# Executive Summary

Note: this earlier version of the ASMS attempts to address the ISRP’s comments on the last draft to improve the information content (see [ISRP/ISAB 2011-1](http://www.nwcouncil.org/library/report.asp?d=37)); comments from a subset of managers and Bonneville consultants have been incorporated. This draft does not represent a final draft and this is not a draft supported by the Columbia River Basin managers.

The Anadromous Salmonid Monitoring Strategy (ASMS) is a coordinated strategy developed by Columbia River Basin fish managers to monitor and evaluate the tributary lifecycle component of wild and hatchery salmonids and their habitat in the Columbia River Basin. This strategy focuses on what monitoring is conducted and how the information collected is evaluated to inform management and policy questions. In fulfilling this role, this strategy is considered a product developed by the managers[[1]](#footnote-1) and a component of the draft Northwest Power and Conservation Council’s (Council) Monitoring Evaluation Research and Reporting (MERR) Plan’s Anadromous Fish Research Monitoring and Evaluation Implementation Strategy. Other components of the MERR Plan’s Anadromous Fish Implementation Strategy will address additional lifecycle monitoring as well as non-listed anadromous fish. This strategy does not summarize the current knowledge of these fish, such as, habitat requirements, status, habitat impairments and limiting factors, as these are summarized within the Northwest Power and Conservation Council’s subbasin plans and in individual project reports.

The ASMS addresses a portion of the salmonid monitoring needed to inform management questions, policy decisions, and reporting needs of the Council’s Fish and Wildlife Program (Program), National Oceanic and Atmospheric Administration (NOAA) Pacific Coast Salmon Recovery Funding (PCSRF), and NOAA’s Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp), and the individual needs of state and tribal fish managers. Specifically, the ASMS describes the coordinated strategy for collecting and sharing data needed to assess viable salmonid population parameters (abundance, population growth rate/productivity, population spatial structure, and diversity), habitat effectiveness (project effectiveness, population/watershed level effectiveness, and status and trend) and hatchery effectiveness monitoring. As some components of the ASMS are evolving the strategy for each monitoring component vary in level of details, as well as the strategy for data sharing and evaluation of commonly reported metrics and indicators.

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# Regional Context for the Anadromous Salmonid Monitoring Strategy

The Columbia River Basin (Basin) is home to many independent populations of anadromous salmonids, which have a complex life history, hatching in freshwater, migrating to the ocean as juveniles, growing there to adulthood and returning to the place of their birth; in some cases to streams that are hundreds of miles inland and thousands of feet above sea level, to spawn and die. Through their travels, anadromous salmonids rely on a diversity of habitats spanning from the Basin’s tributaries, mainstem, and estuary. Adding to this complexity are the multiple jurisdictions managing these salmonids and their habitat as well as the competing needs associated with the Basin, including flood control, irrigation, hydroelectric dam power generation, recreational, tribal and commercial fishing, navigation, recreation, and fish and wildlife. Actions aimed at mitigating, enhancing and protecting the Basin’s species and their habitat are funded and implemented by federal, tribal and state fish and wildlife agencies, as well as interstate compacts and other inter-governmental forums such as the Northwest Power and Conservation Council’s (Council) Fish and Wildlife Program (Program), the National Oceanic and Atmospheric Administration’s (NOAA) Endangered Species Act (ESA) listed salmonid recovery teams, and the ACOE Anadromous Fish Evaluation Program (AFEP).

Within the Basin there reside the Federal Columbia River Power System (FCRPS) projects that are operated by the US Army Corps of Engineers (ACOE) and the Bureau of Reclamation (USBR) for multiple purposes including flood control, fish and wildlife, power generation, navigation, irrigation, and recreation. Bonneville Power Administration (BPA) markets and distributes the power generated by the FCRPS. The presence and operations of these dams effect upstream and downstream fish passage resulting in mitigation actions being implemented at the dams and throughout the Basin. The BPA funded restoration and mitigation program is one of the largest and most extensive in the world, and is implemented in a manner consistent with the Council’s Columbia River Basin Fish and Wildlife Program. As partners in the Basin work to mitigate, enhance, and recover anadromous salmonids, it is important to have comprehensive monitoring that provides the capability to evaluate these efforts, lends transparency to policy decisions, and informs adaptive management.

# Legal Environment

Two of the basinwide statutory obligations that guide a large component of mitigation efforts are the ESA and the Northwest Power Act (ACT). The ESA is administered by the US Fish and Wildlife Service (USFWS) and NOAA to ensure that no species go extinct. The Council was created from the ACT which calls for a balance of cost-effective energy via the FCRPS and adequate protection, mitigation, and enhancement of fish and wildlife. Of the over 190 extant anadromous salmonid populations found in the Basin, 13 evolutionarily significant units (ESU) and distinct population segments (DPS) are ESA-listed (Table 1). The ESA calls for conservation assessments for each ESU and DPS (NOAA 2010b). The assessments describe what steps have been taken to address a species’ conservation needs including pre-listing, ongoing, and post-listing measures (NOAA 2010b). Related to this need, in May 2008 NOAA Fisheries issued a Biological Opinion (BiOp) on the operation of the dams that compose the FCRPS (NOAA 2008A) and in 2010 the related Adaptive Management Implementation Plan (AMIP) was added through the 2010 Supplemental BiOp (NOAA 2010a). The BiOp includes over 100 RME sub-actions that are to be implemented to support adaptive management and performance tracking of the listed populations.

Table . ESUs and DPSs by sub-region within the Columbia River Basin.

|  |  |  |  |
| --- | --- | --- | --- |
| Sub-region | ESU or DPS | Major Population Groups | Extant Populationsa |
| ESA-listed |
| Snake River | Snake River Spring-Summer Chinook | 5 | 31 |
|  | Snake River Fall Chinook | 1 | 1 |
|  | Snake River Sockeye | 1 | 1 |
|  | Snake River Steelhead | 5 | 25 |
| Upper Columbia | Upper Columbia Spring Chinook | 1 | 3 |
|  | Upper Columbia Steelhead | 1 | 5 |
| Middle Columbia | Mid Columbia Steelhead | 4 | 19 |
| Lower Columbia | Lower Columbia Chinook | 6 | 32 |
|  | Lower Columbia Coho | 3 | 24 |
|  | Columbia River Chum | 3 | 17 |
|  | Lower Columbia Steelhead | 4 | 23 |
|  | Upper Willamette Chinook | 1 | 7 |
|  | Upper Willamette Steelhead | 1 | 4 |
| Non ESA-listed |
| Snake River | Clearwater River Spring Chinook | 2 | 6 |
|  | Coho | -- | -- |
| Upper Columbia | Upper Columbia Summer/Fall Chinook | -- | -- |
|  | Upper Columbia Sockeye | -- | -- |
|  | Coho | -- | -- |
| Middle Columbia | Middle Columbia Spring Chinook | -- | -- |
|  | Fall Chinook | -- | -- |
|  | Coho | -- | -- |
| Lower Columbia | Southwest Washington Steelhead | -- | -- |

a Population counts may vary depending on categorization of some populations as functionally extirpated.

Under the ACT, the Council is to prepare, and periodically amend, the Program to protect, mitigate, and enhance fish and wildlife, and related spawning grounds and habitat, that have been affected by the construction and operation of any hydroelectric project in the Basin. The Act directs the Administrator to use the Bonneville Power Administration fund and applicable laws to protect, mitigate and enhance fish and wildlife of the Columbia River and its tributaries in a manner consistent with the Fish and Wildlife Program (ACT 1980). The 2009 Program committed the Council to expand the Program’s monitoring and evaluation framework to ensure that the Program goals, objectives, and actions are monitored, evaluated, and reported in a manner that allows assessment and reporting of Program progress. This resulted in the [2010 draft Monitoring, Evaluation, Research and Reporting (MERR) plan](http://www.nwcouncil.org/fw/merr/Default.asp), and its subsequent versions, which intends to evolve with the Program.

The Anadromous Salmonid Monitoring Strategy (ASMS) aims to provide a coordinated and collaborative approach for conducting salmon and steelhead population and habitat monitoring within the Basin by:

* Informing the adaptive management and performance tracking needs of the BiOP and AMIP for which the BPA, USBR, and ACOE (together referred to as the Action Agencies) are responsible to implement and report to NOAA;
* Providing the monitoring data to inform the viable salmonid population (VSP) parameters used by NOAA in assessing salmonid populations and ESUs under the ESA;
* Fulfilling a portion of the draft MERR’s RME implementation strategy for anadromous fish (Anadromous Fish Implementation Strategy) which serves to describe the RME conducted in the Basin, for what purpose and how coordinated, and identifies gaps in RME coverage.; and,
* Providing monitoring data to inform progress made towards the Program's vision, goals, and objectives and facilitates reporting on the Council’s High Level Indicators (NPCC 2009) for both ESA and non-ESA-listed salmonids.

Several other legal requirements affect the Basin’s fish. These include the fish management responsibilities shared by four states (Idaho, Montana, Oregon and Washington) and 6 sovereign tribes (Confederated Tribes and Bands of the Yakama Nation, Confederated Tribes of the Colville Reservation, Confederated Tribes of the Umatilla Indian Reservation, Confederated Tribes of the Warm Springs Reservation of Oregon, Nez Perce Tribe, Shoshone-Bannock Tribes of the Fort Hall Reservation, and Columbia River Inter-tribal Fish Commission). There are also several legal mandates overseeing the use of hatchery salmonids in the Basin that need to be considered with mitigation actions.

# Scope of the ASMS

Monitoring of anadromous species in the Basin involves numerous complexities, as previously mentioned, including those associated with the anadromous lifecycle, and the Basin’s numerous management jurisdictions, multiple uses, and legal mosaic. Due to these complexities it is not feasible to attempt coordinating monitoring for all life stages and relevant habitats at the same time. Therefore, the ASMS narrowly focuses on the Columbia River Basin tributary habitats and life stages of anadromous salmonids. Monitoring of the other lifecycle components of anadromous salmonids and associated habitats in the mainstem, estuary, and ocean will be addressed in separate coordinated strategy documents, some of which are in-development as a response to the Council’s recommendations for the RME and artificial production project category review completed in June 2011.

The ASMS aims to provide an efficient and effective monitoring strategy that integrates multiple monitoring programs and different geographic scales. The ASMS focuses on three categories of monitoring data for Columbia River Basin tributary habitats and life stages of anadromous salmonids: (1) fish status and trend, (2) habitat status and trend, and (3) effectiveness of habitat actions and hatchery actions at the project and population level (Figure 1).

The data collected by these three categories of monitoring are in varying stages of being identified. The data compiled by fish status and trend monitoring focuses on the four VSP parameters, consisting of abundance, population productivity, spatial structure and diversity (NOAA 2000). Those compiled to assess habitat status and trend parameters are in the pilot stage but should soon be confirmed. Parameters to assess habitat and hatchery effectiveness are in the early stage of development and will be discussed once more information is known. The focus of the ASMS on these monitoring categories for fish, habitat, and hatchery reflects commonality among anadromous fish objectives of state, tribal, federal, and interstate compact monitoring programs, which focus generally on increasing the abundance and condition of anadromous salmonids and their habitat (e.g., Council’s subbasin plans and draft management questions, and NOAA’s Pacific Coastal Salmon Recovery Fund Program and FCRPS BiOp). The monitoring data collected will serve to inform this general objective and related management questions and indicators that inform management and policy decisions.

The ASMS defers the responsibility of conducting implementation and compliance monitoring to individual funding agencies but recognizes its importance especially for informing effectiveness monitoring. Furthermore, although there are unknowns in salmon mitigation and recovery (i.e., the “critical uncertainties” that make management decisions much harder (NOAA 2007)), these research uncertainties are not addressed in the ASMS document at this time. Research uncertainties have been identified in the Council’s Program (NPCC 2009), the Council’s Research Plan (NPCC 2006), FCRPS BiOP (Federal Caucus No-date), NOAA’s Adaptive Management for ESA-Listed Salmon and Steelhead Recovery: Decision Framework and Monitoring Guidance (2007), and by Columbia River Basin fish managers (CSMEP: http://www.cbfwa.org/csmep/web/Content.cfm?ContextID=1, PATH).

The ASMS relied on the Monitoring Guidance for Pacific Northwest Salmon and Steelhead provided by NOAA (Crawford and Rumsey 2011), the Recommendations for Implementing Research, Monitoring and Evaluation for the 2008 NOAA Fisheries FCRPS BiOp (AA/NOAA/NPCC RM&E Workgroup 2010), the AHSWG recommendations (AHSWG 2008), NOAA’s Adaptive Management for ESA-Listed Salmon and Steelhead Recovery: Decision Framework and Monitoring Guidance (NOAA 2007), and the MERR (NPCC 2010) for informing basinwide monitoring guidance.

Projects funded under the Program regularly undergo rigorous scientific review. This includes projects contributing to the implementation of the MERR Plan’s RME Implementation Strategy, including the ASMS, which describes, at a broad scale, the current status of RME. For details on the scientific assessment and recommendations for improvements of individual projects consult past Council recommendations, ISRP reviews, and the project proposal that are available at [www.cbfish.org](http://www.cbfish.org).

# Processes used to develop the ASMS and Supporting Data Sharing Infrastructure

The approach used for developing a coordinated basinwide tributary monitoring strategy differed for fish status and trend, habitat status and trend, habitat effectiveness, and hatchery effectiveness due to the differing status of existing commonalities among entities gathering this monitoring information. All monitoring topics were discussed with state and tribal fish and wildlife managers during the 2009 sub-regional and regional workshops, collectively referred to as the 2009 Columbia Basin Coordinated Anadromous Monitoring Workshops[[2]](#footnote-2) (aka the 2009 Skamania Workshops).The details for the monitoring of habitat status and trend and the effectiveness of habitat and hatchery actions conducted by entities in the Basin, however, were not finalized during the 2009 workshops and instead are being developed through processes described below.

Coordinated basinwide approaches to habitat status and trend and hatchery effectiveness monitoring were proposed through two proposals submitted to the Council’s Independent Scientific Review Panel’s (ISRP) project review for *Research, Monitoring, Evaluation and Artificial Production plus* (RME/AP+) category projects during 2010-2011: (1) The Columbia River Habitat Monitoring Program (CHaMP) and (2) The Columbia River Hatchery Effects Evaluation Team (CRHEET). CHaMP received a Council recommendation to be implemented initially as a pilot to allow modifications for improvements. CRHEET received a ‘meets scientific review criteria’ from the ISRP during the Council’s RME/AP+ category project review process and is undergoing further development with the goal of being implemented in the next few years. The status of these projects will be updated pending further Council recommendations and BPA funding decisions, and as they evolve.

A coordinated basinwide approach to monitoring habitat effectiveness is being discussed at both reach/project and watershed scales. Habitat monitoring at the reach/project scale is being addressed through a subgroup of the Pacific Northwest Aquatic Monitoring Partnership (PNAMP) Effectiveness Workgroup, and their suggested approach is described in a subsequent section, although it has not yet received basinwide or Council approval. Monitoring at the watershed scale is proposed to be addressed by models that would incorporate data from the fish status and trend, habitat status and trend, and habitat effectiveness monitoring.

The ASMS component, most fully developed during the 2009 Workshop, is the coordinated basinwide approach for conducting salmonid fish status and trend monitoring in tributaries. This monitoring component was most ripe for basinwide discussion as most entities already collect salmonid abundance and productivity data and collaborate with NOAA to collect data for ESA-listed salmonid fish status assessments.

During the 2009 Skamania Workshops, tribal and state strategies for monitoring anadromous salmon and steelhead status and trend in tributaries were combined into four subregional strategies: Snake River, Upper Columbia, Middle Columbia, and Lower Columbia (Figure 1). These four subregions differed from the entities involved and in the number and variety of ESA-listed and non-listed species and populations present (Table 1). To aid in standardizing the subregional strategies, each followed a basic set of guidelines for study design and data quality discussed and agreed upon during the 2009 Skamania Workshop and which are described in the Crawford and Rumsey NOAA document (2011) . Once the four subregional strategies were completed, a basinwide strategy that assessed the adequacy of the combined sub-regional monitoring strategies and monitoring priority was agreed upon (described in following sections).



Figure 1. The four sub-regions of the ASMS.

A follow-up, and critical component, of the ASMS is a basinwide data sharing strategy to easily share and compile information needed to address questions at different scales, e.g., local to subregional to basinwide. This need is being addressed by the Coordinated Assessment for Salmon and Steelhead Project (CA Project)[[3]](#footnote-3) with an initial focus on facilitating data sharing for VSP parameters basinwide. This effort includes state, tribal and action agencies in the Basin who work together in developing integrated data sharing for anadromous fish with an initial focus on three VSP parameters: natural spawner abundance, smolt to adult return, and recruit per spawner. As this work progresses, data sharing of derived variables for habitat and hatchery effectiveness assessments will also be addressed. As more information becomes available from this effort, it will be included in future ASMS versions.

# Basinwide Guidance for the ASMS

## Adaptive Management Approach

To successfully achieve the goals and objectives of salmonid mitigation and recovery for the Basin, an adaptive management approach informed by monitoring and evaluation is critical. Adaptive management allows for adjusting future actions based on information gathered about the effect of implementing a previous action (NOAA 2007). Most importantly, given the length and complexity of the salmonid life cycle and the uncertainties involved in improving salmonid survival and status, adaptive management allows for prioritization of alternative strategies for achieving the same effect when there is uncertainty regarding which strategy and action to implement. Monitoring and evaluation data informs adaptive management decision making by providing information on a topic of interest, such as change observed in a habitat limiting factor, that is needed to make decisions about whether a given action should be implemented or modified given the proposed change (Yaffe et al. 2004 cited in NOAA 2007). A basinwide monitoring approach should be built upon an adaptive management framework, consisting of these 6-steps: Assess, Design, Implement, Report, Evaluate, and Adjust to iteratively improve the work conducted to mitigate and conserve species and their habitat in a cost-effective manner (Figure 2).

Figure 2: The 6 steps of the adaptive management cycle. Assess, consists of defining the scope of the problem, synthesizing existing knowledge about the system, and exploring the potential outcomes of alternative management actions. Design, consists of designing a plan and monitoring program that will provide reliable feedback about the effectiveness of the chosen actions. Implementation, involves putting the plan into practice. Evaluation, involves comparing the actual outcomes to what was expected and interpreting the reasons underlying any differences. Adjust, involves making modifications to the implemented actions and expected outcome to reflect new understanding. Modified from: http://planet.botany.uwc.ac.za/nisl/ESS/ESS121/Introductory-Guide-AM.pdf

## Prioritization of Monitoring

In a world of finite resources, choices must be made about what to monitor. Deciding on which choice to make is a complicate decision given the need to balance prioritization at subregional and regional levels. Prioritization at the subregion level is guided primarily by the managers within these subregions who are most intimately aware of what monitoring is needed for conservation and harvest management decision making. The information collected from population level monitoring should serve to inform and guide basinwide policy and management questions, thus guiding prioritization at the regional level. This regional prioritization should be considered during subregional prioritization to ensure that basinwide monitoring needs are adequately addressed. For example, the biological effect of tributary habitat restoration projects is rarely measured at scales as large as that of populations and ESUs; however, for management purposes, the effectiveness of management actions must be assessed at these larger scales. Therefore, consideration of data needs for management and policy decision making when designing individual habitat restoration monitoring efforts can help inform the adequacy of the sampling effort. Basing the design of monitoring programs on the data needs of management and policy decision making will help determine the effort required.

Some general guidance for prioritization of monitoring in the Basin that was agreed upon, and written in a previous draft of the ASMS, by managers during the Skamania Workshops includes the following. Also, see workshop documents at <http://www.cbfwa.org/ams/FinalDocs.cfm>.

* At least one salmonid population per major population group[[4]](#footnote-4) (MPG) should receive intensive monitoring for status and trend of fish abundance and their habitat.
	+ The federal agencies further prioritize BiOp RPA RME requirements and maintaining ongoing status monitoring data sets for ESA listed populations over other monitoring program needs.
	+ The state agencies and tribes do not prioritize BiOp requirements over other management requirements.
* All MPG’s for Steelhead and Chinook salmon will be monitored for status and trend of fish abundance.
* Align habitat status and trend monitoring with fish status and trend monitoring to inform habitat effectiveness monitoring
* Align hatchery monitoring with existing, relevant monitoring focusing on fish and habitat status and trend.
* Strive to incorporate monitoring data from habitat effectiveness monitoring occurring within intensively monitored watersheds and at the project/reach scale into the overall assessment of habitat effectiveness
* effectiveness monitoring
* Collect monitoring data to inform VSP parameters.
* Explore potential for including the approached developed through the PNAMP lead Integrated Status and Trend Monitoring project as a means to assure the data quality within the ASMS with the group

## Study Design for Monitoring

In developing the ASMS, basic guidance on developing a monitoring program and related study design from NOAA were considered (NOAA 2007, Crawford and Rumsey 2011). Below is a summary of the design principles used to guide the development of efficient and effective monitoring programs (modified from NOAA 2007).

To facilitate sharing of collected data used to inform decisions, standardization of, or at least having compatible, monitoring protocols, data, derived variables, and analytical approaches would be beneficial for allowing maximizing on investments. For example, adult fish abundance provides information on a population’s status and is generated by the reduction of a wide range of field-collected data such as redd, weir and carcass counts. If regional standards on population status as indicated by adult abundance were established, then monitoring programs could continue generating data for their needs but would be standardized by generating regionally consistent adult fish abundance from these data. To ensure sharing is possible to meet multiple needs, a well-designed and documented data management plan can help to ensure that data of a specified quality and quantity is available, at a specified time, to meet specified data analysis needs. In general, supporting ways to facilitate data sharing makes it possible to avoid duplication of effort and maximize learning.

When designing a monitoring program, the frequency of sampling needed to detect change should be aligned with the anticipated rate of change; slow rate change can result in less frequent sampling. Monitoring design should also facilitate integrating both status and effectiveness monitoring data, as data collected by status monitoring may be used as a baseline or reference for effectiveness. This can be more easily accomplished by using monitoring designs that treat multiple spatial and temporal scales transparently, e.g., Generalized Random-Tessellation Stratified (GRTS) design (Stevens and Olsen 2003 and 2004). Remote sensing may present an ideal combination of extrapolation and standardization for region-wide information needs.

Further, assessing potential to reduce monitoring cost by collecting data on less costly indirect metrics that are correlated to the metric of interest is encouraged. *A*n explicit mechanism to quantify the risk associated with indirect data sources, however, should be established when this approach is used. The population structure of interior Columbia ESUs is a perfect basis for such a design. Rather than directly monitor the population status of all independent populations, a single population within each MPG could be assessed directly, and the remaining populations represented with a less intense, indirect metric. To avoid a systematic bias in population selection, it would be best to randomly choose which population to monitor and where the data are collected.

Lastly, as most reporting consists of derived data, it is important to quantify the variability among raw observations (NOAA 2007). Variability can arise from two primary sources: intrinsic variability from compiling indicator values over space and time, and extrinsic variability from measurement and sampling error (NOAA 2007).

## Data Management and Sharing

A coordinated monitoring and evaluation approach requires that data be properly managed, compatible among entities collecting similar data and easily accessible to interested parties. Proper management and accessibility of data also requires having metadata in a commonly agreed-upon format. Below are guidelines for ensuring proper management and accessibility of data needed to inform broad scale fish status and trend, habitat effectiveness, and hatchery effectiveness monitoring.

Guidance for this section is based on evolving processes and modified from documents produced by the Pacific Northwest Aquatic Monitoring Partnership (PNAMP), StreamNet and NOAA (NOAA 2007, Crawford and Rumsey 2011). These guidelines should also inform the development of processes/infrastructure to facilitate sharing of data to inform basinwide or ESU/DPS wide indicator and reporting needs from multiple sources. PNAMP is developing tools to facilitate data management and sharing including facilitating the Integrated Status and Trend Monitoring[[5]](#footnote-5) project that is developing random master sample tool and comparing protocols, and assisting in the Coordinated Assessment[[6]](#footnote-6) effort, aimed at evaluating how best to share three data components of VSP parameters. Two documents produced by NOAA contain relevant guidance for data management that informs the general guidelines outlined below (NOAA 2007, Crawford and Rumsey 2011).

For monitoring data that are needed to inform broad scale metrics and questions, such as the VSP parameters, the appropriate information to render the data useable by others need to be made available. Specifically, data should be accompanied by information pertaining to:

* Recording practices and protocols followed through a standardized regional catalogue. Documenting protocols and methods may be facilitated by working with PNAMP in the management of the Protocol and Methods Library Catalog Project called MonitoringMethods.org[[7]](#footnote-7).
* Providing minimum set of required metadata for all data and derived data products, such as described by PNAMP through its Data Best Practices project[[8]](#footnote-8).
* Sufficiently document limitations with respect to the quality of the data (precision, accuracy, coefficient of variation, etc.).
* Specifying when the collected data can be expected to be available for sharing and the process to share data, i.e., accessible from a website or regional database.
* Developing regional databases and regional exchange templates, needed for evaluating indicators. These should be coordinated such that a common set of metadata and common data dictionary are used to track information so that it can be readily reported for basinwide or ESU/DPS needs and shared among the participants.
* Developing internal infrastructure to assess and evaluate data
* Ensure that all methods and calculations are transparent and repeatable to all interested parties.
* Ensure sufficient data management infrastructure to house, store, and share the data as necessary

To address the data management and sharing needs associated with the monitoring data collected under the ASMS, a Basinwide Coordinated Assessment (CA Project) was initiated during 2010 with limited funding available. The CA Project aims to develop an integrated data-sharing plan for anadromous fish data among the managers (state, tribal and federal fish and wildlife agencies) and action agencies of the Columbia River Basin. The initial focus of the project is on three components of the VSP indicators: natural spawner abundance, smolt to adult return, and recruit per spawner. The project, if adequate funding is identified, will later consider high-level indicators for habitat and hatchery effectiveness assessments. Phase I of the project was initiated in February 2010 and consisted of the development of a draft data exchange template (DET) and a workshop in October 2010 of participating federal, state and tribal entities in the Basin. Phase II aimed to: (1) develop individual and basinwide data sharing strategies that identify the capacities and business practices necessary for integrated data sharing of the VSP indicators in the Basin, and, (2) refine and promote the use of data exchange templates among the Basin fisheries managers as a business practice for sharing the VSP indicators. The Columbia River Basin Collaborative Data Sharing Strategy (Strategy) was completed in late 2011 and summarizes the findings from the first two phases of the CA Project.

The strategy clearly identifies four main objectives guiding the data sharing effort which can inform other data sharing efforts. These are to: 1) promote policy-level data sharing that is transparent and supports basinwide assessments for salmon and steelhead; 2) inform the Council’s Data Management and Regional Coordination Category Review in early 2012; 3) inform NOAA and other funders on how to better align with BPA funding for data management in the Basin; and 4) collect anadromous productivity and abundance data to inform high level indicators that will further monitoring of restoration projects (Coordinated Assessments Workgroup 2011). Outcomes of the Strategy should be modifications, over time, in the data management infrastructure to facilitate improved sharing and evaluation of VSP parameters.

Phase III of the CA Project began in January 2012 and will result in the development and implementation of a working DET and salmon data exchange network.

## Status and Trend Monitoring

Status or baseline monitoring is used to characterize existing conditions, establish a database for future comparisons and capture temporal and spatial variability in the parameters of interest. Trend monitoring involves measurements taken at regular time intervals in order to assess the long-term change or trend in a particular parameter. Usually, the measurements are not taken specifically to evaluate management practices; rather, they serve to describe changes in the parameter over time (NOAA 2007, NPCC 2010, Monitoring Methods 2012).

### Fish Population Status and Trend

Monitoring the status and trend of salmonid populations is important to understand the health or extinction risk of the population, and the effects of various management actions (e.g., habitat restoration or hatchery supplementation) on the population status. It is also essential for evaluating the condition of the population relative to management goals (e.g., recovery goals). Importantly, population status and trend data can aid in the development of relationships of habitat conditions or hatchery supplementation with fish performance (e.g., survival, abundance, distribution, biomass, or growth) or population status. These relationships are developed at a watershed- or population-scale, since population status is measured there.

Status and trend monitoring for salmonids is guided by NOAA’s VSP parameters which consist of abundance, productivity, spatial structure and diversity (NOAA 2000). Abundance provides information on the size of the population, with smaller populations generally being at greater risk of extinction, and declining trend being an important risk for viable salmonid populations (Allendorf et al. 1997, Myers et al. 1998, NOAA 2000). Productivity provides information on whether a population is successfully replacing itself (low extinction risk) or not (high extinction risk; NOAA 2000). Spatial structure within a population or group of populations provides information on the spatial distribution of individuals (spawners) and processes that result in this distribution (stray rates) and can give insight on extinction risk not apparent from abundance and productivity (Tilman and Lehman 1997, Cooper and Mangel 1999, NOAA 2000). The last parameter is the diversity in salmonid traits found within and among populations, which provides information on the flexibility of the population to adapt to diverse and changing environments (NOAA 2000). Diversity consists of genetic and life history diversity, with the later including diversity in age-at-return, age-at-emigration, size-at-return, size-at-emigration, adult sex ratio, adult run-timing, spawn-timing, and juveniles emigration timing. Moreover, combining spatial structure and diversity metrics can be used to conduct risk assessments such as those consistent with the Interior Columbia Technical Recovery Team (ICTRT) viability criteria.

Because VSP parameters are derived from many individual monitoring observations, it is important to document variation among observations. Providing information on variability allows managers to understand the magnitude and source of the error.

Abundance

Determining the total numbers of hatchery and natural-origin spawners and natural-origin recruits provides managers with a general index of the viability of the population and can be used as an early warning indicator to determine if a significant decline may be reached in one or two years. Results can be compared to significant decline triggers to see if or when contingency procedures and actions need to be implemented. Implementation of management actions should increase the total number of natural-origin spawners and recruits.

The ASMS recommends the following abundance guidelines:

* Annual adult status and trend data should be collected with high-intensity monitoring (high precision <15% CV), as defined in the Crawford and Rumsey document (2011), within at least one population per life-history type (e.g., spring versus summer run Chinook salmon) per MPG. This level of monitoring should occur within populations with high intensity juvenile and/or smolt abundance monitoring.
* All populations should receive low-intensity population status and trend monitoring (>15% CV) as defined in the Crawford and Rumsey document (2011).
* The proportion of hatchery-origin fish in each population should be estimated where feasible. If a population cannot be monitored, then alternative methods to derive this metric should be developed.
* Adult monitoring should report abundance and precision (confidence intervals, CI’s) on a yearly basis in a manner that will allow abundance and certainty/precision levels to be aggregated at larger spatial scales (e.g., MPG and ESU/DPS).
* Annual estimates should include direct harvest and incidental mortality of natural-origin adults in mainstem and terminal area fisheries partitioned by MPG (or population).
* Calculate the average coefficient of variation (CV) for spawner abundance. Try to achieve a high precision of CV of 15% or less for high-intensity monitoring.

Productivity

As with abundance, productivity results can be early warning signals of population decline and can help determine specific procedures and actions that need to be implemented and when. The ASMS is interested in productivity of naturally produced salmonids and egg-to-smolt survival. Tributary survival (egg-to-smolt survival) or freshwater productivity (smolts per redd or smolts per spawner) provides an index of survival or productivity within spawning and rearing areas that are not influenced by factors outside the population. This index should be more sensitive to tributary actions than adult recruits per spawner and should theoretically increase with the implementation of tributary habitat actions. Relationships between survival and habitat quality and capacity can be revealed in egg-to-smolt survival monitoring (note that habitat status and trend data are needed to develop these relationships). These relationships can then be used to develop fish-habitat models or improve existing models.

Productivity measurements should be collected following these guidelines:

* Annual estimates of adult:adult productivity and CI’s for each population.
* Annual estimates of juvenile and/or smolt migrants and CI’s for at least one population per MPG. Juvenile and smolt monitoring should be done in populations with high-intensity adult monitoring to calculate smolts per female (or smolts per spawner).
* Productivity estimates should include estimates of precision (CI’s), which allow the results to be aggregated at larger spatial scales (e.g., MPG and ESU/DPS).
* For VSP analysis, the adult:adult productivity estimate is a higher priority than the juvenile:adult productivity estimate.
* Estimate on an annual basis the smolt-to-adult survival rate in at least one population per MPG.
* Juvenile production should be based on smolt trap sampling
* The goal for all populations monitored for juvenile migrants 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.

Spatial Structure

Spatial structure of a population is maintained by not destroying habitat or their functions at rates faster than they are created or restored; by maintaining suitable habitats (major and minor spawning areas) even if they contain no listed species; and by addressing man-made barriers to fish migration and movement. Management actions such as barrier removal, habitat restoration, and supplementation should affect changes in population distribution.

The following should be used to measure spatial structure:

* Document the occurrence of spawning within major and minor spawning areas within the population. Major and minor spawning areas for ESA listed salmonids are provided for each of the ESU/DPS within the Technical Recovery Team’s ESA Salmon Recovery Plans (http://www.nwr.noaa.gov/Salmon-Recovery-Planning/ESA-Recovery-Plans/Index.cfm)
* Annually report the number of redds within each major and minor spawning area.
* Develop surrogates for adult spatial distribution in areas where spawning surveys are not feasible.
* Assess juvenile distribution at the population scale at least once every five years.
* Remote detection using PIT tag arrays.

Diversity

Changes with-in populations for both phenotypic (morphology, behavior, and life-history traits) and genotypic (genetic) diversity need to be tracked. Similar to appropriate actions for spatial structure, barrier removal, habitat restoration and supplementation should positively impact population diversity.

To fully monitor diversity, follow these guidelines:

* Monitor population phenotypic characteristics at least once every five years (e.g., juvenile outmigration timing, adult run timing, spawn timing, age distribution, age at maturity, fecundity, sex ratio, size, and weight).
* Sample populations for genetic characteristics at least once every five years, to periodically capture a snapshot of the populations every 1 to 2 generations. Sample wild populations on a rotating five-year basis to maintain genetic baseline for genetic stock identification (GSI) and to evaluate genetic population structure and diversity.

### Fish Habitat Status and Trend

Access to quality tributary habitat is an essential component for the persistence of healthy salmonid populations and for mitigating and restoring other species. When access or quality of tributary habitat is limited or reduced, implementing actions to address these factors may increase productivity and perhaps spawner abundance. In most situations, the status of habitat in a watershed is dynamic with some societal actions resulting in conservation or restoration, while others resulting in habitat degradation. In such scenarios, only broad scale monitoring of habitat status and trend can provide insight to the overall status of fish habitat for a given population, major population group (group of populations), or ESU (Crawford and Rumsey 2011).

Monitoring the status and trend of tributary habitat quality and quantity is important because it describes the physical, chemical, and biological habitat conditions that affect egg-to-smolt survival or productivity at the population or watershed scale (SRFB 2003), and establishes a baseline for future comparisons. Habitat trend monitoring involves measurements that are taken at regular time or space intervals to assess the long-term or large-scale trend in a particular parameter (NOAA 2007, NPCC 2010). These data are needed to determine if a change in egg-to-smolt survival or natural-origin spawners and natural-origin recruits is associated with changes in habitat quality and quantity. If a relationship exists, these can then be used to develop or improve fish habitat relationships for models.

The objectives of tributary habitat status and trend monitoring are to: (1) measure and track over time the quality and quantity of habitat within at least one population per MGP; (2) develop relationships between the status of the population (e.g., egg-to-smolt survival) and habitat quality and quantity conditions; and (3) develop data summaries and maps that will assist habitat project planning groups identify habitat impairments and limiting factors.

The habitat quality and quantity indicators for which data are to be collected include : average alkalinity, conductivity and pH; growth potential; percent below summer temperature and percent above winter temperature thresholds; velocity heterogeneity; embeddedness of fast water cobble; pool frequency; channel complexity, score and volume; residual pool volume; subsurface fines; total drift biomass; bank angle; LWD; fish cover; riffle particle size (such as D16, D50, D84) riparian structure; and solar input. Indicators associated with stream flows include change in peak, base and timing of flow. All of these indicators directly affect both freshwater survival and the capacity of the habitat.

Monitoring these indicators will give managers quantitative measures of the condition of tributary habitat. These data will also identify by population or watershed what habitat conditions are limiting or impaired (SRFB 2003). This information is critically important to planners and implementers, who are responsible for implementing habitat actions; however, it will not tell them which actions are most appropriate for addressing the habitat impairments. That information will come from action effectiveness monitoring.

Habitat status and trend data are also needed to help develop functional relationships between habitat variables and egg-to-smolt survival or freshwater productivity at the population or watershed level. These relationships can then be used to develop fish habitat models or improve existing models. Furthermore, they will assist with the development of life-cycle models (the tributary habitat component of the life-cycle model) and climate change models. Ultimately, the habitat status and trend data will provide some of the raw materials needed to help managers make habitat restoration decisions in light of climate change.

There are currently several watershed scale aquatic habitat monitoring programs (e.g., CHaMP, PACFISH/INFISH Biological Opinion (PIBO), Aquatic and Riparian Effectiveness Monitoring Program (AREMP), etc.). Managers need to compare the results from these different habitat monitoring programs, to determine if the programs can share information and coordinate field sampling activities. Managers will need to work with these programs to determine if methods and protocols should be changed to make the programs more compatible or determine if cross-walk models between the different programs should be developed, which would allow both programs to use their respective methods and still share data.

Following the guidance set by Crawford and Rumsey (2011), habitat status and trend monitoring should rely on a mixture of tools including remote sensing and ground sampling both instream and along the riparian zone. To facilitate data sharing and to allow multiple uses of the data (e.g., answering questions at multiple scales; Hawkins et al. 1993), the monitoring approach should come from a probability-based sampling framework and coordinate with fish abundance status and trend data collection. This framework allows the data to be used at multiple scales to assess the conditions of aquatic and riparian habitat and water quality. Lastly, to ensure data quality and communicate the quality of data obtained, a pre-determined level of confidence should be established and reported. Larsen (2004) demonstrated that a well-designed network of 30-50 sites monitored consistently can detect underlying changes of 1-2% per year in a variety of key habitat characteristics within 10-20 years or sooner.

As a general rule, habitat status and trend monitoring should include:

* Habitat parameters that are sensitive to changes in essential stream conditions.
* Parameters that have a high signal-to-noise ratio (moderate to high values range from 2 to 10) for variability among sites to variability for a given site among years (Kaufmann et al. 1999).
* Parameters that can be easily sampled by crews with low variability between sampling crews (i.e., have low residual mean square error).
* Develop and use the best available model to interpret the status of habitat based on the parameters collected and to inform high-level indicators for watershed conditions (Crawford and Rumsey 2011).
* Habitat trends should be described with high-precision monitoring across the Basin using a probabilistic sampling approach. High precision is defined as <15% CV in the Crawford and Rumsey document (2011).

CHaMP

The ASMS focuses on habitat status and trend monitoring needed for assessments at the population and smaller (e.g., watershed) scales. Currently, the Columbia Habitat Monitoring Program (CHaMP) is being developed to provide recommendations for a standardized approach for monitoring habitat status and trend within the Basin. CHaMP is a fish-centric, habitat quality and quantity monitoring program that aims to characterize responses of habitat to management actions and provides information to improve fish habitat relationships. CHaMP will be implemented in 11 watersheds in 2011, expanding to 18 in 2012. The stream habitat quality and quantity data generated by CHaMP are spatially explicit and will be evaluated in a GIS framework that also considers watershed, valley, and reach-level information, with a focus on covering one population per MPG. In addition, the protocol integrates well with remote sensing information that will be used to collect spatial information over large extents in a fiscally efficient manner. This monitoring program will support habitat restoration, rehabilitation and conservation actions, performance assessments, and the adaptive management requirements of the 2008 FCRPS BiOp. Data collected under the CHaMP protocol will include at a minimum:water quality, temperature and chemistry; stream discharge; macroinvertebrates; canopy cover; riparian structure; human influence; bank morphology; substrate composition; large woody debris; channel morphology; fish cover; particle size distribution and embeddedness; subsurface fines; and solar input.This list of indicators and metrics may be modified based on lessons learned through the pilot phase of the program.

### Hatchery Status and Trend Monitoring

Some published hatchery reform protocols (Cuenco et al 1993, Mobrand et al. 2005) describe process for fish production that are more compatible with the natural environment and can be used to facilitate natural stock restoration. This is called an integrated hatchery program and aims to have hatchery-origin fish that are closely similar to local natural-origin fish (NOAA 2008b, Ford 2002). The opposite approach is a segregated program which is comprised of hatchery fish that are independent of natural-origin fish, with less than 10% of natural-origin fish making up the hatchery broodstock (Hastings 1993, McElhany et al. 2000, Mobrand et al. 2005, NOAA 2008b). Many of the recommended hatchery reform protocols are being used in varying degrees in at least the following hatchery programs:  spring Chinook in the Tucannon, Lostine, and Upper Yakima, mid-Columbia, Clearwater (Snake), Grande Ronde, Johnson Creek (Salmon) and Snake River fall Chinook, and coho in the Yakima, Wenatchee, Methow and Clearwater rivers.  These programs, which include comprehensive monitoring and evaluation components, have demonstrated benefits including:  increased spawner and redd abundance (reduced demographic risk of extirpation), re-establishment of extirpated populations, increased marine-derived nutrients to upriver spawning areas, and detection of point-source juvenile migration bottlenecks (e.g., Roza Dam passage, Wapato Dam bypass blockage). These benefits should be considered transitory or short-term and do not necessarily contribute to abundance and productivity changes needed to meet viability criteria for natural-origin fish (NOAA 2008b). Many of these programs are only now reaching the level of maturity (3-5 salmon generations) for proper evaluation, for which continued monitoring will be crucial.

Many of the metrics collected for fish population status and trend monitoring are relevant for hatchery status and trend monitoring. In most cases, additional information related specifically to the operations within the hatchery environment and in the wild is needed in addition to the data collected for the VSP parameters. For example hatchery specific questions may include: (1) determine if the fish reared within the hatchery are surviving as expected for all life stages; (2) where appropriate, ensure that the percentage of natural-origin fish within the broodstock meets expectations; (3) ensure that fish released are the size and condition that is targeted, (4) ensure fish are raised in an environment as disease-free as possible; (5) track the percentage of hatchery-origin fish on the spawning grounds; (6) track the origin of hatchery fish on the spawning grounds; and (7) track where hatchery fish are spawning naturally. Whereas, basinwide or ESU-wide hatchery monitoring my attempt to address broad uncertainties. There are four major critical uncertainties regarding the effects of hatchery programs on natural populations: (1) demographic, (2) genetic, (3) ecological interactions, and (4) ecosystem carrying capacity limitation (AHSWG 2008, HSRG 2009). All four areas of uncertainty are difficult to study. Demographic benefits from hatchery programs may be difficult to detect because of varying survival rates, lack of reference (no hatchery influence) populations, and sampling difficulties. Genetic fitness effects are difficult to detect beyond one generation. Ecological interaction research can be logistically challenging, and the results may be quite variable. Measuring carrying capacity is difficult because of varying conditions and interactions within streams on an annual basis. Some of these broad uncertainties may be best addressed as part of hatchery effectiveness monitoring which is described in a later section.

Given the importance of the research and the enormous expense of monitoring efforts, it is important wherever possible to coordinate efforts across programs to avoid duplication and maximize statistical power. Ideally, the significant effort that is underway within the Basin to monitor hatchery effects can be coordinated through a basinwide experimental design that will inform managers and stakeholders to a better degree than uncoordinated separate efforts. The need for this type of RM&E coordination has been recognized for some time. A critical step was the development of standardized monitoring measures for hatchery programs by the Collaborative Systemwide Monitoring and Evaluation Project (CSMEP; Parnell et al. 2004), but the most recent relevant effort was done by the Ad Hoc Supplementation Work Group (AHSWG 2008). Responding in large part to a critique of supplementation monitoring by scientific review panels (ISRP/ISAB 2005-15), the AHSWG (2008) reviewed supplementation projects in the Basin and made three key recommendations, presented here in a somewhat simplified form:

1. Standardize M&E protocols for salmon and steelhead populations in the Basin and organize these actions into a regional, multi-tiered framework;
2. Use a two-pronged approach to monitor the effects of supplementation- continue, standardize, and expand monitoring of productivity and abundance in treatment and reference streams; and continue and expand relative reproductive success (RRS) studies; and
3. Maintain the momentum from the CSMEP and AHSWG through creation of an interagency workgroup to (a) communicate information and research results among managers, (b) develop and implement large-scale study designs, and c) continue to work to standardize data collection and analysis and communicate results to managers and policy makers.

Within the Hatchery

Monitoring within the broodstock should include the survival of fish during holding and the percentage of natural-origin fish, which would not include pre-spawning mortality. Estimated survival of various in-hatchery juvenile stages should be tracked, such as green egg to eyed egg, eyed egg to hatch, hatch to ponded fry, fry to parr, parr to smolt and overall green egg to release. This is derived from census count minus pre-release mortalities, or from sample fish-per-pound calculations minus mortalities. Screening procedures for diagnosis and detection of Bacterial Kidney Disease (BKD) in adult female ovarian fluids should occur and any disease incidence during rearing in the hatchery needs to be reported. Size and condition of fish upon release should be measured by the mean fork length measured in millimeters (mm) and mean weight measured in grams (g). The Condition Factor (K) relates length to weight expressed as a ratio is generated by life stage of juveniles using the formula: K = (w/l3)(104) where K is the condition factor, w is the weight (g) and l is the length (mm). Tracking of the percentage of fish marked prior to release can be estimated from a sample of fish as either “present” or “absent.” Managers should keep track of the number of days that fish were reared on the acclimation water source prior to release.

In the wild

The percentage of hatchery-origin fish on the spawning grounds can be estimated through carcass surveys, remote detection of previously tagged fish, and weir counts. The percentage of hatchery-origin fish is the fraction of the total escapement. The origin of hatchery fish on the spawning grounds is estimated from broodstock capture, carcass surveys, or specific sampling of an external marked fish. A combination of spawning surveys, carcass surveys and remote detection is used to determine if hatchery fish are spawning in the same location as natural-origin fish.

## Effectiveness Monitoring

Effectiveness monitoring is designed to determine whether a given action or suite of actions achieved the desired effect or goal. Effectiveness monitoring may be applied at a large scale (e.g., population scale) or small scale (e.g., project scale), depending on the purpose of the management action. The overarching approach for assessing habitat effectiveness includes:

* For all the subbasins, managers want to identify reference areas and ensure that they are maintained as such and that the monitoring in those areas are continued as a long term data set.
* Conduct monitoring for successful implementation of habitat restoration and protection projects.
* Make sure the information obtained during monitoring activities are archived in an appropriate data management system.
* Quantify and model the relationships between fish productivity and habitat conditions under current and restored scenarios.
* Align monitoring for habitat effectiveness with salmonid populations already identified for conducting fish and habitat status and trend monitoring so that data can be used to assess habitat action effectiveness on fish populations

Effectiveness monitoring is research oriented and therefore attempts to reveal correlation and cause-and-effect relationships (NOAA 2007). This type of monitoring is important because it reveals what actions work and which ones do not (Beechie et al. 2003). That is, effectiveness monitoring provides funding entities with information on benefit/cost ratios and managers with information on what actions or types of actions improve habitat and biological conditions. The ASMS describes both habitat and hatchery effectiveness monitoring. Habitat effectiveness monitoring is broken into project-level and population/watershed-level effectiveness monitoring, because they address different questions.

It is important to note that effectiveness monitoring relies heavily upon implementation and compliance monitoring. The latter two types of monitoring provide necessary information on the location, extent, and intensity of the management action implemented. It also provides information on the longevity of the action. This information is needed to guide effectiveness monitoring. Indeed, without some level of implementation and compliance monitoring information, one cannot develop an effectiveness monitoring plan.

### Project-Level Habitat Effectiveness Monitoring

Most habitat projects are implemented at a small scale, with defined sets of actions intended to enhance or restore local habitat features or habitat-forming processes. Project-level effectiveness monitoring is concerned with measuring local habitat and fish parameters to determine whether the actions implemented were effective in creating a desired change in habitat condition and fish performance (Beechie et al. 2003). Here, the focus is on assessing the effects of habitat actions on fish abundance, biomass, growth, movement, habitat use and impairments, local limiting factors and/or distribution. In most cases, it does not assess the effects of habitat actions on fish survival. This is because survival is measured at a larger spatial scale. Project-level monitoring is important because it allows the researcher to assess the effects of specific habitat actions on physical habitat characteristics and on fish performance and is generally not confounded by multiple treatment effects. This level of monitoring is needed to help tease out the effects of different actions on changes in egg-to-smolt survivals, which are measured during population status and trend monitoring or in population/watershed-level effectiveness monitoring.

The objectives of project-level habitat effectiveness monitoring are to: (1) identify which actions are most effective at addressing specific habitat impairments or limiting factors: (2) determine for each habitat impairment or limiting factor which action(s) are most cost effective; (3) provide results to implementers throughout the region so they can recommend the most cost-effective action for addressing a specific impairment; and (4) develop functional relationships between habitat quality and local fish performance (e.g., abundance, biomass, growth, or condition). These relationships can then be used to develop fish-habitat models or improve existing models. Specifically, these relationships can be used to improve the “capacity” component of a multistage Beverton-Holt model (e.g., Shiraz model). Furthermore, they will assist with the development of life-cycle models (the tributary habitat component of the life-cycle model).

An important component of adaptive management is identifying what works and what does not. Implementers should determine the most cost-effective actions for addressing specific habitat impairments and limiting factors. Habitat status and trend data will tell implementers what factors are currently impaired in specific locations; data from action effectiveness monitoring will tell them which actions are most appropriate for addressing the habitat impairments.

A programmatic approach to project-level habitat effectiveness monitoring is still in development and as such parameters have not been finalized. However, a number of metrics specific to different categories of actions are being reviewed as part of the development of this approach. Other monitoring agencies, such as the Washington Salmon Recovery Fund Board and Oregon Watershed Enhancement Board, have taken a broader approach that the ASMS recommends as more cost-effective and informative in understanding project/reach scale effectiveness. Guidance on how this broader approach can be applied to projects implemented under the Program is being developed through the PNAMP Effectiveness Workgroup[[9]](#footnote-9). This broader monitoring approach combines habitat actions into categories, such as culvert replacement actions, and randomly selects a subsample from within a category to monitor for effectiveness. Once priority categories are assigned and actions are randomly selected the monitoring data can be collected either by (1) employing standardized protocols by all proponents implementing a given habitat action type, or (2) employing a third party to monitor the effects of a given habitat action type. Once collected, the data need to be compatible to allow joint analyses of the action category’s effectiveness.

In developing project-level habitat effectiveness monitoring, the following guidance should be considered:

* Projects within a specific category of actions should be randomly selected for effectiveness monitoring at the project level. The number of projects selected within a specific category of actions should be adequate to provide statistically valid information. If there are insufficient actions to subsample for a given category, then sample all or seek coordination with entities funding this type of restoration action.
* Implement a valid experimental design. The use of BACI or before-after (B-A) designs is appropriate for many types of habitat actions. However, they may not be appropriate for all types of actions (e.g., removal of a fish barrier) or when a retrospective sample of actions implemented at different times may be infromative. These types of actions can be assessed with a simple post-treatment design.
* Coordinate monitoring of action categories across funding agencies to conserve limited funding and reduce effort.
* Identify, publish, and maintain standard protocols and field methods to facilitate standardization. To the degree possible, combine monitoring data to enhance statistical power to detect change.
* Where appropriate, use the same protocols for conducting habitat effectiveness monitoring as those used in status and trend monitoring (Crawford and Rumsey 2011).
* Define the decision criteria to determine effectiveness. Collect action effectiveness data from a subset of representative actions following a standardized protocol to facilitate synthesis of data for a given action type. As needed, or when more efficient, consider employing a third party to collect the effectiveness monitoring data for a given action type. Once an action type has adequate monitoring data, assess its effectiveness and have the findings reviewed by independent scientists.
* Ensure that individuals and agencies implementing a specific action are briefed on the results of the effectiveness monitoring so they can make improvements.

### Population/Watershed-Level Habitat Effectiveness Monitoring

It is important to assess the cumulative effects of habitat actions on survival, because some programs (e.g., the FCRPS BiOp) call for the implementation of habitat actions that will increase pre-spawn and/or egg-to-smolt survival of specific populations. The advantage of this level of effectiveness monitoring is that it measures life-stage survival at the watershed or population scale. The disadvantage is that in most cases it cannot by itself determine the effects of specific habitat actions on population survival if more than one type of action is implemented within the watershed. Therefore, wherever possible, project-scale habitat effectiveness monitoring should occur within populations in which population/watershed-level habitat effectiveness monitoring also occurs.

The objectives of population/watershed-level action effectiveness monitoring are to: (1) determine if the implementation of habitat actions increases egg-to-smolt survival of listed fish; (2) to the degree possible, determine which habitat actions contributed most to the survival increase; and (3) develop functional relationships between fish survival and habitat quality.

Implementing habitat actions to address survival gaps should result in improvements in the overall quality and capacity of the habitat within the watershed or population. If the suite of actions implemented within the watershed or population do not improve overall habitat quality, it is unlikely that survival will increase. Data from habitat status and trend monitoring can help address the cumulative effect of actions on watershed health. Success is determined by comparing survival results to a reference watershed, baseline conditions, or desired future conditions. These comparisons are needed to determine that it was the implementation of habitat actions and not some other extraneous factor(s) that caused the increase in survival. In some cases, one may find a positive benefit at the project level, but not at the watershed or population level. Under this scenario, managers will need to evaluate results from population and habitat status and trend monitoring. By considering all the monitoring data in concert, managers should be able to determine if the effects of habitat actions were confounded by other factors such as hatchery effects. As noted earlier, in most cases, watershed/population-level action effectiveness cannot determine which action contributed most to a change in survival if more than one habitat action type was implemented. However, in concert with project-level habitat effectiveness data, it may be possible to determine the importance or contribution of different habitat actions on survival.

Population/watershed-level habitat effectiveness data will be used to develop functional relationships between habitat conditions and fish survival. These relationships can then be used to develop fish-habitat models or improve existing models. Specifically, these relationships can be used to improve both the productivity and capacity components of a multistage Beverton-Holt model (e.g., Shiraz model). Furthermore, they will assist with the development of life-cycle models (the tributary habitat component of the life-cycle model) and climate change models.

Correlation

Correlation monitoring attempts to assess a link between multiple habitat actions (similar and diverse actions) implemented in a single area and the status of the fish population there. Assessing how the status of habitat correlates with change in salmon and steelhead on a broad scale basis is in development (e.g., CHaMP, USFWS, BOR, USEPA). Correlation-based effectiveness monitoring, which may appear similar to cause and effect monitoring, should be used where a more extensive monitoring approach is impractical. Large scale status and trend monitoring of population productivity and habitat condition should be implemented to assess effects of habitat actions via correlation of smolt-to-adult productivity change due to habitat condition.

To assess if there is a correlation in habitat change and changes in fish populations, a model using status and trend data collected for fish habitat and abundance will be used. The process to identify the appropriate model is being initiated by the Action Agencies implementing the BiOP and will involve managers through regional discussions and possibly workshop during 2012. As work progresses the ASMS will be updated to reflect the basinwide strategy for this effectiveness assessment.

Cause-and-effect

Using causal-comparative approaches, one can determine which actions had the greatest effect on survival change. Detecting this relationship is challenging, given the numerous factors affecting the abundance of a fish population. To increase the odds of identifying such a relationship, intensively monitored watersheds (IMW). Habitat restoration actions are concentrated in IMWs, which provide a means of testing and developing a monitoring program based on identifying the problem, such as the mechanisms limiting fish production, and the habitat context leading to this limitation, while collecting status and trends of fish and their habitat. IMWs also engage in experimental manipulation that achieves restoration goals while maximizing learning. This experimental design requires having one treatment watershed and one to several control watersheds. The IMWs serve to inform the potential to develop a monitoring program for large-scale restoration efforts.

Determining the effects of habitat changes on fish response will require that the overall response of the fish populations increases enough to be detectable over the normal annual variation in fish population abundance within ten years. Ideally, IMWs should be conducted to assess the cumulative effects of an action or actions at a population scale by monitoring population productivity and associated habitat conditions. The monitoring sub-framework should ensure that the network of IMWs reflects the variety of habitat action types, ecoregions, species, and life history types. Most watershed/population-level action effectiveness monitoring plans should include before-after comparisons, allowing researchers to collect survival data under a range of habitat conditions. This population/watershed-level habitat effectiveness monitoring data should allow researchers to develop relationships between changes in habitat quality and survival.

Efforts to assess cause-and-effect relationships among freshwater habitat and salmonid populations are on-going and supported by the Washington Salmon Recovery Funding Board, Oregon Watershed Enhancement Board, Idaho Fish and Game, and BPA (i.e., the Integrated Status and Effectiveness Monitoring Project or ISEMP). The ASMS recommends the following specific guidance criteria for IMWs (Bilby et al. 2004, Crawford and Rumsey 2011):

* Implement a BACI experimental design whenever possible. It is the design most likely to detect a treatment effect.
* Conduct a power analysis[[10]](#footnote-10) to determine the treatment level needed to detect a 30-50% change in fish response. Ensure that adequate funding is available to meet the required treatment amount.
* Preference should be given to IMWs that focus on multiple species, because they are more cost-effective than single species programs.
* Because of the cost and long-term investment associated with implementing IMWs, consideration should be given to determine the number of IMWs needed to assess relationships between habitat actions and changes in fish population performance (Crawford and Rumsey 2011).
* Select watersheds that can be efficiently treated and monitored. The watershed should be large enough to encompass all freshwater life stages of the target species.
* Monitoring should provide a reliable estimate of fish into the system (adult abundance, including both hatchery and natural-origin adults) and fish out (smolt production) for the entire watershed.
* Watersheds in proximity with similar physical characteristics can be used as either controls or additional treatment areas.
* Commitment by local agencies and tribes is needed to keep the control watershed(s) unchanged during the life of the project (>10 years).
* Consistent and extensive coordination is needed among the participants to ensure that monitoring and treatments occur as planned and are compatible.
* Data need to be summarized annually to examine trends, ensure that data are compatible, and that the project is on track.

Currently, Washington, Oregon and Idaho have 17 IMWs, 9 of which are in the Basin. These are in various pilot stages with many different parameters being collected and tested through ISEMP, which is designed to measure biological responses to habitat actions. Most of these parameters and metrics are consistent with those identified for CHaMP. As these parameters are further evaluated under these monitoring programs, the rationale for their selection will be discussed in future versions of the ASMS. Although different funders are supporting these IMWs, the ASMS strongly recommends utilizing information learned from all IMWs to improve our understanding of habitat actions and fish response.

### Hatchery Effectiveness Monitoring

Hatchery actions may negatively affect the productivity of natural populations (Beasley et al. 2008). For example, some studies (e.g., Leider et al. 1990, Kostow et al. 2003, Berejikian 2004, Araki et al. 2008) have shown that when hatchery fish spawn under natural stream conditions, among themselves or with natural-origin fish, their ability to produce viable offspring is reduced relative to paired natural-origin fish in the same environment. These differences may be genetic (e.g., Araki et al. 2007 and 2009) and infer progressive loss of fitness of the affected natural population, or they may be associated with non-heritable environmental effects such as homing to a specific release location (e.g., Williamson et al. 2010), size differences (e.g., Knudsen et al. 2008), or rearing strategy (e.g., Mackey et al. 2001). Studies by the Recovery Implementation Science Team (RIST; RIST 2009), Araki et al. 2008, Carofino et al. 2008, Schroder et al. 2008 and 2010, Chittenden et al. 2010, Williamson et al. 2010, and Theriault et al. 2011 show a very wide range in results - from large and rapid loss of fitness, to observation of little or no change in recruits per spawner of hatchery origin fish relative to natural origin fish.  The wide divergence in study results is associated with a variety of factors, including:  choice of salmonid species (Chinook, coho, chum, steelhead, Atlantic, brown trout), use of local versus out-of-basin stock for the hatchery program, the relative use of natural origin (integrated) versus hatchery origin (segregated) fish within the broodstock, choice of juvenile rearing protocols (e.g., intentional temporal segregation – Mackey et al. 2001), and juvenile release locations and protocols (e.g., within or distant from natural spawning areas, direct release versus acclimation).  There is also evidence that any differences are reversible as fish are allowed to “re-naturalize” (e.g., Bosch et al. 2007, Conover et al. 2009).  While recognizing that hatchery effects on natural productivity can be negative, given the current variation among results and small sample sizes among comparably designed studies, the RIST “concluded that little or no evidence of differences in relative fitness of hatchery fish among species for recently developed hatchery programs could be found” (RIST 2009). Thus, there is a need to monitor the effectiveness of hatchery programs on the abundance, productivity, spatial structure, and diversity of natural populations. Most of the information to track these parameters is discussed in the section on status and trend for fish population monitoring.

It is important to note that salmon and steelhead populations that rely on hatchery production are not considered viable, based on VSP parameters that are used to assess recovery (McElhany et al. 2000). Hatchery programs are not a proven technology for achieving sustained increases in natural-origin adult production (NRC 1996), and the long-term benefits and risks of hatchery supplementation remain untested (Araki et al. 2007).

The objectives of hatchery effectiveness monitoring are to: (1) determine what effect naturally spawning hatchery-origin fish have on the long-term productivity of the natural-origin population; (2) determine if management actions to control the percentage of hatchery-origin spawners on the spawning grounds and natural-origin fish in the broodstock reduce potential genetic and potentially demographic risks to the natural-origin population; (3) where appropriate, determine if a hatchery program can reduce the risk of extinction for a target population; and (4) assess what effect ecological interactions between hatchery and natural-origin fish have on the viability of the natural-origin population.

It is important to get a robust census of the origin of the spawning population on a yearly basis to be able to determine the effects of only the hatchery program since many variables affect the metrics collected for the VSP. It is also paramount that a reference or control population or condition be used to compare to the estimated demographic metrics to better sort out the effects of the hatchery. In addition to the VSP parameters, the following data need to be collected:

* Proportion of hatchery-origin spawners (pHOS)
* Proportion of natural-origin broodstock (pNOB)
* Proportion natural influence (PNI)
* Relative reproductive success
* Pre-spawn mortality in natural environment

The pHOS, pNOB, PNI and relative reproductive success parameters provide information on the genetic risk associated with the hatchery program (ISRP/ISAB 2005-15). PNI is a measure of gene flow between hatchery-origin and natural-origin fish within the target population. The two components of PNI are pHOS and pNOB. The relative reproductive success compares the average recruit per spawner (R/S) between natural- and hatchery-origin fish. Previous studies and evaluations (e.g., Leider et al. 1990, Kostow et al. 2003, Chilcote 2003, Berejikian and Ford 2004, Chilcote et al. 2011) have suggested that when hatchery-origin fish spawn naturally, the population reproductive fitness may be reduced. This may arise from disruptive selection between the hatchery and natural environment, whereby traits that prove advantageous in hatchery spawning are disadvantageous in natural spawning. The HSRG (2004) suggests that disruptive selection might be managed by not exceeding a given fraction of hatchery-origin adults on the spawning grounds and natural-origin adults within the broodstock. When disruptive selection occurs, the genetic effects could persist for some number of generations after supplementation is terminated, resulting in reduced natural spawning fitness (ISRP/ISAB 2005-15).

Genetic monitoring should occur approximately every 5 years, and managers of hatchery programs need to determine performance targets (in this case, deviation from the natural-origin population of interest) to compare to and understand when adaptive management of those programs should occur due to a change in genetic diversity that is unacceptable (as determined by the performance target). For phenotypic characteristics, performance targets are also needed for adaptive management purposes. For example, many hatchery programs have seen a reduction in age and fecundity associated with fish returning. Smaller and fewer eggs may have an impact on productivity if the hatchery fish spawn in the natural environment.

Ecological interactions between hatchery and natural-origin fish in the wild are a critical uncertainty for most hatchery programs. Ecological and genetic interactions are a concern to many fisheries management agencies. There is a paucity of information concerning these interactions, especially in mainstem areas, the estuary and ocean. Some of the metrics that could be collected to better understand these interactions include:

* Number of hatchery juveniles that do not migrate after release;
* Number of hatchery fish that are sexually mature at release;
* Hormone levels of hatchery fish prior to release;
* Number of fish consumed by hatchery produced fish;
* Number of hatchery and naturally produced fish consumed (by all predators);
* Number of naturally produced fish emigrating from feeding stations after hatchery release;
* Natural fish per habitat type (includes juvenile rearing and adult holding);
* Hatchery fish per habitat type (includes juvenile rearing and adult holding);
* Number of hatchery and naturally produced fish on in holding areas and spawning grounds; and
* Spawning location (by origin)

Quantifying hatchery effects on natural-origin fish is challenging but is critical to assess potential changes in productivity and diversity traits, such as run timing or age at maturity, and changes to population and species persistence, such as reduced reproductive success. Remember, hatchery effectiveness monitoring occurs both within the hatchery and the natural environment scales.

Managers should consider is whether the hatchery program functionally reduces the carrying capacity of a population or subbasin. Collecting information on demographics, diversity and ecological interactions will help analyze the carrying capacity. It is essential that an assessment of hatchery program effectiveness also consider the social and legal obligations associated with mitigation for salmon production that has been permanently lost (or, at least in the medium to long term) due to dam construction and other natural resource exploitation activities.

* Ongoing work lead by NOAA (2011) through the development of Hatchery Genetic Management Plans (HGMPs) and Columbia River Hatchery Effectiveness Evaluation Team (CRHEET) aim to address how to conduct hatchery specific effectiveness. CRHEET will develop a process to develop a basinwide hatchery effectiveness monitoring strategy that will rely on the recommendations of the AHSWG. This strategy will lay out the specific monitoring designs and analyses needed to assess the effects of hatchery programs on wild fish. CRHEET will employ the use of basinwide managers and other stakeholders to develop the basinwide designs to ensure that all funding and implementing agencies are in agreement with the approach.

In the Wild

* Hatchery effectiveness monitoring in the wild aims to assess the effect of hatchery fish on wild fish and their populations. This should be informed by the AHSWG (2008) recommendations, including developing a large scale treatment/reference design to evaluate long term trends in the abundance and productivity of supplemented populations. The AHSWG specific recommendations include (AHSWG 2008):
* An investigation of the long-term trends in the abundance and productivity of supplemented populations relative to un-supplemented populations.
* Conducting a series of relative reproductive success studies to quantify short-term effects.
* Development of a request for proposals to fund several intensive small-scale studies designed to elucidate various biological mechanisms by which introduction of hatchery-produced fish may influence natural population productivity.
* The creation of a funded interagency workgroup charged with ensuring that relevant project-specific monitoring data are centralized and analyzed within the designs recommended within their report, so as to implement the coordinated basinwide evaluation called for by the ISRP and ISAB (ISRP/ISAB 2005-15).

# 2009 and ongoing Implementation of the ASMS

There are several projects funded under the Program as well as through other federal, state, and tribal fisheries programs. These efforts are captured in tables developed during the regional workshops. These tables also address the gaps and funding prioritization for steelhead, Chinook, and sockeye VSP, habitat effectiveness and hatchery effectiveness monitoring projects. Included in these documents are the list of critical monitoring projects, monitoring strategy statements, prioritized list of monitoring gaps and justification, FCRPS BiOp RPA recommendations to address the monitoring gaps or consolidations, and prioritized list of current projects to be continued as-is, projects to be modified, and new funding proposals with estimate costs to address the monitoring gaps. The three documents are titled: and are available at the below websites:

* Table 1 Critical Steelhead Contracts and Identified Gaps Final Version 1-29-2010
	+ Available at: http://www.cbfwa.org/ams/FinalDocs.cfm
* Table 2 Critical Spring Chinook Contracts and Gaps Final Version 1-29-2010
	+ Available at: http://www.cbfwa.org/ams/FinalDocs.cfm
* Table 3 Critical Sockeye Contracts and Gaps Final Version 1-29-2010
	+ Available at: http://www.cbfwa.org/ams/FinalDocs.cfm

There is also another document produced from this workshop that summarizes the basinwide funding prioritization for steelhead, Chinook, and sockeye VSP, habitat effectiveness and hatchery effectiveness monitoring. This excel document consists of a tab for each of the subregions and is available at <http://www.cbfwa.org/ams/FinalDocs.cfm>.

Given the complexities and abundance of information captured in the above documents, as well as the dynamic nature of this work we do not attempt to re-synthesize this information. We do provide in the below table (table 1) the Program funded projects, title and number, that contribute to the monitoring described above. More detailed information on these projects, including annual reports and modifications that may occur in out-years, can be found at www.cbfish.org

Table 1: Projects funded under the Program that contribute to status and trend and effectiveness monitoring of fish, habitat, and actions.

|  |  |
| --- | --- |
| **Monitoring Type** | **Project title (project number)** |
| ***Status and trend*** |  |
| Fish population Status and Trend | **IDFG BPA Funded Projects:** * Idaho Steelhead Monitoring and Evaluation Studies (1990-055-00)
* Idaho Natural Production Monitoring and Evaluation Program (1991-073-00)
* Salmon Studies in Idaho Rivers (1989-098-00)
* Integrated Status Effectiveness Monitoring Project (2003-017-00)
* Chinook and Steelhead Genotyping for Genetic Stock Identification (GSI) at Lower Granite Dam (2010-026-00)
* Snake River Chinook and Parental Based Tagging (2010-031-00)
* Snake River Sockeye Captive Propagation (2007-402-00)

**IDFG Non-BPA Funded:*** Idaho Fish and Game Dingell-Johnson Sportfish Restoration
* U.S. Canada Pacific Salmon Treaty Management and

Technical Support* Monitoring Idaho Restoration of Salmonid Habitat in the Potlatch River Watershed of the Columbia River Basin, NOAA Intensively Monitored Watershed (IMW) Funds
* Monitoring Restoration of Salmon and Steelhead Habitat in the Lemhi River, Columbia River Basin, NOAA Intensively Monitored Watershed (IMW) Funds
* Potlatch River Steelhead M&E, Pacific Coastal Salmon Recovery Funds

**WDFW*** Nothing provided at this time

**ODFW*** Nothing provided at this time

**NPT*** Nothing provided at this time

**CTUIR*** Nothing provided at this time

**USFWS*** Nothing provided at this time

**NOAA*** Nothing provided at this time

**SBT*** Nothing provided at this time

**USFS*** Nothing provided at this time
 |
| Fish Habitat Status and trend | **IDFG** * Nothing provided at this time

**WDFW*** Nothing provided at this time

**ODFW*** Nothing provided at this time

**NPT*** Nothing provided at this time

**CTUIR*** Nothing provided at this time

**USFWS*** Nothing provided at this time

**NOAA*** Nothing provided at this time

**SBT*** Nothing provided at this time

**USFS*** Nothing provided at this time
 |
| Hatchery Status and trend | **IDFG BPA Funded Projects:** * Snake River Chinook and Parental Based Tagging (2010-031-00)
* Snake River Sockeye Captive Propagation (2007-402-00)
* Spring Chinook Captive Propagation-Idaho (2007-403-00)
* IDFG/Lower Snake River Compensation Plan
* IDFG/Idaho Power Hatchery Monitoring and Evaluation

**WDFW*** Nothing provided at this time

**ODFW*** Nothing provided at this time

**NPT*** Nothing provided at this time

**CTUIR*** Nothing provided at this time

**USFWS*** Nothing provided at this time

**NOAA*** Nothing provided at this time

**SBT*** Nothing provided at this time

**USFS*** Nothing provided at this time
 |
| ***Effectiveness*** |  |
| Project-level habitat effectiveness | **IDFG** * Nothing provided at this time

**WDFW*** Nothing provided at this time

**ODFW*** Nothing provided at this time

**NPT*** Nothing provided at this time

**CTUIR*** Nothing provided at this time

**USFWS*** Nothing provided at this time

**NOAA*** Nothing provided at this time

**SBT*** Nothing provided at this time

**USFS*** Nothing provided at this time
 |
| Population./watershed level effectiveness | **IDFG BPA Funded Projects:** * Integrated Status Effectiveness Monitoring Project (2003-017-00)
* Non-BPA Funded
* Monitoring Idaho Restoration of Salmonid Habitat in the Potlatch River Watershed of the Columbia River Basin, NOAA Intensively Monitored Watershed (IMW) Funds
* Monitoring Restoration of Salmon and Steelhead Habitat in the Lemhi River, Columbia River Basin, NOAA Intensively Monitored Watershed (IMW) Funds
* Potlatch River Steelhead M&E, Pacific Coastal Salmon Recovery Funds

**WDFW*** Nothing provided at this time

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**CTUIR*** Nothing provided at this time

**USFWS*** Nothing provided at this time

**NOAA*** Nothing provided at this time

**SBT*** Nothing provided at this time

**USFS*** Nothing provided at this time
 |
| Hatchery effectiveness  | **IDFG BPA Funded Projects:** * Salmon Studies in Idaho Rivers (1989-098-00)
* Snake River Chinook and Parental Based Tagging (2010-031-00)
* Snake River Sockeye Captive Propagation (2007-402-00)
* Spring Chinook Captive Propagation-Idaho (2007-403-00)
* IDFG/Lower Snake River Compensation Plan
* IDFG/Idaho Power Hatchery Monitoring and Evaluation

**WDFW*** Nothing provided at this time

**ODFW*** Nothing provided at this time

**NPT*** Nothing provided at this time

**CTUIR*** Nothing provided at this time

**USFWS*** Nothing provided at this time

**NOAA*** Nothing provided at this time

**SBT*** Nothing provided at this time

**USFS*** Nothing provided at this time
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# Literature Cited

AA/NOAA/NPCC (Action Agencies, National Oceanic and Atmospheric Administration, Northwest Power and Conservation Council) RM&E Workgroup. 2010. Recommendations for implementing research, monitoring and evaluation for the 2008 NOAA Fisheries FCRPS BiOp. Available online (March 1, 2012) [www.salmonrecovery.gov/Files/BiologicalOpinions/RME%20RPA%20Assessment%20Report%20June%202009%20Draft%20\_4\_.pdf](http://www.salmonrecovery.gov/Files/BiologicalOpinions/RME%20RPA%20Assessment%20Report%20June%202009%20Draft%20_4_.pdf)

ACT (Pacific Northwest Electric Power Planning and Conservation Act). 1980. Pacific Northwest Electric Power Planning and Conservation Act. Available online (March 1, 2012) [www.bpa.gov/corporate/pubs/Pac%20Nw%20Electric.pdf](http://www.bpa.gov/corporate/pubs/Pac%20Nw%20Electric.pdf)

AHSWG (Ad Hoc Supplementation Monitoring and Evaluation Workgroup). 2008. Recommendations for broad scale monitoring to evaluate the effects of hatchery supplementation on the fitness of natural salmon and steelhead populations. Final Report of the Ad Hoc Supplementation Monitoring and Evaluation Workgroup. 82pp. Available online (March 1, 2012) [www.nwcouncil.org/fw/program/2008amend/uploadedfiles/95/Final%20Draft%20AHSWG%20report.pdf](http://www.nwcouncil.org/fw/program/2008amend/uploadedfiles/95/Final%20Draft%20AHSWG%20report.pdf)

Allendorf, F. W., and 9 others. 1997. Prioritizing Pacific salmon stocks for conservation. Conservation Biology 11:140-152.

Araki, H., B. A. Berejikian, M. J. Ford, and M. S. Blouin. 2008. Fitness of hatchery-reared salmonids in the wild. Evolutionary Applications 1:342-355. Available online (March 1, 2012) <http://marking.fishsciences.net/_reports/Arakia_et_al_2008_Evol_App.pdf>

Araki, H., B. Cooper, and M. S. Blouin. 2007. Genetic effects of captive breeding cause a rapid, cumulative fitness decline in the wild. Science 318:100-103.

Araki, H., B. Cooper, and M. S. Blouin. 2009. Carry-over effect of captive breeding reduces reproductive fitness of wild-born descendants in the wild. Biology Letters 5:621-624, doi: 10.1098/rbsl.2009.0315. Available online (March 1, 2012) [http://rsbl.royalsocietypublishing.org/content/5/5/621.full.pdf+html](http://rsbl.royalsocietypublishing.org/content/5/5/621.full.pdf%2Bhtml)

Beasley et al. 2008. Recommendations for Broad Scale Monitoring to Evaluate the Effects of Hatchery Supplementation on the Fitness of Natural Salmon and Steelhead Populations Final report of the the Ad Hoc Supplementation Workgroup (AHSWG). Available online (March 1, 2012) <http://www.pnamp.org/document/3285>

Beechie T. J., E. A. Steel, P. Roni, and E. Quimby. 2003. Ecosystem recovery planning for listed salmon: An integrated assessment approach for salmon habitat. 183pp. NOAA Technical Memo. NMFS-NWFSC-58.

Berejikian B. A., and M. J. Ford. 2004. Review of relative fitness of hatchery and natural salmon 28pp. NOAA Tech. Memo. NMFS-NWFSC-61.

Bilby R. E., and 9 others. 2004. Evaluating watershed response to land management and restoration actions: Intensively monitored watersheds (IMW) progress report. 72pp. Available online (March 1, 2012) [www.rco.wa.gov/documents/monitoring/IMW\_progress\_rpt.pdf](http://www.rco.wa.gov/documents/monitoring/IMW_progress_rpt.pdf)

Bosch, W. J., and 8 others. 2007. Evaluating the feasibility of reestablishing a Coho salmon population in the Yakima River, Washington. North American Journal of Fisheries Management 27:198-214.

Caroffino, D. C, L. M. Miller, A. R. Kapucinski, and J. J. Ostazeski. 2008. Stocking success of local-origin fry and impact of hatchery ancestry: Monitoring a new steelhead (*Oncorhynchus mykiss*) stocking program in a Minnesota tributary to Lake Superior. Canadian Journal of Fisheries and Aquatic Sciences 65:309-318.

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

Chilcote, M. W., K. W. Goodson, and M. R. Falcy. 2011. Reduced recruitment performance in natural populations of anadromous salmonids associated with hatchery-reared fish. Canadian Journal of Fisheries Aquatic Science 68:511–522.

Chittenden, C. M., and 12 others. 2010. Genetic versus rearing – environment effects on phenotype: Hatchery and natural rearing effects on hatchery- and wild-born coho salmon. PLoS ONE 5:e12261. Available online (March 1, 2012) [www.plosone.org/article/info%3Adoi/10.1371/journal.pone.0012261](http://www.plosone.org/article/info%3Adoi/10.1371/journal.pone.0012261)

Conover, D. O., S. B. Munch, and S. A. Arnott. 2009. Reversal of evolutionary downsizing caused by selective harvest of large fish. Proceedings of the Royal Society B.  doi:10.1098/rspb.2009.0003. Available online (March 1, 2012) <http://rspb.royalsocietypublishing.org/content/early/2009/02/27/rspb.2009.0003>

Cooper, A. B., and M. Mangel. 1999 . The dangers of ignoring metapopulation structure for the conservation of salmonids. Fisheries Bulletin 97:213-226.

Coordinated Assessments Workgroup. 2011. Columbia River Basin collaborative data sharing strategy: Salmon and steelhead population abundance and productivity indicators. 24pp. [www.pnamp.org/sites/default/files/ca\_basinwide\_data\_sharing\_strategy\_final\_draft\_nov\_10.pdf](http://www.pnamp.org/sites/default/files/ca_basinwide_data_sharing_strategy_final_draft_nov_10.pdf)

Crawford, B. A., and S. M. Rumsey. 2011. Guidance for monitoring recovery of Pacific Northwest salmon & steelhead listed under the Federal Endangered Species Act: Guidance to salmon recovery partners concerning prioritizing monitoring efforts to assess the viability of salmon and steelhead populations protected under the Federal Endangered Species Act. U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Marine Fisheries Service. Available online (March 1, 2012) [www.nwr.noaa.gov/Salmon-Recovery-Planning/upload/RME-Guidance.pdf](http://www.nwr.noaa.gov/Salmon-Recovery-Planning/upload/RME-Guidance.pdf)

Cuenco, M. L., T. W. H. Backman, and P. R. Mundy. 1993. The use of supplementation to aid in natural stock restoration. Pages 269-293 in Cloud J. G., and G. H. Thorgaard, editors. 1993. Genetic Conservation of Salmonid Fishes. Plenum Press, New York.

Federal Caucus. No-date. Federal Columbia River Power System (FCRPS). Available online (March 7, 2012) [www.salmonrecovery.gov/BiologicalOpinions/FCRPS.aspx](http://www.salmonrecovery.gov/BiologicalOpinions/FCRPS.aspx)

Ford , M. J. 2002. Selection in captivity during supportive breeding may reduce fitness in the wild. Conservation Biology **16**:815-825

Hasting A (1993) Complex interactions between dispersal and dynamics: Lessons from coupled logistic equations. Ecology, 74, 1362–1372.

Hawkins, C. P., and 10 others. 1993. A hierarchical approach to classifying stream habitat features. Fisheries 18:3-12.

HSRG (Hatchery Scientific Review Group). 2004. Hatchery reform: Principles and recommendations of the Hatchery Scientific Review Group. Available online (March 1, 2012) [www.lltk.org/hrp-archive/pdf/hsrg/HSRG\_Princ\_Recs\_Report\_Full\_Apr04.pdf](http://www.lltk.org/hrp-archive/pdf/hsrg/HSRG_Princ_Recs_Report_Full_Apr04.pdf)

HSRG. 2009. Report to Congress on Columbia River Basin Hatchery Reform. Available online (March 1, 2012) <http://www.hatcheryreform.us/hrp_downloads/reports/columbia_river/report_to_congress/hsrg_report_12.pdf>

ISRP/ISAB (Independent Scientific Review Panel/ Independent Scientific Advisory Board). 2005. Monitoring and evaluation of supplementation projects. ISRP/ISAB 2005-15. Northwest Power and Conservation Council, Portland, Oregon. Available online (March 1, 2012) [www.nwcouncil.org/library/isrp/isrpisab2005-15.pdf](http://www.nwcouncil.org/library/isrp/isrpisab2005-15.pdf)

Kaufmann P. R., P. Levine, E. G. Robison, C. Seeliger and D. V. Peck. 1999. Quantifying physical habitat in wadeable streams. U.S. Environmental Protection Agency. Report no. EPA/620/R-99/003.

Knudsen, C. M., and 5 others. 2008. Comparison of female reproductive traits and progeny of first-generation hatchery and wild upper Yakima River spring Chinook salmon. Transactions of the American Fisheries Society 137:1433-1445.

Kostow K., A. R. Marshall, and S. R. Phelps. 2003. Naturally spawning hatchery steelhead contribute to smolt production but experience low reproductive success. Transactions of the American Fisheries Society. 132:780-790.

Larsen, D.P., P.R. Kaufmann, T.M. Kincaid, and N.S. Urquhart. 2004. Detecting persistent change in the habitat of salmon-bearing streams in the Pacific Northwest. Available online <http://www.cbfwa.org/csmep/web/documents/meetings/2004_0609/salmonbearingstreamspnw.pdf>

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

Mackey, G., J. E. McLean, and T. P.Quinn. 2001. Comparisons of run timing, spatial distribution, and length of wild and newly established hatchery populations of steelhead in Forks Creek, Washington. North American Journal of Fisheries Management 21:717-724.

McElhany, P., M. H. Ruckelshaus, M. J. Ford, T. C. Wainwright, and E. P. Bjorkstedt. 2000. Viable salmon populations and the recovery of evolutionarily significant units. NOAA Technical Memo, NMFS-NWFSC-42. 156pp. Available online (March 1, 2012) [www.nwfsc.noaa.gov/assets/25/5561\_06162004\_143739\_tm42.pdf](http://www.nwfsc.noaa.gov/assets/25/5561_06162004_143739_tm42.pdf)

Mobrand, L. E., J. Barr, L. Blankenship, D.E. Campton, T.T.P. Evelyn, T.A. Flagg, C.V.W. Mahnken, L.W. Seeb, P.R. Seidel, and W.W. Smoker. 2005. Hatchery reform in Washington State: Principles and emerging issues. Fisheries 30(6):11-23

Monitoring Methods. 2012. Glossary of Terms. Pacific Northwest Aquatic Monitoring Partnership Monitoring Methods Version 4.5.1246.0. Available Monitoringmethods.org

Myers, J. M., and 10 others. 1998. Status review of Chinook salmon from Washington, Idaho, Oregon and California. 443pp. Available online (March 1, 2012) [www.nwfsc.noaa.gov/assets/25/4234\_06172004\_115524\_chinook.pdf](http://www.nwfsc.noaa.gov/assets/25/4234_06172004_115524_chinook.pdf)

NOAA (National Oceanic and Atmospheric Administration). 2000. Viable salmonid populations and recovery of evolutionarily significant units. NOAA Technical Memo. NMFS-NWFSC-42. Available online (March 1, 2012) [www.nwfsc.noaa.gov/publications/techmemos/tm42/tm42.pdf](http://www.nwfsc.noaa.gov/publications/techmemos/tm42/tm42.pdf)

NOAA (National Oceanic and Atmospheric Administration). 2007. Adaptive management for ESA-listed salmon and steelhead recovery: Decision framework and monitoring guidance. Available online (March 1, 2012) [www.nwr.noaa.gov/Salmon-Recovery-Planning/ESA-Recovery-Plans/upload/Adaptive\_Mngmnt.pdf](http://www.nwr.noaa.gov/Salmon-Recovery-Planning/ESA-Recovery-Plans/upload/Adaptive_Mngmnt.pdf)

NOAA (National Oceanic and Atmospheric Administration). 2008a. Artificial propagation for Pacific salmon appendix: Assessing benefits and risks and recommendations for operating hatchery programs consistent with conservation and sustainable fisheries mandates. Pages 1005-1054 in Supplemental comprehensive analysis of the Federal Columbia River Power System and mainstem effects of the Upper Snake and other tributary actions. 1230pp. Available online (March 1, 2012) [www.nwr.noaa.gov/Salmon-Hydropower/Columbia-Snake-Basin/upload/Final-SCA.pdf](http://www.nwr.noaa.gov/Salmon-Hydropower/Columbia-Snake-Basin/upload/Final-SCA.pdf)

NOAA (National Oceanic and Atmospheric Administration). 2008b

NOAA (National Oceanic and Atmospheric Administration). 2010a. Endangered Species Act section 7(a)(2) consultation supplemental Biological Opinion: Supplemental consultation on remand for operation of the Federal Columbia River Power System, 11 Bureau of Reclamation projects in the Columbia Basin and ESA section 10(a)(I)(A) permit for juvenile fish transportation program. NOAA Fisheries Log Number F/NWR/2010/02096. Available online (March 1, 2012) [https://pcts.nmfs.noaa.gov/pls/pcts-pub/sxn7.pcts\_upload.download?p\_file=F25013/201002096\_FCRPS Supplemental\_2010\_05-20.pdf](https://pcts.nmfs.noaa.gov/pls/pcts-pub/sxn7.pcts_upload.download?p_file=F25013/201002096_FCRPS%20Supplemental_2010_05-20.pdf)

NOAA (National Oceanic and Atmospheric Administration). 2010b. Interim endangered and threatened species recovery planning guidance. Available online (March 1, 2012) [www.nmfs.noaa.gov/pr/pdfs/recovery/guidance.pdf](http://www.nmfs.noaa.gov/pr/pdfs/recovery/guidance.pdf)

NOAA (National Oceanic and Atmospheric Administration). 2011. Hatchery and genetic management plans. Available online (March 1, 2012) [www.nwr.noaa.gov/Salmon-Harvest-Hatcheries/Hatcheries/HGMPs.cfm](http://www.nwr.noaa.gov/Salmon-Harvest-Hatcheries/Hatcheries/HGMPs.cfm)

NPCC (Northwest Power and Conservation Council). 2006. Columbia River Basin research plan. Northwest Power and Conservation Council, Portland, Oregon. Available online (March 9, 2012) [www.nwcouncil.org/library/2006/2006-3.htm](http://www.nwcouncil.org/library/2006/2006-3.htm)

NPCC (Northwest Power and Conservation Council). 2009. High-level implementation indicators to measure success of the Fish and Wildlife Program. Northwest Power and Conservation Council, Portland, Oregon. Available online (March 1, 2012) [www.nwcouncil.org/fw/program/hli/Default.htm](http://www.nwcouncil.org/fw/program/hli/Default.htm)

NPCC (Northwest Power and Conservation Council). 2009. Northwest Power and Conservation Council Columbia River Basin Fish and Wildlife Program. Northwest Power and Conservation Council, Portland, Oregon. Available online (March 1, 2012) [www.nwcouncil.org/library/2009/2009-09.pdf](http://www.nwcouncil.org/library/2009/2009-09.pdf)

NPCC (Northwest Power and Conservation Council). 2010. Monitoring, evaluation, research and reporting (MERR) Plan. Northwest Power and Conservation Council, Portland, Oregon. Available online (March 1, 2012) [www.nwcouncil.org/fw/merr/Default.asp](http://www.nwcouncil.org/fw/merr/Default.asp)

NRC (National Research Council). 1996. Upstream: Salmon and society in the Pacific Northwest. National Academy Press, Washington, D.C.

Parnell I., D. Marmorek, and M. Porter. 2004. Revised table C1 structure and definitions for data descriptors (columns) and performance measures (rows) to guide development of the CSMEP inventory database and data input system. [www.cbfwa.org/csmep/web/documents/meetings/2004\_0701/ESSArevisedTableC1June28.doc](http://www.cbfwa.org/csmep/web/documents/meetings/2004_0701/ESSArevisedTableC1June28.doc)

PNAMP (Pacific Northwest Aquatic Monitoring Partnership). No-date. Data management. Available online (March 1, 2012) [www.pnamp.org/topics/2](http://www.pnamp.org/topics/2)

RIST (Recovery Implementation Science Team). 2009. Hatchery reform science. Available online (March 1, 2012) [www.nwfsc.noaa.gov/trt/rist.cfm](http://www.nwfsc.noaa.gov/trt/rist.cfm)

Schroder, S. L., and 6 others. 2008. Breeding success of wild and first-generation hatchery female spring Chinook salmon spawning in an artificial stream. Transactions of the American Fisheries Society 137:1475-1489.

Schroder, S. L., and 6 others. 2010. Behavior and breeding success of wild and first-generation hatchery male spring Chinook salmon spawning in an artificial stream. Transactions of the American Fisheries Society 139:989-1003.

SRFB (Snake Recovery Funding Board). 2003. Monitoring and evaluation strategy for habitat restoration and acquisition projects. Report no. SRFB MP- 0. Available online (March 1, 2012) [www.rco.wa.gov/documents/monitoring/SRFB\_Monitoring\_Strategy.pdf](http://www.rco.wa.gov/documents/monitoring/SRFB_Monitoring_Strategy.pdf)

Stevens, D. L. Jr., and A. R. Olsen. 2003. Variance estimation for spatially balanced samples of environmental resources. Environmetrics 14:593-610.

Stevens, D. L., Jr., and A. R. Olsen. 2004. Spatially-balanced sampling of natural resources. Journal of American Statistical Association 99:262-278.

Theriault, V., G. R. Moyer, L. S. Jackson, M. S. Blouin, and M. A. Banks. 2011. Reduced reproductive success of hatchery coho salmon in the wild: Insights into most likely mechanisms. Molecular Ecology 20:1860–1869.

Tilman, D., and C. L. Lehman. 1997. Habitat destruction and species extinctions. In Tilman, D., and P. M. Kareiva, editors. Spatial Ecology: The role of space in population dynamics and interspecific interactions. Princeton University Press. 368pp.

Williamson, K. S., A. R. Murdoch, T. N. Pearsons, E. J. Ward, and M. J. Ford. 2010. Factors influencing the relative fitness of hatchery and wild spring Chinook salmon (Oncorhynchus tshawytscha) in the Wenatchee River, Washington, USA. Canadian Journal of Fisheries and Aquatic Sciences 67:1840-1851.

Yaffee, S., S. Schueller, S. Higgs, A. Dotzour, and J. Wondolleck. 2004. Measuring Progress: An Evaluation Guide for Ecosystem and Community-Based Projects. Ecosystem Management Initiative, School of Natural Resources and Environment, University of Michigan, Ann Arbor, MI. Available online (March 1, 2012) [www.snre.umich.edu/ecomgt/evaluation/documents/Measuring%20Progress.pdf](http://www.snre.umich.edu/ecomgt/evaluation/documents/Measuring%20Progress.pdf)

1. Managers in this document refer to the state and federal fish and wildlife agencies and tribes within the Columbia River basin. [↑](#footnote-ref-1)
2. A regional workshop was convened by Bonneville, CBFWA, NOAA and NPCC during October 20-21, 2009 and November 3-5, 2009 in Skamania Washington to develop Basin Coordinated Anadromous Monitoring Strategy. The purpose of the Regional Workshop was to reach agreement among participants on an efficient and effective framework and project specific implementation strategy for anadromous salmon and steelhead monitoring to assess (1) Viable Salmonid Population (VSP) criteria, (2) habitat effectiveness and (3) hatchery effectiveness in the Columbia Basin. The agreed-upon framework and strategy will address the needs of the NPCC’s Fish and Wildlife Program, meet the needs of the Federal Columbia River Power System (FCRPS) BiOp (at a minimum), and contribute to the monitoring needs of ESA recovery planning and other regional fisheries management needs. [↑](#footnote-ref-2)
3. Coordinated Assessments for Salmon and Steelhead. Pacific Northwest Aquatic Monitoring Partnership. Available at: http://www.pnamp.org/project/3129 [↑](#footnote-ref-3)
4. An MPG is a group of independent populations nested within a salmon ESU that serves as a management unit for salmon recovery. [↑](#footnote-ref-4)
5. Integrated Status and Trend Monitoring project, this is a pilot effort with uncertain future funding. http://www.pnamp.org/project/3132 [↑](#footnote-ref-5)
6. Coordinated Assessments, this is a pilot effort with uncertain future funding. http://www.pnamp.org/project/3129 [↑](#footnote-ref-6)
7. Monitoring Methods project http://www.pnamp.org/project/3134 [↑](#footnote-ref-7)
8. Data Best Practices project http://www.pnamp.org/project/3265 [↑](#footnote-ref-8)
9. PNAMP’s effectiveness Monitoring Coordination & Assessment project http://www.pnamp.org/project/3137 [↑](#footnote-ref-9)
10. Hinrichsen R. 2010. Before-After Control-Impact (BACI) power analysis for several related populations. Available: http://www.onefishtwofish.net/baci/ [↑](#footnote-ref-10)