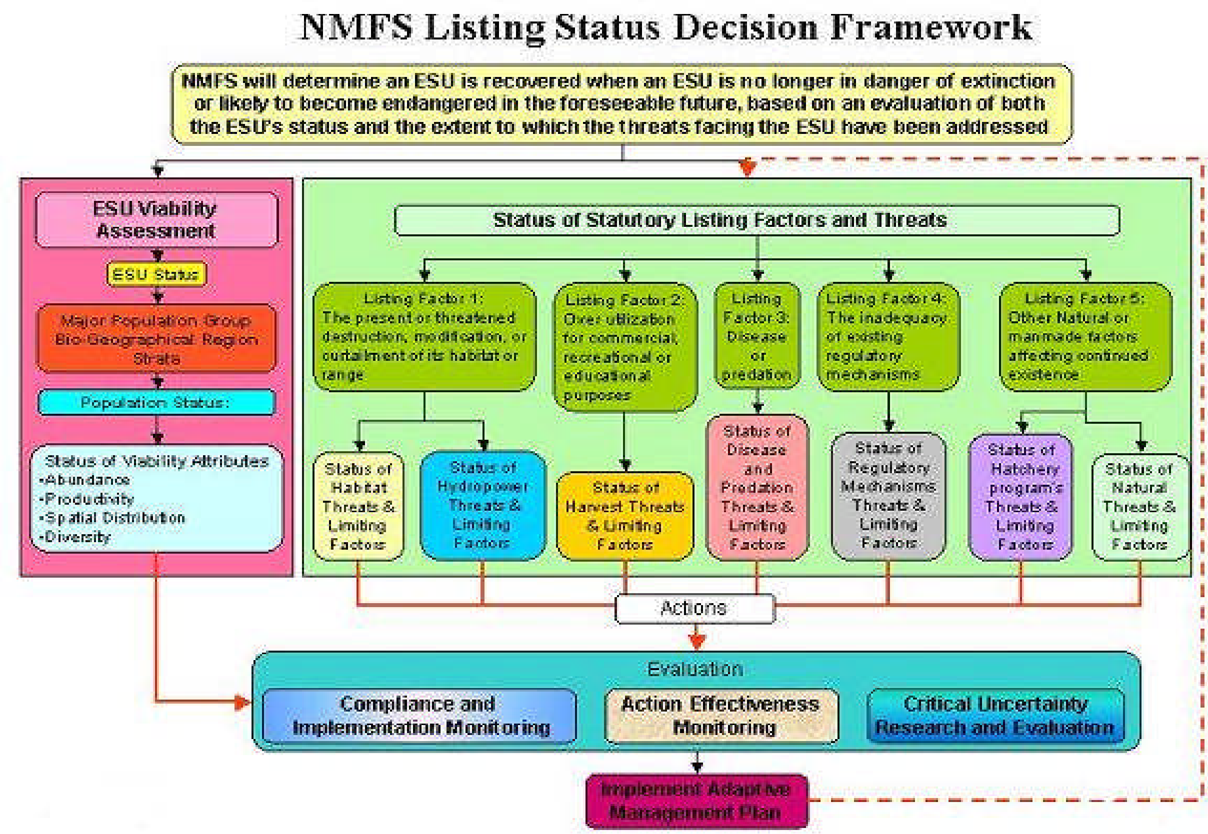


Figure 1. NOAA Fisheries Service Listing Status Decision Framework

2.1 Demonstrated Viability

Section 3 of the ESA defines an endangered species as ‘‘any species which is in danger of extinction throughout all or a significant portion of its range’’ and a threatened species as one ‘‘which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.'' In assessing the level of extinction risk facing a species, NOAA Fisheries Service evaluates the viability of its component populations using four complimentary criteria for "Viable Salmonid Populations" (VSP Criteria: abundance; productivity; spatial structure (connectivity); and diversity (McElhany et al., 2000). These four parameters are universal indicators of species' viability, and individually and collectively function as reasonable predictors of extinction risk.

2.2 Reduction or Elimination of Threats to Viability

The ESA requires NOAA Fisheries Service to determine whether any species is endangered or threatened because of any of 5 listing factors:

- Present or threatened destruction, modification, or curtailment of a species habitat or range
- Overutilization for commercial, recreational, scientific, or educational purposes
- Disease or predation
- Inadequacy of existing regulations
- Other natural or manmade factors affecting continued existence (e.g. Hatcheries, Hydropower)

2.3 Species Status Reviews

NOAA Fisheries Service is preparing for the beginning of five year reviews in 2010 of 28 listed salmon ESUs and steelhead DPSs. These reviews will consider information that has become available since the most recent listing determinations, and make recommendations whether there is substantial information to suggest that a change in listing status may be warranted. For those listed species that may warrant a change in status, NOAA Fisheries Service will convene a biological review team (BRT) and conduct a formal ESA review of the respective species' level of extinction risk, the threats and limiting factors affecting the species, as well a review of the efforts being made to protect the species (consistent with Sec. 4(a) of the Act).

To initiate 5-year status reviews, NOAA Fisheries Service will publish a notice in the *Federal Register* outlining a schedule for these 5-year reviews, and soliciting the most recent scientific and commercial information. In preparation for these reviews NOAA Fisheries Service has developed databases of the population status and trend information used by the Technical Recovery Teams (TRTs) to develop viability criteria and conduct viability analyses. NOAA Fisheries Service will coordinate with appropriate state and tribal staff to include the most up-to-date status and trend information in the database for the 2010 5-year reviews. The Northwest Fisheries Science Center (NWFSC) will provide updated summaries of VSP status for each of the Pacific Northwest listed salmon and steelhead ESUs/DPSs to inform these reviews. The NWR will compile pertinent information that has become available since the last formal ESA status review completed in 2005. In most instances such information will include reports, research findings, Biological Opinions, recovery plans, public comments, and information on protective efforts (e.g., HCPs, HGMPs, regulatory changes). NWR staff will evaluate the updated information on extinction risk, limiting factors and threats, and protective efforts and make a recommendation for each listed ESU/DPS whether there is substantial information to suggest that a change in listing status (i.e., downgrading risk from endangered to threatened, upgrading risk from threatened to endangered, or delisting) may be warranted. NOAA Fisheries Service will consider the NWR recommendations and publish a Federal Register notice announcing formal ESA listing-status reviews, as appropriate.

In order to review the various listed ESUs, NOAA is developing a series of internal tools to expedite the process. The following conceptual model (Figure 2) will be followed. In the event that a formal ESA status review is warranted, the NWFSC will convene a Biological Review Team (BRT), conduct in-depth VSP assessments, evaluate threats and limiting factors, and complete a BRT report. The results of these evaluations will undergo peer review. The NWR will consider the BRT's results, evaluate protective efforts and the adequacy of regulatory mechanisms, and develop a recommended finding. If a change in listing status is warranted, NOAA Fisheries Service will publish a proposed rule in the *Federal Register* 12-months after initiating a review. NOAA Fisheries Service would then have another 12 months to solicit and review public comments, evaluate other available information, and issue a final determination.

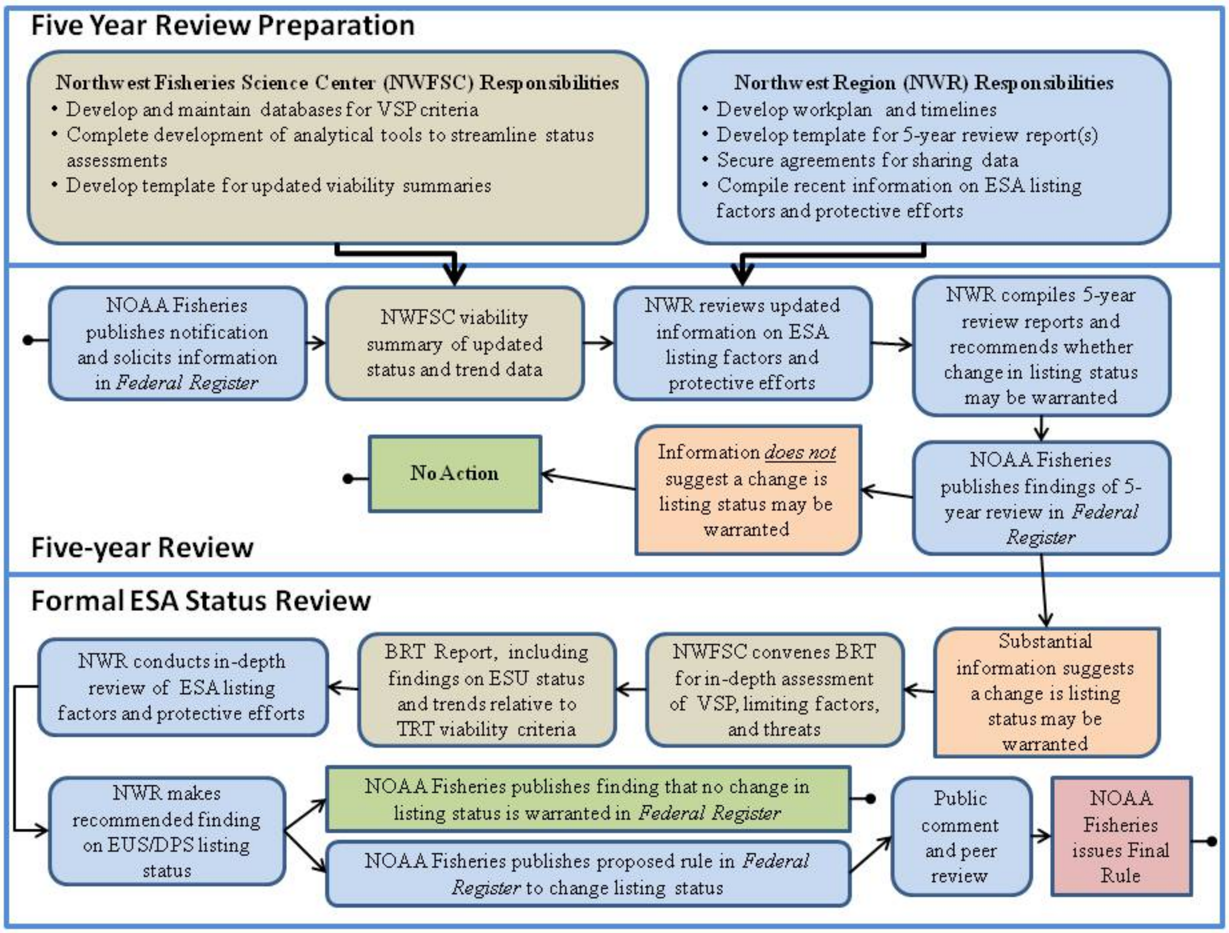


Figure 2. Conceptual model for conducting five year review of listing status under the ESA.

In order to create the greatest clarity for conducting future ESA status reviews, NOAA Fisheries Service is working collaboratively with the recovery entities to:

- Develop an agreed upon data dictionary for VSP metrics (See Appendix 2);
- Produce this M&E Guidance document to clarify the standards that should be attained for monitoring; and
- Develop a cooperative regional strategy that contains an inventory of existing monitoring programs, the gaps that need to be addressed and the funds needed to provide an adequate Pacific Northwest monitoring structure.

The following figure (Figure 3) attempts to explain how these products will complement each other.

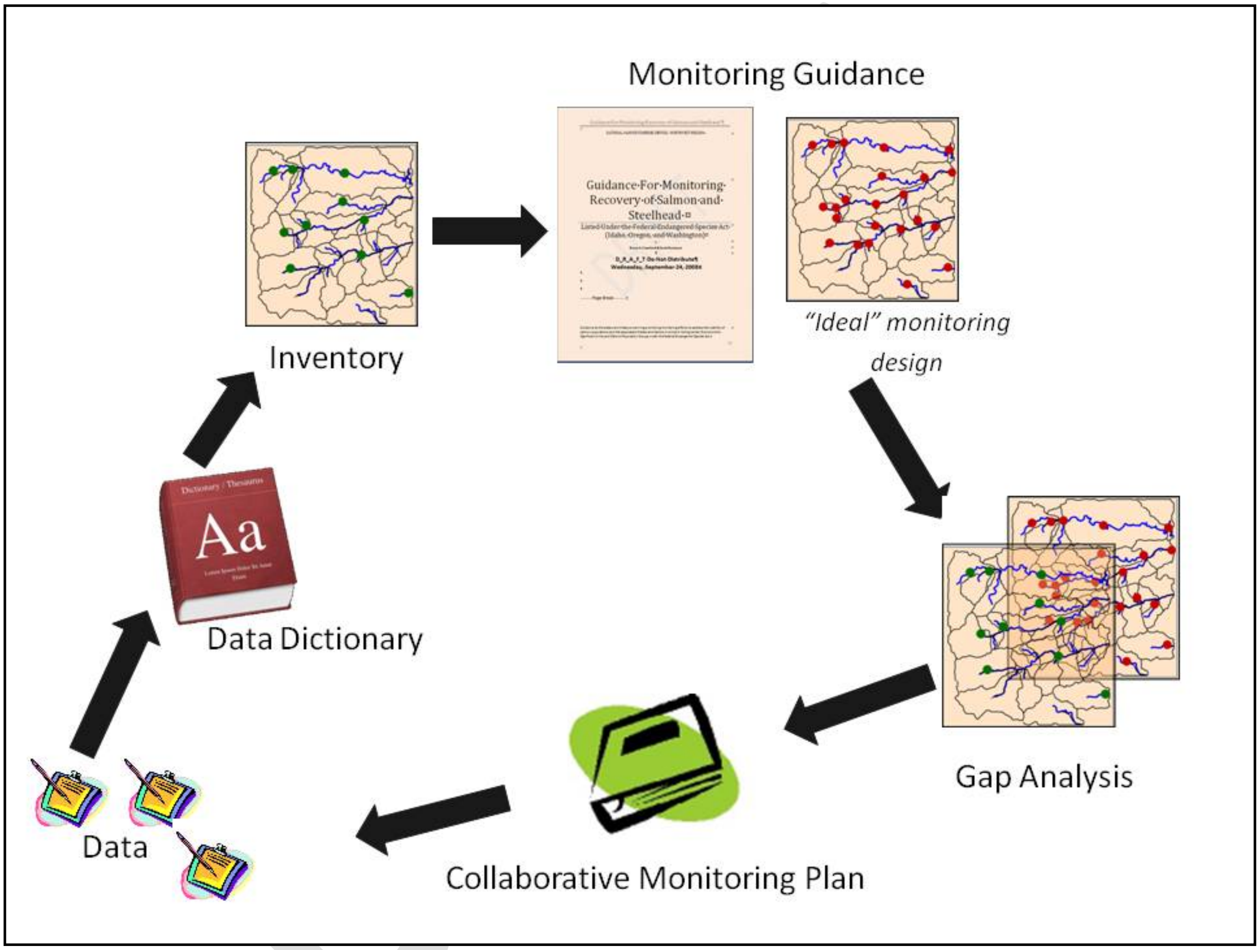


Figure 3. NOAA Fisheries Service Regional Monitoring Guidance and Structure

Key monitoring questions related to the status reviews are shown in Table 1 below along with the related NOAA evaluation question. As can be seen, these are hierarchical questions beginning with each identified population within a major population group (MPG), then an evaluation of each MPG, and finally an evaluation of the entire ESU/DPS.

Under the listing factors and threats status review, it is important to determine for each factor, whether there is sufficient information about the status of the listing factor and its future state. Sufficient data should be available to provide those determinations.

Table 1. VSP viability assessment monitoring questions and NOAA status assessments.

	Population Level Viability Analysis	Major Population Group Level Viability Analysis	ESU or DPS Level Viability Analysis
Key Monitoring Questions	What is the overall status/trend of VSP criteria for each population within each MPG?	What is the overall status/trend of VSP criteria for the MPG?	What is the overall status/trend of VSP criteria for the ESU/DPS?
Key NOAA Evaluations (NOAA Fisheries Service , May 2007)	• What is the abundance/productivity status of the populations based on viability curves or natural origin fish return ratio? • What is the status of spatial structure of the population? • What is the current state, and change in state, of measures of population diversity across each ESU?	• Is the number of populations within the MPG at high viability/low risk consistent with TRT recommended ESU viability criteria? • Do at least one-half of the populations historically within the MPG meet viability standards • Does at least one population within the MPG meet “highly viable” criteria?	• Are all MPGs within the ESU at, or clearly trending toward a low risk status?

3.0 WHAT DATA COLLECTION EVALUATION AND REPORTING PROCESSES NEED TO OCCUR?

3.1 Data Collection

NOAA Fisheries Service does not have the staff or the mandate to collect and maintain most of the information needed for status reviews and listing determinations. The management of salmon and steelhead is a shared responsibility delegated to the states and co-managed under various federal tribal treaties. NOAA Fisheries Service must, therefore depend upon the state fish and wildlife agencies and tribes for much of the information collected for VSP criteria and evaluation of threats. However, each TRT (to varying degrees of specificity) has identified metrics or data types (raw and derived) for use in evaluating status against their criteria. There are a lot of common elements, some specific to particular settings. Likewise for many of the threats and listing factors, local governments, state agencies and others collect and maintain much of the pertinent information. Therefore NOAA and all recovery partners need:

- Access to data that can demonstrate the viability status/trends of listed fish populations and their associated MPGs and ESUs.
- Access to data that can demonstrate whether management actions that address the threats have been implemented.
- Access to data that demonstrates whether the management actions have been effective in reducing or eliminating the threats.

<u>NOAA Recommendation 1: The regional environmental databases should be coordinated such that a common set of metadata and common data dictionaries are used to track information so that it can be readily reported to NOAA Fisheries Service and shared among the participants.</u>

Appendix 2 contains the VSP Abundance and Productivity Data Dictionary proposed by NOAA Fisheries Service for regional adoption through the NWEIS as a first step in beginning to implement Recommendation 1.

Work is underway to input all juvenile migrant information for the Puget Sound and coast into the USEPA sponsored Northwest Data Exchange Network. This platform, if successful, should be expanded to include the Columbia River Basin and include adult spawner information as well.

3.2 Data Evaluation

NOAA needs to know how summarized data used in status determinations are derived to ensure that the derived information is repeatable and transparent. Methodologies generated by experts (usually associated with state agencies or tribes) should be documented, transparent, and consistent from year to year. For example, the Interior Columbia TRT status review of the South Fork Salmon Chinook population required input from Idaho Department of Fish and Game (IDFG) scientists, regional hatchery managers and Nez Perce Tribe scientists to translate from raw data spawning ground surveys and weir counts (raw data) into population level statistics (abundance, productivity, hatchery/wild ratios, age structure, distribution across areas in pop etc. derived data). It is important to document how this was done, the assumptions used, and the calculations involved.

NOAA Recommendation 2: The natural resource agencies and tribes should develop automated internal infrastructure to assess and evaluate their data such that all methods and calculations are transparent and repeatable to all interested parties.

Currently much of the VSP salmon and steelhead data exists in various computers at various locations with little or no metadata available to support the data. Roll up reports require contacting numerous field staff to interpret and provide the data. Methods of calculating spawner abundances and other field protocols are not documented. This has led to inconsistent interpretation of data sets. This infrastructure is more than putting raw data into a computer. Some level of synthesis by technical experts familiar with the particular system is needed. Procedures used in developing the reporting statistics of previous reviews should be defined and the desired applications needed should be identified as metadata. In some cases additional funding will be required to make this happen within desired timelines. Now is the time to create new reporting systems that will be timely and user friendly to the public.

The mark of good science is that the data from a scientific study (e.g. spawner surveys, harvest estimates, juvenile estimates) can be used by other scientists to repeat the evaluation, and that the same results should be produced.

3.3 Data Reporting

NOAA Fisheries Service will use Five Year Status Reviews, the ESA Biennial Report to Congress, the Pacific Coastal Salmon Recovery Fund Report to Congress and other mechanisms reporting progress in implementing recovery plans, providing assessments of status and trends, and reporting progress in reversing limiting factors and threats. These reports rely on accurate data obtained from many collaborative sources.

The PCSRF has been a crucial source of funding for salmon recovery in the PNW. It has also served as the main reporting mechanism to Congress and the President for maintaining support for Pacific Northwest salmon recovery. It has a highly developed habitat project tracking system that can report implementation information for habitat restoration actions, hatchery marking programs, and other specific project information funded by PCSRF. The accountability information entered into this database is provided by state and tribal governments along the Pacific coast and is the backbone of habitat implementation monitoring. This database is being modified to also address effectiveness monitoring associated with habitat recovery, and may also include in the future information about management actions underway to address other threats under the ESA.

NOAA Recommendation 3: All recovery entities should strive to have the elements of the PCSRF database dictionary within their databases and or/ adequate data mapping to be able to provide data to the database when NOAA is conducting a status review.

Restoration actions are being implemented and actions are being tracked through the PCSRF database, Bonneville Power Administration (BPA) PISCES database and other state and local funds and databases. These have been reported through the NOAA PCSRF database and the NOAA Fisheries Service report to Congress. Restoration actions are also reported through the Washington Governor's Salmon Recovery Office "*State of Salmon Report"*, the Oregon Watershed Enhancement Board's "Oregon Plan for Salmon and Watersheds Biennial Report" and the Columbia Basin Fish and Wildlife Authority's *"Status of Fish and Wildlife Resources"*

In keeping with the common need for shared data, we encourage the development of regional distributed data sharing systems using nodes that can provide access to each of the types of data that address the threats and VSP factors. Substantial work has been done in the past to try to address data needs. Most recently the Northwest agencies and some tribes have convened the Norwest Environmental Information Summit (NWEIS) to address sharing information in the region (Idaho, Oregon, and Washington). The 2003 findings and recommendations of the consulting firm Science Applications International Corporation (SAIC) to the Northwest Power and Conservation Council and NOAA Fisheries Service clearly pointed to the regional data needs in the following bullets.

- Currently, Information system development in the Columbia Basin and Puget Sound is, for the most part, ad-hoc.
- As different agencies and tribes, institutions or projects need to manage information they mostly go about it independently, creating for example, their own databases, collection methods and reports.
- While there have been some efforts at consolidation or standardization (CBSIS, NED) they have not succeeded across the Columbia basin and the region as a whole.
- These individual information systems are called disparate systems because they often don't share the same operating system or language, don't collect data of uniform quality or description and usually cannot "talk" directly to each other[1].
- Unless regional executives agree on common approaches to managing raw and processed information, and other approaches that benefit all users, the integration and sharing goals of the region cannot be realized and "business as usual" will remain the norm.

[1] Columbia Basin Cooperative Information System. 2003. Power Point Presentation to the Northwest Power and conservation Council May 7, 2003.

Figure 4 illustrates the dilemma of data management in terms of a pyramid with a broad base and a narrow top. At the bottom of the pyramid, a relatively few number of scientists collect and evaluate a broad based amount of information about specific sites, metrics, and temporal variation. As this information is synthesized and summarized it becomes usable to managers, modelers, and technical staff. Finally, as many metrics are combined they become useful as high-level indicators. High-level indicators generally provide status and trends of the resource that can be understood by the public and that informs congress and senior executives. Higher level indicators cannot be measured without combining and distilling the proper information from the bottom of the pyramid. The proper information at the bottom of the pyramid cannot be collected and funded until senior executives and the public decide what questions at the top of the pyramid need to be answered, how confident they need to be with their answer, what data will answer the question, and how much it will cost. These questions should be identified in the M&E plan and they should be consistent with public reports. The challenge in creating a properly functioning data pyramid is to build one that will answer questions at all scales as one ascends the pyramid.

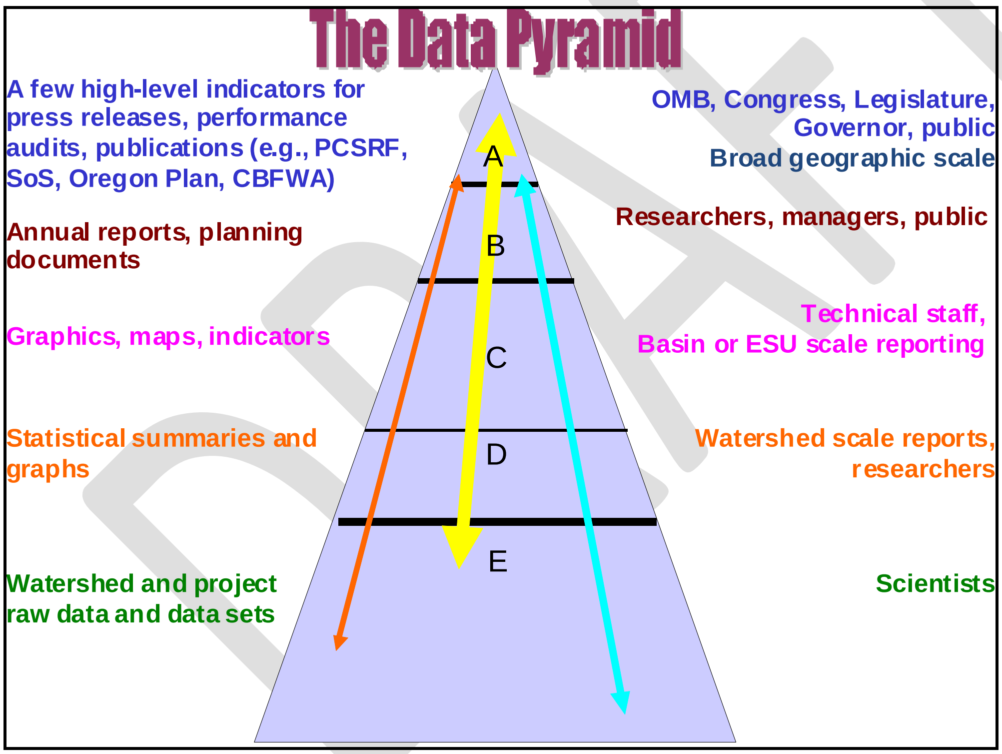


Figure 4. The data pyramid.

The regional executives are taking the following steps to move toward these goals:

1. Integrate information management with regional goals and performance measures. The Executive Summit is approaching this task through its High Level Indicators Work Group. Their goal is to cut across and integrate individual agency mandates and missions to attempt to standardize as much as possible the top of the pyramid.

2. Collaboratively establish a regional implementation and monitoring strategy. This is ongoing through the Columbia River Biological Opinion, state strategies, and NOAA Fisheries Service ESA monitoring needs.
3. Develop and adopt regional information management protocols, data dictionaries, and field protocols so that data are capable of being combined and summarized across jurisdictions and state boundaries. This is being pursued through the Pacific Northwest Aquatic Monitoring Partnership (PNAMP) and other forums.
4. Ensure long term support and commitments through adequate funding.
5. Move toward a system of databases housed at various agencies and tribes that can share data readily through a node or portal. This will require establishing agreed to protocols, data dictionaries and guidelines in order to be able to be part of the regional node.

NOAA Recommendation 4: The regional salmon recovery partners should build a distributed data systems that can communicate between the various agencies and tribes involved in natural resources and report to the public progress in salmon recovery.

An example of a shared distributed database system is the Pacific Northwest Data Exchange Network developed jointly by the US EPA, Washington Department of Ecology, Oregon Department of Environmental Quality, Idaho Department of Environmental Quality and other participants. At present, the Northwest Indian Fisheries Commission (NWIFC) is entering water quality information into the system and a new contract is underway that will put Puget Sound juvenile migrant salmon and steelhead information into the system from the NWIFC and the Washington Department of Fish and Wildlife.

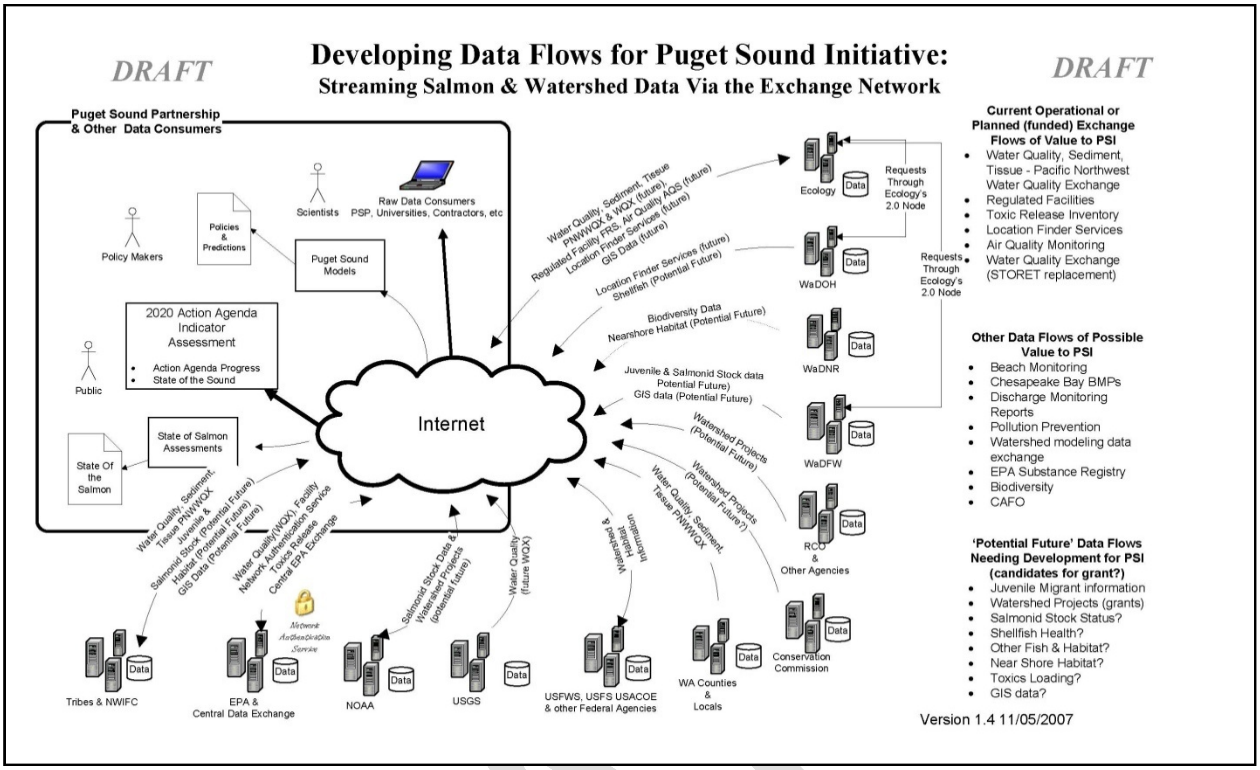


Figure 5. Puget Sound Partnership Data Sharing Conceptual Model. (Courtesy of John Tooley Washington Department of Ecology).

A similar system could be developed for Columbia River fish and habitat data. Figure 5 demonstrates how such a system can benefit all participating agencies and tribes and the public in sharing information.

The Bonneville Power Administration, various ESU recovery regions, and others have implemented computer databases designed to track the implementation of their portion of recovery plans. These are important steps toward documentation of recovery plan implementation.

3.4 Use a Master Sample Design To Integrate Stream Monitoring Programs

One of the objections to implementing new monitoring of fish, habitat, or water quality is based upon the fact that many agencies and tribes have been monitoring fish, habitat, and water quality conditions for a number of years using their own reasons for sampling either daily, weekly, or within some often un-stratified approach. Many of these obstacles can be overcome if a master sample draw is developed for each state and ongoing or subsequent sampling programs at whatever scale of interest are nested within the master draw. See (Larsen, et al., 2008). A number of examples of how this can work are available, including Oregon coastal coho evaluations, PNAMP is currently facilitating such a process in the Lower Columbia River for the Lower Columbiia River ESUs for coho and chinook between Oregon and Washington salmon recovery partners.

NOAA Recommendation 5: The agencies and tribes sampling habitat, water quality, and fish VSP criteria should coordinate their sampling programs to fit within an integrated master sample program for the domain or tri-state region.

Following description is taken from the PNAMP White Paper. "An integrated status and trend monitoring program based on a master sample will help to establish monitoring programs that will meet multiple monitoring objectives. These objectives include general baseline status and trend monitoring; more extensive index status and trend monitoring; project effectiveness monitoring; or intensive monitoring programs like IMWs for validation monitoring to evaluate recovery strategies. The ability to share information will be improved because the use of a master sample will facilitate a statistically rigorous and integrated monitoring design framework. When combined in a web accessible system with documentation (metadata) of the indicators and protocols used to collect the data, local and regional entities will have a powerful resource for coordination and integration of monitoring information."

4.0 WHAT ARE THE MOST IMPORTANT ITEMS TO MONITOR?

4.1 Three Levels of Monitoring

Status and trend monitoring assesses changes in the condition of a metric important for tracking progress in a population or listing factor. It is the main monitoring necessary to determine the biological condition of the species and the status of specific statutory listing factors and threats.

Implementation (compliance) monitoring is used to evaluate whether elements of the recovery plan have been implemented and whether activities are in compliance with sections of the ESA.

Effectiveness monitoring tests whether management actions have been effective in creating the intended outputs of the management action at the project scale; and they validate that the management action or cumulative management actions resulted in the intended outcome. This monitoring maintains accountability for management decisions and provides the basis for adaptive management decisions and actions. For example a project to restore riparian habitat by planting trees can be monitored to determine whether it was implemented according to specifications; it can be monitored to determine whether the tree plantings were effective in creating shade for the stream and improving stream bank stability; and the hypothesis can be validated by monitoring whether the shading of the stream resulted in the intended outcome of lower stream temperatures.

4.2 Monitoring Priorities

Table 2 attempts to show what will be most important for state, tribal, and local governments to monitor for NOAA Fisheries Service to determine recovery. Those components having the highest priority would be most important for developing additional/new accurate monitoring programs and distributing limited funding. Those VSP elements and threats most likely to express actual fish viability were ranked highest

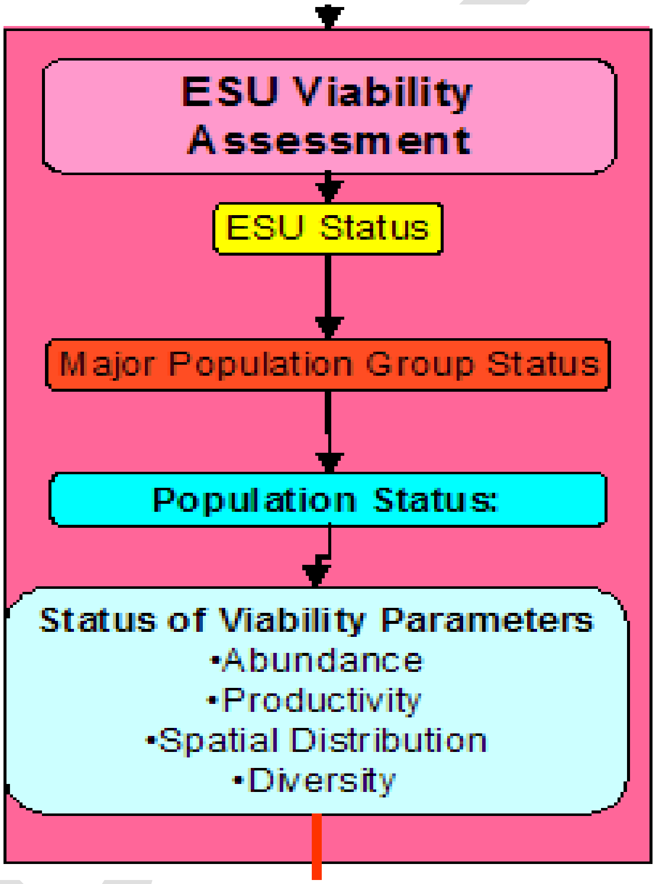
Table 2. NOAA recommended monitoring priorities

Criteria	Monitoring Priority[2]	Confounding Effects or Sources of Error	Comments
VSP CRITERIA			
VSP Adult Abundance (specific evaluation of spawners in natural production areas)	Highest	• Unidentified hatchery spawners • Estimation methods • Inaccurate harvest or abundance estimates • Conversion and confusion between spawners and escapement • Estimates without accuracy and precision • Exclusion or inclusion of jacks • Confusion about conversion of escapement to spawners	• It must be recognized that tracking spawning populations is at the heart of VSP criteria. Measurements at other levels (e.g., run to the Columbia River, total natural production) may also contribute to assessments. • Measuring adult abundance for the populations within the ESU could be sufficient to determine recovery but may take a considerable number of years to be confident that the listing factors are apparently no longer threats to the continued existence of the species.
VSP Juvenile Abundance	Very High	• Trapping efficiencies • Migrating hatchery releases • Rainbow – steelhead interfaces • Supplementation programs • Variable age at migration	• Juvenile migrant abundance estimates are critical in order to estimate freshwater production and survival. • Juvenile parr estimates provide spatial distribution and correlate habitat quality to fish abundance.
VSP Productivity	Very High	• Juvenile and adult supplementation • Hatchery spawners • Hatchery density dependent impacts in the estuary and marine environment • Age class structure	• Productivity is only accurate if the estimates of adult abundance and (where employed) juvenile abundance are accurate. As used by the TRT, productivity is defined in terms of spawner to spawner ratios, juvenile info is valuable where available, but it is not available for many populations.
VSP Spatial Distribution	High	• Lack of a periodic census or valid spatially balanced sampling program • Low abundance can lead to risky conclusions regarding spatial structure.	• Spatial distribution tends to be a collection of one time site records developed over time.
VSP Diversity	High	• Inadequate baseline information for phenotype and genotype diversity • Hatchery effects • Harvest effects • Changes to habitat	• Many diversity traits can be tracked through harvest sampling and spawner surveys. • The region needs some standardization for appropriate reference conditions for phenotype and genotype diversity.

[2] Monitoring priorities for state, tribal, and local governments

Criteria	Monitoring Priority[2]	Confounding Effects or Sources of Error	Comments
LISTING FACTORS AND THREATS			
Threats Due to Curtailment or Destruction of Habitat or Range	High	• Lack of Adequate habitat sampling program. Need to know the status/trends of multiple key habitat attributes. • Only tracking the number of restoration projects completed does not necessarily indicate net improvement in salmon habitat	• The loss of freshwater and estuarine habitat is of major importance in the decline of salmon and steelhead. Quantifying status/trends of habitat conditions continues to be underfunded and sparsely applied
Threats Due to Hydropower	High	• Numerous licenses and consultations with differing standards	• Hydropower is a major source of mortality and loss of range in some watersheds
Threats Due to Overutilization (Harvest)	Very High	• Poor stock identification techniques for naturally produced adults in the fisheries including lack of GSI measurements • Unmarked hatchery adults in the fisheries • Unknown compliance with harvest regulations (unaccounted losses) • Assumptions regarding long term survival of marked fish	• Although harvest is considered a threat, it is integral to calculating productivity and potential spawner abundance. • Since it is probably the threat that can be controlled to the greatest extent, estimating accurately its impact to recovery is crucial.
Threats due to Hatcheries	High	• Lack of spawning ground survey data on hatchery straying into natural production areas • Lack of GSI measurements • Lack of marking of all hatchery fish • Competition	• It will probably not be feasible to determine the effectiveness of hatchery management plans in all locations, but specific studies will be needed.
Threats due to Predation and Disease	Medium	• Actual salmon mortality due to predators is not well documented • Hatchery contributions to disease	
Threats due to Regulatory Actions	Medium	• Unknown compliance with zoning and other land use regulations	• An audit of state and local land use and environmental laws and regulations should be completed periodically to test for effectiveness.
Threat due to Climate and other Conditions	Low	• Spatial and temporal patterns difficult to discern	• This factor is already monitored by the NWFSC and universities, with several models in development. • Marine survival of salmon and steelhead is a direct measure of ocean and climate conditions and is essential for determining viability of salmon. • More focused information is needed at the ESU/DPS scale

5.0 WHAT MONITORING DOES NOAA RECOMMEND TO DEMONSTRATE ESU/DPS VIABILITY?



5.1 VSP Assessment

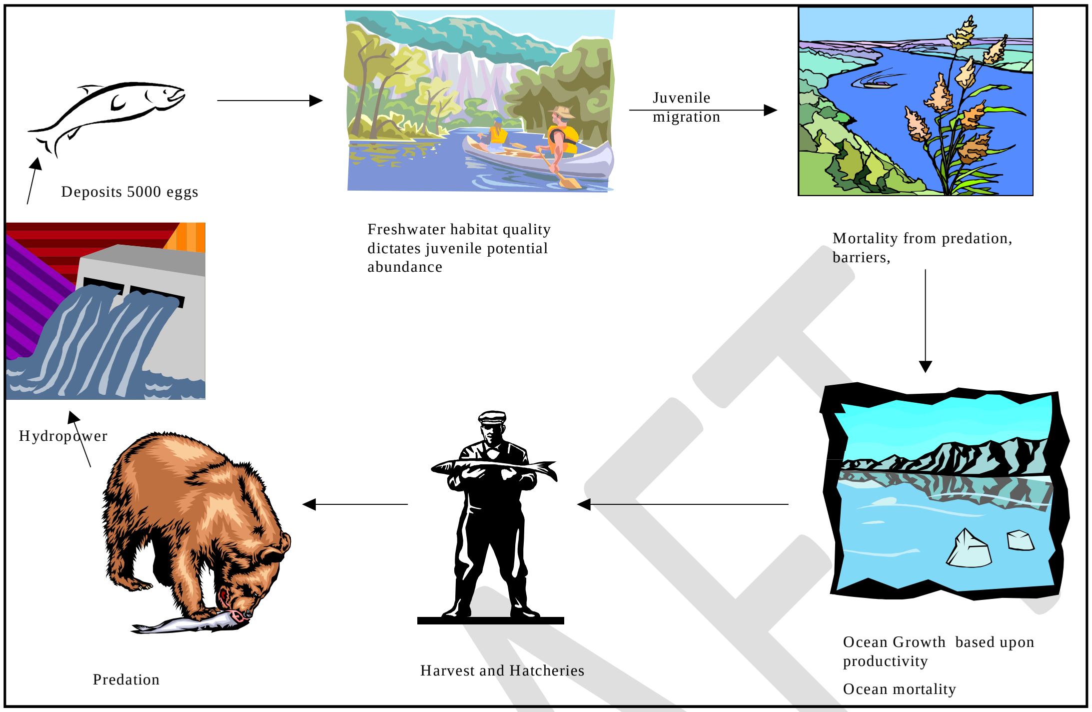


Figure 6. Schematic life history of a salmon showing some threats to recovery. (Taken from the Washington CMS, 2002).

The life history of salmon is familiar to most of those who work in salmon recovery. The adult salmon digs a nest in the gravel of the stream and deposits somewhere between 2500 and 5000 eggs. The eggs hatch and stay in the gravel until the egg sack is absorbed and the fry swim up into the stream. Species such as pink and chum salmon spend only a short time in the stream before moving into the marine environment. The Chinook and coho salmon usually spend about a year in freshwater while the steelhead and the sockeye can spend from two to four years in freshwater. During this time they are known as parr and are subject to mortalities associated with the quality of their habitat and various manmade activities. At the end of their stay in freshwater, they migrate to the sea as smolts. While in the sea salmon migrate along the coastline feeding and growing until they mature and return to their stream of origin. Steelhead may migrate as far as the coast of Japan. During their time in the marine environment they are subjected to fishing mortality and predation. During their migration upstream they are again subjected to fishing mortality and predation as well as other mortalities associated with mankind such as hydroelectric dams, chemicals, and other impacts.

The two large habitat components of anadromous salmon are the freshwater environment and the marine environment. Four scenarios can be painted for how these two environments work together:

1. **Scenario 1 Freshwater survival is low and marine survival is high**. When the freshwater habitat is degraded or climate variations affect freshwater survival, then few smolts survive to migrate to the sea. However, when they reach the sea they encounter abundant food and predators are few.

Those that survive return to their stream often as somewhat larger adults, but probably as a moderately abundant run. These conditions often mask a number of years of declining freshwater habitat conditions. Robust marine survival has been linked to cooler sea surface temperatures and strong coastal upwelling leading to abundant plankton and occurs in 20 year cycles.

2. **Scenario 2 Freshwater survival is high and marine survival is low**. The freshwater habitat produces abundant migrants in good condition who pass downstream to the estuary and ocean where they encounter low numbers of food organisms and numerous predators. Many juveniles are eaten and those that survive are under stress from low food abundance and slower growth than normal. Under these conditions, a potentially strong run returns well below predicted levels and the results may persist for a number of years as a weak year class. This scenario has occurred often in the past 20 years as part of El Nino effects.
3. **Scenario 3 Freshwater survival is high and marine survival is high**. This occurs periodically when conditions are good both in the freshwater and marine environment and often leads to major surpluses that can be utilized as harvest. The boom years often lead to overharvest scenarios in later years as managers may not detect changing conditions immediately.
4. **Scenario 4 Freshwater survival is low and marine survival is low**. This can occur when El Nino events or Pacific Oscillations cause reductions in marine survival and long term degradation of habitat has reduced freshwater production significantly during previous years of good marine survival. This can lead to disastrously low returns of fish below replacement level and can lead to listings under the Endangered Species Act. This occurred during the 1990s for many Pacific Northwest stocks.

The above life history and mortality of a salmon can be more formally represented in a simple formula that reflects the overall complexity of addressing the factors limiting salmon abundance. The basic formula is as follows:

$$SP = R - HAB_F - HYDRO_J - PRED_J - HARV_j - HAB_M - HARV_M - HARV_F - HYDRO_A - PRED_A - HOF$$

where

SP =	the number of adults returning to their river of origin to spawn.
R =	the total number of potential spawner recruits;
HAB_F=	Freshwater natural mortality due to freshwater habitat limiting factors
$HYDRO_J$ =	Mortality to juvenile migrants due to hydropower
$PRED_J$=	Freshwater Mortality to juveniles migrants due to predation
HAB_M=	Marine mortality associated with the ocean conditions that affect food and predation such as El Nino events, Pacific gyre oscillations, Etc.
$HARV_M$=	Harvest of natural stocks associated with coastal fisheries from Alaska to California
$HARV_F$=	Harvest of natural stocks associated with terminal fisheries and in river fisheries.
$HYDRO_A$=	Mortality to adults due to hydropower effects upon upstream migrants
$PRED_A$=	Freshwater and estuarine predation mortality to upstream migrating adults
HOF=	Hatchery origin fish that cannot be counted as natural spawners in determining productivity and total natural adult spawners

As can be surmised from the above simplified formula, calculating salmon abundance and mortality is a complicated task. Determining the cause of decline for a population and the effects of corrective actions with so many variables is also very difficult. Also, not all populations are affected equally by these mortality factors.

Some listing factors and threats act directly upon listed populations and can be quantified. These include: harvest mortalities, hydropower mortalities, and certain specific predation mortalities that can be documented and are essential in reconstructing run size information and cohort analysis. In order to determine viability portions of the formula can be parsed out, combined, or ignored if the information is not available.

Other statutory listing factors and threats to sustainability such as quality of freshwater and marine habitat, large scale climate effects, disease, hatchery effects, and regulatory actions are difficult to quantify and may act indirectly on one or more factors for decline.

Definition of a Viable Salmonid Population (McElhany et al. 2000):
NOAA Fisheries Service will be evaluating each ESU in a manner that takes all four VSP criteria into consideration. A viable Salmonid population is defined as "an independent population of any Pacific salmonid (genus Oncorhynchus) that has a negligible risk of extinction due to threats from demographic *variation, local environmental variation, and genetic diversity changes over a 100-year time frame. An independent population is defined as any collection of one or more local breeding units whose population dynamics or extinction risk over a 100-year time period are not substantially altered by exchanges of individuals with other populations. In other words, if one independent population were to go extinct, it would not have much impact on the 100-year extinction risk experienced by other independent populations. Independent populations are likely to be smaller than a whole ESU".*

"There may be structure above the level of a population as well as below it. This is explicitly recognized in the ESU designations: an ESU may contain multiple populations connected by some small degree of migration. Thus organisms can be grouped in a hierarchic system wherein we define the levels of individual, subpopulation, population, ESU and, finally, species. Other hierarchic systems made up of more or fewer levels could be constructed. All of the TRT viability criteria recognize that populations are an element in a hierarchy). Therefore all of the TRTs have recommended MPG/ESU level criteria that encourage low risk populations across the landscape within an ESU, protecting a range of diversity, providing for something akin to historical levels of exchange

Table 3 below shows the relationship between monitoring category, monitoring effort, and relative risk of having insufficient data for delisting decisions. Break points and criteria are the results of combining various TRT viability documents, Columbia Basin Fish and Wildlife Authority's (CBFWA) Collaborative System-wide Monitoring and Evaluation Project (CSMEP) modeling, and other attempts to determine how much monitoring is needed to reduce risks.

NOAA Fisheries Service created regional TRTs to develop viability criteria for ESUs within their area. This has led to certain differences in the approach to viability and to monitoring needs. Busch et al (2008) has described these differences. Table 4 is adapted from Busch et al and describes the similarities and differences in the Northwest Region (Idaho, Oregon, and Washington) TRT criteria.

Table 3. Relative risk analysis of having insufficient information for ESA status determinations

	Low Risk of Insufficient Data	Moderate Risk of Insufficient Data	High Risk of Insufficient Data
Adult Abundance	• Collecting abundance data in 75% or more of populations within each MPG in the ESU/DPS • Data collected using unbiased sample design with known precision	• Data collected at 50% or more of populations but less than 75% within each MPG in the ESU/DPS. • Data collected using unbiased sample design with known precision	• Data collected on less than 50% of the populations within the MPGs of the ESU/DPS • Data collected using a biased sample design with no estimates of precision
Juvenile Migrant Abundance	• Collecting juvenile migrant abundance data in the same populations where adult abundance is taken for at least one population in each MPG • Juvenile out-migrant abundance measured near the mouth of the streams in which adult abundance is measured • Precision goals and power to detect change standard is met	• Collecting juvenile migrant abundance data in the same populations where adult abundance is taken within the ESU • Juvenile out migrant abundance measured using probabilistic sampling of pre-migrant parr • Precision goals and power to detect change is met	• Collecting juvenile out-migrant data for some locations but not necessarily related to a strategy for selecting primary populations for each MPG. • No estimates available for precision or power to detect change
Spatial Distribution	• Specific spawner abundance estimates in known spawning areas. • Active probabilistic sampling occurring within the ESU to document changes in adult or juvenile fish distribution combined with • Documentation of fish passage blockages removed • Spawner surveys or redd counts that document extent of adult abundance distribution above former blockages.	• Documentation of fish passage blockages removed • Spawner surveys or red counts documenting extent of adult abundance distribution above former blockages. • Specific spawner abundance estimates in known spawning areas.	• Documentation of fish passage blockages removed • Documentation of the presence of any salmonid life stage
Species Diversity	• Annual documentation of age distribution, sex ratio, length, fecundity, weight, run timing, and spawn timing for each population. • Periodic documentation of and genetic diversity by population	• Periodic documentation of age distribution, sex ratio, length, fecundity, weight, run timing, spawn timing and genetic diversity by **MPG**	• Periodic documentation of genetic diversity, length, weight, run timing, and spawn timing by ESU

Table 4. Population metrics used by each TRT to assess viability in the Northwest Region (adapted from Busch et al. 2008).

TRT	Abundance	Productivity	Spatial Structure	Diversity
Puget Sound Chinook	• Population Size • Density	• Productivity Model • Other metrics	• Arrangement of Spawning Areas • Connectivity	• Genotype/phenotype
Puget Sound Chum	• Population Size	• Productivity Model • Other metrics	• Spawning areas or density • Arrangement of Spawning Areas • Connectivity • Range • Ecoregions • Impact of catastrophes	• Effective Population Size • Genotype/ phenotype
Willamette-Lower Columbia	• Population Size	• Productivity Model	• Habitat Quality • Range • Impact of catastrophe	• Effective Population Size • Genotype/ phenotype
Oregon Coast	• Population Size • Density	• Productivity Model • Other metrics	• Spawning areas or density • Quality of habitat • Impact of catastrophes	• Effective Population Size • anthropogenic effects
Interior Columbia	• Population Size	• Productivity Model	• Spawning areas or density • Arrangement of Spawning Areas • Connectivity • Range • Ecoregions	• anthropogenic effects • Genotype/ phenotype

5.2 What Does NOAA Recommend For Monitoring VSP Adult Spawner Abundance?

In order to address the status of naturally produced adult abundance for populations, a number of monitoring questions (Table 5) are of interest at the three scales, population, MPG, and ESU/DPS.

Adult natural abundance is estimated from the number of spawners observed and then adjusted for the number of hatchery fish co-spawning with the natural spawners. Cohorts are calculated from the age structure of the run usually taken from either fishery information or dam counts where fish age can be ascertained. Total cohort reconstruction cannot be completed until all age classes have returned from the sea and this usually requires three or four years. Fisheries conducted along the coasts all contribute to mortalities that should be quantified.

Table 5. Key population abundance status/trend monitoring questions and NOAA determinations.

	Population Level Adult Abundance	Major Population Group Level Adult Abundance	ESU or DPS Level Adult Abundance
Key Monitoring Questions	1. What is the status/trend of **natural origin adult spawners** for the primary populations within each MPG? 2. What is the proportion of **hatchery origin fish** on the spawning grounds for each population within the MPG? 3. What is the age structure and **cohort structure** for each population? 4. What are the **harvest mortalities** of fisheries conducted throughout its range? 5. If this population is supplemented, what is the viability of the population with and without supplementation?	1. What is the status/trend of each MPG? 2. What is the proportion of hatchery fish on the spawning grounds for each MPG? 3. Can the MPG be identified in the fisheries and throughout its range in order to determine harvest mortalities 4. If one or more populations within the MPG are supplemented, what is the viability of the MPG with and without supplementation?	1. What is the status/trend of each ESU/DPS? 2. What is the proportion of hatchery fish on the spawning grounds for each ESU/DPS? 3. Can the ESU be identified in the fisheries and throughout its range in order to determine harvest mortalities 4. If one or more populations within the ESU/DPS are supplemented, what is the viability of the ESU with and without supplementation?
Key NOAA Evaluations	1. Determine whether the populations monitored have exceeded the minimum criteria established in the recovery plan for meeting long term ESU viability. 2. Determine the change in status for each population with information at the time of listing.	1. Is the number of populations within the MPG at high viability/low risk consistent with recommended ESU viability criteria? 2. Do at least one-half of the populations historically within the MPG meet viability standards 3. Does at least one population within the MPG meet "highly viable" criteria?	1. Determine the change in status for each ESU with information at the time of listing. 2. Determine whether the ESU/DPS has met the TRT minimum requirements for long term viability.

Ideally NOAA Fisheries Service would like to have annual adult abundance data for all populations. However, this may not be possible initially for a variety of reasons including cost, river conditions, spawn timing, access, etc. The following are key points that will be taken into consideration in evaluating adult abundance: monitoring design, hatchery contributions, and quality control.

There is often confusion among recovery partners in how escapement and spawner abundance is used. Escapement may be measured via fish passing through a known counting point such as a dam or weir, but does not necessarily equate to spawner abundance depending upon how far way the spawning areas are from the counting point and how long until spawning. This distinction is often not made clear and estimates of pre-spawning mortality due to predation, temperature, terminal area fisheries are sometimes not included in the calculations of spawner abundance where escapement and spawner abundance are considered the same.

5.2.1 Monitoring Design Considerations

Does the ESU/DPS have an adequate monitoring design approach? The following table (Table 6) is based upon work completed by CSMEP for the Snake River basin and shows how different designs can affect the outcome in terms of cost and accuracy of data.

Table 6. Analysis of optional designs for monitoring populations within MPGs (Adaptation of CBFWA CSMEP[3])

MPG Status Monitoring Design and Strategy	Pros and Cons
Design 1: Data from populations within the MPG having data at the time of listing are sampled so that they have data at the time that a five year review is conducted to be able to compare before and after progress.	1. If the data were not accurate or had known flaws this may not be adequate. 2. Populations with no data at the time of listing are excluded from the analysis.
Design 2: Sample all populations within the MPG with even effort. An estimate of population abundance is calculated for each one.	1. Sources of error are within each population 2. Costs are maximized 3. Accuracy for smaller populations may be greater than for larger populations
Design 3: Sample a few populations more intensively than when listed and use this better monitoring data to make inferences to the rest of the MPG	1. Accuracy may be greater for those populations sampled 2. Costs may be equal to or less than previous monitoring. 3. Error is within each population and in the inferences derived for the other populations
Design 4: Place most of the effort on populations that are targeted for recovery and/or are representative of sets of populations.	1. Will provide more accurate information about the greatest percentage of the population in terms of numbers of fish and importance to recovery. 2. Will provide some information about smaller components to address genetic diversity and distribution of the MPG. 3. Costs may be greater than or equal to previous monitoring. 4. Requires assumption that indicator populations are truly representative.
Design 5: Place most of the emphasis on the smaller populations within the MPG	1. May provide a better picture of the overall diversity of the MPG and will be sensitive to declines or improvements in small populations normally not observed. 2. May provide data with no initial comparative information to track changes against 3. Costs may be higher as it may require more intensive monitoring

[3] CSMEP S&T DQO Steps 6 & 7 Nampa 2005 PowerPoint

MPG Status Monitoring Design and Strategy	Pros and Cons
	to detect low populations of spawners and their distribution. 4. Provides little information about greatest percentage of the population in terms of numbers of fish and importance.
Design 6: Completely omit some populations based upon location, difficulty, etc. and make inferences from the other similar sampled populations.	1. May leave holes in the data where it would be difficult to make inferences over time if there were no data to base inferences upon. 2. Requires assumption that indicator populations are truly representative.

5.2.2 Adult Spawner Abundance Sampling Design

NOAA Recommendation 6: Incorporate a robust unbiased adult spawner abundance sampling design that has known precision and certainty.

Estimates of spawner abundance can be made using different methods. Following are methods that can be used. Method 1 and 2 meet NOAA Recommendation 5. Method 3 is commonly used and may need to be continued, but demonstrates a wide range of precision and confidence in the data.

METHOD 1 ESCAPEMENT SAMPLING

In locations where there are weirs, traps, or fish counting stations (video, Didson, etc.) it may be possible to derive an estimate of spawner abundance by adjusting escapement estimates for pre-spawning mortality. Escapement estimates in some cases are a census; however, most often involve mark recapture techniques to account for weir efficiency and expansion for areas downstream of the trapping/counting facility. Escapement estimates generally have associated variance; however, estimates of pre-spawning mortality have no associated variance and are likely biased. In some cases escapement information for all upstream naturally produced spawners can be correlated with GSI information to parse out tributary populations. In some cases it may be possible to count all spawning fish using spawner surveys, carcass counts, or redd counts and produce an estimate based upon known variances in identifying redds, etc.

METHOD 2 PROBABILISTIC SAMPLING

New sampling designs have been incorporated for adult spawners for Oregon coastal and Lower Columbia River coho and for steelhead in the Wenatchee River system. Spawning areas accessible to adults are sampled using unbiased randomized sites with rotating panels. This methodology produces estimates of spawner abundance that are similar to mark recapture methods and produce results that are statistically valid, with known certainty. In many cases this method can also detect changes in spawner distribution when spawner abundances using redd or carcass index areas will not (See Figure 7).

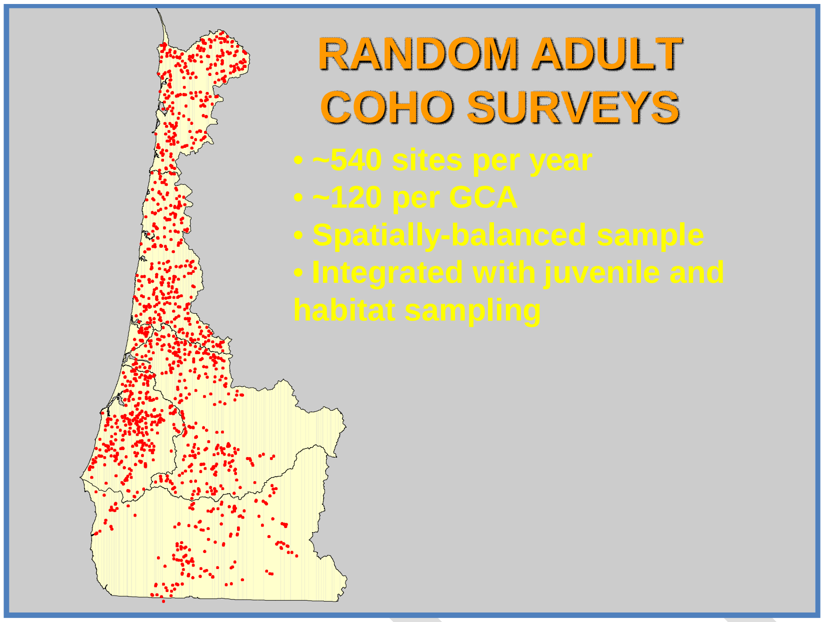


Figure 7. Oregon Coastal Coho ODFW random adult surveys by Gene Conservation Area (GCA) (Courtesy of Steve Jacobs ODFW)

METHOD 3 INDEX AND EXTENSIVE AREA SPAWNER SURVEYS

Index spawner surveys have been used for years to estimate the total number of natural spawners using index areas and then extrapolating to the entire stream. In other cases only a portion of a stream is indexed to detect trends in the population but is not used to estimate total abundance. These surveys either count fish, redds, or carcasses. For those surveys that produce an abundance estimate at some point the entire stream was initially surveyed and a proportion was developed for estimating total abundance from the index sites. Unfortunately, estimates of precision cannot be developed for index spawner surveys because they are biased sample sites (Courbois, 2008). Some index surveys are completed weekly while others may be counted only during the beginning, middle, and peak of the run.

In some cases multiple pass extensive area redd counts are conducted. However, transformation of redd counts into spawner abundance estimates requires fish per redd data which is known to vary.

Because this method is so common, less costly, and can be done with limited personnel, it will continue to provide spawner information in the future. However, wherever possible, index surveys should be periodically recalibrated and verified using probabilistic sampling methods or converted to probabilistic sampling or counting weirs as described earlier. It is NOAA Fisheries intent to encourage transitioning to probabilistic sampling or counting weirs where possible.

5.2.3 Hatchery Contributions

NOAA Recommendation 7: Monitor ratio of marked hatchery origin salmon and steelhead to unmarked natural origin fish in all adult spawner surveys.

The quality of adult abundance information for naturally reared salmon and steelhead is questionable without knowing the contribution of hatchery fish to the spawning grounds. One hundred percent marking of hatchery salmon combined with systematic spawning ground surveys in natural areas and near hatcheries likely to incur hatchery straying will allow for more accurate information. Evaluation of hatchery contributions should be conducted in such a manner as to provide an unbiased sample. Rivers where this cannot be accomplished will have difficulty showing that naturally produced adults are increasing. In those cases where a portion of the hatchery fish are needed for supplementation an internal CWT should be used to insure detection at counting weirs, fisheries, and spawning ground surveys.

5.2.4 Quality Control/Quality Assurance

NOAA Recommendation 8; The agencies and tribes, as a first step to improved data quality, should calculate the average coefficient of variation for all adult NOF spawner databases for ESA populations and provide that information to all interested parties.

The status of adult spawners is the single most important measurement needed for ESA evaluations. The precision and accuracy of adult spawner estimates is, therefore, of major importance when determining whether there has been a change in the number of adult spawners and how much confidence can be placed on the data.

NOAA Recommendation 9: The agencies and tribes should strive to have adult spawner data with a coefficient of variation (CV) on average of 15% or less for all ESA populations.

The use of viability models has been employed to predict extinction risks into the future based upon population variances and productivity. Some evaluations (Paulsen C.M., 2007) indicate that models may not have a strong capability for predicting future risks due to the high natural variability of the populations. The process error associated with the model may be more of a factor in creating erroneous predictions than the measurement errors. Therefore, emphasis should be placed on obtaining strong measurements of annual population status so that the longer term trend can be demonstrated that shows that adult populations are attaining recovery goals.

Carlile et. al. (October 2008) recommended to the PSC that individual estimates of total spawning escapement for a Chinook stock should on average attain an estimated coefficient of variation of 15% or less, and that specific estimates of spawning escapement should be derived with methods that produce unbiased estimates.

It is recognized that this goal may not always be met and that data that do not meet this goal is not necessarily discarded or considered unusable in determining spawner status, but will mean that the data are treated more conservatively in any status evaluation.

NOAA Recommendation 10: Agencies and tribes should conduct a power analysis for each natural population being monitored within an ESU to determine the power of the data to detect a significant change in abundance and to provide that information to all interested parties.

A power analysis should be conducted for each natural population being monitored within an ESU. A power analysis determines the probability of detecting a trend when a trend in fact exists (Zar, 1999). The greater the trend the easier it is to detect and therefore the greater the power. However, a significant trend may not be detectable if there is a high degree of annual variability. As the variance increases, the power to detect change lowers. Increasing the number of years monitored decreases the overall variance as also does increasing the number of populations sampled and pooled. Therefore, the power to detect change can be improved by decreasing the measurement error and/or increasing the number of years or populations evaluated (Monitoring Oversight Committee, 2002).

Paulson and Fisher (Paulsen, 2003) determined that changes of 30% should be detectable for Snake River spring-summer Chinook within 7 years using a BACI experimental design. Bisson, (2008) estimated that to be 80% certain could take 26 years to detect a 50% change in a population. The fishery managers should obtain adult spawner data for specific populations that have the power to be able to detect a change in abundance of ± 30% with 80% certainty within ten years.

The ability of regression analysis to detect trends depends upon the number of years and the unexplained variance associated with the regression. The more unexplained variation, the more years will be required to detect a trend. Reducing the unexplained variation improves the quality of the data, while continuing the analysis over more years increases the quantity of data (Monitoring Oversight Committee, 2002). An optimum strategy will be a compromise between the quality and quantity of the data. Measurement error is how well abundance is measured in any year. Process error is the error built into the assumptions about the statistic and the statistical model used. Because process error cannot be known entirely, the only option is to reduce measurement error by improving sampling methods and by using detailed protocols. If process error is the main source of error, then improved measurements will not improve overall accuracy (Hinrichsen, July 2008) substantially.

The use of transformations to the data may help explain the variation and improve statistical power by removing from the equation those known sources of annual variation. A transformation might be made using known marine mortalities that fluctuate over time or other environmental factor such as flow. For example, It has been shown that there is a high correlation of flow at the time of spawning with overall production of smolts for coho salmon and that this is correlated with how far they can penetrate into tributary streams during the fall migration period.

5.2.5 Fish Abundance Field Sampling Protocols

NOAA Recommendation 11: Agencies and tribes should strive to utilize the protocols published in the American Fisheries Society Field Protocols Handbook whenever possible in order to standardize methodologies across the region in evaluating population abundance.

Although water quality sampling protocols have been standardized for many years, it still remains for fisheries scientists to standardize field approaches to estimating abundance. Recently steps have been taken to begin to provide standard approaches. In keeping with this movement NOAA Fisheries Service encourages the fish recovery partners to coordinate protocols and field methodologies to the extent possible. The Salmonid Field Protocols Handbook (Johnson, 2007) was developed by a varied team of Pacific Northwest biologists representing state, federal, and tribal agencies from Alaska to California. It can be viewed as the beginning of a fisheries standard protocol reference for the future and should be updated and endorsed by the fisheries agencies and tribes in order to take this important step.

5.3 What Does NOAA Recommend For Monitoring VSP Productivity?

Monitoring questions that address productivity can be found in Table 7.

Table 7. Monitoring questions that address population productivity.

	Population Level Productivity (Population growth rate)	Major Population Group Level Productivity (Population growth rate)	ESU or DPS Level Productivity (Population growth rate)	What steps have been taken to address knowledge gaps in natural populations?
Key Monitoring Questions	1. What is the Adult to adult productivity ratio of primary population's natural abundance? 2. What is the smolt to adult ratio of selected primary population's natural abundance? 3. What is the long term trend in productivity for the primary populations? 4. What is the variance about the adult and smolt estimates?	1. What is the proportion of populations within the MPG that are meeting viability standards? 2. What is the smolt to adult ratio within each MPG? 3. What is the long term trend in productivity for the MPG?	1. What is the proportion of populations within the ESU that are meeting viability standards? 2. What is the composite smolt to adult ratio of MPGs within each ESU/DPS?	1. Do current adult spawner estimates and smolt estimates for each population have known variance and confidence limits within the ESU/DPS?
Key NOAA Evaluations	1. Determine the change in adult to adult productivity for each population. 2. Determine the change in smolt to adult productivity for those populations where juvenile abundance is monitored. 3. Determine whether populations monitored have met the TRT productivity goals	1. Determine the change in adult to adult productivity for each MPG with information at the time of listing. 2. Determine the change in smolt to adult productivity for those MPGs where juvenile abundance is monitored. 3. Determine whether the MPGs have met the TRT productivity goals for meeting long term viability.	1. Determine the change in adult to adult productivity for each ESU/DPS with information at the time of listing. 2. Determine the composite change in smolt to adult productivity for those populations within the ESU where juvenile abundance is monitored. 3. Determine whether the ESU has met the TRT	1. Determine whether the variance associated with the estimates are within allowable limits for determining a change of listing status.

	Population Level Productivity (Population growth rate)	Major Population Group Level Productivity (Population growth rate)	ESU or DPS Level Productivity (Population growth rate)	What steps have been taken to address knowledge gaps in natural populations?
	for meeting long term viability.		productivity goals for meeting long term viability.	

5.3.1 Adult to Adult Productivity

Adult to adult productivity is the measure of the viability of natural salmon populations based upon the number of adult fish that returned to spawn from those that spawned who were the parents of the returning fish. A non-listed ESU must be naturally self-sustaining and must be able to persist without input of hatchery-produced fish. Adult to adult ratios are used because it provides the best available information and for many streams it is the only possible measure due to lack of juvenile migrant information. Adult to adult information indicates whether the number of fish returning to spawn are viable, but it does not indicate what may have happened to the recruits between the time they hatched and left the gravel as alevins and when they returned to their river of origin. In order to address low viability it is necessary to trace a population's life history and to determine the factors limiting recovery

Information needed to determine annual productivity for natural origin spawners include:

- Spawners by cohort and origin;
- Sex ratio of spawners
- Percent of spawners of hatchery origin

NOAA Recommendation 12: Agencies and tribes should develop at least 12 brood years of accurate spawner information as derived from cohort analysis in order that NOAA Fisheries can use the geometric mean of recruits per spawner to develop strong productivity estimates.

The geometric mean is not the only method of calculating productivity but is informative and the first step to understanding population viability. Productivity has been calculated using both the recruits per spawner ratio (R/S=1) and developing minimum target escapements that will maintain the population above the quasi extinction threshold assuming that there is somewhat random movement of the response (Brownian Motion). See TRT explanations from Sands et al. (2007) and Cooney et. al.(2007). Another method assumes a density dependent relationship between recruits and spawners and uses a more traditional Beverton Holt model or other model and a fixed fishery exploitation rate to develop the R/S relationship. To develop these relationships total recruitment information is needed. Total recruitment estimates can include the number of adults caught in Canadian and US fisheries, and fish that spawn naturally. Where information is quantified, observed predation and dam losses may also be included. Recruitment is calculated from run reconstruction analyses. It cannot be overemphasized that the estimates of productivity and viability are only as accurate as the spawner information and the harvest information where harvest has been considered. Estimates of growth rate, lambda (λ) has an associated variance (σ^2) about the lambda regression line. This variance is highly influenced by hatchery fish, inaccurate harvest estimates on natural origin spawners and other factors. Hatchery fish count as spawners but not as recruits thus distorting the R/C ratio. It is implicit in this measure of productivity that accurate measures of harvest mortality and in some cases mortality due to predation and hydroelectric facilities are extremely important in determining how the viability would change with and without those threats.

Adult abundance estimates and productivity estimates will ultimately need to be combined and compared to produce appropriate viability curves for each ESU. Viability curves are developed from a population viability analysis. Sets of viability curves can be generated using ESU-specific estimates of age structure and variability in brood year productivity.

5.3.2 Freshwater and Ocean Productivity: Simultaneous Monitoring of Juvenile Migrants and Adult Spawners

In some areas smolt to adult returns (SAR) will be needed to calculate productivity. Incorporating SAR results into population productivity estimates can be a powerful tool in reducing uncertainties due to high variations in marine survivals (Cooney, 2008).

In order to estimate marine survival and freshwater survival juvenile migrant data is necessary. By separating freshwater effects from marine effects limiting factors can be determined with greater accuracy. Specific data needed includes:

- Smolt trap/weir abundance estimates;
- Adult spawner abundance by cohort and origin estimated from fish counts, redd counts, or carcass counts;
- Adult sex ratios taken from carcass counts or females per redd expansions
- Adult harvest estimates for all fisheries

NOAA Recommendation 13: Agencies and tribes should obtain simultaneous estimates of both juvenile migrants and adults for at least one population for each MPG within an ESU or DPS.

a. ***The goal for all populations monitored for juvenile salmon migrants is to have data with a CV on average of 15% or less and steelhead migrant data with a CV on average of 30% or less.***

b. ***A power analysis for each juvenile migrant population being monitored within an ESU should be conducted to determine the power of the data to detect a significant change in abundance and to provide that information to all interested parties.***

These juvenile estimates are normally associated with a screw trap or inclined plane trap located at the mouth of a river or stream where it may capture emigrants from one or more populations. Ideally the trap would collect only one population. Where smolt trapping is used, the researcher should be able to measure trap efficiency and that the trapping is of sufficient duration to encompass at least 90% of the out-migration period. Trapping of larger rivers and primary populations can provide important information, but may be difficult and expensive due to the size and characteristics of the river. See (Seiler, 2001) (Tussing, 2008) for examples of smolt trapping and estimation methods for larger rivers.

In other areas, a tributary stream of a population may be used to estimate smolt to adult productivity and to determine marine and freshwater survival (life cycle streams). These sites are easier to monitor and to install due to their much smaller size. They are also less hazardous to operate, but assumptions must be made about the overall watershed smolt production based upon the smaller tributary index sites (Nickelson, 1998).

Ideally juvenile migrant data should be available for all populations within an MPG, but this is not cost effective or logistically possible. One strategy would be to incorporate 2 traps per MPG, one as a continuous location for a population index and the other trap to be rotated among the other populations as a random sample.

5.3.3 Juvenile Salmonid Parr Estimates

In some areas it may be necessary or desirable to estimate overall juvenile migrant production from low flow summer parr estimates. This has most often been done for coho and for steelhead (Rodgers, 2002). For areas where juvenile in-stream population estimates are generated using probabilistic sampling, a clear statistical relationship between juvenile parr abundance estimates and total adult and juvenile migrant production should be demonstrated.

5.4 What Does NOAA Recommend For Monitoring VSP Spatial Distribution?

"A population's spatial structure is made up of both the geographic distribution of individuals in the population and the processes that generate that distribution. Spatially structured populations are often generically referred to as "meta-populations," though the term meta-population has taken on a number of different meanings. A population's spatial structure depends fundamentally on habitat quality, spatial configuration, and dynamics as well as the dispersal characteristics of individuals in the population" (McElhany, 2000).

The historic distribution of species of salmon and steelhead has in many instances been severely impacted by the construction of hydroelectric and other kinds of impoundments substantially reducing the former range and biomass of the species. In other cases the degradation of suitable habitat has constrained where spawning can be successful. In order to determine the extent that spatial structure has changed specific monitoring questions should be answerable through specific monitoring actions as shown in Table 8.

Table 8. Key monitoring questions for determining spatial structure of populations within an ESU.

	Population Level Distribution	Major Population Group Level Distribution	ESU or DPS Level Distribution	What steps have been taken to address knowledge gaps in natural populations?
Key Monitoring Questions	1. Has there been a change in the spawner distribution within populations? 2. What is the variance about the estimate?	1. Has there been a change in relative distribution of natural production across populations within each MPG?	1. Has there been a change in the relative distribution of natural production across MPGs within each ESU?	1. Do current adult and/or juvenile distribution estimates for each population have known variance and confidence limits within the ESU?
Key NOAA Evaluations	1. Determine the percent of occupied habitat in adult and juvenile distribution for each population with information at the time of listing. 2. Determine whether the change in distribution improves the TRT	1. Determine the change in adult and juvenile distribution for each population with information at the time of listing. 2. Determine whether the change in distribution improves the TRT productivity goals for meeting	1. Determine the change in adult and juvenile distribution for each population with information at the time of listing. 2. Determine whether the change in distribution improves the TRT productivity goals for meeting	1. Determine whether the variance associated with the estimates are within allowable limits for determining a change of listing status

	Population Level Distribution	Major Population Group Level Distribution	ESU or DPS Level Distribution	What steps have been taken to address knowledge gaps in natural populations?
	productivity goals for meeting long term viability.	long term viability.	long term viability.	

NOAA Recommendation 14: Determine spatial distribution of listed Chinook, coho, and steelhead with the ability to detect a change in distribution of ± 15% with 80% certainty.

Estimates of spatial distribution can be made using different methods. Following are methods that can meet NOAA Recommendation 8:

METHOD 1 TOTAL CENSUS.

In some cases it may be possible to census an entire stream using snorkeling, electrofishing, or adult spawners to obtain distribution. In this case we can be certain of the distribution within that population. This is often not possible for an entire ESU or MPG and it must be repeated periodically.

METHOD 2 PROBABILISTIC SAMPLING OF JUVENILE PARR

Randomized probabilistic sampling of instream juveniles can provide accurate estimates of changes in distribution over time with known precision and confidence. This is accomplished using a sampling regime similar to the one employed by Oregon Department of Fish and Wildlife for coastal coho juveniles as illustrated in Figure 8. Since distribution of juveniles is more extensive than adults, juvenile monitoring will identify distribution in smaller tributary streams where adult spawners will not go. This is especially important in evaluating the effectiveness of habitat restoration actions such as repair or removal of passage blockages to smaller tributary streams. However, steelhead and rainbow population interfaces may be difficult to discern.

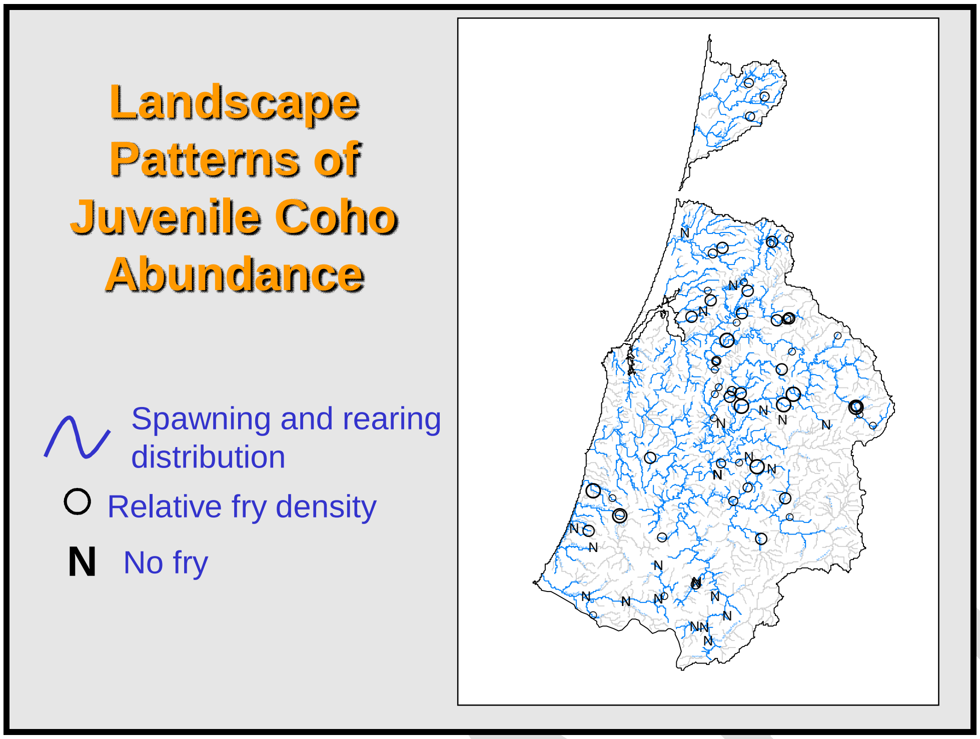


Figure 8. Example of coho distribution obtained from juvenile sampling of Oregon Coast ESU (Courtesy of Steve Jacobs ODFW).

METHOD 3 ESTIMATING CHANGES IN ADULT SPAWNING AREAS USING PROBABILISTIC SAMPLING

Estimates of changes in distribution may be made by comparing spawner survey information for each year to determine if spawner densities and distribution have shifted or increased. This method is especially important for pink and chum salmon that have limited juvenile freshwater residence.

OTHER METHODS NOT RECOMMENDED

Estimating changes of adult spawning areas using non-random spawner index areas has been used because the data are available. However, simply surveying the same index sites for spawners does not provide information on sites where spawning may be occurring in new areas. Periodic full basin surveys may be capable of calibrating spawner index sites and discovering new spawning areas. However, estimates of precision are still not possible, and this method is not recommended.

Estimates of distribution may be developed using various historic and recent non-random site visits. In other cases it may be possible to determine the upper extent of anadromy in each population watershed and assume that if the species of concern is present and blockages have been removed, then all sites downstream can also be expected to have the species present. In these two scenarios an estimate of variance or certainty cannot be obtained.

5.5 What Does NOAA Recommend For Monitoring Species Diversity?

Behavioral, morphological, and genetic traits of listed populations can be monitored through sampling regimes in place for monitoring incidental harvest of listed species and through sampling of adult spawners, juvenile parr, and migrants at traps. Many traits such as, DNA markers, juvenile and adult migration timing, spawn timing, and other traits can often be monitored with existing fishery and hatchery management systems.

NOAA Recommendation 15: As a short term strategy, utilize species distribution information, and spawn timing, run timing, age distribution, fecundity, and sex ratios to determine status/trend in species diversity of natural populations.

Traditional diversity indicators such as run timing, sex ratios, age at maturity, etc… are all windows into the process and may be informative that changes in phenotypic/genotypic diversity are taking place. However we may never really be sure whether such changes are good or bad for the population in terms of survival and persistence. The monitoring questions in Table 9 will be difficult to answer considering the number of traits that encompass species diversity not only within populations, but also the effect of meta-populations as well.

Table 9. Monitoring questions associated with evaluating species diversity

	Population Level Diversity	Major Population Group Level Diversity	ESU or DPS Level Diversity	What steps have been taken to address knowledge gaps in natural populations?
Key Monitoring Questions	• Has there been a change in the species diversity of populations within the MPG?	• Has there been a change in the species diversity within the MPG?	• Has there been a change in the species diversity within the ESU?	Have species diversity estimates been performed for each population ESU?
Key NOAA Evaluations	Determine the change in species diversity for each population.	Determine the change in species diversity for each MPG.	Determine the change in species diversity for each ESU/DPS.	Determine whether estimates are usable for listing status

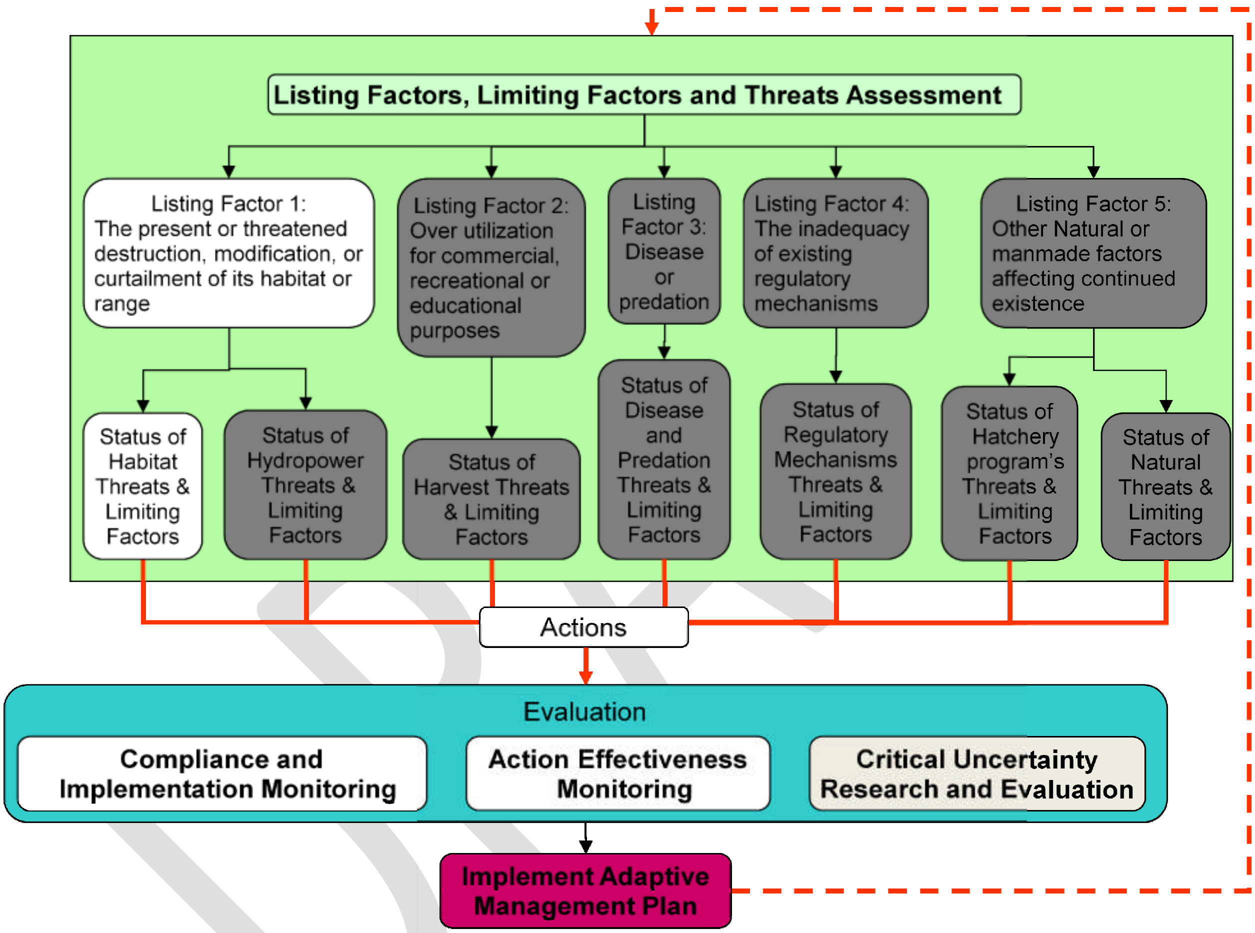
NOAA Recommendation 16: As a long term strategy, develop a baseline of DNA microsatellite markers based on single nucleotide polymorphism (SNPs), allozyme and DNA genotypes and phenotypes for each population within each MPG and ESU.

The fish and wildlife agencies and tribes have been collecting genetic information for a number of years using both allozyme and DNA processes. Progress has been made now to the point where a standardized approach can be used by all genetics laboratories and at least a genetic fingerprint can be made of each population. This can be accomplished using SNPs.

SNPs are DNA sequence variations that occur when a single nucleotide (A,T,C,or G) in the genome sequence is altered. For example a SNP might change the DNA sequence A**A**GGCTAA to A**T**GGCTAA. For a variation to be considered a SNP, it must occur in at least 1% of the population. (U.S. Department of Energy Office of Science, 2008)

SNPs are a class of genetic marker for which data may be compared to external DNA sequences, and thus data are automatically standardized across chemistries, hardware platforms, and laboratories. (Smith, 2005). However, the SNP may or may not influence population survival.

6.0 WHAT DOES NOAA RECOMMEND FOR MONITORING THREATS DUE TO LOSS OF HABITAT OR RANGE?



6.1. Habitat Status/Trend Monitoring

The capacity of the marine and freshwater environments to produce salmon and steelhead are the basic building blocks of salmon recovery. If the freshwater spawning and rearing habitat is not sufficient and intact, then insufficient migrants are produced to fully utilize the habitat offered by the estuary and ocean to be able to prevail over marine mortality factors. Conversely, if marine conditions are hostile to juvenile and adult survival, insufficient numbers may return to freshwater to spawn to maintain the species.

Basic hypotheses surrounding management actions to reduce this threat include:

- If the freshwater habitat conditions are limiting the recruitment and early survival of salmon and steelhead, then restoring habitat damaged by human and natural actions will increase freshwater production of migrants to the sea.
- If habitat is being lost continually due to manmade and natural causes and other habitat is being restored through funded restoration programs, then the sum total of habitat quality for any population, MPG, or ESU can only be determined through broad scale monitoring of its status/trend. TOTAL HABITAT AVAILABLE = REMAINING USABLE HABITAT + RESTORED HABITAT – HABITAT LOST OR DEGRADED

Table 10 provides the key monitoring question that should be addressed when monitoring habitat status/trends.

Table 10. List of monitoring questions for loss of habitat

Type of M&E	Monitoring Actions	Key NOAA Evaluations
Habitat Status/Trend Monitoring	1. What is the overall status/trends of habitat for each population within an ESU?	1. Determine the trend for habitat within each ESU given the sum total of both habitat restoration actions and habitat losses due to natural and manmade causes

With the exception of the ODFW work on the Oregon coast and the U.S. Forest Service AREMP and PiBo programs, there are no current broad scale habitat evaluation systems in practice in the Pacific Northwest that can provide the status and trends necessary to inform the public and meet federal ESA recovery purposes. This is in contrast to existing efforts for monitoring fish populations. The status of habitat at any point in time is the sum total of original habitat available plus habitat gained due to restoration actions minus habitat lost due to natural and human causes.

NOAA Recommendation 17: Implement a randomized geospatially referenced tessellated habitat status/trend monitoring program incorporating on the ground protocols coupled with remote sensing of land use and land cover. Coordinate and correlate habitat status/trend monitoring with fish in and fish out monitoring wherever possible.

A monitoring system that addresses the status of habitat conditions and addresses the associated threats would provide additional corroborating information and evidence that the threat to the species from habitat loss was addressed.

A habitat sampling framework should rely upon remote sensing and instream and riparian sampling using a probabilistic sampling design and field protocols. The habitat framework should have the following characteristics.

- It provides status and trends of land use and land cover using remote sensing.

- It provides a probability-based sampling framework that can be used at the state, domain, ESU, MPG and population scales by all levels of government and volunteers to assess the conditions of aquatic and riparian habitat, and water quality.
- Initiates a sampling site selection process that provides a pre-determined level of confidence in the estimated status of wadeable and non-wadeable rivers and streams.
- It provides information about aquatic and riparian invasive species and the distribution of salmonids by conducting IBI evaluations for fish and macro-invertebrates at the randomly selected sites.

.

Probabilistic sampling is advantageous because it provides environmental information about the characteristics of wadeable streams and their associated riparian areas with known statistical certainty and precision for an array of physical parameters (Kaufmann, 1999) (Larsen, 2004). Larson demonstrated that a well designed network of 30-50 sites monitored consistently over years can detect underlying changes of 1-2% per year in a variety of key habitat characteristics within 10-20 years or sooner.

The monitoring agencies and tribes should consider using remote sensing by acquiring high altitude satellite imagery or LIDAR to compare changes in land conversion, impervious surfaces, and floodplain area for each ESU. Remote sensing data provides “big picture” metrics of land use changes and avoids intrusion into private property. Remote sensing, however, cannot measure some aspects of water quality, stream sedimentation and other parameters needed to quantify some aspects of watershed health. Therefore, a combination of remote sensing and on-the-ground probabilistic sampling is necessary. This will complement ongoing US Forest Service actions on federal forestlands in Washington, Oregon, and Idaho where the Aquatic Resource Effectiveness Monitoring Program (AREMP) and Pacific Intermountain Biological Opinion (PIBO) sampling programs are using satellite imagery to typify forest seral changes and roads on the national forests while also conducting on the ground EMAP type habitat sampling.

6.1.2 Incorporate Consistent Habitat Monitoring Protocols

PNAMP sponsored a comparison of regionally popular watershed condition field sampling protocols in the John Day River, Oregon. Based upon preliminary information, the following protocols appear to provide comparable watershed condition information with adequate precision sufficient to be used for large scale comparisons across jurisdictions in determining watershed riparian and instream health:

- US EPA EMAP Protocols published by (Peck, 2003)
- US Forest Service AREMP protocols (U.S. Department of Agriculture, 2006)
- US Forest Service PIBO protocols (Heitke, 2006)
- Upper Columbia River Protocols (Hillman, 2006)

Other probabilistic protocols may provide information designed to answer specific monitoring questions, but may not meet the broad criteria discussed above for these four protocols.

6.1.3 Habitat Evaluation Assessment Criteria and Models

Habitat attributes in themselves do not provide an easily interpreted status of the habitat, but must be combined into a model that can interpret ranges of attributes. The US Forest Service EMDS model is an example of how this can be accomplished. Ecosystem Management Decision Support (EMDS) is the software used to develop and run decision-support models for determining watershed conditions on national forest lands. EMDS evaluates individual data then aggregates this information to make an overall assessment of condition. Evaluation criteria were developed by the US Forest Service through an expert panel of users to evaluate individual data parameters. Data were compared to the criteria and given an evaluation score such that a good, fair, or bad condition could be designated.

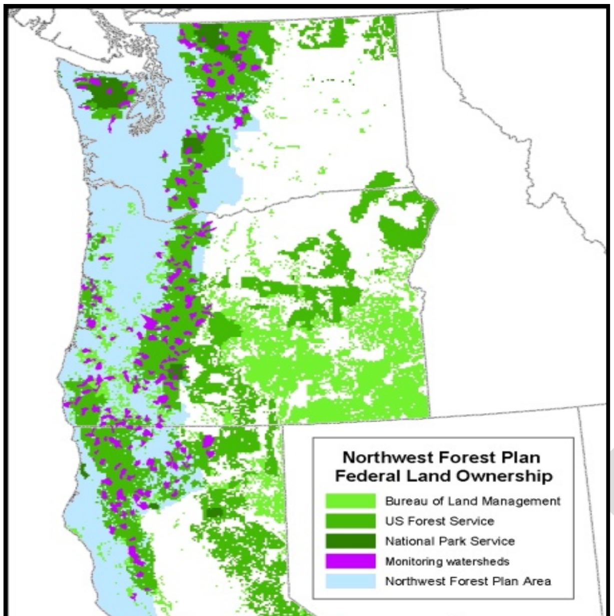


Figure 9. Northwest Forest Plan AREMP status/trend locations

Regional collaboration will be required to develop broad models in a similar manner that can be used within the ESUs and across the Pacific Northwest to generate summarized high level indicators of watershed conditions.

6.1.4 Toxics

Toxics are a concern to recovery of listed salmon in the Pacific Northwest. The recently completed *Biological Opinion for the Environmental Protection Agency Registration Of Pesticides Containing Chlorpyrifos, Diazinon, and Malathion* contain results of ongoing EPA monitoring and the current deficiencies in monitoring. Studies indicate that these chemicals at small concentrations can have a deleterious impact on survival, growth, swimming, reproduction, olfaction and other functions necessary for survival.

Results from non-random monitoring conducted by USEPA and California indicate that these toxics are present in detectable concentrations for 6% of the sites sampled for malathion, 49% of sites for chlorpyrifos), and 67% of sites for diazinon. The true levels of concentrations are not known due to the lack of information on peak events and frequency of use. Because the conditions for creating these frequencies are not known, the monitoring data may be useful for measuring real time exposure at specific locations, but may not be adequate to predict the actual exposure of ESA listed salmonids to these toxics. They concluded that all populations of salmonids listed in the PNW will likely show reductions in viability as a result of exposure to these chemicals.

NOAA Recommendation 18: USEPA, state agencies, and local governments should monitor storm water and cropland runoff for status/trends of concentrations of toxics and identify their sources.

6.1.5 Estuaries

Probabilistic sampling has been used to measure habitat parameters in the marine environment in a manner similar to those previously described for riparian and freshwater. Parameters measured include water quality, sediment composition, toxics, and eelgrass and kelp distribution. Other habitat studies have looked at intertidal nursery areas, dykes, bulkheads, tide gates and other infringements upon marine and nearshore habitat. The principles and guidance described for freshwater and riparian habitat can be extended into the marine and nearshore environment.

6.2 Monitoring Habitat Restoration Actions

Habitat Restoration actions operate under the following basic **hypotheses**

- If the habitat that is identified as a limiting factor and is in poor condition is restored, then the limiting factors identified for the population should be reduced or eliminated leading to improvements in habitat conditions;
- If the habitat conditions are improved, then this should lead to the production of more salmon and steelhead because stream carrying capacity has been increased.

6.2.1 Habitat Restoration Implementation Monitoring

NOAA Recommendation 19: To the extent possible all regional and local restoration efforts should be capable of being reported and correlated with habitat limiting factors as defined in the PCSRF data dictionary so that the cumulative effects of restoration actions can be tracked and given proper credit by population, MPG and ESU/DPS.

Section 7 consultations have been conducted with other participating federal agencies including the Biological Opinion for the Columbia River Federal Power System. NOAA Fisheries Service will be required to evaluate the extent that the provisions of Section 7 have been implemented.

6.2.2 Habitat Restoration Effectiveness Monitoring

Table 11 provides the main monitoring questions necessary for determining effectiveness of habitat restoration actions.

Table 11. List of effectiveness monitoring questions for restoring lost habitat

Type of M&E	Monitoring Actions	Key NOAA Evaluations
Monitoring Effectiveness of Habitat Restoration Programs, Habitat Conservation Plans, and Biological Opinions	1. Have the recovery participants monitored whether habitat restoration actions at the site level were effective in improving habitat and range? 2. Have the recovery participants monitored whether the cumulative restoration actions at the watershed level been effective in improving fish production? 3. Have the HCPs, BiOps, or FERC requirements been effective in restoring and protecting habitat?	1. Review the evidence available from effectiveness studies to ascertain that restoration actions are shown to be effective 2. Review the BMP effectiveness studies associated with HCPs to determine their effectiveness. IMWs could be used to perform this evaluation. 3. Review data for habitat on HCP lands to determine whether BMPs have been effective

The following table (Table 12) attempts to guide monitoring by demonstrating the amount of risk associated with having monitoring capable of answering various habitat monitoring questions.

Table 12. Levels of risk associated with monitoring designs for determining the status of critical habitat.

	Low Risk of Insufficient Action	Moderate Risk of Insufficient Actions	High Risk of Insufficient Actions
Status of Threats due to Loss of Habitat	• GRTS monitoring data available demonstrating status/trends of salmon habitat within the ESU • Data available demonstrating that restoration projects were effective in improving targeted habitat. • Data available demonstrating that the cumulative effect of habitat improvements within selected watersheds have been effective in increasing freshwater productivity	• GRTS monitoring data available demonstrating status/trends of salmon habitat within the ESU	• Restoration actions alone do not provide information about the net condition of habitat given that habitat is also being lost due to natural and manmade causes. Also without some form of effectiveness monitoring we can only assume that the actions undertaken were effective and appropriate for the habitat conditions.

Although many habitat restoration actions have taken place, each type may have a given life expectancy and effectiveness. Monitoring information demonstrating whether habitat restoration actions have been effective in improving habitat and species distribution will be valuable additions in determining whether listing threats have been addressed. Some kinds of restoration projects, such as large wood placement (LWD), may address a limiting factor, but it may have only a finite life expectancy of a few years. If watershed management actions are not taken to insure that large wood is recruited to the stream naturally, the LWD projects will need to be repeated in the future. Although habitat recovery planning can be quite detailed based upon modeling and assessment of limiting factors, there remains significant uncertainty that the recovery actions will be effective (Beechie et. al, 2003).

NOAA Recommendation 20: Reach scale effectiveness monitoring should be conducted for various habitat improvement categories using a Before and After Control Impact (BACI) design whenever possible. Recovery entities should coordinate their monitoring to reduce costs and improve sample size.

The BACI design provides the greatest statistical power to detect significant changes in the treated areas compared to areas where no habitat improvement has taken place, See (Roni, 2002). However, where this cannot be conducted, an extensive post-treatment design is likely a cost-effective and suitable substitute for BACI design. Although the development and enforcement of BMPs in forest practices and other areas is important, they do not demonstrate overall effectiveness.

6.2.3 Intensively Monitored Watersheds (IMWs)

Monitoring should be able to tie cumulative restoration actions within a basin or watershed to the actual improvement in fish production and carrying capacity. Ongoing monitoring sponsored by the Washington Salmon Recovery Funding Board, Oregon Watershed Enhancement Board, Idaho Fish and Game, and the BPA's Integrated Status and Effectiveness Monitoring Project (ISEMP) are examples of watershed scale IMW effectiveness monitoring that support evaluation of cumulative restoration actions and their impact upon freshwater salmon and steelhead production. IMWs are not needed in every MPG or population. Sufficient IMWs would address multiple limiting factors and geographic provinces throughout the Pacific Northwest. These have been identified by PNAMP and can be accessed at

http://www.pnamp.org//web/workgroups/PEM/meetings/2007_1018/2007_1018PNAMPIMWcontext.doc.

Research into the linkages and connectivity between the IMW efforts are needed so that the results of IMW work can be extrapolated to as many areas and conditions as possible. See Figure 10 for locations of existing and potential IMW sites.

Essential elements of an IMW (Bilby, 2004) include:

1. Experimental design should use a Before-after/control-impact (BACI) experimental design wherever possible. Other designs have a lesser chance of detecting true change due to habitat improvements.
2. Use watersheds small enough that sufficient habitat may be effectively treated and monitored to effect a detectable change in fish abundance (i.e. greater than 20%). This should include estimating the percentage of the basin that will need to be improved by habitat restoration projects in order to cause a 20% increase in smolt production.
3. Choose streams large enough to encompass all freshwater life stages of the target species Chinook, coho salmon, steelhead and cutthroat trout. The hypothesis being the longer the

residency in freshwater, the more likely to detect a response in fish abundance due to habitat changes.

4. Monitoring should provide a reliable estimate of fish into the system (adult abundance) and fish out (smolt production) for the entire basin.
5. There are one or more watersheds in close proximity with similar physical characteristics that can be used as either controls or additional treatment watersheds
6. Commitment by funding entities to support the IMW in terms of granting habitat restoration funds sufficient to meet condition 2 above.
7. Commitment by local agencies and tribes to keep the control stream(s) unchanged during the life of the project (>10 years) and to maintain the needed monitoring (Bayley, May 2002).
8. Consistent and extensive coordination is needed among the participants to assure monitoring and treatments occur as planned and are compatible.
9. Data need to be summarized annually to examine trends, assure that data are compatible, and project is on track.

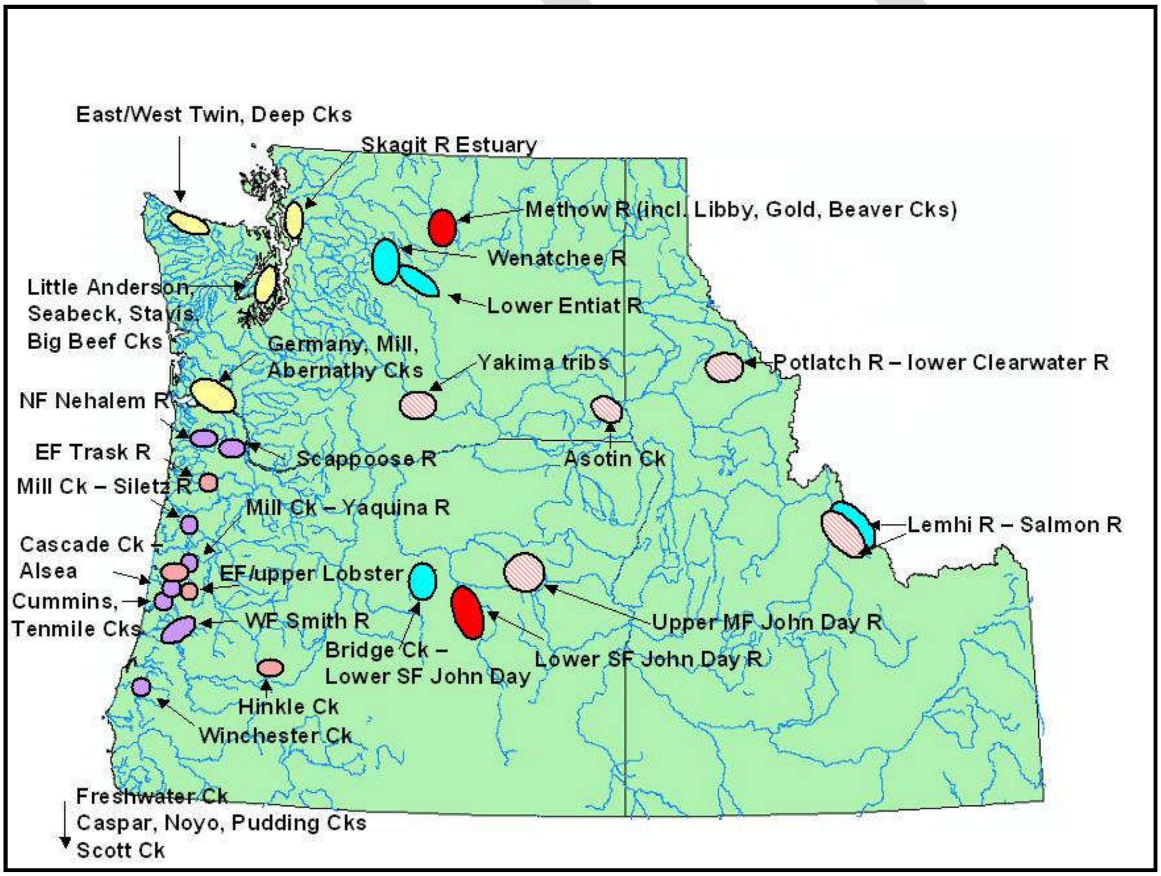


Figure 10. Potential network of intensively monitored watersheds across the Pacific Northwest. (Courtesy of PNAMP)

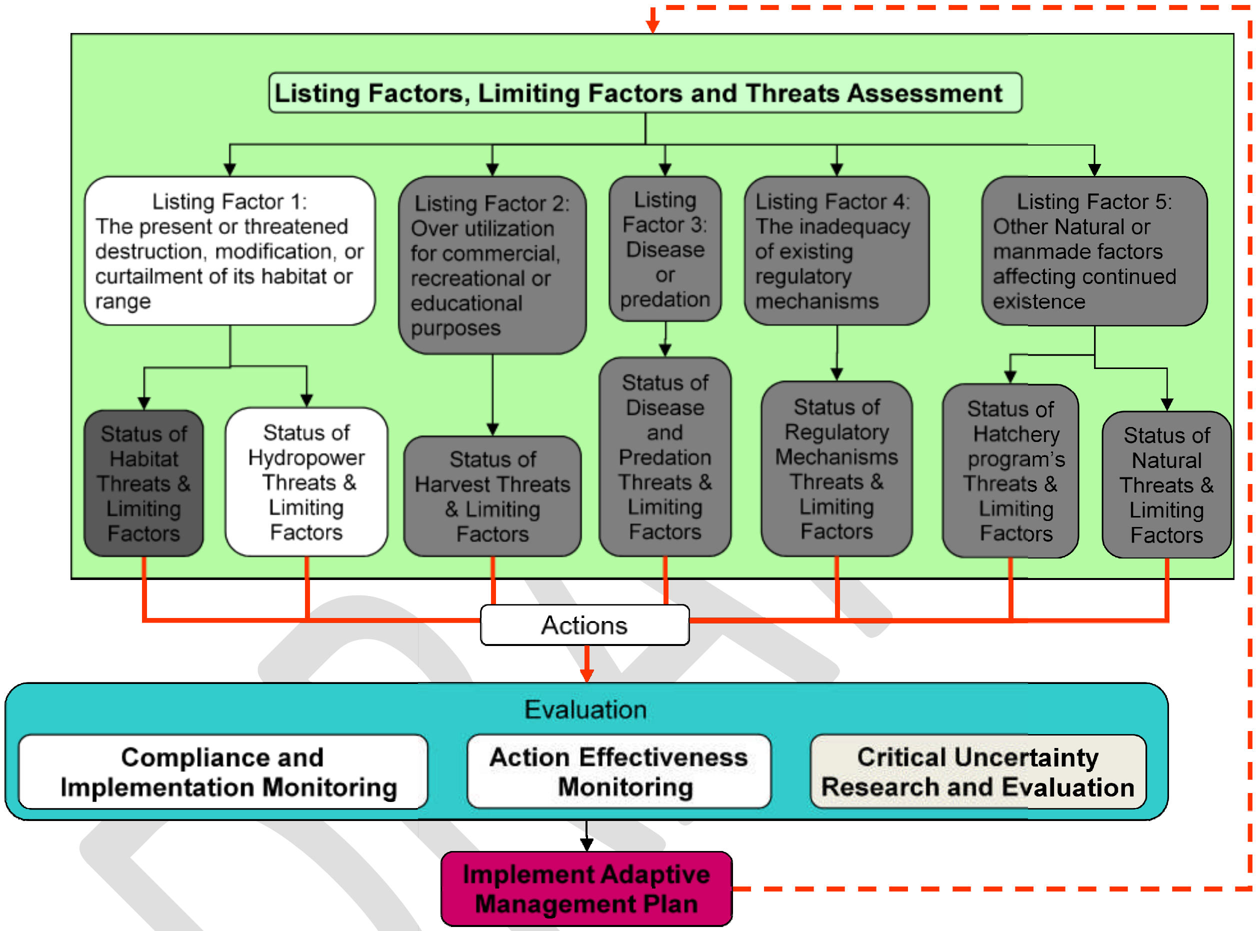
NOAA Recommendations 21: (1) Implement at least one IMW for each domain and address different limiting factors by coordinating IMW sites and designs across the Pacific Northwest; and (2) utilize a BACI design wherever possible.

Although many individuals are attracted to creating IMW watersheds, the costs associated with these watersheds should be carefully evaluated and the political and economic issues should be addressed before significant funds are expended in monitoring habitat and fish populations. Determining the effects of habitat upon fish response will require that the overall response of the fish populations must increase enough to be detectable over the normal annual variation in fish population abundance within ten years. As previously mentioned, Paulson and Fisher (Paulsen, 2003) and Bisson et al. (Bisson, 2008) estimated that it could take 10-26 years to detect a 30-50% change in the population. IMWs can generate information that will complement habitat status/trend monitoring and reach scale effectiveness monitoring and help establish future BMPs for addressing habitat restoration for salmonids but they also have the highest risk of not being able to demonstrate the change in fish abundances that are expected due to natural variation and sampling error.

Because BACI use a before and after project implementation scenario and compares a control to the treatment (impact) area, the variation due to within year natural changes is detectable and dampened providing the greatest power to detect statistically significant change.

NOAA Recommendation 22: For maximum ability to detect change and to avoid poorly designed studies that cannot detect change, IMWs should have a power analysis completed early in the project to determine the amount of the watershed required to be treated in order to detect a 30-50% change in fish response.

7.0 WHAT DOES NOAA RECOMMEND FOR MONITORING THREATS DUE TO HYDROPOWER?



Hydropower has been treated as a separate habitat component in much of the ESA analysis as it has had significant impacts to the Columbia River and to other Pacific Northwest watersheds as well. The majority of hydropower monitoring requirements have been developed and written into the Federal Columbia River Power System (FCRPS) Biological Opinion, through the Federal Energy Regulatory Commission's (FERC) licensing requirements, and habitat conservation plans (HCP) developed with various public utilities. For detailed monitoring requirements, those documents should be consulted.

Basic hypotheses surrounding management actions to reduce this threat include:

- If the hydroelectric facilities can be properly engineered and modified, then the benefits of hydropower generation can be obtained while improving the upstream and downstream migration survival of salmon and steelhead such that dams are no longer considered a major threat to the survival of listed species.

- If the engineered solutions are effective then the results should be detectable through monitoring the status/trends of juvenile and adult passage through each of the hydroelectric facilities.

NOAA Recommendation 23: Monitor all hydropower facilities for status/trends of survival impacts to upstream migrating adults and downstream migrating juvenile salmon and steelhead.

7.1 Status/Trends Of Hydropower Impacts To Fish Survival

7.1.1 FCRPS Hydrosystem Status/Trend Monitoring

Columbia-Snake River adult and Figure 11. Federal Columbia River Power System (FCRPS) (courtesy of the Corps of Engineers)

As shown in Figure 11, the Federal Columbia River Power System is a consortium of the Bonneville Power Administration (BPA), the U.S. Army Corps of Engineers (ACE) and the Bureau of Reclamation (BOR). Collectively, these agencies have been tasked with mitigating the impacts upon fish and wildlife and providing for monitoring of actions to reduce those impacts upon salmon recovery at the 31 federally owned multipurpose dams on the Columbia and its tributaries.

The main stem dams are operated in accordance with the operative biological opinions and the Army Corps Fish Passage Plan. Adult fish facilities are operated year round and juvenile fish are transported from various collector points at dams in the Snake and Columbia according to the BiOp. Spill is provided for juvenile fish passage under the Fish Passage Plan.

The hydroelectric facilities of the northwest impact both juvenile and adult survival through a number of impacts including juvenile impingement, nitrogen effects, turbine injuries, passage delays, increased predation and more. In order to determine overall mortalities of listed salmon, documentation of hydro effects is essential.

Salmon and steelhead survival during upstream and downstream passage is critical for maintaining and building ESA listed species. Key monitoring questions associated with Hydro Actions M&E are shown in Table 13.

Table 13. Key monitoring questions for addressing hydropower threats

Monitoring Actions	Target Goals
1. Determine status/trends of smolt survival passing dams 2. Determine migration timing at dams sites 3. Determine the condition of smolts at all dam sites	• Snake River Spring summer Chinook change in hydro survival from 55% to 59% • Hydro passage improvements are now targeted at a dam survival performance standard of 96% for spring migrants and 93% for summer migrants.

7.1.2 Other Hydropower Projects

Although the Federal Columbia River Power System is the largest cluster of dams impacting salmon and steelhead and has the largest number of stakeholders, there are significant non-federal hydropower actions in regional basins as well including the Puget Sound, Columbia River, and coastal rivers of Oregon. These projects have been the result of local public utility districts licensed by the Federal Energy Regulatory Commission. Some of these licenses have been combined under Habitat Conservation Plans. Specific requirements have been written into each license and should be reviewed periodically to insure that required monitoring and habitat modifications have been implemented. Following table demonstrates some completed hydropower HCP standards and their status/trend monitoring targets.

Table 14. Some Hydropower HCP status requirements enacted.

Monitoring Actions	Target Goals
• Determine status/trends of smolt survival passing dams • Determine status/trends of adult survival passing dams sites • Implement predator control at specific dam sites	• 93% Juvenile passage survival • 98% Adult passage survival • Site specific

7.2 Monitoring Hydropower Management Actions To Improve Fish Passage and Survival

7.2.1 Federal Columbia River Power System Monitoring and Evaluation Actions

The FCRPS M&E goals are to provide information needed to support planning and adaptive management and demonstrate accountability related to the implementation of FCRPS ESA hydropower and offsite actions for all ESUs. The goals in this section of the RPA (Table 15) relate to the other sections already described above and many of the actions have been placed under the appropriate tables above.

Table 15. FCRPS RM+E Proposed

Type of M&E	Monitoring Actions
Implementation (Compliance) with Hydropower Biological Opinions, FERC licensing, and HCPs	1. Did the FCRPS implement and maintain the Columbia River PIT Tag information system under RPA 50? 2. Did the FCRPS monitor juvenile and adult returns at main stem hydro dams per RPA 50? 3. Did the FCRPS fund implementation of status and trend salmon monitoring for the Wenatchee, Methow, Entiat, Lemhi, South fork Salmon, and John Day Rivers under RPA 45. 4. Did the FCRPS provide additional status monitoring of B Run steelhead such that a majority of the populations are monitored for abundance and productivity by 2013 per RPA 50? 5. Did the FCRPS review and modify existing Action Agencies' fish population status monitoring to meet existing regional standards, protocols. And ensure they are prioritized on critical performance measures by 2010? 6. Did the FCRPS mark all hatchery releases from Action Agency facilities by 2013 7. Did the FCRPS implement a data system to make available annually information on population viability by 2009? 8. Did the FCRPS collaborate with the fish management agencies and tribes to support the coordination of data management and annual synthesis of fish information? 9. Did the FCRPS facilitate and participate in ongoing regional M&E collaboration process to develop a regional strategy for status trend monitoring for key ESA fish populations by 2009?
Monitoring Effectiveness of Hydropower Biological Opinions, actions (RPAs)	1. Were the hydro operations effective in managing the reservoirs for improved juvenile and adult fish survival? 2. Were the efforts to relocate Caspian terns from Sand Island effective? 3. Were RPA actions implemented for Spring/summer Chinook, and Snake River steelhead effective in maintaining their natural population and genetic diversity? 4. Were the sea lion excluders effective in barring entrance to sea lions?
Validation Monitoring	1. Were the number of juveniles consumed by Pike minnows reduced to target levels? 2. Were the numbers of juvenile salmon saved from Caspian tern predation reduced to target levels by 2013? 3. Were excluders and harassment techniques effective in reducing adult predation to levels targeted?

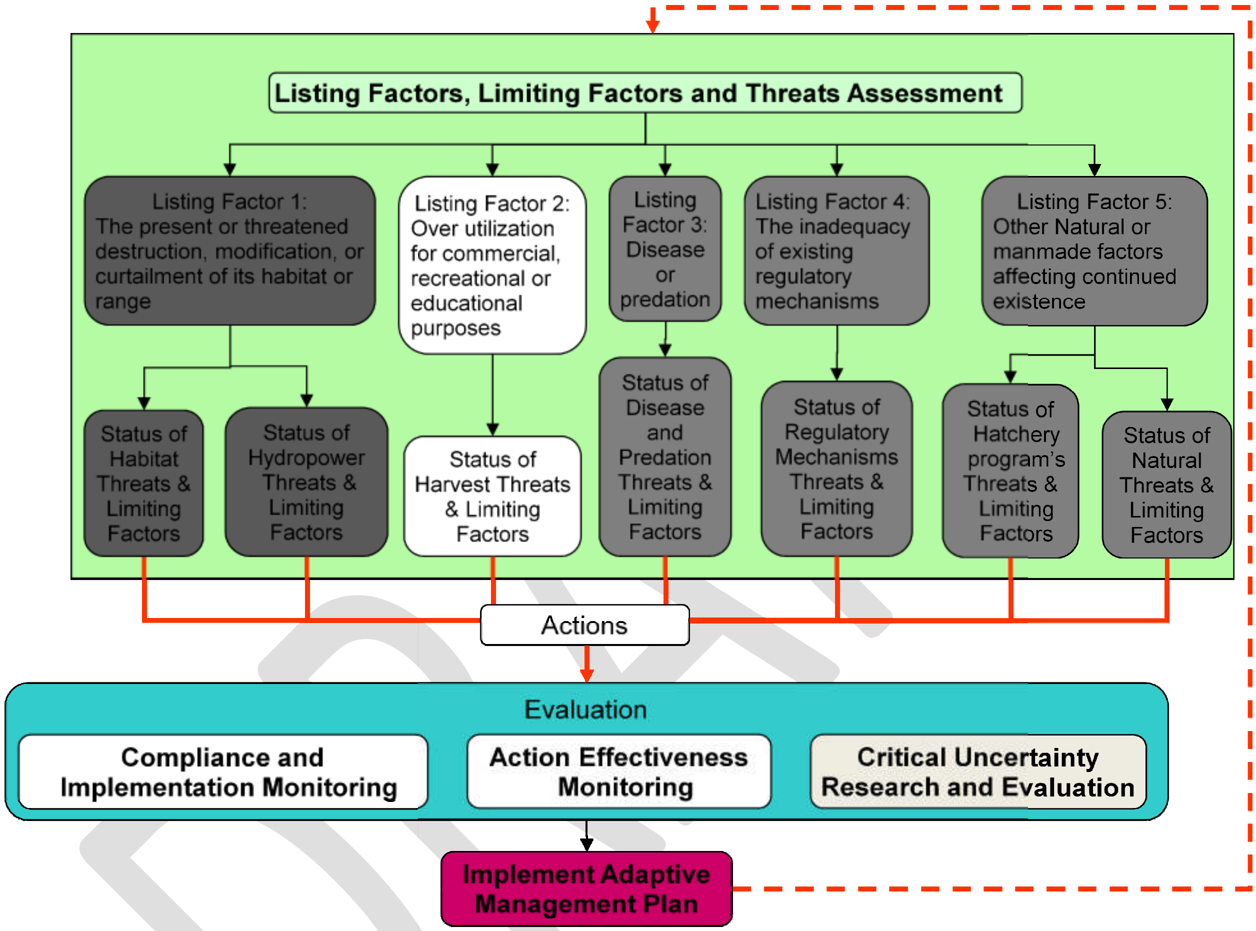
7.2.2 Other Hydroelectric Projects

Table 16 below represents kinds of implementation and effectiveness monitoring requirements contained within those appropriate agreements such as HCPs and FERC licenses.

Table 16. Some Completed PUD Hydropower HCPs and FERC licenses.

Entity	Consultation	Monitoring Questions
Wells Dam Douglas County Hydroelectric projects	HCP Columbia River FERC Section 10 Douglas PUD	1. Did the Douglas PUD implement and maintain 98% adult passage survival and 93% juvenile passage survival? 2. Did Douglas PUD provide non turbine bypass for 95% of the juvenile migrants? 3. Did Douglas PUD implement a predator control and harassment program? 4. Did the PUD fund and implement habitat restoration actions in the tributary streams?
Rocky Reach Dam	HCP Columbia River FERC License Columbia River 2002	1. Did the Douglas PUD implement and maintain 98% adult passage survival and 93% juvenile passage survival? 2. Did the PUD conduct control efforts for both northern pikeminnow and piscivorous bird populations for the protection of juvenile Plan Species.
Rock Island Dam	HCP Columbia River	1. Did the Chelan PUD implement and maintain 98% adult passage survival and 93% juvenile passage survival? 2. Did the PUD conduct control efforts for both northern pikeminnow and piscivorous bird populations for the protection of juvenile Plan Species.
City of Tacoma PUD	Completed 50 year HCP for Howard Hansen Dam on the Green River in Washington State, July 2001. FERC Section 10 Incidental Take Permit	1. Did the City monitor and maintain continuous flow and minimum flow requirements? 2. Did the City maintain and provide for downstream and upstream passage? 3. Did the city implement listed habitat restoration and conservation measures?
City of Seattle Public Utilities	Cedar River Watershed 50-year HCP, signed in April 2000	1. Did the City monitor and maintain instream flow conditions? 2. Did the City fund and establish a long term stream and riparian monitoring program?

8.0 WHAT DOES NOAA RECOMMEND FOR MONITORING THREATS DUE TO OVERUTILIZATION (HARVEST)?



Incidental take of ESA listed salmon and steelhead is regulated with authorizations or permits issued under section 4(d), section 7, or section 10. Harvest of listed species, though incidental, can have a major impact on small populations.

Basic hypotheses surrounding management actions to reduce this threat include:

- If the naturally produced salmon and steelhead can be identified in the fisheries and on the spawning grounds then selective harvest measures will allow the taking of abundant hatchery fish and preserve listed natural origin fish for spawning escapement.
- If incidental taking of listed salmon can be reduced sufficiently, then the natural runs can be rebuilt without the total closure of offshore and terminal fisheries utilizing abundant hatchery and natural stocks not listed under the ESA thereby preserving tribal treaty rights and economies of fishing dependent communities and businesses.

- If habitat is to be restored in order to improve natural production, then those entities making habitat improvements should be confident that sufficient numbers of adults will survive and return to utilize the new habitat made available.

8.1 Harvest Status/Trend Monitoring

It is important that the management agencies and tribes directing harvest regimes can demonstrate that harvest is not a threat to recovery (Table 17).

Table 17. Key ESA harvest monitoring questions and NOAA evaluations

Type of M&E	Monitoring Actions
Status/trend Monitoring	1. What is the individual and cumulative impact of authorized coastal and terminal fisheries on each identified population within an ESU/DPS? 2. What is the individual total catch and escapement of natural origin fish (NOF) and hatchery origin fish (HOF)?

8.1.1 Structures For Managing Natural Populations

NOAA Recommendation 24: Manage exploitation rates and total catch in coast-wide fisheries and terminal fisheries for TRT identified natural populations phasing out the use of all hatchery-wild stock aggregates by 2020.

In the past hatchery fish have been used to determine harvest percentages in coastal fisheries because they are easily accessed and marked with a CWT. It has been assumed that nearby natural stocks will migrate in a similar manner to hatchery fish and also encounter fisheries in a similar manner. These assumptions may not hold true for many populations. NOAA Fisheries Service will need the contribution of TRT identified natural populations in each of the coastal Pacific Salmon Commission (PSC) managed fisheries in terms of exploitation rates and total catch from the southeast Alaska fisheries (SEAK), coastal British Columbia fisheries (NBC, CBC, GS, JS, and WCVI) to southern US fisheries managed through the PFMC and North of Falcon processes.

NOAA Recommendation 25: Cohort reconstructions for natural populations should be made available to the science community within one year of the return of all age classes in the cohort.

The ability to determine the coast-wide harvest Impacts on specific stocks of fish was impossible until the advent of the coded wire tag (CWT) and its use in hatchery fish. Through the use of large scale tagging with CWTs, it has been possible to detect the occurrence of tags in fisheries from Southeast Alaska, British Columbia, the coastal fisheries of Washington, Oregon, California, and the in-river and terminal fisheries of Washington, Oregon, and Idaho. These tag recoveries have been used in run reconstruction scenarios to estimate the percent harvest and harvest exploitation rate in each of the identified coastal and inland fisheries. Although this system provided huge improvements in stock management, the “stocks” managed have been by necessity aggregates of hatchery and wild populations based upon assumed common migration routes and common geographic origins. Hatchery

CWT recoveries have been used as the surrogate for estimating interceptions of wild populations as part of stock aggregates but not successful in delineating individual populations within the stock aggregate. It is recognized that stock aggregates no longer provide the management resolution necessary for estimating harvest impacts to recovering populations listed under the ESA. Therefore, either a shift must be made from stock aggregate management to population management, or existing fisheries will no longer be able to function due to the inability to quantify their jeopardy impact on listed populations and ESUs.

Problems with stock identification in the coast wide fisheries have been identified by the Pacific Salmon Commission (Hankin, November 2005) and the Pacific Fishery Management Council. This conclusion was clearly presented by the Findings of the expert panel on the future of the Coded Wire tag recovery program

How these findings and recommendations can be accomplished is still being developed by PNW harvest managers. In some cases it may be possible to CWT enough naturally produced fish to estimate population contributions to the fisheries. In other cases the use of genetic stock identification techniques through the use of DNA or some combination of both techniques may prove possible.

In terms of steelhead harvest, and escapement, there have never been sufficient numbers of CWT steelhead to obtain coast-wide estimates of harvest. However, most steelhead harvest occurs in terminal fisheries. The difficulty of tracing wild steelhead populations indicate that the use of GSI techniques may be necessary for estimating escapements as well as harvest fractions.

In order to meet the above monitoring questions and NOAA evaluations, fishery managers should consider the risk of providing insufficient data to determine whether harvest is sufficiently curtailed for current monitoring programs.

Recent progress has been made in developing a standardized DNA database for Chinook salmon (Seeb, 2007). Now is the time to create new scientific monitoring systems that will build harvest management credibility into the future.

8.1.2 Improving Models For Predicting Natural Population Harvest Impacts

The Fishery Regulation Assessment Model (FRAM) is currently used by the Pacific Fishery Management Council (PFMC) and the North of Falcon Process to annually estimate impacts of proposed ocean and terminal fisheries on Chinook and coho salmon stocks (Pacific Fishery Management Council, October 2008). FRAM is a single-season modeling tool for Chinook and coho salmon. The FRAM has been used in recent years, not only to model harvest fisheries, but to determine compliance with ESA restrictions on allowable take. The model assumes that CWT fish accurately represent the modeled stock. In nearly all cases wild stocks are aggregated with hatchery stock and both are represented by the hatchery stock. As the coast moves toward stock identification that goes beyond CWTs, the FRAM model will continue to need to be modified.

Recommendation 26: The states and tribes should recalibrate the FRAM model to reflect harvest management of natural populations.

Recommendation 27: Initiate snapshot sampling programs in the various coastal fisheries to capture the distribution of the TRT populations within the specific fisheries in preparation for a coast-wide annual coordinated approach to monitoring harvest status/trends by 2020.

For example, the 21st Annual Report of the Pacific Salmon Commission reported in the Fraser River that the Racial Identification Program provided estimates of stock composition for sockeye catches in commercial, Aboriginal, and test fisheries. Scale and DNA data were used in the analyses. Stock composition data were used to estimate the run size and gross escapement of individual stock groups. DNA estimates of stock composition confirmed the presence of Late-run sockeye at critical times during the season. Genetic stock identification (GSI) techniques were used to estimate the contribution of Fraser River pink salmon in commercial and test fisheries.

The following chart (Table 18) provides some guidance on what kinds of data could be available to reduce the risk that insufficient monitoring data is available for ongoing fisheries coast-wide.

Table 18. Monitoring levels of risk for evaluating threats due to harvest

	Low Risk of Insufficient Data	Moderate Risk of Insufficient Data	High Risk of insufficient data
Status of Threats due to Overutilization (Harvest)	• Implemented harvest restrictions reflecting incidental take exploitation rates that can rebuild natural populations and meet population viability objectives. • Implemented stock identification strategies that reflect impacts to natural ESA listed populations rather than surrogate hatchery stocks. • Marked all hatchery fish externally • Demonstrated >90% compliance rate within fisheries having incidental takes of listed fish. • Collected data on size, age, sex, and other stock characteristics in the fishery that can be used to evaluate possible selective pressures of harvest on species diversity.	• Implemented harvest restrictions that reflects incidental take exploitation rates that can rebuild natural populations and meet population viability objectives. • Marked all hatchery fish externally • Collected data on size, age, sex, and other stock characteristics in the fishery that can be used to evaluate possible selective pressures of harvest on species diversity.	• Implemented harvest restrictions that reflects incidental take exploitation rates that can rebuild natural populations and meet population viability objectives.

8.2 Monitoring Management Actions Intended To Control Overutilization (Harvest)

Type of M&E	Monitoring Actions
Implementation (Compliance) with Harvest Restrictions	1. Did state and tribal fisheries comply with "take" quotas and other terms and conditions stipulated in section 7, 4(d) limits or section 10 authorizations? 3. Did the states and tribes enforce rules and quotas in their allowable fisheries? 4. How many state fisheries and tribal fisheries that take listed fish have ESA authorizations 5. By fishery, what percentage of fishers reported total catch by turning in annual commercial, tribal, and sport results?

Monitoring of harvest should be able to demonstrate that approved plans were implemented within approved or authorized limits, and that the pre-harvest forecasts of run size and incidental take of listed species are accurate and track with "in season" and "post season" analysis.

NOAA Recommendation 28: The states and tribes should be able to demonstrate that there was a greater than 90% compliance with adopted fishery regulations designed to minimize incidental take of listed species.

Type of M&E	Monitoring Actions
Effectiveness of Harvest restrictions	1. Are harvest restrictions implemented in the PST, PFMC and local state and tribal fisheries adequate to enable populations to increase as productivity improves? 2. Which gear types are more effective in reducing mortality and by catch? 3. Is harvest an effective means to reduce the ratio of natural origin spawners and hatchery spawners on the spawning grounds?
Validation of Harvest restriction outcomes	1. Have listed populations been able to meet their recovery plan escapement goals within the harvest restrictions per ESU? 2. What is the effect of harvest seasons on the observed abundance, productivity, spatial distribution and diversity of the natural origin fish in the population, MPG, and ESU?

8.2.1 Effectiveness Monitoring

Harvest curtailment to address ESA listed species has been used as a strategy to increase spawner escapements and therefore viability of listed populations. However, monitoring is needed to demonstrate that these strategies have been effective in meeting the desired reductions in interceptions of ESA populations.

NOAA Recommendation 29: Allowable incidental harvest rates identified for coast wide, in river, and terminal fisheries should be modeled annually to determine their effectiveness in providing for ESU population spawner escapement goals in terms of years to recovery and jeopardy

Because harvest removes potential spawners from the population and thus reduces the potential number of eggs that could be deposited and the potential number of emergent fry available to fill the habitat, it is important to understand what impact exploitation rate regimes are having on the rate of recovery in terms of time and spatial distribution. If it can be shown that the number of available spawners is fully capable of seeding all available habitats, then recovery rates will depend upon improvements in habitat or some other threat. If it cannot be demonstrated that sufficient spawners are available to fully seed the habitat, then any allowable exploitation rate will potentially prolong the recovery process. Those impacts should be modeled and available for all recovery participants to evaluate. Monitoring of natural origin adults should demonstrate that harvest exploitation rates on natural origin listed populations were minimal and that the escapements necessary for building populations back to target viability levels were achieved.

In conjunction with selective harvest strategies targeting hatchery fish, the states and tribes should continue their evaluation of selective fishing gear and methods to demonstrate reductions in impacts to natural origin spawners.

The effectiveness of harvest curtailment strategies is validated when the adult to adult productivity ratios are calculated, and the percent of total natural production that is harvested is determined to be at a level that does not interfere with meeting or achieving viability productivity goals (See Section 5.3.1).

Although spawner abundance is the defining information needed to determine viability, one of the metrics of interest to those working toward recovery is the total number of adults returning from the sea and how did harvest affect the number available for spawning and recovery. This metric is crucial in validating that the management actions taken by federal, state, and tribal harvest managers have been sufficient.

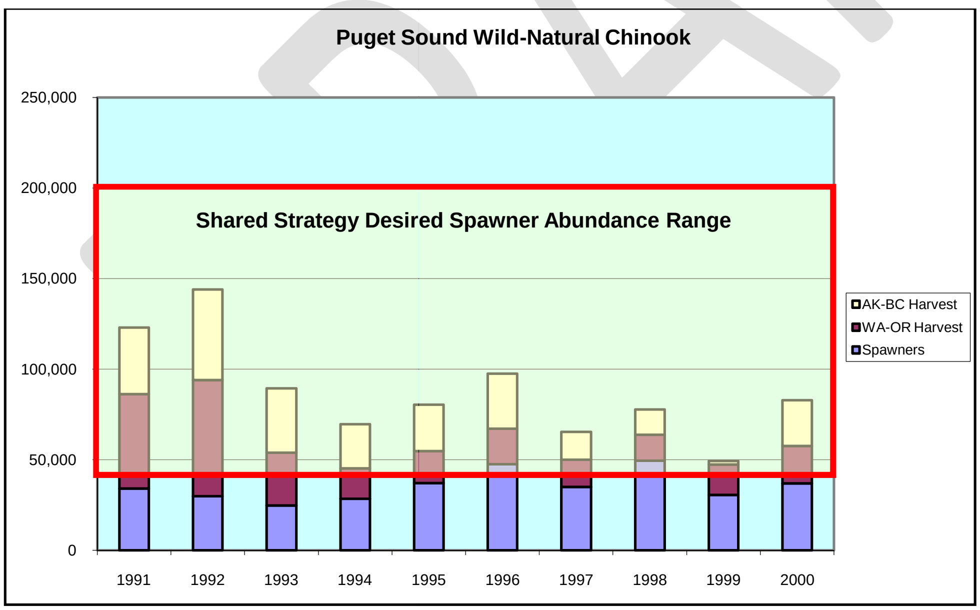
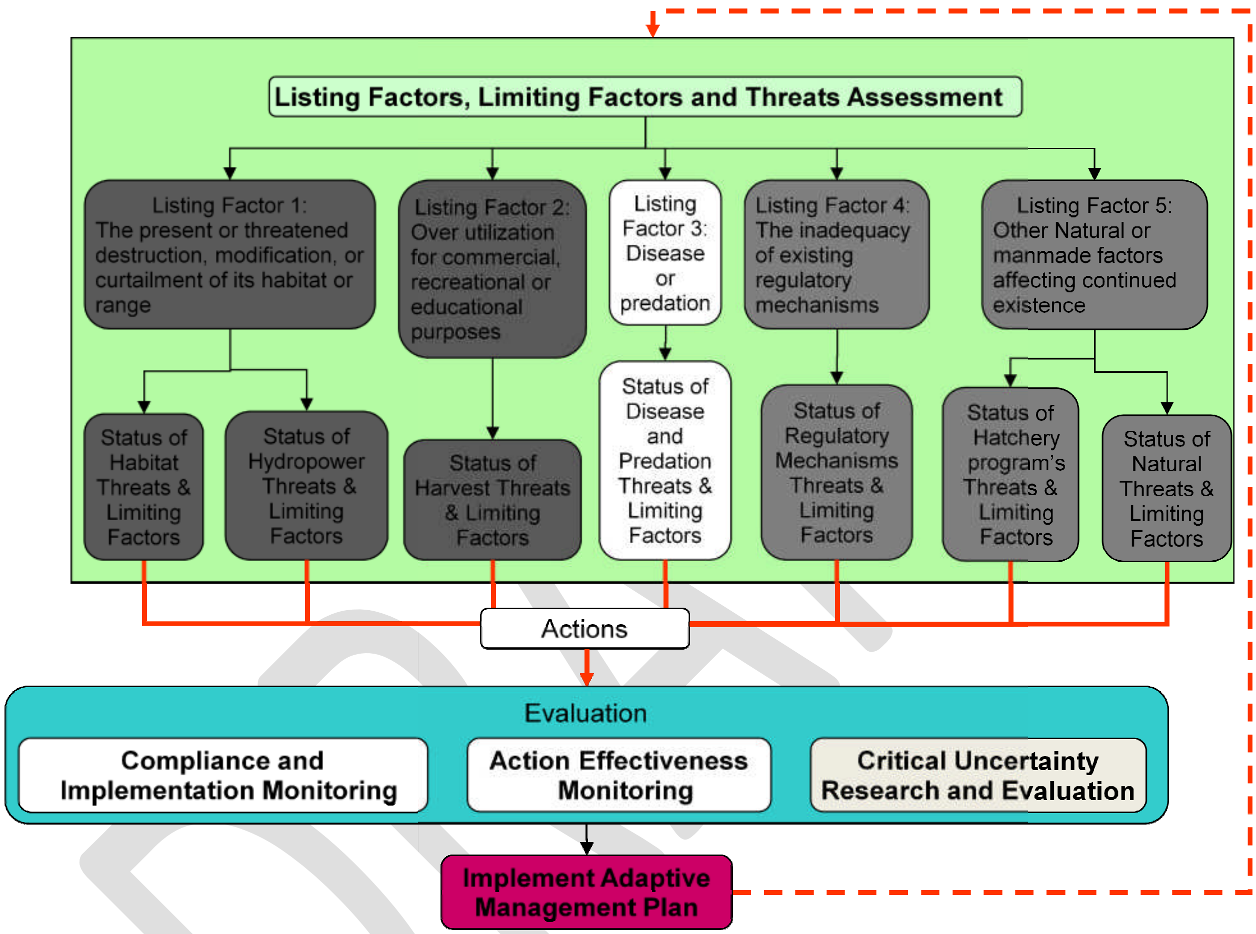


Figure 12. Example of how the cumulative effects of harvest on spawner abundance can be portrayed.

9.0 WHAT DOES NOAA RECOMMEND FOR MONITORING THREATS DUE TO DISEASE AND PREDATION?



9.1 Predation

Certain conditions, often caused by the activities of society encourage local intensive predation upon salmon and steelhead. This has occurred for steelhead adults at the Hiram Chittenden Locks at Seattle with sea lions and for salmon and steelhead upstream migrating adults in the Columbia River associated with seals and sea lions at the base of Bonneville Dam. Caspian terns and cormorants at the Columbia River estuary, and pikeminnow predation in the pools of the hydro facilities in the Columbia River also have been identified as a significant problem for downstream migrating juvenile salmon and steelhead. See (Federal Columbia River Power System, 2007).

In order to reduce predation, three general hypotheses have been developed.

- If more adult salmon and steelhead are to pass upstream, then seals and sea lions must be denied access to areas where the fish congregate and problem animals must be transported and/or removed from the area.
- If more juvenile migrant salmon and steelhead are to survive while migrating through the Columbia River reservoirs, then the number of large adult pikeminnow must be reduced so that the predation level will decline.
- If more juvenile migrant salmon and steelhead are to survive while migrating through the Columbia River and estuary, then the numbers of Caspian terns and cormorants in that area must be reduced significantly.

In order to be confident that the hypotheses are valid and that the management actions were effective, some kind of status monitoring should be able to demonstrate the changes effected by the reduction in predation and disease. This should include a baseline estimate of pre-action predation and another estimate of post-action predation. A target level of predation should have been established so that an analysis can determine whether the benchmark has been obtained.

9.1 Predation Status/Trend Monitoring

9.1.1 OCEAN PREDATION

Predation upon salmon in the ocean is not well understood but can be a major factor under certain conditions. For example El Nino effects can bring warm water north along the coast of Oregon and Washington with increases in jack mackerel, blue sharks, and other predators that can target juvenile and adult migrating salmon. In addition, the Orca populations of Puget Sound and the Georgia Strait are significant predators upon salmon. Currently there are no real measures of distinct predation effects from the individual contributing factors and they are lumped into estimates of overall marine survival of migrating salmon and steelhead stocks estimated from smolt and adult abundances.

9.1.2 FRESHWATER PREDATION

Predation in freshwater is better known and documented and has included predation by harbor seals and sea lions both in Puget Sound, the Columbia River on adult salmon and steelhead. Some predation rates have been estimated based upon tag recoveries and observations for the Columbia River where3% of adult spring Chinook and 7.8% of adult winter steelhead were taken. Predation by Caspian terns and cormorants were documented in the Columbia River and it has been recently estimated that terns consume annually between 6-13% of all migrants reaching the estuary while cormorants are estimated to consume another 2.8 percent. Pikeminnow have been identified as a major predator in the hydroelectric dam impoundments of the Columbia River with an estimated annual salmonid mortality of 8%. Channel catfish, walleye, and smallmouth bass have also been identified as significant predators on juvenile salmon and steelhead. In smaller streams hatchery produced steelhead have been shown to consume coho salmon fry and other smaller salmon fry. Many streams have introduced trout species such as brook trout and brown trout. These species can consume and compete with native salmon and steelhead.

Type of M&E	Monitoring Actions
Predation Status/trend Monitoring	1. What is the status/trend of mortality due to freshwater competition with invasive trout species? 2. What is the status/trend of pikeminnow populations within the Columbia River reservoirs? 3. What is the status/trend of mortality due to pikeminnows in the Columbia River pools 4. What is the status/trend of seal and sea lion populations in coastal Oregon and Washington? 5. What is the status/trend in salmon and steelhead mortality due to seal and sea lion populations at selected problem sites 6. What is the status/trend of Caspian tern and cormorant predation upon Columbia River and other coastal populations of salmon and steelhead? 7. What is the status/trend of salmon and steelhead mortality due to bird predation?

9.1.2 Monitoring Management Actions That Address Predation

9.1.2.1 FCRPS PREDATION MANAGEMENT ACTIONS

The overall predation management objective for the FCRPS BiOp is to improve the survival of juvenile and adult fish as they pass through the hydro system. The Action agencies are pursuing a series of strategies to control predation. The Oregon Department of Fish and Wildlife and the Washington Department of Fish and Wildlife have played an important part in evaluating and administering the pike minnow reduction program. The following table (Table 19) describes ongoing predation control programs in the Columbia basin and the key monitoring questions to be answered.

Table 19. FCRPS Predator Monitoring

Type of M&E	Monitoring Actions
Implementation (Compliance) with Hydropower Biological Opinions, FERC licensing, and HCPs	8. Did the FCRPS implement piscivorous predation control measures to increase juvenile survival by implementing the Northern Pikeminnow Management Program under RPA 43? 9. Did the FCRPS develop and implement a predation management strategy per RPA 44? 10. Did the FCRPS reduce Caspian tern habitat at Sand Island from 6.5 acres to 1.5 acres to increase juvenile survival in the Snake and Lower Columbia River under RPA 45? 11. Did the FCRPS develop a double crested cormorant management and avian predation management plan by 2013 per RPA 46 and 47? 12. Did the FCRPS implement and improve avian deterrents at all Snake River and Columbia River dams? 13. Did the FCRPS install sea lion excluder gates at all main adult fish ladder entrances at Bonneville dam annually and support efforts by the fish and wildlife agencies in harassing sea lions to keep them away from the fish ladders?
Monitoring Effectiveness of Hydropower Biological Opinions, actions (RPAs)	1. Were the efforts to reduce the populations of large pikeminnow in the John Day and Dalles reservoirs effective? 2. Were the efforts to relocate Caspian terns from Sand Island effective? 3. Were the avian deterrents at the dams effective? 4. Were the sea lion excluders effective in barring entrance to sea lions?

Validation Monitoring	1. Were the number of juveniles consumed by Pike minnows maintained at target levels? 2. Were the numbers of juvenile salmon saved from Caspian tern predation reduced to target levels by 2013? 3. Were excluders and harassment techniques effective in reducing adult predation by sea lions to levels targeted?

Table 20 describes ongoing predation control programs in the Columbia basin and the key monitoring questions to be answered.

Table 20. Data risks associated with threats due to predation.

	Low Risk of Insufficient Data	Moderate Risk of Insufficient Data	High Risk of insufficient data
Status of Threats Due To Disease and Predation	• Monitored status/trend of Columbia River pikeminnows. • Monitored status/trend of Columbia estuary Caspian tern and cormorant populations • Monitoring status of sea lion populations below Bonneville Dam. • Demonstrated compliance with RPAs modifying dam operations. • Estimated changes in juvenile salmon consumption rates in pikeminnows • Estimated changes in sea lion predation on adult salmon and steelhead. • Estimated changes in avian predation rates in the Columbia River estuary	• Monitored status/trend of Columbia River pikeminnows. • Monitored status/trend of Columbia estuary Caspian tern and cormorant populations • Monitoring status of sea lion populations below Bonneville Dam. • Demonstrated compliance with RPAs modifying dam operations.	• Demonstrated compliance with RPAs modifying dam operations. • Demonstrated compliance with northern pikeminnow management program. • Developed a double crested cormorant management and avian predation management plan

9.2 Disease and Other Factors

9.2.1 Monitoring Disease

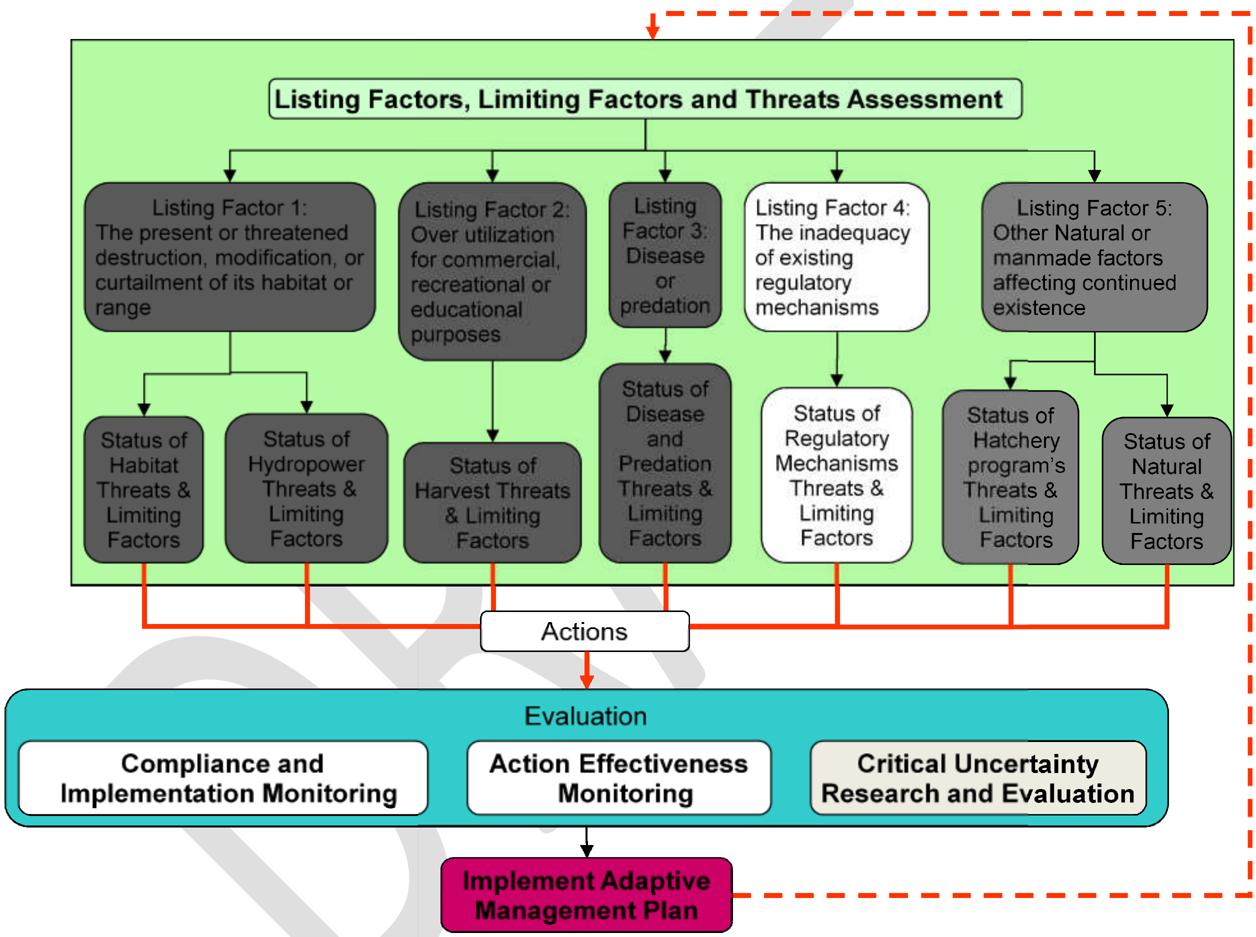
The effect of disease upon natural populations of salmon and steelhead is not well understood. The widespread use of hatcheries and hatchery salmon and steelhead has allowed documentation of the occurrence of a number of diseases affecting salmon that previously were unknown. Please refer to section **"11.0 Threats Due to Hatcheries"**. For example, the detection and spread of infectious hematopoietic necrosis (IHN) virus in salmon and steelhead in the Columbia River has been well documented when certain hatchery stocks strayed into various tributaries during the volcanic eruption of Mt. St. Helens. Millions of hatchery fish have been destroyed in order to control the spread of the virus, but its overall impact on wild populations is not well understood. Under natural conditions rearing densities are significantly lower and contact is limited due to stream reach characteristics. As part of hatchery management actions, the detection and control of disease is a significant expenditure and monitoring need. Some status monitoring of natural populations is conducted by the U.S. Fish and Wildlife Service on an ad hoc basis.

9.2.2 Aquatic Invasive Species

Aquatic invasive species have become a growing threat to native fish and wildlife of the Pacific Northwest as well as agriculture and other important water related activities. Several states have initiated invasive species councils and there is a growing awareness that non-native species are having devastating impacts to our resources. Some species likely to affect salmon include: *Spartina*, knotweed, purple loosestrife, green crab, and mitten crab, quagga, and zebra mussel.

NOAA Recommendation 30: In order to determine the extent of the threat from aquatic invasive species, existing invasive species information should be compiled and watershed assessments for those species known to affect salmon and steelhead should be conducted.

10.0 WHAT DOES NOAA RECOMMEND FOR MONITORING THREATS DUE TO INADEQUACY OF REGULATORY MECHANISMS



NOAA Fisheries Service will evaluate the inadequacies of regulatory action by reviewing individual and programmatic (group) actions for compliance with ESA section 7 consultations and all ESA related permits, by the amount of take and adverse modification of habitat allowed per population, and by analyzing the number and severity of ESA violations through coordination with our Enforcement Division. Review of regulations should follow the questions posed in Table 21 and the risk analysis in Table 22.

Table 21. Key monitoring questions that address threats due to inadequacy of regulations

Type of M&E	Monitoring Actions
Implementation (Compliance) with Existing Regulatory Mechanisms	1. Did federal, state, tribal, and local entities enact regulations designed to adequately protect salmon or adequately maintain or improve salmon habitat as identified in section 7 consultations, recovery plans and HCPs? 2. Did federal, state, tribal, and local entities adequately monitor and enforce regulations designed to protect or maintain or improve salmon habitat as identified in section 7 consultations, recovery plans and HCPs?

Table 22. Risks associated with monitoring regulatory actions.

	Low Risk of Insufficient Data	Moderate Risk of Insufficient Data	High Risk of insufficient data
Status of Threats Due To Regulatory Mechanisms	• Data showing that regulatory actions implemented are adequate to obtain recovery • Data demonstrating that existing regulatory actions are in compliance with statutes. • Data indicating BMPs implemented as a result of programmatic section 7 consultations and HCPs have been effective in protecting salmon and their habitats as described in the parent documents	• Data showing that regulatory actions implemented are adequate to obtain recovery • Data demonstrating that existing regulatory actions are in compliance with statutes.	• Data showing that regulatory actions implemented are adequate to obtain recovery

8.5.1 Implementation Monitoring

NOAA Recommendation 31: Implement a recovery plan tracking system that will be capable of recording whether local state and federal agencies have implemented regulatory actions proposed in recovery plans.

An example of how this monitoring can take place is found with the Washington Hood Canal Coordinating Council where a programmatic actions database using Microsoft Access has been developed to track implementation actions (Peterson, 2007). The programmatic actions database is a repository for information related to the programmatic actions that are outlined in the Hood Canal and Eastern Strait of Juan de Fuca Summer Chum Salmon Plan. While these actions are being carried out, information pertaining to their completion status, points of contact, sub-tasks, etc. are gathered and input into this database. Among the actions monitored are regulatory actions by the counties involved.

NOAA Recommendation 32: Develop a randomized sampling program to test whether permits issued under local and state regulatory actions designed to protect riparian and instream habitat are in compliance and that the provisions have been enforced. Compliance rate should be equal to or greater than 90%.

Although habitat is being restored through state and federal funding processes such as the Pacific Coastal Salmon Recovery Fund, habitat continues to be degraded due to the activities of our society. Salmon recovery plans have detailed how salmon habitat is protected under current federal, state, and local environmental laws. However, if those laws are not enforced or permits issued are not in compliance with existing law, then the threat to salmon and steelhead survival remains. An unbiased sampling program that addresses permits issued for work within the riparian zones of shorelines and other related activities should be monitored for compliance.

NOAA Fisheries Service will evaluate the inadequacies of regulatory action by reviewing compliance with ESA approved plans or permits, types, and quantity of ESA enforcement violations and working with planning partners to evaluate implementation of additional regulations where needed. Review of regulations should follow the questions posed in Table 23 and the risk analysis in Table 24.

Table 23. Key monitoring questions that address management actions due to inadequacy of regulations

Type of M&E	Monitoring Actions
Implementation (Compliance) with Existing Regulatory Mechanisms	1. Did federal, state, tribal, and local entities enact and/or enforce regulations designed to adequately protect salmon and/or to adequately maintain or improve salmon habitat as identified in section 7 consultations, recovery plans, and HCPs?
Effectiveness of Existing Regulatory Mechanisms	1. Are the existing regulatory actions effective in protecting salmon and maintaining or restoring critical habitat? 2. Are the existing regulatory actions effective enough to allow fish populations to reach recovery viability within protected timelines?
Validation of Existing Regulatory Mechanisms outcomes	1. Are watershed habitats adequately protected due to the cumulative effects of regulatory mechanisms? 2. Are adults and juveniles adequately protected to allow populations to reach abundance and productivity goals and timelines?
Status/Trend Monitoring	None

Table 24. Risks associated with monitoring regulatory actions.

	Low Risk of Insufficient Data	Moderate Risk of Insufficient Data	High Risk of insufficient data
Status of Threats Due To Regulatory Actions	• Data showing that regulatory actions implemented are consistent with the recovery plan • Data demonstrating that existing regulatory actions are in compliance with	• Data showing that regulatory actions implemented are consistent with the recovery plan • Data demonstrating that existing regulatory	• Data showing that regulatory actions implemented are consistent with the recovery plan

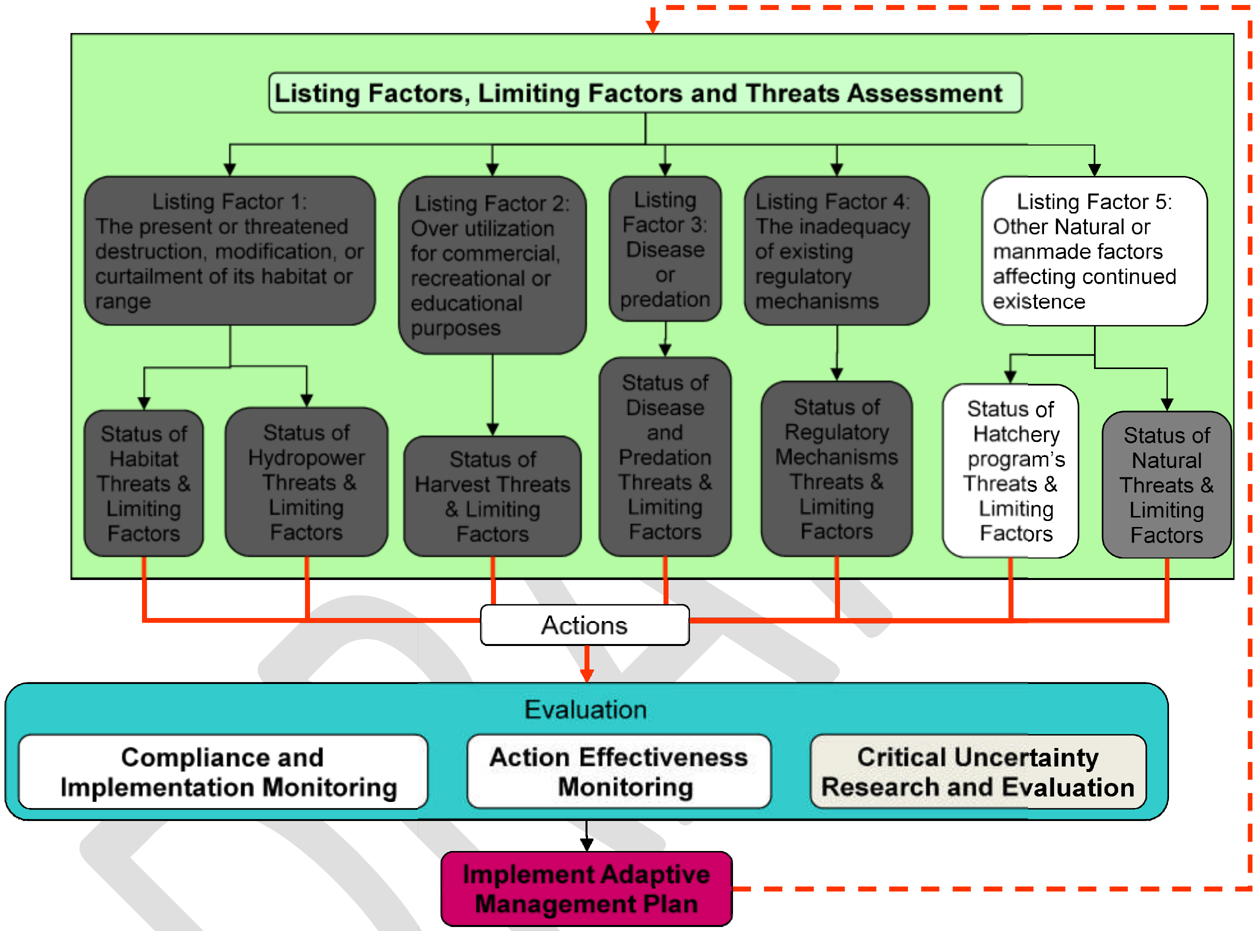
	statutes. • Data indicating BMPs implemented for forest practices and other HCPs have been effective in protecting habitat	actions are in compliance with statutes.	

8.5.1 Effectiveness Monitoring

Although there are many efforts underway to revise practices for managing storm water in urban areas and along major highways, there remains much to be done to improve the removal of contaminants and other pollutants before they enter our rivers, streams, and estuaries.

Forest practices have continued to make improvements in protecting streamside riparian zones. Currently the Forest Service and the Bureau of Land Management are using broad-scale habitat status/trend monitoring at the HUC 6 scale to determine the effectiveness of the Northwest Forest Plan and the Pac Fish In Fish Biological Opinion in addressing federal forest practices.

11.0 WHAT DOES NOAA RECOMMEND FOR MONITORING THREATS DUE TO HATCHERY PRODUCTION?



Hatcheries have been in existence in the Pacific Northwest for over 100 years, and have had a variety of effects upon natural populations of salmon and steelhead. They are implicated in causing overharvest of wild populations due to the commingling of harvestable hatchery stocks with weaker wild stocks. Concern for hatcheries also includes changes in run timing, size, and age structure as well as other morphological and behavioral characteristics. Also, more recently, studies show that many hatchery raised salmon and steelhead are less genetically fit than their wild counterparts and that this may play an important role in preventing natural populations from reaching viable levels of production due to genetic introgression. For more information on hatchery requirements under the ESA consult *"Recommendations for Planning and Operating Hatchery Programs"* (NOAA Fisheries Service, 2008), *"Hatchery Reform: Principles And Recommendations Of The Hatchery Scientific Review Group"*

Hatchery programs operate under a wide range of biological and environmental conditions and they are funded to serve different mandates. Among those mandates are:

- International and Native American treaty obligations
- Water Resources Development Act of 1986 that authorized the Lower Snake River Compensation Plan for loss of fish resources associated with the construction of Snake River hydroelectric dams by the US Army Corps of Engineers.
- Mitchell Act which provided funding for hatcheries in the Columbia River to compensate for the loss of fish resources associated with harvest and development of water resources.
- Federal Energy Regulatory Commission license agreements such as the Baker River dam in Puget Sound, the Rock Island dam in the upper Columbia River, and Pelton Dam and Round Butte dam on the Deschutes River in Oregon.
- Providing harvest opportunities in urban and suburban environments where natural habitat has been permanently damaged or lost.
- Supplementation programs designed to reintroduce species into portions of their former range or to prevent extinctions due to loss of habitat or the effects of hydroelectric facilities.

Basic hypotheses surrounding management actions to reduce this threat include:

- If the hatchery program brood stock can be modified genetically, then the genetic impacts to natural origin fish will be minimized;
- If the hatchery operation can be modified, then the percent of hatchery origin fish on the spawning grounds will be minimized.

NOAA Fisheries Service under the federal Endangered Species Act has required hatcheries affecting listed species of salmon and steelhead develop an approved Hatchery and Genetic Management Plan (HGMP). In the Pacific Northwest over 300 HGMPs are in need of revision or development to comply with the new ESA recovery needs and HSRG recommendations. These include programs associated with the FCRPS, Mitchell Act, and the Puget Sound EIS. Status/trend questions to be answered for a five year review include those shown in Table 25.

Table 25. Key monitoring questions that address hatchery threats to recovery.

Type of M&E	Monitoring Questions
Status/Trend Monitoring	1. What is the hatchery and natural stock DNA genotype and phenotype? 2. What is the annual status/trend of HOS/NOS percentages for each primary and contributing population by ESU/DPS?

11.1 Hatchery Status and Trend Monitoring

Although it is challenging to quantify the impact of changes in specific diversity traits, such as run timing or age at maturity, on eventual population and species persistence, one likely outcome of adverse changes in diversity is loss of reproductive success. For example, hatchery reared fish are believed to genetically diverge from wild fish as they adapt to survive in the novel hatchery environment. A number of studies (e.g. (Leider, 1990); (Kostow, 2003); (Berejikian, 2004) (Araki, 2008) have reported that when such hatchery fish return and spawn under natural stream conditions among themselves or with a wild fish, their ability to produce viable offspring is much reduced relative to paired wild fish in the same environment. The magnitude of this difference has generally been found to be quite large and may be related directly to population productivity. For example, Chilcote (2003) found that a spawning population of equal numbers of hatchery and wild steelhead would produce up to 63% fewer recruits per spawner than one comprised entirely of wild fish. If these findings can be applied broadly, then there could be situations where wild production of smolts could be increased by up to three times by restoring genetic diversity to the natural wild populations where such diversity has been lost and by excluding hatchery fish from spawning areas so that additional erosion of genetic fitness cannot occur.

NOAA Recommendation 33: The states and tribes should be able to determine annually the percent hatchery origin spawners (PHOS) and natural origin spawners (PNOS) for each population. Estimates should be able to detect changes of ± 5% with 80% certainty and determine the trend toward reaching HGMP targets.

PHOS levels will be determined on a case by case basis in specific hatchery HGMPs. Integrated stocks are those watersheds where the hatchery product is to be as similar as possible to natural origin spawners. Segregated stocks are those hatchery products where it is the goal to segregate to the greatest extent possible the NOS from the HOS genetically and spatially. Integrated stocks may be able to withstand a higher PHOS than segregated stocks.

NOAA Recommendation 34: The proportion of natural influence (PNI) for primary populations within the ESU for supplementation programs should be calculated periodically.

The PNI measures gene flow between hatchery origin and natural origin fish. It is calculated by determining the percent natural origin fish in the hatchery brood stock and dividing this by the percent of natural spawners in the stream comprised of hatchery origin fish plus the percent natural origin fish in the hatchery brood stock. The influence of natural spawners' increases and PNI increases as the proportion of natural spawners comprised of natural origin fish increases and as the proportion of hatchery origin brood stock comprised of natural origin fish increases. Therefore, a successful program would have few hatchery fish straying into the spawning grounds and many natural fish available for cross spawning in the hatchery.

Where supplementation programs have been developed, the PNI may be smaller due to problems with survival of natural origin fish. Those conditions can occur when:

- A natural population is at very low levels of abundance but the limiting factors have been rectified
- A natural population is in danger of extinction and hatchery intervention is necessary until limiting factors are rectified;
- A natural population is being re-established throughout all or some portion of their natural range.

11.2 Management Actions To Address Threats Due To Hatchery Production

NOAA Fisheries Service under the federal Endangered Species Act has required hatcheries affecting listed species of salmon and steelhead to have an approved Hatchery and Genetic Management Plan.

Questions to be answered for a five year review include those shown in Table 26:

Table 26. Key monitoring questions that address hatchery threats to recovery.

Type of M&E	Monitoring Actions
Implementation (Compliance) with Hatchery Genetic and Management Plans	1. Do all hatcheries in the ESU have an approved HGMP per 4(d) rule or Section 10? 2. Did federal, state and tribal entities implement their HGMPs? 3. Are hatchery actions implemented that address threats?
Effectiveness of Hatchery Genetic and Management Plans	1. Have the HGMP strategies demonstrated that they have been effective in addressing genetic and other hatchery threat effects on abundance and productivity? 2. Are the hatchery programs effective in reducing the ratio of HOS through the use of harvest, weirs, or a mixture of techniques?
Validation of Hatchery Genetic and Management Plans outcomes	1. Have the fitness of natural populations within the watersheds improved or remained static due to the HGMPs?

The following risk table (Table 27) attempts to provide guidance on the amount of risk associated with different amounts of monitoring related to hatchery programs.

Table 27. Risk evaluation for monitoring levels for hatcheries

	Low Risk of Insufficient Data	Moderate Risk of Insufficient Data	High Risk of insufficient data
Status of Threats Due to Hatcheries	Adopted HGMP for each hatchery In the ESU. Implemented HGMP and HSRG plans and recommendations for each	Adopted HGMP for each hatchery In the ESU. Implemented HGMP and HSRG plans and recommendations for each	Adopted HGMP for each hatchery In the ESU Implemented HGMP and HSRG plans and recommendations for each

	Low Risk of Insufficient Data	Moderate Risk of Insufficient Data	High Risk of insufficient data
	hatchery in the ESU. Developed baseline genetic and stock characteristic profile for each hatchery stock within the ESU. Tested whether HGMP was effective in maintaining genetic diversity of natural populations for all hatchery stocks within the ESU. Developed measurable criteria for successful completion of supplementation programs	hatchery in the ESU. Tested whether HGMP was effective in maintaining genetic diversity of natural populations for at least one hatchery stock within the ESU.	hatchery in the ESU.

8.6.1 Implementation (Compliance) Monitoring

The operation of fish hatcheries has provided huge benefits in terms of harvest opportunities for recreational and commercial fisheries as well as tribal ceremonial and subsistence fisheries. They also have played a key role in preserving some stocks that would have become extinct without artificial culture. Examples include: Puget Sound White River Chinook, Idaho Redfish Lake sockeye, and upper Columbia River steelhead and Chinook. However, growing evidence has indicated that hatcheries can have substantial adverse impacts upon wild populations due to competition, genetic introgression, harvest exploitation rates, and disease.

8.6.1.1 HATCHERY GENETIC MANAGEMENT PLANS

NOAA Required Monitoring 35: A Hatchery and Genetic Management Plan must be developed for each hatchery and submitted to NOAA Fisheries Service for approval.

Every hatchery program must monitor and record brood stock collection and juvenile fish release levels, the practices and protocols the program follows, and be ready to report this information on an annual basis. NOAA will evaluate each hatchery based upon whether a Hatchery and Genetic Management Plan was completed, if it has been authorized, and if completed was it implemented in compliance with the authorized regulations.

NOAA Recommendation 36: Documentation should be available that demonstrates that Hatchery and Genetic Management Plans have been implemented and to what extent.

The basic hypothesis is: "If the hatchery and genetic threats associated with the fish hatchery can be identified, then a solution can be created that will address the genetic problems and obtain approval for the hatchery operations." Implementation of the plan is often complex, expensive, and may take years to complete. Annual and five year evaluations of the extent to which the plans have been implemented and are compliant are necessary to provide confidence that the threats due to hatcheries are being addressed. This information should include the hatchery practices and protocols for operating the hatchery. In the Columbia River, the Bonneville Power Administration began funding the development of over 200 HGMPs in 2000 and completed the projects in 2006. The HGMPs have been submitted to NOAA Fisheries Service for approval. The following recommendations will improve implementation and compliance reporting for HGMPs.

NOAA Recommendation 37: Every hatchery program should monitor and record the practices and protocols it follows through a standardized regional data dictionary and regional approach and be ready to report this information on an annual basis.

This information is necessary to help evaluate hatchery effects and to monitor compliance with regulatory requirements. Documenting protocols and methods may be facilitated by working with PNAMP in the management of the Protocol and Methods Library Catalog Project.

NOAA Recommendation 38: Every hatchery program should monitor the residence time, spatial and temporal distribution of juvenile fish released from the program.

Understanding the spatial and temporal overlaps between HOF and NOF juveniles is necessary to determine the potential for competitive interactions, predation, and density dependent effects at the population level as well as at the basin level. This information is also available for determining how the program can be adjusted to decrease the duration of interaction, and temporal and/or spatial overlap, between juvenile fish released through the program and natural fish populations rearing and emigrating in the watershed and adjacent estuarine areas. This monitoring should include hatchery release data including timing and location of releases and passage information including tagging and telemetry data which should be coordinated with VSP abundance information being collected for natural origin fish so that efficiencies in sampling can occur. Collection of this kind of information could be accomplished with EMAP type sampling of juvenile parr. Further coordination on data storage and transfer for this data should occur through the Fish Passage Center and NOAA.

8.6.1.2 MANAGEMENT ACTIONS TO SUPPLEMENT NATURAL PRODUCTION DEFFICIENCIES

NOAA Recommended Monitoring 39: Implement effectiveness monitoring recommended by the Ad Hoc Supplementation Monitoring and Evaluation Workgroup and develop a large scale treatment /reference design to evaluate long term trends in the abundance and productivity of supplemented populations. This strategy should be incorporated into each ESU and DPS containing supplementation hatcheries and should be coordinated across broader geographic scales such as the recovery domains, Columbia River and Puget Sound basins.

McElhany (2000) concluded that valid estimates of natural productivity are impossible to obtain for supplemented populations in which the abundance of naturally produced and hatchery produced fish on the spawning grounds are not estimated separately. Average R/S estimated provide the most realistic assessment of the likelihood that a population will trend toward recovery in the absence of continued hatchery programs (i.e. natural productivity). This is because the metric considers only the survival and productivity of natural origin fish. This metric also requires the most data for each population since brood year specific estimates of hatchery fraction and age structure are necessary. For a number of populations derivation of R/S estimates requires extrapolation of data from other populations due to the lack of adequate productivity information. Inadequacy of recruit and spawner data for a population may also require inclusion of stock productivity recorded for past rather than recent time periods when productivity conditions in the natural environment may have differed from current conditions.

This information should also be collected in conjunction with ongoing VSP sampling of adult spawners and should be coordinated with hatchery programs to insure that external markings of hatchery fish is complete and to take into account any special conditions associated with supplementation or other programs where 100% marking may not have taken place. In those instances we are recommending that all hatchery fish not marked externally be coded wire tagged so that they are detectable with CWT wands in the fisheries, at counting facilities, and on the spawning grounds.

Valid estimates of hatchery fish fitness in nature are needed to assess the benefits and risks of hatchery programs that produce fish that spawn with natural origin fish. It is necessary to know or estimate the relative fitness of hatchery fish compared with natural fish in order to estimate natural productivity of the population (Berejikian, 2004). In the 2000 Federal Columbia River Power System Biological Opinion NOAA Fisheries Service estimated productivity (lambda) twice for 152 salmon and steelhead populations assuming that HOF in general were either 20% or 80% as fit as NOF. New information has become available since 2000, and it is now possible to assign hatchery fish to fitness categories based on a common set of factors that studies show influence hatchery fitness in the natural environment. This allows better estimates of lambda for natural populations where hatchery and natural fish co-occur in spawning areas. This is a new area of research and further studies are needed to improve the accuracy of hatchery fitness predictions including replicate studies on other species subject to different hatchery practices and particularly on species with abbreviated freshwater life histories (e.g. ocean type Chinook salmon).

Galbreath, (October 2008) have described some possible large scale approaches to monitoring supplementation programs including treatment reference approach to evaluate the long term trends of supplementation relative to un-supplemented populations; relative reproductive success studies designed to measure the reproductive success on productivity over a short time span; and the development of research studies that address critical uncertainties that are not discernible through the treatment-reference or reproductive success approach.

NOAA Recommendation 40 The genotype and phenotype of every hatchery brood stock program should be monitored periodically to determine effectiveness of maintaining the goals of the hatchery product.

Programs need to monitor the genetic characteristics of brood stock to prevent the homogenization of the stock or alteration of gene flow over time. Baseline genetic monitoring is essential and should support current GSO work with salmonids across the Pacific Northwest.

8.6.1.3 MANAGEMENT ACTIONS TO CONTROL DISEASE ASSOCIATED WITH HATCHERIES

The widespread use of hatcheries and hatchery salmon and steelhead has allowed documentation of the occurrence of a number of diseases affecting salmon that previously were unknown. Refer to Section 12.2 under Threats Due to Disease and Predation for a discussion on disease monitoring. Following table describes key monitoring questions to be answered for hatchery disease issues Table 28.

Table 28. Questions to be answered for monitoring disease at hatchery facilities

Type of M&E	Monitoring Actions
Implementation (Compliance) with Disease Restrictions	1. Are the state and tribal hatcheries maintaining a disease monitoring program at all hatchery facilities in compliance with regional co-manager disease policies and the recommendations of the Pacific Northwest Fish Health Protection Committee's "Model Comprehensive Fish Health Protection Program"? 2. Are the state and tribal hatcheries following disease related requirements within their HGMPs?

In order to determine the success of hatchery disease policies and programs, the states and tribes should annually report the following information adapted from the Salmonid Disease Control Policy of The Fisheries Co-Managers of Washington State (July 2006):

- The number of juvenile and adult stocks that were tested for regulated pathogens in the previous spawning cycle by facility and by MPG and ESU/DPS.
- The number of juvenile and adult stocks that tested positive for a regulated pathogen by pathogen type in the previous spawning cycle by facility and by MPG and ESU/DPS.
- The number of regulated pathogen detections that occurred in watersheds or fish stocks that previously had a negative history for the regulated pathogens. This would include detections both within the hatchery and within the watershed natural population.
- The suspected sources of the infections.
- Whether the positive species were transferred as eggs or fish.

8.7.1 Effectiveness Monitoring (Outputs)

The creation of a Hatchery and Genetic Management Plan and the further review of whether it was implemented led to the next question associated with the hypothesis, did it work? The effectiveness monitoring should be tailored to the specific strategy employed with the hatchery program and the characteristics of the natural population. Since hatchery operations are unique in relation to the stocks affected and the geographic area, one approach to all situations is not appropriate. Much of the effectiveness monitoring for hatchery programs can be evaluated from the basic information about ratios of natural origin fish (NOF) and hatchery origin fish (HOF) in the hatchery and on the spawning grounds, spatial and temporal distribution of HOF in the stream, and genetic phenotype and genotype information collected prior to implementation of hatchery reform measures and periodically after their implementation. Additional data on NOF juvenile abundance and densities and habitat quality should also be considered in the overall evaluation.

8.7.1.3 EFFECTIVENESS OF MANAGEMENT ACTIONS TO ADDRESS PASSAGE AND PREDATION ISSUES AND OTHER THREATS AT HATCHERIES

NOAA Recommendation 41: Assess Effectiveness of actions taken to address threats to NOF due to hatchery operations

It is necessary to understand and monitor the effects of threats associated with hatchery facilities and hatchery operations (e.g. hatchery water intakes, outflows, hatchery screening, weirs) on the survival, distribution, and productivity of adult and juvenile salmon and steelhead populations. Providing this information will insure continued authorizations under the HGMPs.

8.7.1.4 EFFECTIVENESS OF DISEASE PREVENTION ASSOCIATED WITH HATCHERIES

The widespread use of hatcheries and hatchery salmon and steelhead has allowed documentation of the occurrence of a number of diseases affecting salmon that previously were unknown. Refer to Section 12.2 under Threats Due to Disease and Predation for a discussion on disease monitoring. Following table describes key monitoring questions to be answered for hatchery disease issue Table 29.

Table 29. Questions to be answered for monitoring disease at hatchery facilities

Type of M&E	Monitoring Actions
Effectiveness of Disease detection and control measures	1. Have disease detection and prophylaxis been effective in controlling the occurrence and spread of fish pathogens in the hatchery and natural populations of the Columbia River, Puget Sound and the coast?

In order to determine the effectiveness of hatchery disease policies and programs, the states and tribes should annually report the following information adapted from the Salmonid Disease Control Policy of the Fisheries Co-Managers of Washington State (July 2006):

- The number of juvenile and adult stocks that were tested for regulated pathogens in the previous spawning cycle by facility and by MPG and ESU/DPS.
- The number of juvenile and adult stocks that tested positive for a regulated pathogen by pathogen type in the previous spawning cycle by facility and by MPG and ESU/DPS.
- The number of regulated pathogen detections that occurred in watersheds or fish stocks that previously had a negative history for the regulated pathogens. This would include detections both within the hatchery and within the watershed natural population.
- The suspected sources of the infections
- Whether the positive species were transferred as eggs or fish.

8.7.2 Validation Monitoring (Outcomes)

Validating the success of hatchery plans and implemented changes will likely involve specific watershed and population genetic studies to determine the effects of the hatchery program on reproductive success of NOF. Monitoring of genetic change is of such long term nature that a few long term studies will be needed, perhaps one in each ESU to demonstrate reproductive success while at the same time documenting allozyme and DNA frequencies over time for all NOF and HOF populations and comparing those changes to NOR baselines (Chilcote, 2003). This evaluation is necessary to determine whether the program has had any effect on natural origin population abundance, productivity, diversity, and distribution.

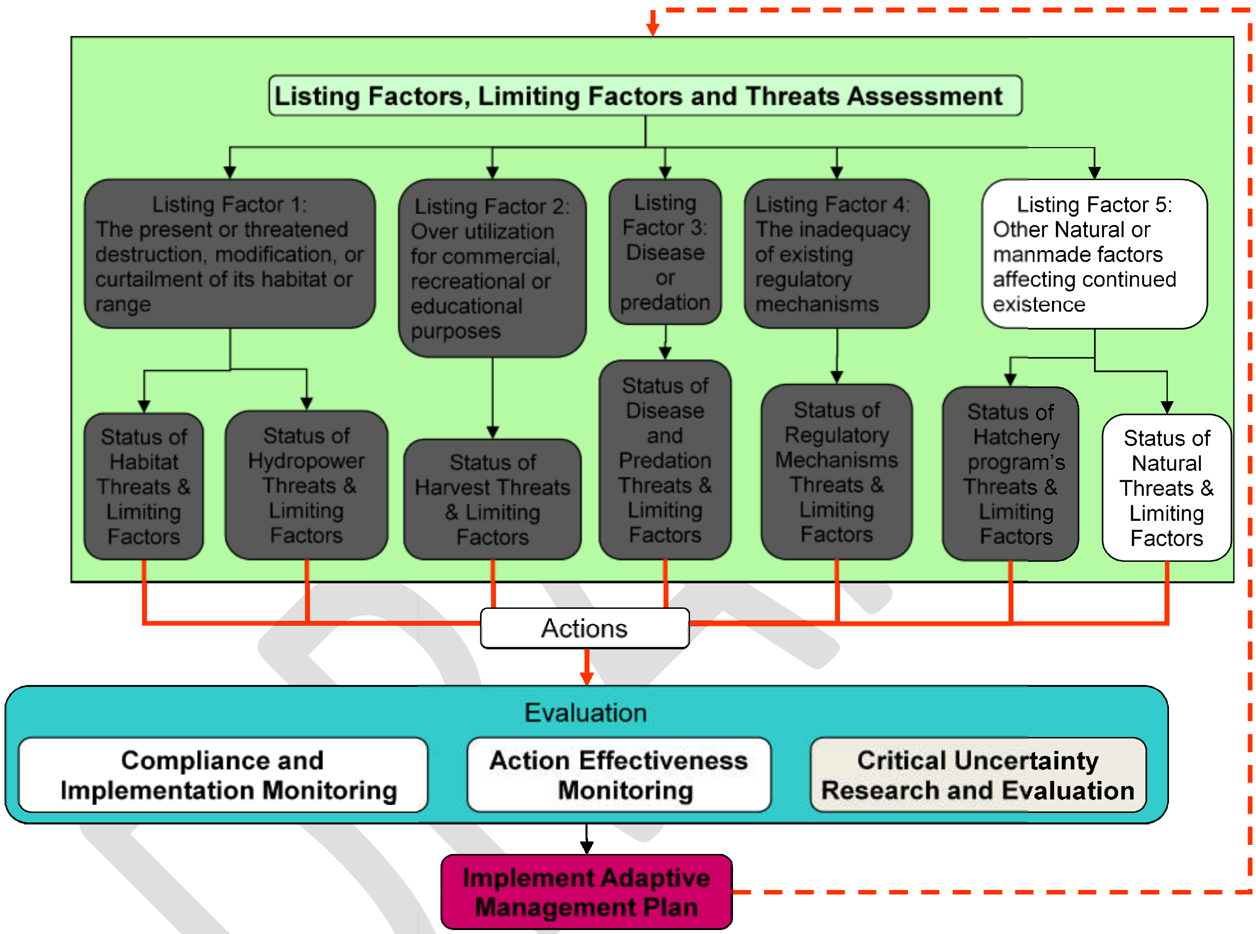
8.7.2.1 FCRPS HATCHERY MONITORING ACTIONS

The FCRPS Biological Opinion calls for the funding of hatcheries in a way that contributes to reversing the decline of downward trending ESUs. Hatchery monitoring questions and actions are found in table

Table 30. FCRPS Hatchery Monitoring Actions

Type of M&E	Monitoring Actions
Implementation (Compliance) with Hydropower Biological Opinions, FERC licensing, and HCPs	1. Did the FCRPS implement the updated HGMPs and adopt program criteria per RPA 39 at FCRPS funded facilities? 2. Did the FCRPS fund reforms to hatchery operations to reduce genetic and ecological effects per Table 6 of RPA40?
Monitoring Effectiveness of Hydropower Biological Opinions, actions (RPAs)	1. Were the efforts to create a local brood stock for steelhead for the Tucannon and Touchet Rivers and for the Winthrop NFH effective? 2. Were the safety net programs in Table 7 RPA 41 for Snake River sockeye, Snake River Spring/summer Chinook, and Snake River steelhead effective in maintaining the natural population and genetic diversity?

12.0 WHAT DOES NOAA RECOMMEND FOR MONITORING THREATS DUE TO NATURAL CAUSES



Although climate change is a possible major player in salmon survival, the tracking of climate change will, for the most part, remain the purview of the universities and of NOAA for the near future. The responsibilities of salmon monitoring agencies and tribes will fall more indirectly upon monitoring marine and freshwater survival and in correlating that with larger scale phenomena such as decadal oscillations, El Nino effects and coastal upwelling.

North Pacific Gyre Oscillations (NPGO) affect on salmon survival have been noted for data collected on North Pacific buoys for oscillations in sea surface temperature (Figure 13). When surface temperatures are cooler salmon survival increases (DiLorenzo, 2008).

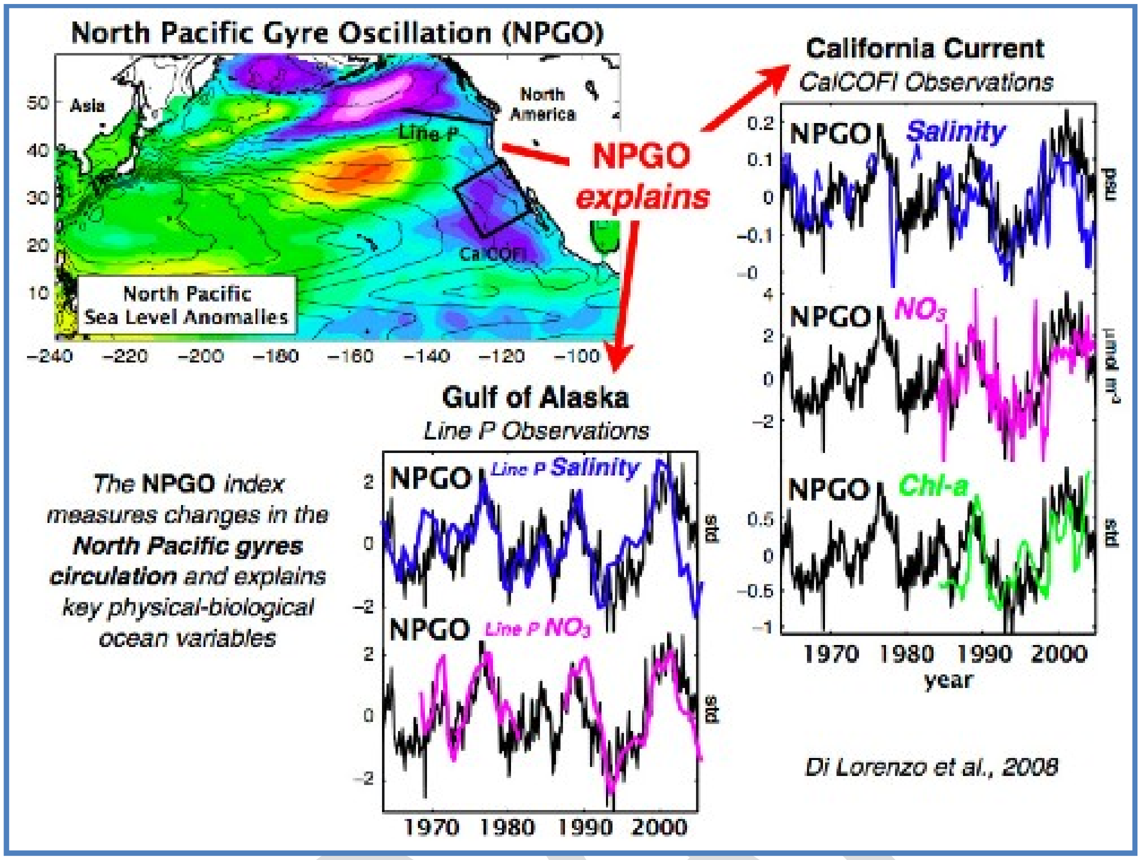


Figure 13. Charts showing oscillations in the North Pacific and California since 1960 (Taken from DiLorenzo, 2008)

El Nino and La Nina events are also factors in influencing climate and conditions for migrant salmon. When El Nino conditions occur in the mid Pacific and warmer waters are pushed north from California into Oregon and Washington waters, species such as mackerel and blue sharks become abundant off of the coast and plankton is suppressed due to lack of nutrients from coastal upwelling Figure 14 .

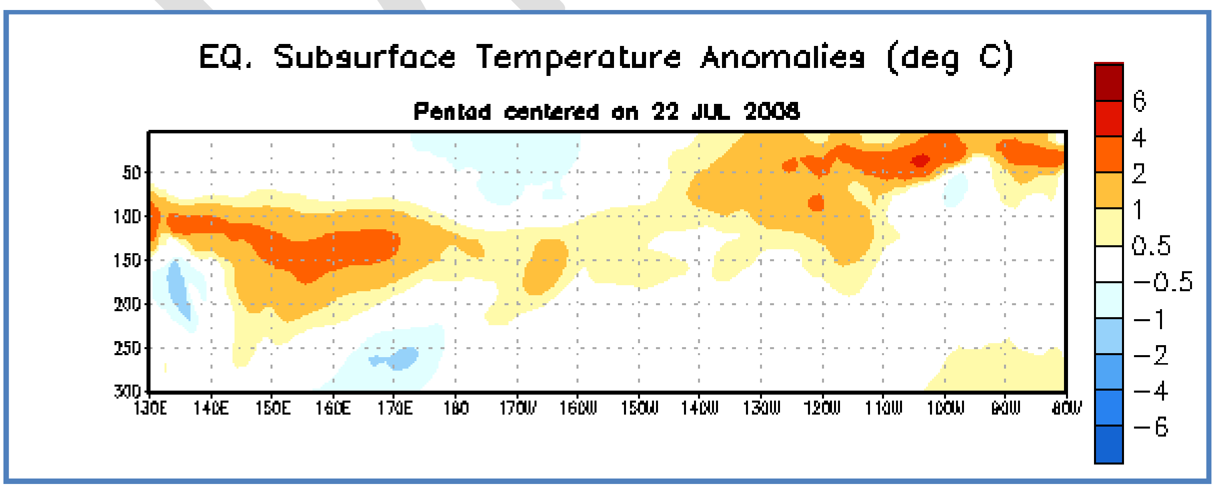


Figure 14. El Nino warm layers in the mid pacific Ocean.

There are a number of natural causes of mortality in freshwater streams that significantly impact salmon and steelhead survival. For instance: low stream flows (drought), high water temperatures; freshets and floods; landslides and erosion; forest fires; winter stream ice conditions; snow pack and snow melt conditions continue to cause annual fluctuations in freshwater survival. These could be measured as a surrogate for measuring the larger scale influences on all of the above kinds of events. Table 31 contains key monitoring questions that are potentially within the monitoring scope of the Pacific Northwest salmon recovery partners.

NOAA Recommendation 42: The states and tribes can assist in monitoring the effects of changes in climate upon salmon and steelhead populations by monitoring changes in stream flow, temperature, and their effects upon freshwater survival at all life stages.

Table 31. Key monitoring questions that address threats due to climate and other natural causes.

Type of M&E	Monitoring Actions
Status/Trend Monitoring	1. What is the status/trend of PNW stream flow? 2. What is the status/trend of Pacific Ocean Gyre sea surface temperatures? 3. What is the status/trend of PNW snowpack water content? 4. What is the status/trend of stream temperatures?

13.0 WORKS CITED

Araki H., B.A. Berejikian, MJ Ford, MS Blouin Fitness of hatchery-reared salmonids in the wild [Journal] // Evolutionary Applications. - [s.l.] : Blackwell Publishing Ltd, 2008. - 2 : Vol. 1. - pp. 342-355.

Bayley P.B. A review of studies on responses of salmon and trout to habitat change, with potential for application in the Pacific Northwest [Report] / Department of Fisheries and Wildlife. - Corvallis : Oregon State University, May 2002. - p. 26. - Report to the Washington State Independent Science Panel.

Beechie T.J, E.A. Steel, P. roni, and E. Quimby Ecosysten Recovery Planning for Listed Salmon [Report] : Memorandum / National Oceanic and Atmospheric Administration ; National Marine Fisheries Service. - Seattle : U.S Department of Commerce, National Marine Fisheries Service, 2003. - p. 183. - NMFS-NWFSC-58.

Berejikian B.A., and M.J. Ford Review of relative fitness of hatchery and natural salmon [Report]. - Seattle, WA : US Department of Commerce, 2004. - p. 28. - NOAA Tech. Memo. NMFS-NWFSC-61.

Bilby R.E. Evaluating watershed response to land management and restoration actions: Intensively Monitored Watersheds (IMW) Progress Report. Submitted to Washington Salmon Recovery Funding Board. [Report]. - Olympia : Washington Salmon Recovery Funding Board, 2004. - Prepared by the PNAMP IMW Committee.

Bisson P.A., S.V. Gregory, T.E. Nickelson, and J.D. Hall The Alsea Watershed Study: A comparison with other multi-year Investigations in the Pacific Northwest [Book Section] // Hydrological and Biological Responses to Forest Practices / book auth. Stednick John D.. - [s.l.] : Springer, 2008.

Blouin Michael Hood River Steelhead Genetics Study; Relative Reproductive Success of Hatchery and Wild Steelhead In the Hood River, 2002-2003 Final Report [Report] / US Department of Energy. - Portland, OR : Bonneville Power Administration, 2003. - p. 25. - Project No. 198805312.

Busch S, P McElhany, and M Ruckelshaus A Comparison of the Viability Criteria Developed for Management of ESA listed Pacific Salmon and Steelhead [Report] : Informal Report / Northwest Fisheries Science center. - Seattle, WA : National Marine Fisheries Service, 2008. - p. 30.

Carlile J, R. McNicol, and R. Sharma Bilateral data standards for estimates of escapement for chinook escapement indicators [Report] : Memo to Sentinel Stocks Committee. - Vancouver, B.C. Canada : Pacific Salmon Commission Chinook Technical Committee, October 2008. - p. 8.

Chilcote M.W. Relationship between natural productivity and the frequency of wild fish in mixed spawning populations of wild and hatchery steelhead (Oncorhynchus mykiss) [Journal]. - [s.l.] : Canadian Journal of Fisheries Aquatic Science, 2003. - Vol. 60. - pp. 1057-1067.

Chilcote M.W., T. Nickelson, and K. Moore Oregon coastal coho assessment: Part 2: Viability Criteria and Status Assessment of Oregon Coastal Coho [Report]. - Salem, OR : Oregon Department of Fish and Wildilfe, 2005.

Cooney T, M. McClure, C. Baldwin, R. Carmichael, P. Hassamer, P. Howell, D. McCullough, H. Schaller, P. Spruell, C. Petrosky, and F. Utter Viability Criteria for Application to Interior Columbia Basin Salmonid ESUs [Report]. - Portland : National Marine Fisheries Service, 2007. - p. 93.

Cooney T., M. McClure, C. Baldwin, R. Carmichael, P. Hassemer, P Howell, H. Shaller, P. Spruell, C. Petrosky, F. Utter, D. Holzer, D. Matheson, and L. Wright Current Status Reviews: Interior Columbia Basin Salmon ESUs and Steelhead DPSs Volume III Middle Columbia River Steelhead [Report] / NOAA Fisheries Service. - [s.l.] : NOAA Fisheries Service, 2008. - p. 23.

Courbois J., S.L. Katz, D.J. Isaak, E.A. Steel, R.F. Thurow, A.M.W. Rub, T. Olsen, and C.E. Jordan Evaluating probability sampling strategies for estimating redd counts: an example with Chinook salmon (Oncorhynchus tshawytscha) [Journal]. - [s.l.] : Canadian Journal of Fisheries and Aquatic Sciences, 2008. - Vol. 65. - pp. 1814-1830.

DiLorenzo E., N. Schneider, K.M. Cobb, K. Chhak, P.J.S. Franks, A.J. Miller, J.C. McWilliams, S.J. Bograd, H. Arango, E. Curchister, T.M. Powell, and P. Rivere North Pacific Gyre Oscillation Links Ocean Climate and Ecosystem Change [Journal]. - [s.l.] : Geophysical Research letters, 2008. - LO8607 : Vol. 35. - doi:10.1029/2007GL032838.

Federal Columbia River Power System Biological Assessment For Effects of the Federal Columbia River Power System and Mainstem Effects of other Tributary Actions on Anadromous Salmonid Species Listed Under the Endangered Species Act Appendix A Overhaul of the System [Journal]. - Portland, OR : FCRPS, 2007.

Galbreath P.F., C.A. Beasley, B.A. Berejikian, R.W. Carmichael, D.E. Fast, M.J. ford, J.A. Hesse, L.L. McDonald, A.R. Murdoch, C.M. Pevan, and D. A. Venditti Recommendations for Broad Scale Monitoring to Evaluate the Effects of Hatchery Supplementation on the Fitness of Natural Salmon and Steelhead Populations [Report]. - Portland, OR : Northwest Power and Conservation Council, October 2008. - p. 82.

Hahn P., C. Kraemer, D. Hendrick, P. Castle, and L.Wood Washington State Chinook spawning escapement assessment in the Stiilaguamish and Skagit Rivers [Report]. - Olympia, WA : Washington Department of Fish and Wildlife, 1998.

Hankin D.G., J.H. Clark, G.S. Morishima, B.E. Riddell, R.B. Deriso, C. Schwarz, J.C. Garza, and J.B. Scott Report Of The Expert Panel On The Future Of The Coded Wire Tag Recovery Program For Pacific Salmon [Report]. - Vancouver BC : Pacific Salmon Commission, November 2005. - p. 230.

Heitke J.D., E.J. Archer, D.D. Dugaw, B.A. Bouwes, E.A. Archer, R.C. Henderson, and J.L. Kershner Effectiveness Monitoring For Streams and Riparian Areas: sampling protocol for stream channel attributes. [Report] : Unpublished manuscript / Forest Service. - [s.l.] : U.S. Forest Service, 2006. - p. www.fs.fed.us./biology/fishecology/emp..

Hillman T.W. Draft Monitoring Strategy For the Upper Columbia Basin, [Report]. - Eagle, ID : Bioanalyists Inc, 2006. - Prepared for the Upper Columbia Basin Regional Techincal Team and the Upper Columbia Salmon Recovery Board.

Hinrichsen R.A. Effect of measurement on quasi-extinction probabilities [Report] : Unpublished manuscript. - Portland, OR : Bonneville Power Administration, July 2008. - p. 6.

Johnson D.H., B.M. Shrier, L.S. O'Neal, J.A. Knutzen, X. Augerot, T. A. O'Neil, and T.N. Pearsons Salmonid Protocols Handbook: Techniques for assessing status and trends in salmon and trout populations. [Journal]. - Bethesda MD : American Fisheries Society, 2007. - p. 478.

Kaufmann P.R., P. Levine, E.G. Robison, C. Seeliger, and D.V. Peck Quantifying Physical Habitat in Wadeable Streams [Report]. - Washington, DC : U.S. Environmental Protection Agency, 1999. - EPA/620/R-99/003.

Kostow K., A.R. Marshall, & S.R. Phelps Naturally Spawning Hatchery Steelhead Contribute to Smolt Production But Experience Low Reproductive Success [Journal]. - [s.l.] : Transactions of the American Fisheries Society, 2003. - Vol. 132. - pp. 780-790.

Larsen D.P. and A.R. Olsen and D.L. Stevens Jr Using a Master Sample to Integrate Stream Monitoring Programs [Journal]. - [s.l.] : Journal of Agricultural, Biological, and Environmental Statistics, 2008. - 3 : Vol. 13. - pp. 243-254.

Larsen D.P., P.R. Kaufmann, T.M. Kincaid, and N.S. Urquhart Detecting Persistent Change in the Habitat of Salmon-bearing Streams in the Pacific Northwest [Journal]. - [s.l.] : Canadian Journal of Aquatic Science, 2004. - Vol. 61. - pp. 283-291.

Leider S.A., P.L. Hewitt, J.J. Loch, & M.W. Chilcote Electrophoretic comparison of reproductive success of naturally spawning transplanted and wild steelhead trout through the returning adult stage [Journal]. - [s.l.] : Aquaculture, 1990. - Vol. 88. - pp. 239-252.

McElhany P., M.H. Ruckelshaus, M.J. Ford, T.C.Wainright and E.P Bjorkstedt Viable Salmonid Populations and the Recovery of Evolutionarily Significant Units [Report] / NW Fisheries Science Center. - Seattle, WA : NOAA Fisheries Service, 2000. - p. 156 p.. - NOAA Tech. Memo. NMFS-NWFSC-42.

Monitoring Oversight Committee The Washington Comprehensive Monitoring Strategy For Watershed Health and Salmon Recovery: Volume 2 [Report]. - Olympia, WA : Washington Interagency Committee, 2002. - p. 377. - Volume 2.

Nickelson T.E. A Habitat-Based Assessment of Coho Salmon Production Potential and Spawner Escapement Needs for Oregon Coastal Streams [Report] / Northwest Region. - Portland, Oregon : Oregon Department of Fish and Wildlife, 1998. - p. 15. - Information Report Number 98-4.

Nickelson T.E. ODFW Coastal Salmonid Population and Habitat Monitoring Program [Report]. - Corvallis, Oregon : ODFW, 1998. - p. 50.

Nickelson T.E., M.F. Solazzi, S.L. Johnson, and J.D. Rodgers An Approach to Determining Stream Carrying Capacity and limiting habitat for Coho Salmon (Oncorhynchus kisutch) [Report] / Proceedings of the Coho Workshop. - Nanaimo, British Columbia, Canada : L. Berg and P.W. Delaney, 1992. - pp. 251-260.

NOAA Fisheries Service Adaptive Management for ESA-Listed Salmon and Steelhead Recovery: Decision Framework and Monitoring Guidance [Report] : Informal Guidance Document. - Seattle, WA : Northwest Region and Fisheries Science Center, May 2007. - p. 56.

NOAA Fisheries Service Draft Artificial Propagation of Pacific Salmon: Assessing Benefits and Risks and Recommendations for Planning and Operating Hatchery Programs [Report] / Salmon Recovery Division. - Portland, OR : US Dept. of Commerce NOAA's National Marine Fisheries Service, 2008. - p. 43.

NOAA Fisheries Service Pacific Coastal Salmon Recovery Fund Performance Goals, Measures, and Reporting Framework [Report]. - Seattle, WA : NOAA Fisheries Service, December 2006. - p. 10.

Pacific Fishery Management Council Fishery Regulation Assessment Model (FRAM) An Overview for Coho and Chinook v30 [Report] / Model Evaluation Workgroup. - Portland OR : Pacific Fishery Management Council, October 2008. - p. 39.

Paulsen C.M. and T.R. Fisher Detecting juvenile survival effects of habitat actions: power analysis applied to endangered Snake river spring-summer chinook (Oncorhynchus tsawytscha) [Journal]. - [s.l.] : Canadian Journal of Aquatic Science, 2003. - Vol. 60. - pp. 1122-1132.

Paulsen. C.M. R.A. Hinrichsen, and T.R. Fisher Measure Twice, Estimate Once: Pacific Salmon Population Viability Analysis for Highly variable Populations [Journal]. - [s.l.] : Transactions of the American Fisheries Society, 2007. - Vol. 136. - pp. 346-364.

Peck D., Lazorchak, J.M., D.J. Klemm Environmental Monitoring and Assessment Program - Surface Waters: Western Pilot Study Field Operations Manual for Wadeable Streams. [Report] : field manual. - Corvallis, OR : U.S. Environmental Protection Agency, Western Division, 2003. - p. www.epa.gov/r10earth/offices/oea/ieu/WADEABLE_MANUAL_APR_2003.PDF. - EPA/620/R-94/004F.

Peterson G. and S. Brewer Hood Canal Chum Recovery Plan Appendix H. Programmatic Actions Database, Summary Report [Report] : Appendix to Chum Recovery Plan. - Shelton, WA : Hood Canal Coordinating Council, 2007. - p. 9.

Rodgers J.D. Abundance Monitoring of Juvenile Salmonids in Oregon coastal Streams, 2001 [Report] / Western Oregon Rearing Project. - Corvallis : Oregon Department of Fish and Wildlife, 2002. - p. 50.

Roni P., T.J. Beechie, R.E. Bilby, F.E. Leonetti, M.M. Pollock, and G.R. Pess A review of stream restoration techniques and a hierarchical strategy for prioritizing restoration in Pacific Northwest watersheds [Journal] // North American Journal of Fisheries Management. - [s.l.] : American Fisheries Society, 2002. - Vol. 22. - pp. 1-20.

Sands NJ, K. Rawson, K. Currens, B. Graeber, M. Ruckelshaus, B. Fuerstenberg and J. Scott The Hood Canal Summer Chum Salmon ESU [Report] : ESA Special Team / Natioanl Marine Fisheries Service. - Seattle : Puget Sound technical Recovery Team, 2007. - p. 64.

Seeb L.W., A. Antonovich, M.A. Banks, T.D. Beacham, M.R. Belinger, S.M. Blankenship, M.R. Campbell, N.A. Decovich, J.C. Garza, C.M. Guthrie, T.A. Lundrigan, P. Moran, S.R. Narum, J.J. Stephenson, K.J. Supernault, D.J. Teel, W.D. Templin, J.K. Wenburg, etc Development of a Standardized DNA Database for Chinook Salmon [Journal] // Fisheries. - [s.l.] : American Fisheries Socierty, 2007. - 11 : Vol. 32. - pp. 540-549.

Seiler D., S. Neuhauser, L. Kishimoto 2000 Skagit River Wild 0+ Chinook Production Evaluation: Annual Project Report [Report]. - Olympia : Washington Department of Fish and Wildlife, 2001. - p. 45.

Smith C.T., J. Baker, L. Parks, L.W. Seeb, C. Elfstrom, S. Abe, and J.E. Seeb Characterization of 13 single nucleotide polymorphism markers for chum salmon [Journal]. - [s.l.] : Molecular Ecology Notes, 2005. - Vol. 5. - pp. 259-262.

Tussing S.P. A Field Manual of Scientific Protocols for Downstream Migrant Trapping within the Upper Columbia Monitoring Strategy Version 1.0. - Wauconda Washington : Terraqua Inc, 2008. - p. 35. - Published for BPA ISEMP Program.

U.S. Department of Agriculture Field Protocols Manual: Aquatic and Riparian Effectiveness Monitoring Program. Regional Interagency Monitoring for the Pacific Northwest Forest Plan [Report] : 2006 Field Season / Forest Service ; AREMP. - Portland, OR : U.S. Forest Service, 2006. - http://www.reo.gov/monitoring/watershed/AREMP/2004/aremp.htm..

U.S. Department of Commerce 2007 Report to Congress Pacific Coastal Salmon Recovery Fund FY2000-2006 [Report] : Annual Report. - Seattle : National Marine Fisheries Service Northwest Region, 2007. - p. 47.

U.S. Department of Energy Office of Science Human Genome Project Information [Online] // Genomic.energy.gov. - September 19, 2008. - November 20, 2008. - http://www.ornl.gov/sci/techresources/Human_Genome/faq/snps.shtml.

Washington Department of Fish and Wildlife &participating Treaty tribes The Salmonid Disease Control Policy of the Fisheries Co-Managers of Washington State [Report]. - Olympia WA : Washington Department of Fish and Wildlife, July 2006. - p. 38.

Zar Jerrold H. Biostatistical Analysis. 4th Edition [Book]. - Upper Saddle River, NJ : Prentice-Hall, Inc, 1999. - p. 931.

APPENDIX 1 LIST OF ACRONYMS AND DEFINITIONS

Acronym	Title or name	Explanation of Abbreviation or Definition
ACE	Army Corps of Engineers	A branch of the US Army charged with maintaining navigation and flood control on the nation's waters
ARS	Aquatic Resource Schema	
BACI	Before After Control Impact	A sampling design where a control area and the intended impact area of the management action are compared both before and after the management action has occurred using biological or physical metrics. The BACI has strong statistical power to detect significant change in parameters in the impact area.
BOR	Bureau of Reclamation	Reclamation is a federal water management agency that will help the Western States, Native American Tribes and others meet new water needs and balance the multitude of competing uses of water in the West. Its mission is to assist in meeting the increasing water demands of the West while protecting the environment and the public's investment in these structures.
Brownian Motion	Brownian Motion	A continuous spatial model for populations that are not density-regulated. A mathematical theory applied to populations where random and unknown environmental and manmade changes can cause a population to respond in unpredictable highly variable ways.
BRT	Biological Review Team	A team convened by NOAA Fisheries Service when conducting a formal review of change of status of an ESU. Their task is to evaluate information about an ESU to evaluate extinction risk and status of listing factors
CSMEP	Collaborative System-wide Monitoring and Evaluation Project	A Columbia Basin Fish and Wildlife Authority program funded by the Bonneville Power Administration to review and coordinate monitoring approaches in the Columbia basin
CBFWA	Columbia Basin Fish and Wildlife Authority	The Columbia Basin Fish and Wildlife Authority is an organization whose membership consists of the four state and two federal fish and wildlife management entities and eleven Indian tribes of the Columbia River Basin. The members are the legally recognized managers of the fish and wildlife resources. The members established the Authority by charter in 1987 to coordinate joint planning and action; exchange information and develop unified positions; assure comprehensive implementation of the NPCC Fish and Wildlife Program; improve the quality of decision making; and to influence other regional decision makers.
Cohort	Cohort Construction or cohort analysis	A group of migrating salmon all derived from the same parents spawning together in a stream or river at the same spawning cycle commonly called a brood year who may migrate to sea at different times and return from the sea at different times. For example in steelhead there are cohorts who will return after one year at sea, two years at sea and three years at sea.

Acronym	Title or name	Explanation of Abbreviation or Definition
		Therefore to develop an estimate of the overall production and survival of a particular spawning cycle, one must evaluate the numbers of adults returning at different ages and add them together to establish the cohort survival. By definition this may take several years to collect and analyze the data in order to reconstruct the overall survival and associated mortalities such as harvest of any one year class of salmon or steelhead
CTC	Chinook Technical Committee	A committee of the PSC that evaluates the science and current statistics for managing Chinook salmon in the PSC.
CV	Coefficient of variation	A normalized measure of dispersion of a probability distribution. It is defined as the ratio of the standard deviation to the mean. The coefficient of variation is useful because the standard deviation of data must always be understood in the context of the mean of the data. The coefficient of variation is a dimensionless number. So when comparing between data sets with different units or wildly different means, one should use the coefficient of variation for comparison instead of the standard deviation.
CWT	Coded Wire Tag	A small wire implanted in the snout of salmon that contains a code identifying the location and data of tagging.
DNA	Deoxyribo Nucleic Acid	A nucleic acid that contains the genetic instructions used in the development and functioning of all known living organisms and some viruses. The main role of DNA molecules is the long-term storage of information. DNA is often compared to a set of blueprints or a recipe, or a code, since it contains the instructions needed to construct other components of cells, such as proteins and RNA molecules.
Domain	Domain	An administrative geographic area created by NOAA Fisheries Service to cluster ESUs and DPS having common watersheds and geographic boundaries.
DPS	Distinct Population Segment	Under the ESA, the term species includes any subspecies of fish or wildlife or plants and any distinct population segments of any species or vertebrate fish or wildlife which interbreeds when mature (ESA Sec. 3 (15)). The ESA thus considers a DPS to be a species. Under NOAA Fisheries Service policy for Pacific Salmon, a population or group of populations will be considered a DPS if it represents an evolutionarily significant unit (ESU) of the biological species.
EMAP	Environmental Monitoring and Assessment Program	A probabilistic sampling design and specific protocols developed by the USEPA for assessing watershed conditions for riparian and instream physical characteristics.
EMDS	Ecosystem Management Decision Support	A model that facilitates evaluation of complex, abstract topics, such as forest type suitability, that depend on numerous, diverse subordinate conditions by developing weighted scoring of various habitat metrics.
ESA	Endangered Species Act	Federal endangered species act of 1973 as amended
ESU	Evolutionarily Significant Unit	For Chinook, coho, chum, sockeye, pink salmon a population or group of populations that is considered distinct because (1) they are substantially reproductively isolated from other con-specific groups and because (2) they represent an important component in the evolutionary legacy of the biological species. An ESU qualifies as a species under the federal ESA.
FERC	Federal Energy Regulatory Commission	Federal agency charged with regulating the licensing and approval of hydroelectric projects and other energy projects nationally.
FCRPS	Federal Columbia River Power System	The consortium of federal agencies that operate hydroelectric dams on the Columbia River and includes the Bonneville Power

Acronym	Title or name	Explanation of Abbreviation or Definition
		Administration, Army corps of Engineers, and the Bureau of Reclamation.
FRAM	Fishery Regulation Assessment Model	A model currently used by the PFMC to annually estimate impacts of proposed ocean and terminal fisheries on Chinook and coho salmon.
GCA	Gene Conservation Area	A term used by Oregon Department of Fish and Wildlife to describe discrete groupings of coastal coho salmon populations. This term has been overshadowed by the use of MPG.
GRTS	Generalized Random Tessellation Stratified	A method for selecting sampling locations based upon randomly selected stream segments that are sampled according to a rotating sampling design or panel. It provides for both status sample sites and trend sample sites
GSI	Genetic Stock Identification	The use of genetic information either at the protein allozyme level or DNA level to characterize a population of fish.
HCP	Habitat Conservation Plan	An agreement between the federal government and a private or public entity to make specific changes to their management practices in order to preserve and restore habitat necessary for salmon and steelhead and to avoid a jeopardy decision.
HGMP	Hatchery Genetic Management Plan	A plan required for hatcheries that impact ESA listed species.
HOF	Hatchery Origin Fish	Salmon or steelhead from parents (i.e. From either HOF or NOF parents) selected for brood stock and spawned artificially.
HOS	Hatchery Origin Spawners	Adult salmon or steelhead that are of hatchery origin and actively spawning in the natural environment.
HSRG	Hatchery Scientific Review Group	A blue ribbon panel established by congress to review the hatchery programs of the Pacific Northwest and to make regulations for hatchery reform to make hatcheries more responsive to ESA recovery.
HUC	Hydrologic Unit Code	A hierarchical classification of hydrologic drainage basins in the United States. Each hydrologic unit is identified by a unique hydrologic unit code (HUC) consisting of two to eight digits based on the four levels of classification in the hydrologic unit system.
IHN	Internal Hematopoietic Necrosis	A virus that attacks salmonids. It is highly contagious with a high mortality rate and no known treatment or inoculation.
IMW	Intensively Monitored Watershed	A watershed that is monitored to the extent that the limiting factors are followed and the impact of management actions on fish or habitat can be demonstrated
ISEMP	Integrated Status and Effectiveness Monitoring Project	ISEMP was initiated in 2003 with funding through the Bonneville Power Administration (BPA) in response to the need for status and trend and effectiveness monitoring called for by the 2000 Biological Opinion
MPG	Major Population Group	A grouping of independent populations at the sub-ESU level based on shared geography, shared ecosystems, genetic similarity. The groupings have also been called strata
NOAA	National Oceanic and Atmospheric Administration	A branch of the Department of Commerce and the home of the National Marine Fisheries Service
NOAA FISHERIES SERVICE	National Marine Fisheries Service	The branch of the Department of Commerce responsible for fisheries and marine mammals within the exclusive economic zone of the United States
NOF	Natural Origin Fish	Fish originating from naturally spawning parents. This includes fish from naturally spawning natural-origin parents and fish from naturally spawning hatchery-origin parents
NPGO	North Pacific Gyre Oscillation	Oscillations of the sea surface temperatures related to large scale ocean conditions
NWEIS	Northwest Environmental Information	A collaborative assemblage of federal, state, and tribal

Acronym	Title or name	Explanation of Abbreviation or Definition
	Summit	executives intending to collaborate and implement environmental information sharing mechanisms in the Pacific Northwest.
NWFSC	Northwest Fisheries Science Center	Pacific Northwest laboratory of the National Marine Fisheries Service under the
NWPCC	Northwest Power and Conservation Council	The council charged with managing the use of hydroelectric power and protecting fish and wildlife in the Columbia River basin.
PCSRF	Pacific Coastal Salmon Recovery Fund	A fund established by Congress in 1999 to address loss of habitat in the Pacific Northwest as a component of the Pacific Salmon Treaty
PISCES	PISCES	Pisces is a software tool for managing BPA's Fish and Wildlife Program. BPA created Pisces to help manage fish and wildlife projects throughout the Columbia River Basin.
PFMC	Pacific Fishery Management Council	One of the councils established by the Magnuson Act to manage coastal marine fisheries outside the three mile limit in California, Oregon, and Washington.
PNAMP	Pacific Northwest Aquatic Monitoring Partnership	A forum for coordinating state, federal, and tribal aquatic habitat and salmonid monitoring programs. Improved communication, shared resources and data, and compatible monitoring efforts provide increased scientific credibility, cost-effective use of limited funds and greater accountability to stakeholders.
PSC	Pacific Salmon Commission	A commission established by treaty between the United States and Canada to manage the coastal salmon fisheries of the North Pacific
PUD	Public Utility District	A publicly owned utility that operates and generates electric power, water, wind, natural gas or other energy product.
QET	Quasi Extinction Threshold	The minimum number of individuals (often females) below which the population is likely to be critically and immediately imperiled with extinction.
RIST	Recovery Implementation Science Team	A group of scientists established by NOAA Fisheries Service and taken from the TRT members to form task teams for analysis, review, or evaluation of specific questions posed by management to assist in recovery implementation.
RPA	Reasonable and Prudent Alternatives	A provision of the ESA that recommends actions that can be taken to avoid jeopardy to the listed species.
SAR	Smolt to adult returns	A ratio derived from number of smolts migrating to the sea divided by the numbers of adults returning to spawn.
SNPS	Single Nucleotide Polymorphism	DNA sequence variations that occur when a single nucleotide in the genome sequence is altered. For a variation to be considered a SNP it must occur in at least 1% of the population.
S.P.A.Z	Salmon	A computer model developed by the NWFSC that evaluates ESA listing factors and threats
S.P.S.	Salmon Population Summary	A database developed by the Northwest Fisheries Science Center of the NOAA Fisheries Service to compile information concerning population viability for the ESUs listed under the ESA
TRT	Technical Review Team	Teams of experts appointed by NOAA Fisheries to determine the technical needs and requirements for determining the viability of each salmon and steelhead species listed under the ESA
USEPA	United States Environmental Protection Agency	Federal agency charged with regulating clean water and clean air.
US FS	United States Forest Service	A branch of the Department of Agriculture charged with

Acronym	Title or name	Explanation of Abbreviation or Definition
		managing the national forests of the country.
USBLM	United States Bureau of Land Management	The BLM is responsible for carrying out a variety of programs for the management and conservation, of resources on 258 million surface acres, as well as 700 million acres of subsurface mineral estate, These public lands make up about 13 percent of the total land surface of the United States and more than 40 percent of all land managed by the Federal government.
VSP	Viable Salmonid Populations	A publication produced by the NOAA Fisheries Service Northwest Fisheries Science center that describes the four criteria for determining whether a population is viable

APPENDIX 2 VSP ABUNDANCE AND PRODUCTIVITY DATA DICTIONARY

Primary Indicator	Primary Indicator Definition	Spatial Representation of Primary Indicator	Temporal Representation of Primary Indicator	Life Cycle Representation of Primary Indicator	Frequency Indicator is updated	Primary Indicator Method	SOP for Indicator	SOP for Indicator CI	Metrics from which Primary Indicator is derived	SOP for metric data collection	SOP for metric data reduction	SOP for metric Conf. Int. calculation
ABUNDANCE												
Natural Origin Spawning population abundance	Total number of adults that spawned within the population boundary in a single spawning season.	population/watershed	annual, run year	Individuals that spawned	Annual	**Survey-census.** Redd surveys done in a spatially continuous manner over the entire spawning domain.	Redd counts for population area are expanded by Male & Female/redd and decremented by the Hatchery Origin fraction.	Redd counts are census, so uncertainty in indicator arises due to Male & Female/redd and Hatchery Origin fraction	Redd count - spatial census	Spawning ground survey - spatial-temporal census. Spawning grounds are censused spatially, and with a sufficient short repeat visit interval to also be a temporal census (revisit period < redd visibility	Raw counts are assumed to be final metric due to census design. Repeat visits (different crew repeating measurements)	Error model contains only a measurement error term parameterized by repeat visits.

Primary Indicator	Primary Indicator Definition	Spatial Representation of Primary Indicator	Temporal Representation of Primary Indicator	Life Cycle Representation of Primary Indicator	Frequency Indicator is updated	Primary Indicator Method	SOP for Indicator	SOP for Indicator CI	Metrics from which Primary Indicator is derived	SOP for metric data collection	SOP for metric data reduction	SOP for metric Conf. Int. calculation
										life period).		
					Annual	**Survey-sampled.** Redd surveys done in a spatially sampled manner over the entire spawning domain.	Total spawners calculated by multiplying the estimated total redds in all currently used habitat by an estimated number of fish per red. Value reduced by percent of hatchery fish estimated based upon	Three-pass stratified random design; uncertainty estimate provided by comparison of multiple passes.	Redd count - spatial sampling	Three-pass stratified random design;	Estimated redd densities for the sampled spawning area are multiplied by the total miles of currently utilized habitat. Total estimated redds multiplied by 2.1 and reduced by percent of estimated hatchery fish to	

Primary Indicator	Primary Indicator Definition	Spatial Representation of Primary Indicator	Temporal Representation of Primary Indicator	Life Cycle Representation of Primary Indicator	Frequency Indicator is updated	Primary Indicator Method	SOP for Indicator	SOP for Indicator CI	Metrics from which Primary Indicator is derived	SOP for metric data collection	SOP for metric data reduction	SOP for metric Conf. Int. calculation
							observed adipose-fin clipped fish during surveys				obtain abundance estimate	
									Females per redd	Population specific focal observations, or parentage analysis		
									Males per redd	Population specific focal observations, or parentage analysis		
									Hatchery Origin fraction	Population specific carcass surveys for marks	Carcass recovery and mark recapture process to estimate	Mark recapture process to estimate CI for recovery

Primary Indicator	Primary Indicator Definition	Spatial Representation of Primary Indicator	Temporal Representation of Primary Indicator	Life Cycle Representation of Primary Indicator	Frequency Indicator is updated	Primary Indicator Method	SOP for Indicator	SOP for Indicator CI	Metrics from which Primary Indicator is derived	SOP for metric data collection	SOP for metric data reduction	SOP for metric Conf. Int. calculation
											carcass recovery rate.	
Spawning escapement	Total number of adults returning to a certain point (e.g., the river mouth of the population watershed)	population/watershed	annual, run year	Escapement to population watershed	annual	Mark-recapture	Calculated with mark recapture methods from weir data. Estimate reduced by pre-spawn mortality at and above weir, estimated harvest, and brood stock removals. Estimate expanded for redds located below the weir. Natural-origin		Weir/trap count			

Primary Indicator	Primary Indicator Definition	Spatial Representation of Primary Indicator	Temporal Representation of Primary Indicator	Life Cycle Representation of Primary Indicator	Frequency Indicator is updated	Primary Indicator Method	SOP for Indicator	SOP for Indicator CI	Metrics from which Primary Indicator is derived	SOP for metric data collection	SOP for metric data reduction	SOP for metric Conf. Int. calculation
							escapement calculated by multiplying by the proportion of natural-origin fish.					
					annual	Direct Count	Complete adult counts for entire run. .Estimate reduced by pre-spawn mortality at and above weir/dam, estimated harvest, and brood stock removals.		Weir/Dam Count	Combination of trapping and video monitoring	Complete adult counts at dam	

Primary Indicator	Primary Indicator Definition	Spatial Representation of Primary Indicator	Temporal Representation of Primary Indicator	Life Cycle Representation of Primary Indicator	Frequency Indicator is updated	Primary Indicator Method	SOP for Indicator	SOP for Indicator CI	Metrics from which Primary Indicator is derived	SOP for metric data collection	SOP for metric data reduction	SOP for metric Conf. Int. calculation
							Estimate expanded for redds located below the weir/dam. Natural-origin escapement calculated by multiplying by the proportion of natural-origin fish.					

Primary Indicator	Primary Indicator Definition	Spatial Representation of Primary Indicator	Temporal Representation of Primary Indicator	Life Cycle Representation of Primary Indicator	Frequency Indicator is updated	Primary Indicator Method	SOP for Indicator	SOP for Indicator CI	Metrics from which Primary Indicator is derived	SOP for metric data collection	SOP for metric data reduction	SOP for metric Conf. Int. calculation
					annual	Extrapolated Count	Total natural spawner escapement estimated by expanding abundance of spawners above weir/dam by an expansion factor. The expansion factor developed from the ratio of current smolt capacity (based on EDT) of the entire watershed divided by the current smolt capacity above the weir/dam. Estimate		Weir/Dam Count	Video monitoring	Complete adult counts at dam	

Primary Indicator	Primary Indicator Definition	Spatial Representation of Primary Indicator	Temporal Representation of Primary Indicator	Life Cycle Representation of Primary Indicator	Frequency Indicator is updated	Primary Indicator Method	SOP for Indicator	SOP for Indicator CI	Metrics from which Primary Indicator is derived	SOP for metric data collection	SOP for metric data reduction	SOP for metric Conf. Int. calculation
							reduced by pre-spawn mortality at and above weir/dam, estimated harvest, and brood stock removals. Estimate expanded for redds located below the weir/dam. Natural-origin escapement calculated by multiplying by the proportion of natural-origin fish.					

Primary Indicator	Primary Indicator Definition	Spatial Representation of Primary Indicator	Temporal Representation of Primary Indicator	Life Cycle Representation of Primary Indicator	Frequency Indicator is updated	Primary Indicator Method	SOP for Indicator	SOP for Indicator CI	Metrics from which Primary Indicator is derived	SOP for metric data collection	SOP for metric data reduction	SOP for metric Conf. Int. calculation
									Pre-spawn mortality	Percent of female adults that die after reaching the spawning grounds but before spawning. Calculated as the number of females 25% spawned divided by the total number of female carcasses sampled. [25% spawned = female that contains 75% of the egg compliment].		
									Spawning below weir/trap/	Carcass survey		

Primary Indicator	Primary Indicator Definition	Spatial Representation of Primary Indicator	Temporal Representation of Primary Indicator	Life Cycle Representation of Primary Indicator	Frequency Indicator is updated	Primary Indicator Method	SOP for Indicator	SOP for Indicator CI	Metrics from which Primary Indicator is derived	SOP for metric data collection	SOP for metric data reduction	SOP for metric Conf. Int. calculation
									dam			
									Hatchery Origin fraction	Population specific carcass surveys for marks, or observations of marked fish at weir/trap/dam		
									Brood stock removals			
									Harvest	Total harvest represents the sum of commercial, recreational, and tribal landings. Harvest rate calculated as the total number of fish		

Primary Indicator	Primary Indicator Definition	Spatial Representation of Primary Indicator	Temporal Representation of Primary Indicator	Life Cycle Representation of Primary Indicator	Frequency Indicator is updated	Primary Indicator Method	SOP for Indicator	SOP for Indicator CI	Metrics from which Primary Indicator is derived	SOP for metric data collection	SOP for metric data reduction	SOP for metric Conf. Int. calculation
										harvested divided by the total run size		
Spawning escapement	Total number of adults returning to a certain point (e.g., the river mouth of the population watershed)	population/watershed	annual, run year	Escapement to population watershed	annual	Extrapolated Count	Area Under the Curve (AUC) estimate derived from live fish counts		Weir/Dam Count			
					annual	Extrapolated Count	Sum of dead fish sampled (in instances where few live fish are observed and AUC is not possible).		No. Carcasses	Carcass survey		

Primary Indicator	Primary Indicator Definition	Spatial Representation of Primary Indicator	Temporal Representation of Primary Indicator	Life Cycle Representation of Primary Indicator	Frequency Indicator is updated	Primary Indicator Method	SOP for Indicator	SOP for Indicator CI	Metrics from which Primary Indicator is derived	SOP for metric data collection	SOP for metric data reduction	SOP for metric Conf. Int. calculation
Spawner Abundance Index estimate	Index of abundance	population/watershed	index area sampling period	Individuals that spawned	annual	Index Survey	Observed redd densities extrapolated to un-surveyed occupied spawning habitat by multiplying redds/weighted area in surveyed reaches by total weighted area of currently occupied habitat.	Surveys not statistically designed, or conducted systematically. Unknown whether bias exists in assumed spatial distribution or if variable spawning timing may affect estimates. Estimated hatchery portion may be biased.	Peak redd count	Single pass spawning ground survey at peak	N/A	N/A

Primary Indicator	Primary Indicator Definition	Spatial Representation of Primary Indicator	Temporal Representation of Primary Indicator	Life Cycle Representation of Primary Indicator	Frequency Indicator is updated	Primary Indicator Method	SOP for Indicator	SOP for Indicator CI	Metrics from which Primary Indicator is derived	SOP for metric data collection	SOP for metric data reduction	SOP for metric Conf. Int. calculation
									Hatchery Origin fraction	Population specific carcass surveys for marks, or observations at weir/trap/dam		
		index area	annual, run year	individuals that spawned	annual	Index Survey			index redd count	Multiple pass spawning ground survey over index areas	Area Under the Curve estimator	
					annual	Index Survey			index redd count	Single pass spawning ground survey over index area	Observed redd densities expanded to fish by multiplying by fish/redd ratio.	N/A
					annual	Index Survey			Peak redd count	Judgment-based sample of non-randomly selected sites (e.g., ease of access,	Number of redds divided by the total number of miles surveyed. Reported metric is	

Primary Indicator	Primary Indicator Definition	Spatial Representation of Primary Indicator	Temporal Representation of Primary Indicator	Life Cycle Representation of Primary Indicator	Frequency Indicator is updated	Primary Indicator Method	SOP for Indicator	SOP for Indicator CI	Metrics from which Primary Indicator is derived	SOP for metric data collection	SOP for metric data reduction	SOP for metric Conf. Int. calculation
										likelihood of observing spawners)	peak redd count, not a season-long spawning abundance.	
					annual	Index Survey			index redd count	Single or double pass aerial red survey over index area	Observed redd densities expanded to fish by multiplying by fish/redd ratio. Reduced for estimated hatchery fish.	N/A
									Hatchery Origin fraction	Population specific carcass surveys for marks, or observations at weir/trap/dam		

Primary Indicator	Primary Indicator Definition	Spatial Representation of Primary Indicator	Temporal Representation of Primary Indicator	Life Cycle Representation of Primary Indicator	Frequency Indicator is updated	Primary Indicator Method	SOP for Indicator	SOP for Indicator CI	Metrics from which Primary Indicator is derived	SOP for metric data collection	SOP for metric data reduction	SOP for metric Conf. Int. calculation
Escapement Index	Total number of adults intercepted at trap, the location of which does not necessarily coincide with a population boundary	major spawning aggregation (MSA), Index Area	annual, run year	Adults returning above trap	annual	Fixed site	100% count of fish returning above the trap are counted. Hatchery fish are removed.	N/A	Weir/trap count	Trap all fish returning to the hatchery weir. Hatchery fish are removed and natural origin fish are enumerated and allowed to pass upstream.		N/A
									Hatchery Origin fraction	computed directly from trapping data collected at a downstream weir trap.		

Primary Indicator	Primary Indicator Definition	Spatial Representation of Primary Indicator	Temporal Representation of Primary Indicator	Life Cycle Representation of Primary Indicator	Frequency Indicator is updated	Primary Indicator Method	SOP for Indicator	SOP for Indicator CI	Metrics from which Primary Indicator is derived	SOP for metric data collection	SOP for metric data reduction	SOP for metric Conf. Int. calculation
Escapement Index	Total number of natural-origin adults returning to several index areas in a major watershed.	index area	annual, run year	adults returning to index area tributaries	annual	survey	Escapement is derived by expanding redd counts by the number of redds/female and then by the sex ratio of the "population" samples at a downstream weir/trap.		index redd count	Weekly surveys of several 1 miles index areas within each major tributary of the watershed, followed by a final survey of all index areas plus 50% of the remaining unsampled tributary reaches.	Total redds are calculated by expanding observed redds by the estimated redd life (erasure rate) and by the percent of each reach sampled.	
									Hatchery Origin fraction	computed directly from trapping data collected at a downstream weir trap.		

Primary Indicator	Primary Indicator Definition	Spatial Representation of Primary Indicator	Temporal Representation of Primary Indicator	Life Cycle Representation of Primary Indicator	Frequency Indicator is updated	Primary Indicator Method	SOP for Indicator	SOP for Indicator CI	Metrics from which Primary Indicator is derived	SOP for metric data collection	SOP for metric data reduction	SOP for metric Conf. Int. calculation
Juvenile Abundance	total juvenile estimate at the tributary comprised of each juvenile life stage (par, pre-smolt, and smolt) to a common point in the main stem.	population/watershed	entire emigration year	parr, pre-smolts, and smolts	annual	trapping and PIT tagging	Calculated by multiplying the life-stage specific abundance estimate (with standard error) by the life stage specific survival estimate to the common point in the main stem (e.g., main stem dam) (with standard error).	standard error around the smolt equivalent estimate is calculated using the following formula; where X = life stage specific juvenile abundance estimate and Y = life stage specific juvenile survival estimate: Var (X Y) = E(X)^2 x Var(Y) + E(Y)^2xVar(X) + Var(X)xVar(Y)				

Primary Indicator	Primary Indicator Definition	Spatial Representation of Primary Indicator	Temporal Representation of Primary Indicator	Life Cycle Representation of Primary Indicator	Frequency Indicator is updated	Primary Indicator Method	SOP for Indicator	SOP for Indicator CI	Metrics from which Primary Indicator is derived	SOP for metric data collection	SOP for metric data reduction	SOP for metric Conf. Int. calculation
Juvenile Abundance Index	Index estimate of abundance	index area	annual	parr	annual	survey	Parr abundance estimates (numbers per 100m2) using underwater survey methodology conducted at pre-established transects		survey transects	Snorkel and electrofish surveys (Thurow, 1994)	Hanken and Reeves estimator	
PRODUCTIVITY												
Smolt-to-adult return rate	The number of adult returns from a given brood year returning to a point (stream mouth, weir) divided by the number	population/watershed, population/watershed to some downstream point (e.g., dam),	brood year	smolt, adult	annual	trapping and PIT tagging	Smolt abundance estimated using observations of PIT-tagged juveniles at smolt monitoring sites (weirs, dams) divided by adult returns		Smolt Abundance	[See entries for Abundance Primary Indicator, above]		

Primary Indicator	Primary Indicator Definition	Spatial Representation of Primary Indicator	Temporal Representation of Primary Indicator	Life Cycle Representation of Primary Indicator	Frequency Indicator is updated	Primary Indicator Method	SOP for Indicator	SOP for Indicator CI	Metrics from which Primary Indicator is derived	SOP for metric data collection	SOP for metric data reduction	SOP for metric Conf. Int. calculation
	of smolts that left this point 1-5 years prior. Calculated for wild and hatchery origin conventional and captive brood fish separately.						back to the monitoring site (weirs, dams) using adult PIT-tag observations.					
									Adult Escapement	[See entries for Abundance Primary Indicator, above]		
									Hatchery Origin fraction	[See entries for Abundance Primary Indicator, above]		

Primary Indicator	Primary Indicator Definition	Spatial Representation of Primary Indicator	Temporal Representation of Primary Indicator	Life Cycle Representation of Primary Indicator	Frequency Indicator is updated	Primary Indicator Method	SOP for Indicator	SOP for Indicator CI	Metrics from which Primary Indicator is derived	SOP for metric data collection	SOP for metric data reduction	SOP for metric Conf. Int. calculation
Progeny-per-parent Ratio	Adult to adult ratio of the abundance of returning adults to the abundance of parents for that brood year. for that brood year. May be calculated for 1) escapement, and 2) spawners. May be calculated for naturally spawning fish and hatchery fish separately.	population/watershed, monitoring site	brood year	Entire life cycle	annual	Escapement	Calculated for naturally spawning fish and hatchery fish separately as the brood year ratio of return adult escapement to parent escapement.		adult escapement	[See entries for Abundance Primary Indicator, above]		

Primary Indicator	Primary Indicator Definition	Spatial Representation of Primary Indicator	Temporal Representation of Primary Indicator	Life Cycle Representation of Primary Indicator	Frequency Indicator is updated	Primary Indicator Method	SOP for Indicator	SOP for Indicator CI	Metrics from which Primary Indicator is derived	SOP for metric data collection	SOP for metric data reduction	SOP for metric Conf. Int. calculation
		population/watershed	brood year	Entire life cycle	annual	Natural spawners	calculated for naturally spawning fish and hatchery fish separately as the brood year ratio of return adult natural spawners to parent natural spawner abundance.		spawner abundance	[See entries for Abundance Primary Indicator, above]		
									Hatchery Origin fraction	[See entries for Abundance Primary Indicator, above]		

Primary Indicator	Primary Indicator Definition	Spatial Representation of Primary Indicator	Temporal Representation of Primary Indicator	Life Cycle Representation of Primary Indicator	Frequency Indicator is updated	Primary Indicator Method	SOP for Indicator	SOP for Indicator CI	Metrics from which Primary Indicator is derived	SOP for metric data collection	SOP for metric data reduction	SOP for metric Conf. Int. calculation
Smolts-per-spawner ratio	Juvenile production to some life stage or monitoring site, divided by adult spawner abundance. Represents the quantity of juvenile fish resulting from an average redd or female (total smolts divided by total redds or females)	population/watershed, population/watershed to monitoring site	annual	Egg-Smolt	annual	trapping and PIT tagging	Juvenile (parr, pre-smolt, smolt total abundance) or smolt abundance at a tributary mouth or monitoring size divided by the number of redds or females above the juvenile monitoring site.		juvenile abundance (parr, pre-smolt, smolt total abundance)	Juvenile trap or PIT tag array		
									Natural-origin population spawning abundanc	[See entries for Abundance Primary Indicator, above]		

Primary Indicator	**Primary Indicator Definition**	**Spatial Representation of Primary Indicator**	**Temporal Representation of Primary Indicator**	**Life Cycle Representation of Primary Indicator**	**Frequency Indicator is updated**	**Primary Indicator Method**	**SOP for Indicator**	**SOP for Indicator CI**	**Metrics from which Primary Indicator is derived**	**SOP for metric data collection**	**SOP for metric data reduction**	**SOP for metric Conf. Int. calculation**
									e			
Lambda	A measure of population growth rate incorporating overlapping generations and running sums of cohorts.	population/watershed	Multiple years.	Entire life cycle	annual	Holmes, 2001; Holmes and Fagan, 2002	Calculated assuming hatchery-origin spawners have zero reproductive success, and have reproductive success equivalent to natural spawners.	Calculates 95% confidence intervals based on individual population variance estimates (Holmes, 2001; Holmes and Fagan, 2002)>	Natural-origin population spawning abundance	[See entries for Abundance Primary Indicator, above]		
									Hatchery Origin fraction	[See entries for Abundance Primary Indicator, above]		
									Age-structure			
									Average age @ reproduction			