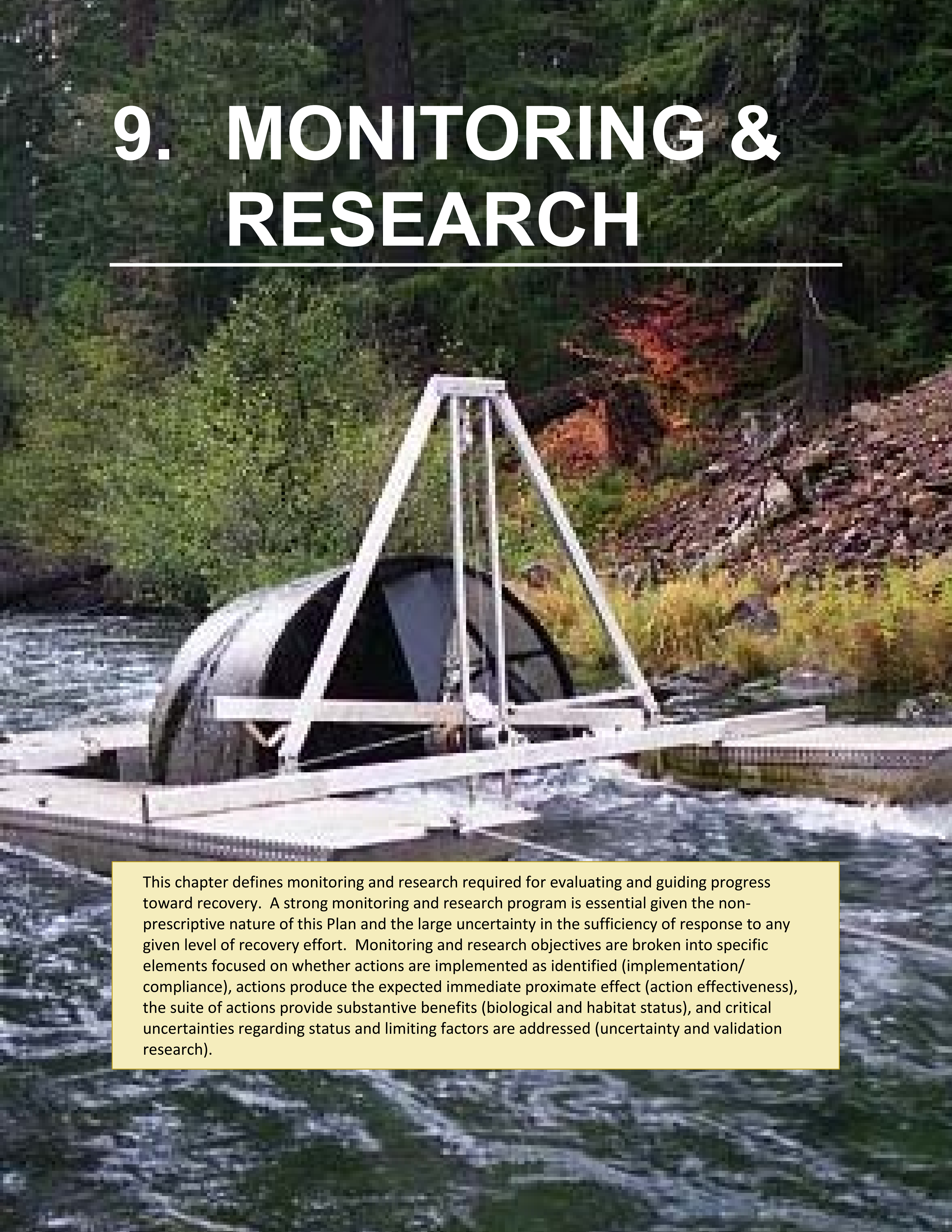
9. MONITORING & RESEARCH



This chapter defines monitoring and research required for evaluating and guiding progress toward recovery. A strong monitoring and research program is essential given the non-prescriptive nature of this Plan and the large uncertainty in the sufficiency of response to any given level of recovery effort. Monitoring and research objectives are broken into specific elements focused on whether actions are implemented as identified (implementation/ compliance), actions produce the expected immediate proximate effect (action effectiveness), the suite of actions provide substantive benefits (biological and habitat status), and critical uncertainties regarding status and limiting factors are addressed (uncertainty and validation research).

9. MONITORING & RESEARCH

Tables

Figures

9.1. Framework

Given the non-prescriptive nature of this Plan, a comprehensive and adaptive monitoring and research effort will be critical for evaluating progress toward recovery and making appropriate course adjustments along the way. The strategies and measures contained herein are based on the best current knowledge of factors and threats limiting fish viability. The Plan has constructed working hypotheses regarding focal species and their response to changes in ecosystem conditions or management practices. While science can identify a reasonable course of action, it will never be able to predict with precise certainty whether a prescribed set of actions will be sufficient to meet objectives. Some measures may not produce the desired effects. Other measures will exceed expectations. Unexpected events will occur. Uncertainties exist and must be managed. In this regard, a recovery program is fundamentally an experiment.

Monitoring and evaluation strategies and measures are designed to answer five questions regarding progress in recovery (Figure 9-1). Corresponding monitoring and research elements include:

- Biological status and trend monitoring that describes progress toward ESU recovery objectives and establishes a baseline for evaluating causal relationships between limiting factors and a population response.
- Habitat status monitoring that identifies the cumulative effect of human activity trends and recovery measures on critical limiting factors.
- Implementation/compliance monitoring that tracks whether actions were implemented as planned and/or meet established laws, rules, or criteria.
- Action effectiveness monitoring that determines if specific habitat, hydropower, hatchery, harvest, and ecological interaction measures produce the specific intended effect.
- Uncertainty and validation research that targets specific issues that constrain effective Recovery Plan implementation including evaluations of cause and effect relationships between fish, limiting factors, and actions that address specific threats related to limiting factors.

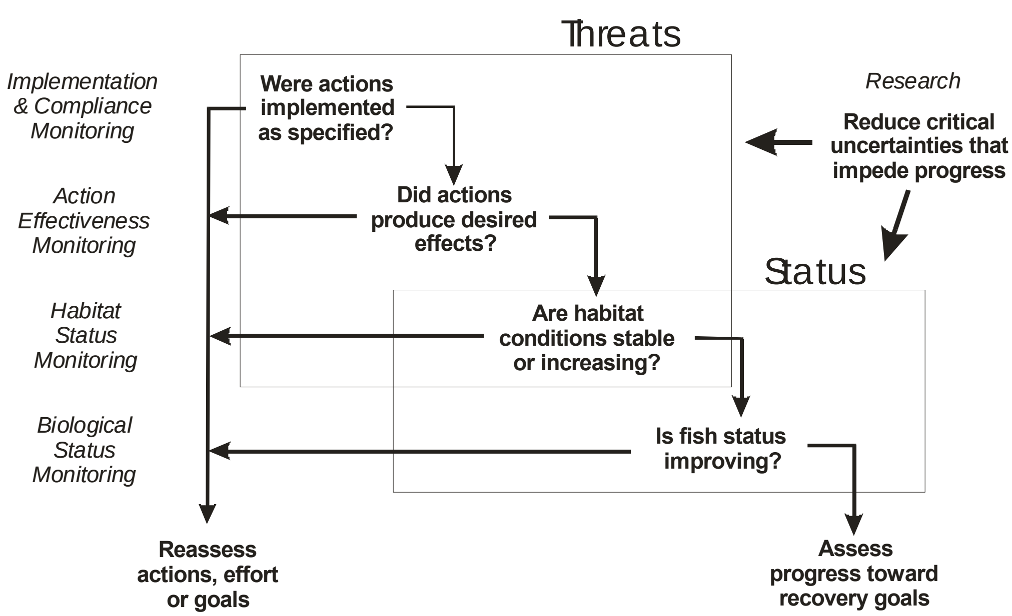


Figure 9-1. Monitoring, research and evaluation program elements.

For each monitoring and research element, the Recovery Plan identifies: A) objectives, B) strategies, C) indicators, D) sampling and analytical design, and E) implementation actions. Information reporting strategies are also addressed to ensure efficient implementation of a comprehensive and complementary program as well as accessibility and effective application of the associated data.

Program elements were designed to address salmon status and threats consistent with ESA listing and recovery planning criteria and goals. Risk status is addressed through a combination of biological and habitat monitoring related to the Viable Salmonid Population concept (McElhany et al. 2000). Threats are evaluated based on habitat status, implementation/compliance, and action effectiveness monitoring. For the purposes of this program, action effectiveness refers to salmonid life-cycle based effects of habitat, harvest, habitat, hatchery, and ecological actions on biological status.

Monitoring, research, and evaluation elements of this Recovery Plan were adapted from and are consistent with other regional strategies and plans developed by the ISAB (2003), SRFB (2002), NOAA/NMFS (NOAA 2003; NMFS 2009), and UCRTT (2004), and PNAMP (2004). The various programs describe monitoring in slightly different terms but generally address the same goal (UCRTT 2004).

This Recovery Plan provides the framework for a systematic regional approach. It generally identifies what needs to be done and how to do it. It does not drill down into specific implementation details such as desired confidence levels, statistical power, data collection protocols, sample sizes, etc. These details will depend on additional refinements to the monitoring, research, and evaluation elements of this Plan that will be developed as implementation planning proceeds. Refinements will be predicated on the availability of resources for conducting an integrated monitoring, research, and evaluation program.

9.1.1. Working Hypotheses

Working hypotheses provide a sound basis for identifying and scaling a suite of appropriate recovery actions but substantial refinements in the scope and focus of measures will be needed as the recovery effort unfolds. Working hypotheses include:

- Successful implementation of this recovery/subbasin plan is predicated on an effective monitoring, research, and evaluation plan. Working hypotheses upon which the Recovery Plan is based provide clear direction but many hypotheses are uncertain. Future course corrections will be required based on research, monitoring, and evaluation (MR&E).
- Programmatic "top-down" and project "bottom up" MR&E approaches each provide useful guidance and an effective plan will incorporate elements of both approaches.
- Existing programs meet many but not all MR&E needs of this Plan.
- There are direct tradeoffs in time and resource costs between MR&E and recovery actions that more directly affect species of interest.
- It is not feasible to fund and implement projects to monitor, research, or evaluate every focal fish population, uncertainty or action.

9.1.2. Umbrella Strategy

Umbrella strategies provide overarching guidance for a comprehensive monitoring and research framework. Strategies include:

M.S1. Develop a programmatic regional framework for MR&E to address Ecosystem and ESU-wide concerns of fish recovery.

M S2. Recognize different spatial and temporal scales appropriate to a variety of programmatic and project-specific applications of MR&E with a framework that incorporates routine and

statistical status monitoring, action effectiveness monitoring, implementation monitoring, and critical uncertainty research.

M.S3. Optimize efficiencies by incorporating and adapting existing MR&E activities into the Plan.

M S4. Utilize other Columbia Basin ecosystem and oceanographic MR&E efforts.

M S5. Identify information gaps that need to be addressed with new monitoring and evaluation activities while also balancing a recognition that the available resources limit implementation to the highest priorities and that tradeoffs exist between MR&E activities and measures that more directly contribute to fish recovery.

M.S6. Focus selected monitoring and research activities in intensively monitored watersheds (IMW's) to optimize opportunities for identifying cause and effect relationships while also providing cost efficiencies.

M.S7. Focus research on the effective implementation of recovery measures rather than detailed mechanistic studies of relationships between fish and limiting factors.

M.S8. Incorporate provisions for regional coordination and data distribution to maximize accessibility and applicability.

M.S9. Incorporate an adaptive evaluation framework with clear decisions points and direction to guide future actions.

9.2. Biological Status Monitoring

9.2.1. Objectives

Biological status monitoring is intended to characterize the likelihood of long term persistence (and conversely the risk of extinction) relative to the baseline condition at listing, periodic checkpoints in Recovery Plan implementation, and recovery goals. In addition to describing progress toward ESU recovery objectives, biological status monitoring also provides data necessary for action effectiveness monitoring and research to resolve critical uncertainties.

Null hypothesis:	**Fish status is unchanged or has continued to decline since listing.**
Alternative:	**Fish status has improved since listing.**

9.2.2. Strategy

This monitoring program identifies target sample numbers for strata by sampling intensity level based on the following guidelines:

M.S10. Biological monitoring needs to address both ESU and population level viability recovery criteria and population parameters related to viability (abundance, productivity, spatial structure, and diversity).

Explanation: Evaluations of biological status are based on a series of indicators that are measured or derived variables defined at different hierarchical scales. Status and trends are evaluated at ESU, strata, and population levels. Each ESU is comprised of multiple geographical strata delineated to consider ecological differences among different geophysical regions within an ESU. Each stratum includes one or more populations. Recovery criteria defined by the TRT are detailed in the Recovery Plan.

M.S11. Status of every population needs to be assessed but all populations don't need to be monitored.

Explanation: Assessments of progress toward recovery require information on the status of each population. Recovery Plan goals developed based on Technical Recovery Team criteria prescribe population levels consistent with ESU viability. Goals are based on average viability levels exceeding moderate for each strata as well as at least two populations per strata at high levels of viability. Ideally every population would be independently monitored. A combination of Indicator, Inventory, and Intensive monitoring will provide an appropriate basis for inferring the status of every population. More comprehensive analysis for a representative subset of population will provide a valid basis for inference. However, status of some populations might be inferred from monitoring of other like-populations or habitat conditions, particularly for small unproductive populations targeted only for stabilization by the recovery strategy.

M.S12. Highest priorities for monitoring are assigned to populations targeted in recovery strategies for high viability or large improvements.

Explanation: A fundamental recovery strategy involves protection and restoration of key populations to high levels of viability. These populations also provide the best opportunities for effective implementation of an intensive monitoring program which represents a full suite of population dynamics information. Ideally, monitoring programs would be allocated across a representative range of population types but resource limitations will constrain the feasibility of conducting comprehensive monitoring programs for multiple populations within a species. Because only a subset of populations will ultimately drive recovery, the monitoring program is focused on identifying the status of that subset rather than of all populations in the ESU. The Recovery Plan identifies population priorities based on

Primary, Contributing, and Stabilizing categories. Primary populations are those targeted for restoration to high or very high levels of viability. Contributing populations are those for which significant restorations will be needed to achieve a strata wide average of medium viability. Stabilizing populations are those that would be maintained at current levels.

M.S13. Representative samples are needed for Primary and Contributing populations for every species/life history type and strata (major population group) based on intensive or inventory monitoring.

Explanation: Recovery will depend on improvements in both strong and weak populations. Status varies significantly among populations within a stratum. Different populations are subject to different limitations and can be expected to respond in varying ways to recovery actions. Not every Primary or Contributing population needs to be monitored at an Intensive or Inventory level but those that are rigorously monitored must be representative of those that are monitored at a lesser intensity.

M.S14. Intensive monitoring of juveniles and adults should occur for at least one population of every species/life history type and strata (major population group).

Explanation: It is not realistic to expect to intensively monitor every population to assess status of each at the highest levels of precision and accuracy. A full suite of abundance, productivity, distribution, and diversity information based in intensive monitoring will provide a basis for analysis of fundamental relationships and assumptions of the monitoring program. This monitoring should include intensive monitoring of both adults (fish in) and juveniles (fish out) to provide life stage-specific information on production and factors affecting production. High levels of monitoring will include one intensively monitored population per species. Very high levels of monitor occur when one population per strata is intensively monitored.

M.S15. Higher priority is assigned to additional coverage of populations at intensive or inventory sampling intensity than coverage of multiple populations within a species/life history (major population group) at an intensive sampling level.

Explanation: There is a tradeoff between the intensity of monitoring of a limited number of populations and the depth of monitoring of a greater number of populations. This Plan prioritizes monitoring more populations at an Intensive or Inventory levels rather than monitoring fewer populations at in intensive level.

9.2.3. Indicators

Attributes and Metrics: We have categorized indicators as attributes, metrics, and statistics. Attributes of biological status include viability and Viable Salmonid Population (VSP) characteristics including abundance, productivity, distribution, and diversity (Figure 9-2). Table 9-1 details specific metrics that can be statistically quantified for each attribute. For instance, mathematical persistence probabilities (and conversely extinction risks) can be estimated using population trend or life cycle models parameterized with attribute data on abundance and productivity.

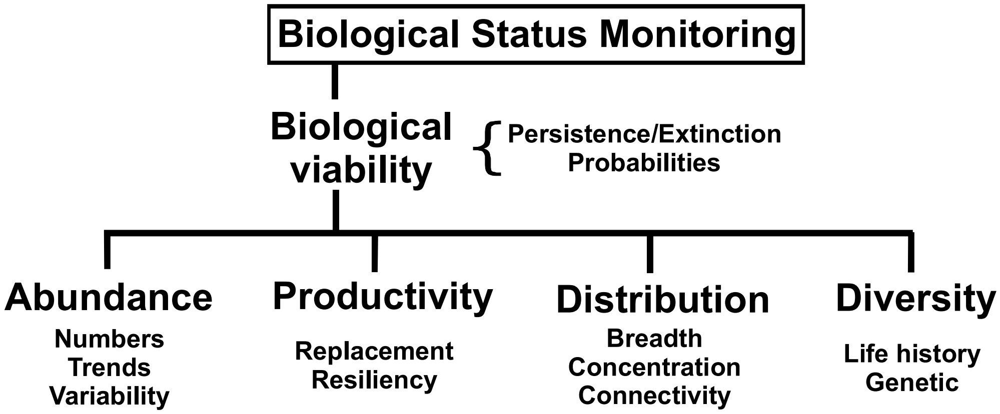


Figure 9-2. Elements for biological status monitoring for salmon recovery.

Status Criteria: Assessments of progress toward biological viability goals will rely on quantitative and qualitative interpretations of attribute metrics and statistics (Table 9-1). Interpretations will be based on changes in indicators over time as well as comparisons with criteria values. Criteria are goal-related reference points or standards against which to compare performance achievements. Many different combinations of attribute conditions might satisfy recovery goals. Criteria provide useful reference points for the evaluation of attribute conditions in the absence of ESU or population-specific goals at the attribute level.

Table 9-1. Attributes, metrics, and example statistics for use as indicators of biological status. (Every statistic is not expected to be available for every population.)

Attributes	Metrics	Example statistics
Biological viability	Persistence probability	Extinction risk
		Categorical scores based on criteria
Abundance (adults or juveniles)	Numbers	Geometric mean (4-, 12-, 20-yr)
		Median (4-, 12-, 20-yr)
		Stock-recruitment equilibrium abundance
	Trends	Time series slope (4-, 12-, 20-year)
		Median annual population growth rate (λ)
	Variability	Range (4-, 12-, 20-year)
		Variance (4-, 12-, 20-year)
		Coefficient of variation
Productivity	(Adult spawners)	
	Replacement	Spawner recruits per spawner (averages)
	Resiliency	Geometric mean recruits per spawner at low spawner nos.
		Stock-recruit function intercept parameter
	(Juveniles)	
	Replacement	Smolts per spawner (averages)
	Resiliency	Juvenile production function intercept
Distribution	(Spawning & rearing habitat)	
	Breadth	Miles accessible
	Concentration	Spawners per mile
	Connectivity	Miles occupied, % of historical usage
Diversity	Life History	% hatchery origin spawners & origin (pHOS),

Attributes	Metrics	Example statistics
		% natural origin broodstock (pNOB) % natural influence (PNI) Age at migration (frequency distribution) Age at maturation (frequency distribution) Run timing (mean & range) Fecundity (by size)
	Genetic	Frequency of population bottlenecks (generational geometric mean < threshold) Heterozygosity Frequency of rare types

9.2.4. Sampling & Analytical Design

This program identifies a stratified, representative, multi-level sampling framework for monitoring the biological status at a population unit scale. It is not realistic to monitor every VSP parameter for every population in every year at a high level of precision due to costs of intensive biological monitoring, other monitoring and research needs, and tradeoffs in funding priorities between monitoring and other recovery actions. Instead, this Plan identifies a biological sampling program that provides information on every population, but samples different populations at different intensities, and employs a stratified subsampling distribution of effort among populations to ensure representative coverage of all ESUs. The design incorporates existing activities and identifies priorities for additional biological monitoring efforts necessary to address identified gaps. This program is designed to provide the information necessary to assess progress toward achieving recovery goals and objectives. The stratified, representative, multi-level sampling design addresses the following four elements:

1. Population strata (Species, Life History & Ecoregion)
2. Intensity (Intensive, Inventory, Indicator)
3. Life stage (Juveniles, Adults)
4. Frequency (Annual, Periodic)

Three levels of sampling intensity are distinguished by the depth and breadth of adult and juvenile sampling activities (Table 9-2). Any given sampling activity typically addresses multiple VSP parameters. Rather than repeating descriptions of the sampling activities needed to address each individual VSP parameter, this program identifies integrated suites of activities that address complementary VSP elements at a given level of accuracy and precision.

The ***Intensive*** sampling level provides the most comprehensive and detailed information on abundance, distribution, productivity, and diversity based on adult or juvenile direct census, marking or tagging, and individual fish sampling. Intensive sampling is distinguished by direct empirical measurements of attribute metrics and critical assumptions of the sampling method.

The ***Inventory*** sampling level provides similar information on VSP attributes but with less rigorous testing of assumptions and greater uncertainty. For instance, expansions of adult index counts into estimates of absolute abundance might rely on historical or periodic rather than annual estimates of the proportional representation of index areas and periods. Tradeoffs in detailed assessments of assumptions can allow a much broader coverage of populations using Inventory sampling than could be accomplished for the same cost and effort with Intensive sampling.

Indicator sampling is the least rigorous of the proposed sampling levels but provides key information on relative abundance and distribution at a population scale for a modest cost. It provides a means for status assessment of many populations where the available resources are not adequate to support Intensive or Inventory sampling.

Intensive, Inventory, and Indicator sampling may be focused on adult and juvenile samples. Intensive sampling protocols typically involve both adult and juveniles sampling. Comparisons of adult and juvenile numbers provide very powerful information for interpreting patterns of variation in abundance as well as driving factors. Adult and juvenile sample levels are allocated independently. For instance, an extensive juvenile sampling program might be implemented for the same population as an intensive adult sampling program. Sampling methods associated with different sampling intensities for adult and juvenile salmonids are summarized in Table 9-2. The table also describes how the sampling relates to the VSP parameters.

Table 9-2. Description of representative multi-level sampling design components of biological status monitoring.

Level, Life stage	Attribute	Information type	Sampling activities[1]	Frequency
1. Intensive				
Adults	Abundance	Spawner census (total abundance)	Weir/dam counts, mark-recapture, or comprehensive time & area spawner surveys	Annual
	Distribution	Core & dispersed production areas	Spawner surveys of index & extensive reaches (e.g. EMAP style design)	Annual
	Productivity	Spawner recruits per spawner	Hatchery origin & age samples for brood year reconstructions	Annual
	Diversity	Hatchery fraction, age composition	Individual fish or carcass sampling for marks, CWTs, and scales	Annual
Juveniles	Abundance	Migrant census (total numbers)	Migrant trap counts, trap efficiencies from mark-recapture	Annual
	Distribution	Mainstem & ocean occurrence, timing	CWT of juveniles, ocean fishery recoveries	Periodic
	Productivity	Parr or smolts per spawner	Brood year comparisons with adult data	Annual
	Diversity	Run timing, size/age distribution	Seasonal trap catch rates, individual fish subsampling at traps	Annual
2. Inventory				
Adults	Abundance	Spawner no. (estimated abundance)	Spawner index surveys (standardized expansions for time & area)	Annual
	Distribution	Core & dispersed production areas	Spawner surveys of extensive reaches	Periodic
	Productivity	Spawner recruits per spawner	Hatchery origin & age samples for brood year reconstructions	Annual
	Diversity	Hatchery fraction, age composition	Individual fish or carcass sampling for marks, CWTs, and scales	Annual
Juveniles	Abundance	Migrant index (relative numbers)	Migrant trap, seine, or electrofishing catch per unit effort	Annual
	Distribution	Core & dispersed production areas	Surveys of index & extensive reaches (e.g. EMAP style design)	Periodic
	Productivity	Index migrants per spawner	Brood year comparisons with adult data	Annual
	Diversity	Run timing or seasonal abundance	Seasonal catch rates	Periodic
3. Indicator				
Adults	Abundance	Spawner index (relative abundance)	Index area fish, carcass, or redd peak surveys (ground, aerial or snorkel)	Annual
	Distribution	Adult presence/absence	Reconnaissance surveys of non-index areas	Periodic
	Productivity	n/a	n/a	
	Diversity	n/a	n/a	
Juveniles	Abundance	Parr presence/absence	Snorkel or electrofishing surveys in rearing areas	Periodic
	Distribution	Parr presence/absence	Distributed sampling regime	Periodic
	Productivity	n/a	n/a	
	Diversity	n/a	n/a	

[1] Representative activities. Variations can result from different cases. n/a = not available.

This Plan establishes criteria for biological monitoring at major population group (MPG) and population levels. Criteria are based on general statistical principles rather than prescribed statistical power analyses and are most useful as planning descriptive reference points rather than specific targets. Criteria include both Oregon and Washington populations.

MPG-level criteria were identified based on numbers of populations at low, moderate, and high sampling coverages corresponding to the relative degree of certainty in the biological status assessment (Table 9-3). The monitoring strategy for this Recovery Plan targets a high level of relative certainty for every MPG stratum.

Table 9-3. Major Population Group-level sampling guidelines at low, moderate, and high levels of coverage for biological monitoring (number of populations monitored by sampling intensity).

Relative certainty	Sampling depth Intensive	Sampling breadth Inventory or Intensive	Sampling coverage Indicator or Inventory or Intensive
Low	<1 per species/life history (juveniles & adults)	<2 per species/life stage & strata (adults or juveniles)	<33% of populations (adults or juveniles)
Moderate	1 per species/life history (juveniles & adults)	2 per species/life stage & strata (adults or juveniles) [1]	≥33% of populations (adults or juveniles)
High	>1 per species/life history & strata (juveniles & adults)	>2 per species/life stage & strata (adults or juveniles)[2]	>50% of populations (adults or juveniles)

[1] Or two populations, if only two in the strata.
[2] Or two or three populations in strata with only two or three, respectively.

Population-level criteria were identified for sampling levels consistent with population priorities for recovery (primary, contributing, stabilizing categories). The sampling strategy directs that populations slated for recovery to high viability or large improvements will require significant sampling efforts to determine with some certainty whether goals are met. Thus, primary populations will require more intensive sampling than contributing populations, and contributing populations will require more intensive sampling than stabilizing populations (Table 9-4). Population priority criteria are based on a relative data quality scale related to the depth and breadth of sampling efforts for each population. This Plan targets sampling of Primary populations at an A or B data quality standard, and contributing populations at a data quality standard of C or above.

Table 9-4. Population-level data quality criteria for Primary and Contributing populations based on adult and juvenile sampling intensity. Quality ratings as based on a subjective relative scale (A to D).

Data quality	Adult sampling		Juvenile sampling	Adequate for primary?	Adequate for contributing?
A	Intensive	and	Intensive	Yes	Yes
	Intensive	and	Inventory	Yes	Yes
B	Intensive	or	Intensive	Yes	Yes
	Inventory	and	Inventory	Yes	Yes
C	Inventory	or	Inventory	No	Yes
D	Indicator	or	Indicator	No	No
--	none		none	No	No

Figure 9-3. Salmon redd and carcass surveys are often the basis for inventory or intensive sampling of adults.

9.2.5. Implementation Measures

M.M1. Maintain current biological sampling efforts for representative priority populations of all species and strata.

<u>Explanation</u>: Current biological monitoring programs are implemented and funded by a variety of parties and provide the basis for current status assessments, recovery plans, and ongoing harvest management. Current programs are adequate for some recovery plan applications but fall short in other areas. Thus, effective monitoring and evaluation will require more funding, not less. This MR&E program seeks a balance in commitments between monitoring, protection, and restoration activities. This Plan does not prescribe intensive monitoring of every parameter in all populations of every stratum. However, this approach places a premium value on information and data provided by existing programs. The long-term nature of many programs provides particularly valuable information for distinguishing real trends from sampling noise or normal variation. Current monitoring activities have been implemented with a mixture of hard and soft funds. In many cases, long term funding of key programs is not assured. Loss of significant components of current biological monitoring programs would significantly reduce the accuracy and precision of evaluations of progress or lack thereof to recovery goals. Table 9-3 identifies priorities for maintaining current biological sampling efforts for representative populations in each stratum.

M.M2. Implement additional intensive biological monitoring for juveniles and/or adults in all strata to meet representative monitoring needs of multiple species.

<u>Explanation</u>: Intensive biological monitoring activities of adults and juveniles in one subbasin can provide critical information for multiple species with significant economy. For instance, juvenile migrant trapping during spring can provide abundance, productivity, and diversity information on both coho and steelhead. Fall spawner surveys can index overlapping distributions and timing of chum, fall Chinook, and coho in different portions of a subbasin. Current IMW efforts in Mill, Abernathy, and Germany subbasins are an example of a comprehensive intensive monitoring program that meets numerous biological sampling moderate sampling level needs for species in the Coast strata while also providing valuable information on habitat action effectiveness and uncertain linkages in fish and habitat

relationships. Intensive biological monitoring activities in the Cascade strata are primarily associated with spring Chinook, coho, and steelhead reintroduction efforts above tributary hydro facilities. This is critical information for both basic biological status assessment and hydro action effectiveness monitoring. However, these intensive reintroduction monitoring efforts do not adequately represent other species and subbasin types in the cascade strata. Intensive monitoring of tule fall Chinook, chum, and coho is currently inadequate to reach moderate certainty MPG criteria in the Cascade strata. Intensive monitoring in all strata does not meet high certainty MPG criteria. East Fork Lewis and Coweeman subbasins are recommended candidates for an intensive biological sampling program of adult and juveniles in the Cascade strata to include fall Chinook, chum, coho, winter steelhead and summer steelhead. Grays and Elochoman/Skamokawa subbasins are recommended candidates for additional intensive sampling in the Coast strata.

M.M3. Implement a comprehensive natural coho sampling program in Washington in all strata.

Explanation: Adult and juvenile coho monitoring efforts in all watersheds are currently insufficient to adequately assess population status and viability parameters. A comprehensive coho monitoring program consisting of a combination of Intensive, Inventory, and Indicator adult and juvenile sampling is among the highest of priorities for recovery monitoring in the lower Columbia River domain. A cost effective program can be implemented in conjunction with additional monitoring of winter steelhead.

M.M4. Expand current chum salmon sampling efforts to include more Intensive and Inventory monitoring of adults and juveniles.

Explanation: Chum adult spawning and juvenile surveys are currently funded with “soft funds” and continued funding will need to be solidified. Moreover, the current funding provides the minimum resources needed to count fish and redds and does not include monies to conduct a thorough investigation of the accuracy of the methods used to estimate total adult spawning escapement, adult or juvenile productivity, or diversity, in all watersheds.

M.M5. Augment current sampling programs for fall Chinook and winter steelhead with more intensive adult and juvenile sampling levels in selected areas.

Explanation: Although, existing monitoring programs for fall Chinook and winter steelhead provide significant data on a majority of populations of all strata, much of this information is based on Intensive or Inventory surveys which do not adequately evaluate critical assumptions of current sampling and evaluation. Supplemental sampling is needed to validate the accuracy of the existing approach.

9.3. Habitat Status Monitoring

Habitat monitoring provides critical information for salmon and watershed-related decision making at a variety of institutional levels and scales. Adaptive Plan implementation, in the face of uncertainties in future trends and recovery and watershed restoration efforts, mandates regular check points on habitat conditions relative to recovery criteria in order to identify the need for course corrections. Without effective habitat protection and a means to distinguish long-term habitat trends, benefits of investments in recovery activities will not be realized or recognized. Without demonstrable improvements in critical habitat conditions, recovery and watershed restoration goals will not be achieved.

Habitat information addresses a multitude of critical questions including long-term cumulative effects of recovery measures and other human activities, inferences of fish potential where biological data is incomplete, identification of key limiting factors and functional relationships, and site-specific effects of specific recovery measures. This chapter focuses primarily on habitat status monitoring of cumulative effects of recovery and watershed restoration measures and human activities in order to assess related listing factors identified by NMFS. However, much of this same information will have application to biological status monitoring, effectiveness monitoring of specific habitat measures, and uncertainty or validation research. These linkages are highlighted in this chapter.

Habitat monitoring, more than any other element of this program, is complicated by issues of multiple and overlapping objectives, scales, information needs, and jurisdictional responsibilities. Each of these elements implies a specific set of information needs and sampling regimens. This program identifies a comprehensive set of habitat monitoring activities designed to address this hierarchy of needs. The program identifies sampling components at three habitat scales: 1) stream, riparian, and floodplain characteristics which are referred to in this Plan as “stream corridor”, 2) watershed, hillslope/upland, and wetland conditions which are referred to in this Plan as “landscape,” and 3) water quality and quantity (Figure 9-4). Monitoring components are identified for each of the three habitat scales.

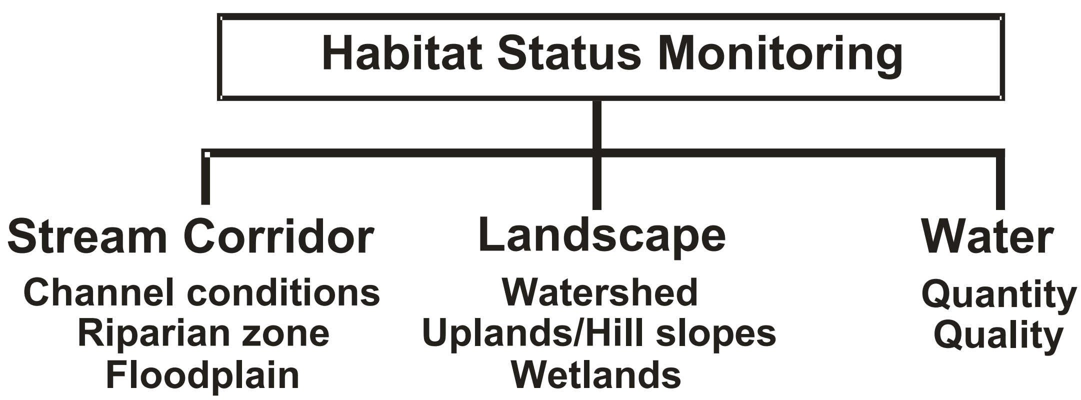


Figure 9-4. Elements for habitat status monitoring of fish recovery.

9.3.1. Stream Corridor

Objectives

Habitat status monitoring at the stream scale is primarily intended to characterize conditions for salmon relative to a baseline at listing and improvements consistent with recovery. Stream habitat conditions serve as an evolving record of aquatic ecosystem health that in turn affects the viability of fish populations. Stream conditions reflect the direct effects of actions at the stream habitat scale as well as watershed-scale actions and conditions that influence stream habitat forming processes. Monitoring of stream conditions will identify long-term trends and cumulative effects of recovery measures and other human activities at the stream and watershed scale (Box 9-1).

Stream habitat information has a variety of applications critical to effective salmon recovery. A primary application will be to evaluate the status of habitat-related statutory listing factors identified by the NMFS listing status decision framework (NOAA 2007) as per NMFS guidance for monitoring recovery (NMFS 2009). Stream habitat information is also useful for comparisons of observed and benchmark habitat conditions based on favorable values for salmon to identify critical limiting factors and help focus actions for maximum effect and efficiency. Comparisons of habitat suitability and potential for fish among stream reaches and subbasins guide prioritization of areas for preservation and restoration. Stream habitat information may be used to infer fish status in areas where biological data is incomplete. Stream habitat information is also used to evaluate the effectiveness of site-specific habitat actions. Finally, comparisons of landscape, stream, water, and biological information are the basis for uncertainty and validation research designed to identify key functional relationships and to reduce fundamental uncertainties which might constrain effective Recovery and Watershed Plan implementation.

Box 9-1. Questions and hypotheses addressed by stream habitat monitoring.

1. Are habitat conditions stable or changing as a result of fish protection and restoration actions, and other factors?
2. How are fish limiting factors affected by stream habitat status and trends?
3. Which streams and stream reaches are most important to fish protection and/or restoration?
4. What is the fish production and abundance capacity of the stream habitat and how has it changed?
5. Have specific stream habitat improvement actions achieved the desired physical and biological effects? (see action effectiveness monitoring section)
6. How is fish status related to stream conditions and how are stream conditions affected by landscape/watershed factors and stream flow patterns? (see uncertainty and validation research section)

Strategy

The strategy includes a series of overarching guidelines consistent with the monitoring objectives. For stream habitat monitoring, these include:

M.S16. Complete comprehensive assessments of stream habitat status and significance to salmon at 12 year intervals as prescribed by the Recovery Plan.

Explanation: A 12 year assessment interval is identified by the Recovery Plan for the assessment of stream habitat status relative to baseline conditions and criteria. The assessment will require a rotating panel of habitat samples to be repeated in a 12-year cycle. The relatively long interval between assessments provides the opportunity to distribute sampling efforts in the region across multiple years so that a massive effort does not need to be completed within a short time period. The interval also recognizes the gradual or episodic nature of change at the habitat scale and provides enough time for potential changes to accrue before reassessment.

M.S17. Utilize a multi-level stream habitat sampling approach to address the multitude of objectives and applications of this information.

Explanation: Stream habitat information is needed for a wide variety of purposes including characterizing conditions across the region, detecting trends, identifying problems and restoration opportunities, evaluating action effectiveness, and characterizing linkages with fish. No single stream habitat sampling design, level, or protocol is adequate for all of these purposes.

M.S18. Assess stream habitat status of every subbasin in a representative fashion (although every subbasin doesn't need to be monitored at the same sampling level).

Explanation: Listing factor criteria identified by NMFS are evaluated at the population scale. Therefore, stream habitat monitoring must occur at the subbasin scale. Stream habitat sampling meets a variety of needs including providing some indication of changes in habitat suitability or potential for salmon populations where biological data is sparse. Habitat assessments can be a much more cost-effective alternative to evaluating the freshwater production potential, particularly for populations existing at very low levels in degraded habitats. Habitat information also provides a systematic means of inferring relative status of less intensively-monitored populations from more intensively-monitored populations.

M.S19. Stratify habitat monitoring in order to represent the full range of conditions and to maximize sampling power to detect changes.

Explanation: Statistical power of tests for differences over time is increased by a spatial stratification scheme which reduces the error variation among samples by removing between-strata differences. Given the geographic extent of the lower Columbia and the complexity of habitat conditions, acquiring habitat data for all locations in the region is unrealistic. Given the very large habitat variation across the region among strata, lack of a stratified design would greatly inflate the number of samples needed to characterize conditions throughout the basin and to detect even moderate-sized changes in habitat conditions.

M.S20. Replicate samples within each stratum in order to provide a statistical basis for evaluating differences.

Explanation: There can be substantial variation in stream habitat conditions among streams and among reaches in a stream within any given strata. Replication (collecting data from more than one reach or site) is needed for statistical analysis of differences and trends. Differences among strata or within strata over time can only be demonstrated by comparison to differences within strata (Green 1979).

M.S21. Employ both a probabilistic sampling scheme designed to representatively survey conditions across the landscape and an index site sampling scheme designed for sensitivity to detect significant changes in salmon habitat threats over time.

Explanation: The two primary habitat sampling objectives require fundamentally different approaches to sample site selection. Survey sampling to describe the average and range of conditions within a stratum requires random (probabilistic) sampling in order to provide representative coverage. Index sampling for characterizing long term trends is most efficient where sample sites are selected based on sensitivity to likely changes and value to fish.

M.S22. Employ a range of sampling intensities consistent with the multiple objectives.

Explanation: A multi-level habitat monitoring approach is the best avenue for providing adequate coverage of stream habitat information. Inventory sampling provides a big picture context for evaluating habitat patterns across the region. Indicator monitoring will provide representative breadth across the region and also representative index sites for periodic re-sampling. Intensive monitoring of selected reaches that are significant to fish recovery will provide more sensitive indications of temporal changes.

Reconnaissance sampling provides a means of rapidly assessing problems not reflected in habitat sub sampling sites as well as restoration or preservation opportunities.

M.S23. Monitor subbasins that are a higher priority for recovery at a greater intensity.

Explanation: This habitat monitoring program is specifically designed to address salmon recovery needs. A fundamental recovery strategy involves protection and restoration of key populations to high levels of viability. These populations will be the focus of the most intensive stream habitat monitoring efforts. Ideally, monitoring programs would be allocated across a representative range of population types but resource limitations will constrain the feasibility of conducting comprehensive monitoring programs for multiple populations within a species.

M.S24. Design stream habitat monitoring for salmon recovery evaluations to make maximum use of other regional monitoring where consistent.

Explanation: The scale of habitat monitoring required for salmon recovery applications is very large. Information collected for specific purposes is often useful for a variety of applications and opportunities to utilize this information should not be overlooked. An economical habitat monitoring program takes advantage of all potential sources of information even where they were not specifically intended for the desired application. Stream habitat assessments should make optimum use of all available information rather than relying on completely new and dedicated sampling efforts. The design will also need to be flexible in order to recognize and qualify potential limitations in other sampling. The key is to understand the limitations and applicability of each type of information.

M.S25. Adopt habitat monitoring protocols for dedicated salmon recovery habitat monitoring that are compatible with other regional monitoring efforts.

Explanation: Most of the current baseline habitat information has been collected with relative standard protocols in wide use for salmon habitat monitoring. Unless existing protocols fall significantly short of monitoring needs for salmon recovery or a critical mass of standard methodology has not been applied, any new work undertaken should attempt to emulate past protocols as much as possible. It is also likely that regular protocols will have to be supplemented with additional methods or metrics in order to meet all information needs.

Indicators

Attributes and Metrics: Stream habitat conditions are characterized through a set of habitat indicators including attributes, metrics, and statistics that reflect the suite of conditions that are relevant to salmonid protection and recovery (Table 9-5). Channel morphology and complexity, riparian condition and function, and habitat access are included as stream habitat attributes for the purposes of this monitoring program. Metrics include attributes such as channel morphology, substrate, woody debris, riparian cover, and bank stability.

The program recognizes the subjectivity of defining a boundary between stream and watershed attributes due to the complexity of connectivity and functional relationships. These attributes were grouped under the stream habitat category because they lend themselves to common sampling and analysis protocols. Specific metrics and example statistics are also identified for each attribute. Indicators are consistent with those identified in NMFS's listing status decision framework for the habitat category and with other diagnostic methods implemented in the region including the Ecosystem Diagnosis and Treatment model (EDT) (LCFRB 2004).

Criteria: Assessments of habitat suitability for fish and the effects of habitat changes will rely on quantitative and qualitative interpretations of indicators. Interpretations will be based on changes in indicators over time as well as comparisons with benchmark values. Criteria do not represent goals but are goal-related reference points or standards against which to compare performance achievements.

Given the inherent variability and complexity of natural systems, it is impractical to establish broadly-applicable goals for habitat conditions. A more effective approach for stream and watershed characteristics is to develop relative measures of trends over time. Many different combinations of attribute conditions might satisfy recovery goals. Criteria provide useful reference points for the evaluation of attribute conditions in the absence of ESU or population-specific goals at the attribute level. The Recovery Plan identifies habitat criteria based on Properly Functioning Conditions (PFCs) identified by NMFS to reflect freshwater habitat conditions generally favorable for salmonids' spawning and rearing (NMFS 1996b). PFCs are not goals or requirements for reaching salmon recovery. They are, however, useful reference points for comparative purposes.

Table 9-5 Attributes, metrics, and example statistics for use as indicators of stream habitat status.

Attribute	Metric	Example statistics	Relevance to Fish
Channel conditions	Channel cross-section form	Width-to-Depth ratio, entrenchment, artificial confinement	Quality of physical habitat
	Channel gradient & channel form	Channel gradient, length & sinuosity	Suitable hydraulics and channel dynamics for habitat formation and maintenance
	Erosion and sedimentation	Percent fines, embeddedness, bed-material composition	Adequate substrate for spawning, egg incubation, and early rearing
	Habitat types	Percent & frequency pools, riffles, glides, off-channel areas	Spawning and rearing habitat availability
	Large Woody Debris	Abundance, size, and distribution	Availability of cover and complexity
Riparian zone	Vegetative Cover	Percent cover by vegetation type	Food source production, nutrient exchange, LWD recruitment, bank stability
	Shade	Percent shade	Stream temperature moderation
	Invasive Species	Presence/Absence and mapping	Natural riparian function
	LWD recruitment potential	Buffer width, tree size, stand density	Large woody debris recruitment
	Stream bank stability	Stream bank stability indices	Stream bank stability and sedimentation
Floodplain and channel migration processes	Channel migration zone encroachment	Width of channel migration zone	In-channel habitat formation and maintenance, off-channel habitat creation, nutrient exchange, flood abatement, flood refuge, temperature moderation
	Floodplain connectivity	Extent of connected floodplains	
Accessibility	Anthropogenic & natural barriers	Miles/acreage of blocked habitat by type Barrier characteristics - location (GPS), type, width, length, gradient, drop, bedload, % passability etc.)	Fish passage, spawning habitat, juvenile rearing, outmigrant survival, adult migration timing

Table 9-6. Salmonid freshwater indicators for stream habitat based on the Matrix of Pathways and Indicators (NMFS 1996b).

Pathway	Indicators	Properly Functioning	At Risk	Not Properly Functioning
Stream channel & habitat units	Pool Frequency	meets pool frequency standards (below) and large woody debris recruitment standards for properly functioning habitat (above) channel width (ft): pools/mi[1] (5:164, 10:96,15: 70, 20: 56, 25: 47, 50: 26, 75: 23, 100: 18)	meets pool frequency standards but large woody debris recruitment inadequate to maintain pools over time	does not meet pool frequency standards
	Pool Quality	pools >1 meter deep (holding pools) with good cover and cool water, minor reduction of pool volume by fine sediment	few deeper pools (>1 meter) present or inadequate cover/ temperature, moderate reduction of pool volume by fine sediment	no deep pools (<1 meter) and inadequate cover/ temperature, major reduction of pool volume by fine sediment
	Substrate	dominant substrate is gravel or cobble (interstitial spaces clear), or embeddedness <20%	gravel and cobble is subdominant, or if dominant, embeddedness 20-30%	bedrock, sand, silt or small gravel dominant, or if gravel and cobble dominant, embeddedness >30%
	Sediment	< 12% fines (<0.85mm) in gravel	12-l7% (west-side), 12-20% (east-side)	>17% (west-side), >20% (east side) fines at surface or depth in spawning habitat
	Large Woody Debris	>80 pieces/mile >24"diameter >50ft. length; and adequate sources of woody debris recruitment in riparian areas	currently meets standards for properly functioning, but lacks potential sources from riparian areas of woody debris recruitment to maintain that standard	does not meet standards for properly functioning and lacks potential large woody debris recruitment
	Off-channel Habitat	backwaters with cover, and low energy off-channel areas (ponds, oxbows, etc.)	some backwaters and high energy side channels	few or no backwaters, no off-channel ponds
	Refugia (important remnant habitat)	habitat refugia exist and are adequately buffered (e.g., by intact riparian reserves); existing refugia are sufficient in size, number and connectivity to maintain viable populations or sub-populations	habitat refugia exist but are not adequately buffered (e.g., by intact riparian reserves); existing refugia are insufficient in size, number and connectivity to maintain viable populations or sub-populations	adequate habitat refugia do not exist[1]
	Width/Depth Ratio	<10	10-12 (we are unaware of any criteria to reference)	>12 (we are unaware of any criteria to reference)
	Streambank Condition	>90% stable; i.e. on average, less than 10% of banks are actively eroding	80-90% stable	<80% stable

Pathway	Indicators	Properly Functioning	At Risk	Not Properly Functioning
	Floodplain Connectivity	off-channel areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession	reduced linkage of wetland, floodplains and riparian areas to main channel; overbank flows are reduced relative to historic frequency, as evidenced by moderate degradation of wetland function, riparian vegetation/ succession	severe reduction in hydrologic connectivity between off-channel, wetland, floodplain and riparian areas; wetland extent drastically reduced and riparian vegetation/ succession altered significantly
Riparian Zone	Reserves	the riparian reserve system provides adequate shade, large woody debris recruitment, and habitat protection and connectivity in all subwatersheds, and buffers or includes known refugia for sensitive aquatic species (>80% intact), and/or for grazing impacts: percent similarity of riparian vegetation to the potential natural community/composition >50%	moderate loss of connectivity or function (shade, LWD recruitment, etc.) of riparian reserve system, or incomplete protection of habitats and refugia for sensitive aquatic species (≈70-80% intact), and/or for grazing impacts: percent similarity of riparian vegetation to the potential natural community/composition 25-50% or better	riparian reserve system is fragmented, poorly connected, or provides inadequate protection of habitats and refugia for sensitive aquatic species (<70% intact), and/or for grazing impacts: percent similarity of riparian vegetation to the potential natural community/ composition <25%
Habitat Access	Physical Barriers	any man-made barriers present in watershed allow upstream and downstream fish passage at all flows and life stages	any man-made barriers present in watershed do not allow upstream and/or downstream fish passage at base/low flows	any man-made barriers present in watershed do not allow upstream and/or downstream fish passage at a range of flows

Sampling and Analytical Design

This Plan identifies a stratified, representative, multi-level sampling framework for monitoring stream habitat to meet multiple needs including characterization of habitat status, habitat trends, habitat action effectiveness, and fish status inferences. Elements of the design framework are identified in Figure 9-5.

Element	Definition	Categories
Goals	Purpose of the specific monitoring component	Status Trends Problems Effects
Spatial Strata	Hierarchy of areas and subareas by which sampling is organized in order to ensure adequate representation of the full range of conditions that occur within the region	Ecoregion WRIA Subbasin Physiographic zone Stream Size
Salmon Recovery Priority	Significance of an area or site to salmon (sample strata pertinent to some objective applications)	Stream reach tiers
Units, Replicates, Frequency	Units are the subbasins, reaches or sites sampled. Replicates are the number of units sampled per strata. Frequency refers to resampling interval.	Dependent on subsample type
Sampling Levels	Scope and intensity of sampling at any given site	Indicator Reconnaissance Index Intensive
Sampling Protocols	Data collection methods for sampling at any given level	Dependent on sampling level
Indicators	Attributes to be measured & criteria describing reference conditions	Statistics (see Table 9-5)

Figure 9-5. Elements of a systematic stream habitat sampling framework.

Objectives: Stream habitat monitoring addresses a variety of goals needed to evaluate salmon recovery. Each goal requires slightly different but overlapping sampling strategies and protocols. These goals can be classified into four categories:

Status is a characterization of conditions across the region within and among sampling strata at any given point in time.

Trends are changes in status over time.

Problems are specific habitat features or sites potentially targeted for action (e.g. hydromodifications, habitat impairments, or fish barriers.)

Effects refers to specific habitat information needs for action effectiveness evaluation or research into linkages between habitat and fish.

Spatial Strata: Stream habitat monitoring is organized by a nested series of regions and watersheds including ecoregions, WRIAs, subbasins, and physiographic zones.

Ecoregions are areas of similar geographical, climate, and habitat conditions used by NMFS to identify major population groups of salmon which together comprise an ESU. Three ecoregions (Coast, Cascade, and Gorge) have been identified in the lower Columbia Region (Figure 9-6).

Watershed Resource Inventory Areas (WRIAs) are major watershed basins identified by Washington for administrative and planning purposes. The lower Columbia Region includes 5 WRIAs including the Grays-Elochoman, Cowlitz, Lewis, Salmon-Washougal, and Wind-White Salmon basins.

Subbasins are smaller watershed areas within each WRIA, generally corresponding to salmon populations identified by the TRT.

Physiographic zones reflect topographic, watershed condition, and land use patterns of significance to fish habitat (Figure 9-6). Boundaries of the physiographic zones do not align with watershed boundaries but do distinguish different areas within each watershed subject to different activities and watershed processes which translate into fish habitat effects. Four physiographic zones are defined (Table 9-7). Physiographic zones are also related to land use and management patterns and authorities.

Stream size varies throughout the region from small headwater tributaries to large river mainstems. This monitoring program includes representative sampling and analysis across the available range of stream sizes. Stream size is often categorized by stream order which is a systematic number scheme ranging from headwater streams (1^{st} order) though large mainstems (4^{th} order or above).

Salmon Recovery Priority: The Salmon Recovery Plan categorized stream reach in each subbasin into one of four reach tiers based on the number of fish populations that utilize habitat in that reach, the importance of each fish population relative to regional recovery objectives, and the significance of the reach to the specific fish populations.

Tier 1 includes reaches with significant production or restoration potential for one or more primary populations. Primary populations are those targeted for restoration to high or very high levels of viability.

Tier 2 has reaches not included in Tier 1 that are of medium priority for one or more primary species and/or high priority reaches for one or more contributing populations. Contributing populations are those for which significant restoration will be needed to achieve a strata wide average of medium viability.

Tier 3 includes other reaches which are medium priority for Contributing populations and/or high priority reaches for Stabilizing populations.

Tier 4 includes medium priority reaches for Stabilizing populations and/or low priority reaches for all populations.

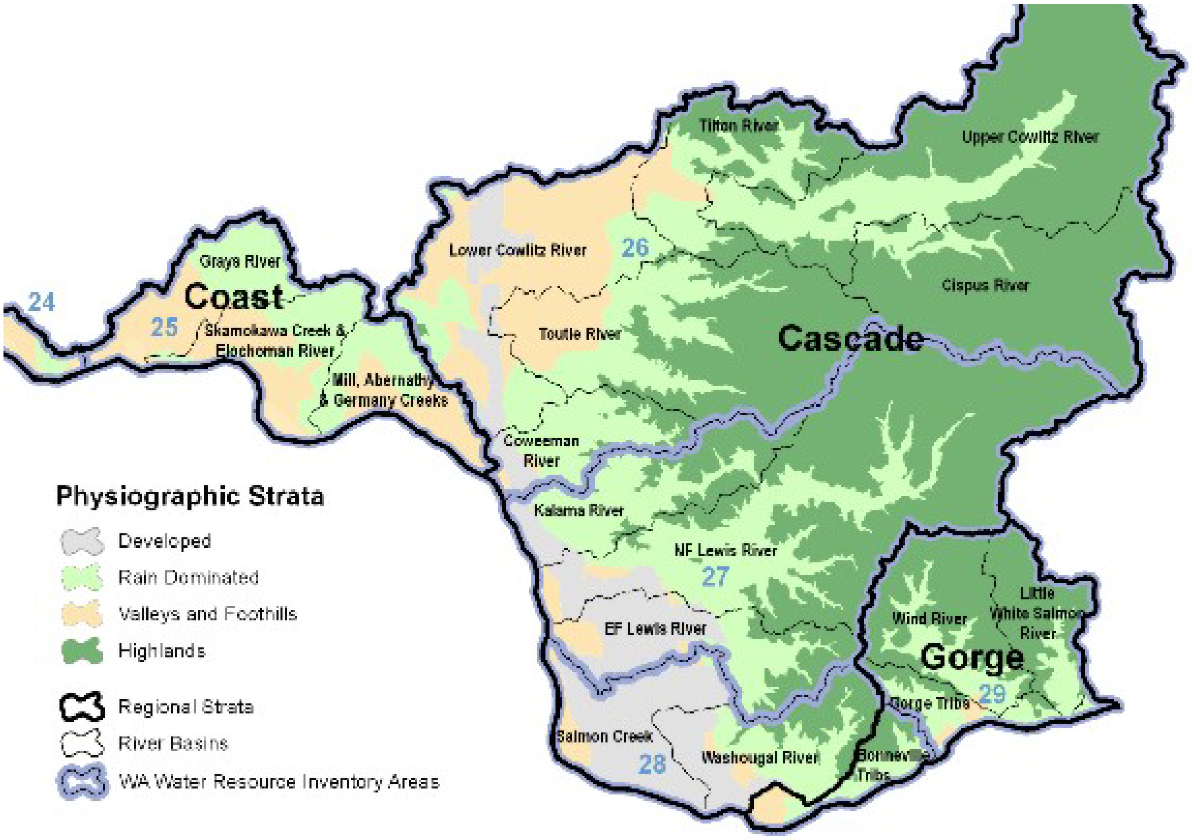


Figure 9-6 Spatial and physiographic strata within the lower Columbia Basin.

Table 9-7. Definitions of physiographic zones used to in stream habitat sampling strata.

Zone	Definition
Developed	Large urban and residential zones in lower elevation valley floor areas along the Columbia River and I-5 corridor from Vancouver to Longview. Developed areas were distinguished based on population densities of greater than 100 persons per square mile using 2004 census data. (Small developed areas were eliminated from the Coast and Gorge ecoregions and were incorporated into other classifications.) Fish habitat in these areas, typically including river mainstems and small low gradient streams has been severely impacted by development.
Valley and Foothill	Undeveloped low elevation areas, typically in rural, agricultural, managed forest, or mixed use. This zone was derived from the lowland classification in the WDNR rain-on-snow GIS layer, with the exception of small developed areas as described above. These areas are expected to absorb much of the future population growth expected in the region. These areas include most of the historically-productive habitat for fall Chinook and chum salmon.
Rain Dominated	Low to mid elevation areas, typically in mixed or managed forest use. The zone was identified from the WDNR Rain Dominated area classification, with the exception of small developed areas as described above. These areas historically produced significant numbers of coho, spring Chinook, and winter steelhead.
Highland	Higher elevation areas, typically forest lands. This zone was derived from WDNR rain-on-snow area classifications (highlands, snow dominated, and peak rain-on-snow). Small areas of highlands in the Coast Strata were lumped into the Rain Zone. Highlands areas, where still accessible to fish, are among the most productive or potentially-productive salmon habitats in the region, particularly for summer steelhead and coho.

Units, Replicates and Frequency: Samples might be collected at multi-year, annual, seasonal, or even daily intervals depending on the scale of examination, the intended application, and the variability in the conditions being characterized. Longer sampling intervals are appropriate for large-scale landscape level features where changes are gradual or periodic and changes tend to be persistent. Thus, indicator level sampling based on remote sensing information is effectively applied at multi-year or even decadal intervals. In contrast, local site-specific conditions are more likely to display discernable changes at shorter time intervals which may warrant more frequent sampling.

Sampling Levels: This program describes four sampling levels of varying scope and intensity (Table 9-8). Sampling level is generally related to certainty of results with more intensive sampling expected to provide more precise and accurate information but typically at a greater cost. Any level might be applied to any given sampling goal or involve a variety of stratification, site selection, or sampling protocols.

Indicator level sampling identifies standard attributes of a stream based on a synthesis or analysis of available remote sensing and GIS information. Indicator level sampling generally involves summary and interpretation of existing information while sitting in an office at a computer. Indicator sampling does not require on-the-ground sampling but can provide broad coverage of selected indicators at a modest cost. Indicator level sampling is readily applicable across the region or can be concentrated on a particular focal area. Remote sampling is best suited to provide broad-scale geographic coverage and reflect large-scale patterns in space and over time. Satellite imagery provides low cost answers to large scale habitat questions and also avoids intrusion onto private property (Crawford 2007). Measurement protocols depend on the metrics of interest and the information available.

Reconnaissance level sampling typically involves walking or floating sections of stream to quickly obtain qualitative information. This level of sampling effort is most effective for providing general descriptions of stream habitat conditions across broad areas. It is also particularly effective for identifying problem sites such as potential fish migration barriers, restoration opportunities, and the upstream extent of suitable fish habitat.

Inventory level sampling involves field sampling of stream and riparian characteristics at the stream reach and the habitat unit scale. It can also involve detailed analysis of remote sensing information (e.g. aerial photos) for some metrics. This level involves a systematic sampling regime and measurements or estimates of habitat metrics at multiple subsample sites within a reach at the habitat unit scale.

Intensive sampling is typically based on ground surveys of stream habitat conditions at the site scale to collect detailed quantitative measurements at specified points or transects. It is distinguished from inventory sampling by more rigorous sampling protocols and use of quantitative rather than qualitative metrics. It can incorporate all of the elements of indicator and inventory sampling as well as additional rigor specific to its intended purpose.

Sampling Protocols: A variety of sampling protocols have been developed to standardize methods used to collect stream habitat data (Figure 9-7). Standardized protocols are essential for quality assurance/quality control (QA/QC), for consistent implementation by disparate entities, and for the integration of independently sampled data. Sampling and reporting methods provide a transparent and defensible source of information that can be accessed by interested parties. Protocols and sampling levels are typically closely related but a given protocol may be used for a variety of sampling levels.

Sampling Targets: Sampling targets outline the requirements necessary to carry out the monitoring program and measure progress toward accomplishing program goals. Targets are based on minimum requirements or criteria necessary to address all monitoring objectives consistent with the prescribed strategy. Targets are based on a systematic multi-tiered stratified statistical sampling design to address survey, trends, problems, and effects (Table 9-9).

Table 9-8. Features of different stream habitat sampling levels.

Feature	Sampling Level			
	Indicator	**Reconnaissance**	**Inventory**	**Intensive**
Metrics	Limited	Limited	Moderate to many	Typically many
Activity	Remote / office	On-the-ground	On-the-ground	On-the-ground
Focus	Stream, reach or site	Stream or reach	Reach & habitat unit	Site-specific
Data type	Quantitative or Qualitative	Typically Qualitative	Quantitative or Qualitative	Typically Quantitative
Repeatability	Moderate	Low	Moderate	High
Cost per area sampled	Very Low	Low	Moderate	High
Example protocols	USFS Level I Remote sensing	USFS Visual Assessment EPA Rapid Assessment LCFRB Watershed Assessments	USFS Level II LCFRB Restoration Strategies Oregon Stream Inventories	USFS Level III EPA EMAP
Application	Survey, Index, Focal	Diagnostic, Survey	Survey, Index	Survey, Index, Focal

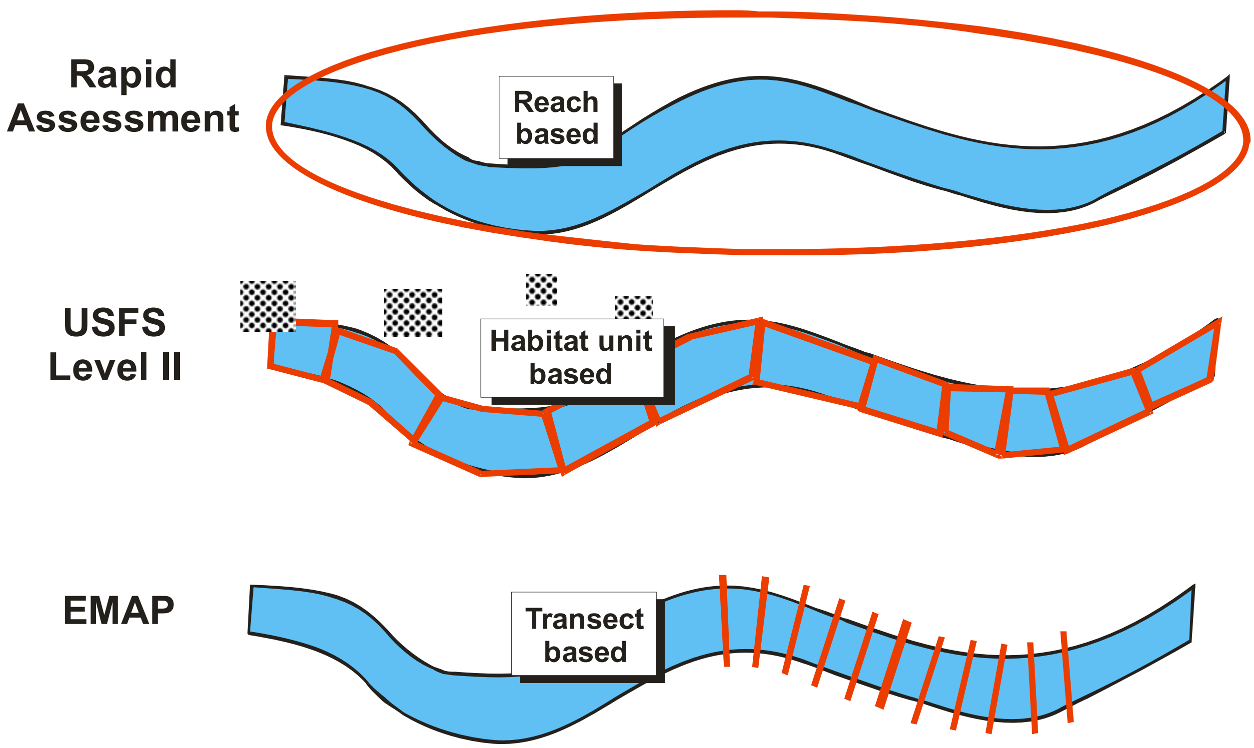


Figure 9-7. Examples of stream habitat measurement protocols.

Table 9-9. Sampling targets for stream habitat monitoring by sampling goal.

	Status	Trends	Problems	Effects
Application	Represent conditions at the subbasin level	Detect trends in sensitive indicator sites	Identify significant habitat and passage problem sites & restoration opportunities	Design and evaluate site specific projects, action effectiveness, and fish linkages
Site selection criteria	Stratified Probabilistic	Non-random based on fish values & expected impacts	All high priority salmon habitat reaches	Action-specific
Sampling level	Indicator + Inventory	Indicator + Intensive	Indicator + Reconnaissance	As appropriate
Sample unit	Reach	Site	Reach	As appropriate
Subsample stratification	Subbasin x Zone x Order	Subbasin x Zone	Subbasin	As appropriate
Total # strata	18 x 3 x 4 = 216	18 x 3 = 54	18	As appropriate
Replicates / strata	3	1	variable	As appropriate
Samples total	648	54	360 (approx.)	As appropriate
Samples / subbasin	36	3	20 (approx.)	As appropriate
Sampling frequency	12-year rotation	3-year rotation	12-year rotation	As appropriate
Samples / year	54	18	30 (approx.)	As appropriate
Representation	>10% of available 1:100,000 scale reaches	not applicable	90% of tier 1 reaches 50% of tier 2 reaches	As appropriate
Example protocol	USFS level II or equivalent	EMAP or equivalent	Rapid / Visual Assessment	As appropriate
Approx allocation of total sampling effort	50%	20%	20%	10%

Implementation Measures

M.M6. Maintain current habitat monitoring efforts for representative priority areas.

Explanation: Current habitat monitoring programs are implemented and funded by a variety of parties and provide the basis for current status assessments and recovery plans. Current programs are adequate for some recovery plan applications but fall short in other areas. Thus, effective monitoring and evaluation will require more funding, not less. This MR&E plan seeks a balance in commitments between monitoring, protection, and restoration activities. Current monitoring activities have been implemented with a mixture of hard and soft funds. In many cases, long term funding of key programs is not assured. Many previous habitat sampling efforts are not part of any ongoing program. Loss of significant components of current habitat monitoring programs would significantly reduce the accuracy and precision of evaluations of progress, or lack thereof, with respect to recovery goals.

M.M7. Establish a baseline habitat characterization and database of current stream conditions in the lower Columbia region based on existing data for use as a reference point in future analysis as well as specific guidance for additional sampling needed to fill information gaps.

Explanation: Significant habitat information exists from current and past sampling programs by a wide variety of parties for a multitude of purposes. This information is identified in this Plan and used to identify significant information gaps. Much of this information was also utilized in the recovery and subbasin plan to generally characterize existing conditions and to identify priorities for protection and restoration actions. A considerable amount of data has already been collected by federal, state, tribal, and local entities; however, a comprehensive baseline, extending down to the stream scale, has yet to be established. The existing information has not been synthesized and summarized for the purposes of clearly identifying baseline conditions for future reference. Existing information has been compiled from a variety of sources but source protocols and references have not always been effectively captured in metadata. Recovery planning analyses using Ecosystem Diagnosis and Treatment and Integrated Watershed Assessment methodologies relied primarily on readily available and easily summarized data sources and did not incorporate the full scope of the available data needed to characterize the baseline. More intensive synthesis, analysis, and documentation are needed than was required for recovery and subbasin planning purposes. Without this upfront work, future habitat monitoring evaluations will have difficulty discerning the baseline conditions, some current information may be lost, and gaps in current status information will be overlooked. The baseline habitat characterization will also provide an explicit template to guide future habitat evaluations at Recovery Plan implementation checkpoints.

M.M8. Develop and implement an empirical sampling program to fill specific data gaps in the habitat baseline relative to sampling criteria identified by this program.

Explanation: Existing data is not adequate to clearly establish baseline habitat conditions. Lack of a clear description of baseline habitat status will preclude future determination of trends. Without clear evidence for trends, it will be impossible to determine the cumulative effect of recovery activities and other influences on habitat conditions, whether further actions are needed or whether past actions have achieved objectives. Even where actions produce significant benefits, due credit for results could not be given. In order to track progress with respect to the Recovery Plan goals for threat reduction and delisting criteria, existing data must be supplemented with additional sampling and analysis. Attempts to establish a current habitat status baseline will identify significant data gaps for specific areas and conditions that will require inferences from other sites or related information. An accurate baseline will require a sample set representative of the larger population at both the reach and watershed scale within each physiographic strata of the region. Targeted sampling will be required.

M.M9. Develop and implement a sampling program to address long-term watershed, stream, and water quality monitoring needs not currently being addressed by other parties.

Explanation: No systematic stream habitat monitoring program currently exists for the Washington lower Columbia salmon Recovery Region. Habitat monitoring is currently conducted by a variety of parties for a variety of purposes, but activities and results are not coordinated or captured for application to salmon recovery monitoring and evaluation purposes. A dedicated sampling program is necessary to meet salmon recovery needs. This monitoring needs to incorporate a mixture of existing programs, new programs implemented by parties to address various needs, and new sampling of representative long term index sites.

9.3.2. Landscape – Watersheds, Uplands/Hill slopes, Wetlands

Objectives

Habitat status monitoring at the landscape scale is primarily intended to characterize watershed upland/hill slope and wetland conditions that affect stream habitat for salmon relative to a baseline at listing and improvements consistent with recovery. The objective at this scale is to detect broad changes in watershed conditions that affect stream habitat forming processes. Stream conditions reflect the direct effects of actions at the stream habitat scale as well as watershed-scale actions and conditions that influence stream habitat forming processes. Monitoring of watershed conditions will identify long-term trends and cumulative effects of recovery measures and other human activities (Box 9-2).

Landscape-scale habitat information has a variety of applications critical to salmon recovery. A primary application will be to evaluate the status of habitat-related statutory listing factors identified by the NMFS listing status decision framework (NOAA 2007). Comparisons of observed and benchmark watershed and floodplain conditions with salmon habitat distribution also help to identify problem areas and focus actions for maximum effect and efficiency. Landscape scale information is also used to evaluate the effectiveness of actions at that scale. Finally, comparisons of landscape, stream, water, and biological information are the basis for uncertainty and validation research designed to identify key functional relationships and to reduce fundamental uncertainties which might constrain effective Recovery Plan implementation.

Box 9-2. Questions addressed by salmon-related landscape monitoring.

1. Are landscape conditions stable or changing as a result of fish protection and restoration actions, and other factors?
2. Which landscape-level areas and factors are most important to stream habitat conditions in key fish production areas?
3. Have specific landscape-level actions achieved the desired physical effects? (see action effectiveness monitoring section)
4. How are stream conditions affected by landscape/watershed factors? (see uncertainty and validation research section)

Strategy

The strategy includes a series of overarching guidelines consistent with the monitoring objectives. For landscape-scale monitoring, these include:

M.S26. Complete comprehensive assessments of landscape condition status and trends at 12 year intervals as prescribed by the Recovery Plan.

Explanation: A 12 year assessment interval is identified by the Recovery Plan for the assessment of stream habitat status relative to baseline conditions and criteria. Landscape-scale information will be compiled uniformly across the entire study area at 12-year intervals corresponding with habitat assessment checkpoints identified in the Recovery Plan.

M.S27. Derive landscape-scale data for status and trends monitoring primarily from existing datasets or other regional activities.

Explanation: This monitoring program does not anticipate intensive development or derivation of landscape-scale information across the region for the dedicated salmon recovery applications other than for watershed action effectiveness monitoring or research on watershed-stream habitat linkages. Rather, this monitoring program focuses on stream habitat conditions which are the more proximate driving factor in fish status and trends.

Indicators

Attributes and Metrics: Landscape scale conditions are characterized through a set of indicators including attributes, metrics, and statistics that reflect the suite of conditions that are relevant to salmonid protection and recovery (Table 9-10). The program recognizes the subjectivity of defining a boundary between watershed, floodplain, riparian zone and stream attributes due to the complexity of connectivity and functional relationships. Watershed indicators include geomorphology, land use, vegetation cover, road density, and landslides. Floodplain indicators include channel migration zones, connectivity, and wetlands. Indicators are consistent with those identified in NMFS's listing status decision framework for the habitat category and with other diagnostic methods implemented in the region including the Integrated Watershed Assessment (IWA) (LCFRB 2004).

Table 9-10. Attributes, metrics, and example statistics for use as indicators of watershed and floodplain status.

Attribute	Metric	Example statistics	Relevance to Fish
Watershed conditions & hillslope processes	-Road Density & stream crossing frequency -Mass Wasting -Impervious Surfaces -Land Use / Land Cover	Density and type of road & stream crossing Number and size/scale of events Percent impervious surfaces Area of land use and cover class	Habitat access Supply of spawning substrate Fine sediment supply Landslides and debris flows Flood magnitude and timing Summer low flow availability Pollutant runoff
Floodplain and wetland function; channel migration processes	-Channel migration zone encroachment -Wetland availability -Floodplain connectivity	Width of channel migration zone Acres of wetlands Extent of connected floodplains	In-channel habitat formation and maintenance Off-channel habitat creation Nutrient exchange Flood abatement Flood refuge Temperature moderation

Criteria: Assessments of habitat suitability for fish and the effects of habitat changes will rely on quantitative and qualitative interpretations of landscape indicators. Interpretations will be based on changes in indicators over time as well as comparisons with benchmark values. Given the inherent variability and complexity of natural systems, it is impractical to establish broadly applicable goals for habitat conditions, particularly at the watershed level. A more effective approach is to develop relative measures of trends over time. Many different combinations of attribute conditions might satisfy recovery goals. Criteria provide useful reference points for the evaluation of attribute conditions in the absence of ESU or population-specific goals at the attribute level.

This Recovery Plan identifies habitat criteria (Table 9-11) based on Properly Functioning Conditions (PFCs) identified by NMFS to reflect freshwater habitat conditions generally favorable for salmonids spawning and rearing (NMFS 1996b). NMFS defines PFCs as "the sustained presence of natural habitat-forming processes in a watershed (e.g., riparian community succession, bedload transport, precipitation runoff pattern, channel migration) that are necessary for the long-term survival of the species through the full range of environmental variation." PFC criteria vary between different landscapes based on unique physiographic and geologic features. For example, aquatic habitats on timberlands in glacial mountain valleys are controlled by natural processes operating at different scales and rates than are habitats on low-elevation coastal rivers. PFC criteria are not goals or requirements for reaching salmon recovery. They are, however, useful reference points for comparative purposes.

Table 9-11. Salmonid watershed indicators based on "Properly Functioning Conditions" Matrix of Pathways and Indicators (NMFS 1996b) and Northwest Forest Plan (1994).

Pathway	Indicators	Properly functioning	At risk	Not properly functioning
Watershed Conditions	Road Density & Location	<2 mi/mi² , no valley bottom roads	2-3 mi/mi², some valley bottom roads	>3 mi/mi² many valley bottom roads
	Disturbance History	NMFS <15% ECA (entire watershed) with no concentration of disturbance in unstable or potentially unstable areas, and/or refugia, and/or riparian area;	<15% ECA (entire watershed) but disturbance concentrated in unstable or potentially unstable areas, and/or refugia, and/or riparian area;	>15% ECA (entire watershed) and disturbance concentrated in unstable or potentially unstable areas, and/or refugia, and/or riparian area;
		NWFP-area (except adaptive Management Areas (AMA)), ≥15% retention of Late Successional/Old Growth (LSOG) in watershed	NWFP area (except AMAs), ≥15% retention of LSOG in watershed	does not meet NWFP standard for LSOG retention
	Riparian Reserves	the riparian reserve system provides adequate shade, large woody debris recruitment, and habitat protection and connectivity in all subwatersheds, and buffers or includes known refugia for sensitive aquatic species (>80% intact), and/or for grazing impacts: percent similarity of riparian vegetation to the potential natural community/composition >50%	moderate loss of connectivity or function (shade, LWD recruitment, etc.) of riparian reserve system, or incomplete protection of habitats and refugia for sensitive aquatic species (≈70-80% intact), and/or for grazing impacts: percent similarity of riparian vegetation to the potential natural community/composition 25-50% or better	riparian reserve system is fragmented, poorly connected, or provides inadequate protection of habitats and refugia for sensitive aquatic species (<70% intact), and/or for grazing impacts: percent similarity of riparian vegetation to the potential natural community/ composition <25%

Sampling & Analytical Design: Landscape-scale analyses will rely on region-wide land use and land cover metrics, as well as impairment ratings related to hydrology, fine sediment supply, and riparian function. Watershed-scale attributes are typically broad-scale and slow to change and monitoring is therefore relatively infrequent and covers a wide spatial-scale. An exception might be rapidly developing areas where land cover may change dramatically within a period of years; these areas can warrant a more intensive monitoring focus. More intensive studies in developing areas will be identified but will also rely on existing GIS data sources compiled by cooperating agencies. Intensive watershed-scale studies will be driven by land use trends and data availability.

Implementation Measures

M.M10. Maintain current landscape scale habitat monitoring efforts for application as available in periodic status and trend assessments.

Explanation: Current habitat monitoring programs are implemented and funded by a variety of parties and provide the basis for current status assessments and recovery plans. Habitat status and trend evaluations identified in this program are focused on monitoring at the stream habitat rather than landscape scale but landscape information for other sources will be incorporated into evaluations. Because dedicated landscape scale data collection efforts are not a focus of this monitoring program, future assessments will rely on other sources for information needed to provide a context for evaluation of habitat patterns at the stream scale.

M.M11. Seek and utilize opportunities to supplement existing landscape scale information collection, synthesis, and reporting activities appropriate.

Explanation: Ongoing activities are expected to provide most of the landscape-level information needed to provide a watershed and floodplain context for stream habitat condition status and trends that are the focus of habitat monitoring in this Plan. Opportunities may occasionally arise to augment existing efforts by other parties to increase depth and breadth of coverage of various landscape attributes. In this case, existing efforts might be substantially leveraged with very cost effective contributions.

9.3.3. Water – Quantity & Quality

Objectives

Water quantity and quality are key components of this salmon recovery monitoring program. Water quantity and quality either reflect or affect virtually every other habitat characteristic in the watershed and stream habitat feature. These factors can have broad ranging effects on fish populations (e.g. temperature changes alter species distribution and persistence) as well as discrete point source impacts (e.g. chemical discharge at lethal toxicity levels). As with other habitat monitoring, the primary focus is to characterize conditions for salmon and watershed health relative to a baseline at listing and improvements in statutory listing factors consistent with recovery. This information will also meet other objectives as identified in Box 3, including identification of limiting factors to focus actions, determination of habitat suitability and potential to guide prioritization of areas for preservation and restoration, fish status inferences where biological data is incomplete, action effectiveness evaluations, and research on fundamental linkages among fish, watersheds, and streams.

This program describes monitoring needs specific to Salmon Recovery and comprehensive Watershed Plans completed for Washington lower Columbia subbasins in 2006 (LCFRB 2006b, 2006c). It also considers stream flow and water quality monitoring needs for a full spectrum of human and fish concerns (Box 9-3). The habitat monitoring program described herein incorporates elements of Watershed Plan monitoring pertinent to fish. The Watershed Plans are designed to address the salmon-related monitoring needs for water quantity or quality data. Water quantity and quality monitoring is also conducted in association with hydropower operations – these elements are addressed in the Action Effectiveness section later in this document.

Box 9-3. Water quantity and quality monitoring needs identified in Washington lower Columbia Watershed Plans (LCFRB 2006b, 2006c).

Flow

- Provide basic data needed to assess current status and long-term trends in stream flow.
- Provide basic data to determine how various components of the watershed contribute to flow.
- Assess how short-term or long-term changes in watershed conditions affect flows.
- Evaluate the effectiveness of specific management actions designed to improve the flow regime.

Water quality

- Determine the effects on human health for drinking water systems relying on surface water.
- Determine the effects on human health through contact recreation.
- Determine the effects on fish species listed under the Endangered Species Act and other aquatic life.

Strategy

The strategy includes a series of overarching guidelines consistent with the monitoring objectives. For water quality and quantity monitoring, these include:

M.S28. Complete comprehensive assessments of water quality and quantity status and trends at 12 year intervals as prescribed by the Recovery Plan.

Explanation: A 12 year assessment interval is identified by the Recovery Plan for the assessment of stream habitat status relative to baseline conditions and criteria.

M.S29. Monitor water quality and quantity as prescribed in the WRIA 25/26 and 27/28's Watershed Management Plans.

Explanation: The Watershed Management Plans identify a water flow and quality monitoring strategy program designed to address the multiple objectives of this information (LCFRB 2006b, 2006c). Strategies and priorities identified in this comprehensive monitoring program were adopted directly from the Watershed Management Plans.

Indicators

Attributes & Metrics: Water quantity and quality are characterized through a set of indicators including attributes, metrics, and statistics relevant to salmonid protection and recovery (Table 9-12). Instream flow measurements of water quantity are calculated in cubic feet per second and expressed in terms of average low flows during summer or early flow, or in terms of peak flows. Low-flow levels during late summer and early fall can be defined at the 90th percentile, 50th percentile (median), and 10th percentile (flows expected on average in 1, 5, or 9 years out of ten, respectively). Peak flows are similarly expressed based on frequency of occurrence. For instance a 2-year flood has a 50% chance of occurring in any single year while a 10-year flood has a 10% chance of occurring in any single year. Frequency statistics generally require historical flow records at stream-gaging sites. Water quality indicators of particular interest to fish include temperature and dissolved oxygen. Other water quality parameters addressed by watershed plans include pH, conductivity, turbidity, nutrients, and indicator bacteria.

Table 9-12. Attributes, metrics, and example statistics for use as indicators of stream habitat status.

Attribute	Metric	Example statistics	Relevance to Fish
Instream flows	Normal hydrograph Low flow Peak flow	Seasonal pattern Annual average & minimum Flood size and frequency (2-year, 10-year, 100-year) Exceedence levels for low flow target regime	Summer flow availability for juvenile rearing Juvenile/adult migration timing & access Spawning/rearing habitat availability & quality
Water quality	Temperature Dissolved oxygen Turbidity & suspended sediments pH Conductivity Nutrients Contaminants - metals & pollutants	Seasonal average & range (º C) mg/L NTUs Unit measure µS/cm Nitrogen, Phosphorus Concentration and extent relative to threshold	Cool, clean water for adult, egg and juvenile survival Access to suitable habitat

Criteria: Assessments status and trends in water quantity and quality relative to habitat suitability for fish will be evaluated based on changes in indicators over time as well as comparisons with benchmark values. Criteria for water quantity are based on broad guidance identified in Properly Functioning Conditions (PFCs) for salmon and on target flows identified in the watershed plans. Criteria for water quality were based on PFCs and state water quality criteria.

PFCs were identified by NMFS to reflect freshwater habitat conditions generally favorable for salmonids spawning and rearing (NMFS 1996b). PFCs are not goals or requirements for reaching salmon recovery. They are, however, useful reference points for comparative purposes. PFCs for water quality and quantity are broadly described in terms of functions rather than specific parameter values. The exception is water temperature where specific ranges were identified for salmonids by life stage.

Target flows are intended to reflect a realistic flow regime that could be achieved in most years by following sound management techniques over a long period of time (LCFRB 2006b, 2006c). Targets include both low flows and high flows and their frequency of occurrence over a period of years. These statistics are developed from historical flow conditions, current and projected water uses, and fish habitat needs. Target flows have not been developed for all streams in the region at this time, but could be developed in the future in additional areas where significant flow data has been collected over a long period of time (or where acceptable simulated flow data has been generated). Target flows should not be confused with “minimum instream flows” which are stream-specific seasonal or annual low flow rates specifically defined in state law for allocation limitations on the issuance of new water rights.

Sampling and Analytical Design

Water quantity monitoring requires continuous, long term data on flows. The monitoring design recognizes that installation and operation of gages requires funding, and it may be impossible to fund gages in every location desired. Therefore Watershed Management Plans identified criteria to focus funding resources on selected subbasins, such as the presence of existing gages, degree of flow impairment, size of subbasin, LCFRB stream priority, etc. Based on these criteria, subbasins were prioritized within the Watershed Plans for installation and maintenance of permanent, continuously-recording stream gages. In addition, pilot subbasins were identified in Watershed Plans for more intensive flow monitoring to explore the applicability of stream flow management approaches.

The water quality monitoring strategy (Barber 2004a, 2004b) incorporated two elements. First, data are needed to characterize water quality conditions in surface waters. Second, it is valuable to gather information on point and non-point sources of water quality impairment to provide a basis for actions to improve water quality. The Watershed Management Plans designed monitoring to address human health concerns and fish and other aquatic life issues. However, collecting information for improved fisheries management (particularly those listed under ESA) was an essential driver. Note that this strategy does not entail intensive monitoring of flows and water quality in every subbasin. In order to provide representative data on all subbasins and salmon populations throughout the region, sampling of specific water quantity and quality is incorporated into the stream habitat assessment protocols described previously.

Table 9-13. Salmonid freshwater habitat indicators for water quantity and quality based on "Properly Functioning Conditions" Matrix of Pathways and Indicators (NMFS 1996b).

Pathway	Indicators	Properly Functioning	At Risk	Not Properly Functioning
Flow/Hydrology:	Change in peak/ base flows	watershed hydrograph indicates peak flow, base flow and flow timing characteristics comparable to an undisturbed watershed of similar size, geology and geography	some evidence of altered peak flow, baseflow and/or flow timing relative to an undisturbed watershed of similar size, geology and geography	pronounced changes in peak flow, baseflow and/or flow timing relative to an undisturbed watershed of similar size, geology and geography
	Increase in drainage network	zero or minimum increases in drainage network density due to roads	moderate increases in drainage network density due to roads (e.g. ≈5%)	increases in drainage network density due to roads (e.g. ≈20-25%)
Water Quality:	Temperature	50-57° F	57-60° (spawning), 57-64° (migration & rearing)	> 60° (spawning), > 64° (migration & rearing)
	Turbidity	turbidity low	turbidity moderate	turbidity high
	Chemical contamination & nutrients	low levels of chemical contamination from agricultural, industrial and other sources, no excess nutrients, no CWA 303d designated reaches	moderate levels of chemical contamination from agricultural, industrial and other sources, some excess nutrients, one CWA 303d designated reach	high levels of chemical contamination from agricultural, industrial and other sources, high levels of excess nutrients, more than one CWA 303d designated reach

Table 9-14. Examples of Washington State water quality standards for surface waters related to aquatic life uses of listed lower Columbia River salmonids (Ecology 2006).

	Temperature[1]	Dissolved oxygen[2]	Turbidity[3]	Dissolved gas[4]	pH[5]
Char spawning	9°C (48.2°F)	--	--	≤110%	--
Char spawning and rearing	12°C (53.6°F)	9.5 mg/l	5 NTU or 10% increase	--	6.5-8.5 (0.2 units)
Salmon and trout spawning	13°C (55.4°F)	8.0 mg/l	--	--	--
Core summer salmonid habitat (June 15-September 15)	16°C (60.8°F)	9.5 mg/l	5 NTU or 10% increase	≤110%	6.5-8.5 (0.2 units)
Salmonid spawning, rearing & migration (September 16 – June 14)	17.5°C (63.5°F)	8.0 mg/l	5 NTU or 10% increase	≤110%	6.5-8.5 (0.5 units)
Salmonid rearing and migration only	17.5°C (63.5°F)	6.5 mg/l	20 NTU or 20% increase	≤110%	6.5-8.5 (0.5 units)

[1]Highest 7-day average of the daily maximum temperatures. Criteria also include 1 day maxima.

[2] Lowest 1-day minimum

[3] Based on background below or above 50 NTU.

[4] Percent saturation.

[5] Range and allowable human-caused variation.

Implementation Measures

M.M12. Maintain existing stream flow gauges over the long term and install additional permanent gages as per recommendations and priorities identified in Watershed Plans.

Explanation: For purposes of improving stream flow management in the region, it is important that existing stream gauges be maintained over the long term and that additional, permanent stream gauges are installed. Recommendations for stream gauging at specific sites are provided in the Watershed Plans (LCFRB 2006b, 2006c).

M.M13.Implement a systematic water quality monitoring program based on existing and enhanced activities as per recommendations and priorities identified in Watershed Plans.

Explanation: Water quality monitoring activities currently in place are designed to meet specific needs of various programs but are not comprehensive in terms of either the network of streams or the types of parameters monitored (LCFRB 2006b, 2006c). In the absence of a comprehensive monitoring framework at the regional scale, it is difficult to identify impaired water bodies, characterize status and trends in surface water quality, or develop effective approaches to improving water quality.

M.M14. Incorporate selected water quantity and quality metrics into systematic stream habitat survey protocols identified in section 1.2.6 of this program in order to provide broad regional coverage of key limiting factors.

Explanation: Monitoring activities identified in the Watershed Plans provide detailed information on selected sites and are also concentrated in subbasins where water management issues are intensive. Additional information is needed in other areas in order to provide broad regional representation of parameters that limit fish (temperature, dissolved oxygen) or are related to limiting factors (conductivity). These parameters can be easily and inexpensively incorporated into standard stream habitat sampling protocols.

9.4. Implementation/Compliance Monitoring

Implementation and compliance monitoring will determine whether recovery measures were implemented as planned or meet established laws, rules, and criteria. Salmon Recovery and Watershed Plans for the lower Columbia Region identify over 650 specific actions for implementation by approximately 82 partners. Partners include a broad spectrum federal, state, and local governmental agencies, as well as a variety of nongovernmental organizations. Neither of these plans has the authority to mandate implementation of these actions. Objective success will thus depend on voluntary implementation of actions. Implementation & compliance monitoring is one of the simplest and most direct measures of whether the plan is being implemented as designed.

The Salmon Recovery and Watershed Plans were developed with the assumption based on the best available scientific information that completion of the recommended implementation actions and strategies will lead to the desired goals and objectives. However, given uncertainties relating to the significance of limiting factors and variation in management responses, the implementation of all actions may or may not achieve the desired goals and objectives. NOAA (2007) notes that implementation/compliance monitoring cannot directly link restoration actions to response as physical, chemical or biological parameters are not measured. However, failure to implement significant actions identified in these plans is likely to result in failure to achieve the desired outcomes.

9.4.1. Objectives

The objectives of implementation/compliance monitoring are to: A. determine whether actions identified in the Salmon Recovery and Watershed Plans were implemented as planned, and B. determine whether actions meet established laws, rules, and criteria specific to each action.

9.4.2. Strategy

M.S30. Complete comprehensive assessments of action implementation and compliance at 2-year intervals for the purpose of evaluating Salmon Recovery and Watershed Plan progress.

Explanation: A 2-year assessment interval is identified by the Recovery Plan for implementation & compliance monitoring. The assessment may involve annual collection and compilation of data and ongoing adaptive management based on results. The 2-year assessment is simply a formal checkpoint for evaluating progress and net effects in all areas.

M. S31. Rely on implementing partners to identify, evaluate and report on progress in the implementation and compliance of specific actions identified by the Plan.

Explanation: Implementing partners are identified in the Plan for every action. Partners are expected to implement these actions by maintaining current programs where adequate, revising existing programs where necessary, and developing new programs where missing. As outlined in both the Recovery and Watershed Plans, partners are expected to document their approach for implementing their actions through development of 6-Year Implementation Work Schedules (IWS). Tracking and reporting progress for actions under their responsibility is part and parcel to their accountability for Plan implementation.

M. S32. Develop and maintain a centralized clearinghouse and database to track and summarize action implementation.

Explanation: Periodic evaluations of Plan progress and appropriate course corrections will be based on a summary and review of action implementation and compliance. This evaluation will be facilitated through use of a centralized clearing house and database, Salmon PORT.

9.4.3. Indicators

Action implementation and compliance is evaluated based on identification and completion of activities and tasks specific to each action. Activities and tasks are identified by the implementing agent, during development of the 6-Year Implementation Work Schedule (IWS). Evaluations are based on partner and action assessments. Partner assessments describe progress in the implementation of all activities, actions and tasks under the responsibility of each implementing partner. Action assessments describe progress in the implementation of all activities and tasks across partners.

Partners can enter and maintain information on salmon recovery and watershed management actions for their program using the web-tool Salmon PORT (Salmon Partners Ongoing Recovery Tracking, Figure 9-8). This interactive system was designed to track actions and activities identified in the Plan in an efficient and effective manner. Salmon PORT can answer basic questions regarding how and when recovery actions are completed, and at what cost. This system will help to establish tasks, criteria and milestones, and identify impediments to implementation such as budgetary and logistical constraints. It will also allow users, agencies and the public to access information and view a variety of reports related to implementation of salmon recovery efforts. Salmon PORT also provides added levels of functionality to participating entities/users pertaining to its own progress and tasks.

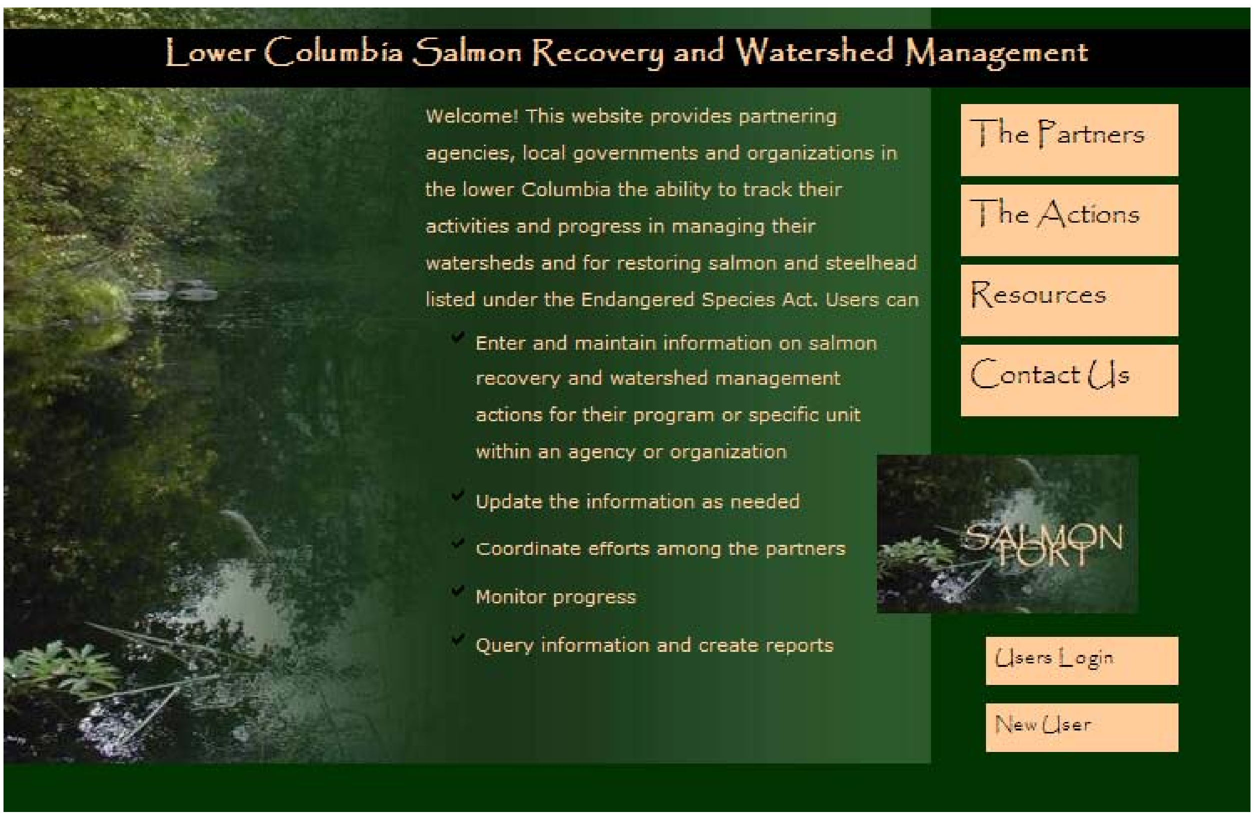


Figure 9-8. Salmon PORT interface page at http://www.lowercolumbiasalmonrecovery.org/.

9.4.4. Implementation Measures

M.M15. Maintain a coordinated database of federal, tribal, state, local, and non-governmental programs and projects implemented throughout the recovery region.

Explanation: The LCFRB has been specifically charged with development and oversight of Recovery Plan implementation throughout the Washington lower Columbia River region. In order to determine if recovery actions are being conducted and objectives met, implementation and compliance monitoring will be spearheaded using the newly developed SalmonPORT database.

M.M16. Periodically summarize and report action implementation progress at the task level using the LCFRB Salmon PORT database system.

Explanation: Reporting will occur at biennial intervals.

M.M17. Prepare biennial reports of progress in implementation and compliance of recovery actions.

Explanation: The LCFRB has been specifically charged with development and oversight of Recovery Plan implementation throughout the Washington lower Columbia River region.

9.5. Action Effectiveness Monitoring

Action effectiveness monitoring is designed to evaluate the significance and status of threats to listed salmon and steelhead status, and changes in threat levels associated with specific types of recovery actions. This monitoring is specifically intended to evaluate the status and trends in statutory listing factors identified by NMFS (NOAA 2007).

In this focused monitoring effort, functional effectiveness has been purposefully distinguished from biological effectiveness. Although biological effectiveness is the ultimate goal in recovery planning, population trends take many years to appear and are frequently confounded by the effects of environmental variability and uncertainty. As such, functional effectiveness serves as a more proximate and tractable measure of progress. Where species and habitat status and trend monitoring weighs the aggregate effect of a full complement of protection and restoration actions, action effectiveness monitoring considers the incremental effects of specific actions or suites of actions that affect habitat, hydropower, hatchery, harvest, and ecological interaction threats. Action effectiveness monitoring ultimately helps determine which actions work the best and what level of contribution toward recovery is contributed by an action or suite of actions.

Effects of actions may be estimated directly based on estimates of fish population attributes (e.g., abundance, productivity, spatial structure, diversity) or watershed health indicators (e.g., stream flows, water quality, etc), or indirectly based on effects on limiting factors or causative mechanisms. Formal experiments and rigorous statistical analysis involving both test and control populations may be required. In most cases, action effectiveness monitoring complements and utilizes the same types of information needed for status and trend monitoring of fish and habitat.

Monitoring and evaluation plans in other regions have sometimes adopted an alternative definition of action effectiveness monitoring specifically focused on research of cause and effect relationships and population or subpopulation scale biological responses to one or more actions. This Plan considers evaluations of such cause and effects relationships and mechanisms as research. An example of habitat action effectiveness monitoring under our definition might involve things like monitoring the numbers and types of shrubs and trees in the riparian zone following fence construction or estimating the effect on pool frequency and size or substrate composition following the addition of instream structure.

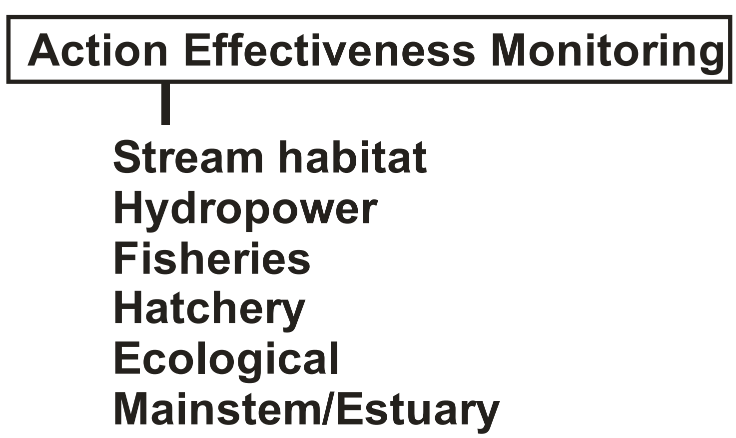


Figure 9-9. Categories of action effectiveness monitoring addressed by this Plan.

9.5.1. Habitat

Objectives

Habitat action effectiveness monitoring is intended to determine if specific protection and restoration projects function as planned. Where the baseline habitat status and trend monitoring generally provides a more global picture of the net effects of all activities and programs on conditions for fish, habitat action effectiveness monitoring is focused on the specific proximate effect of a particular action. Where habitat action implementation/compliance monitoring evaluates whether actions were implemented as planned, action effectiveness monitoring evaluates whether they function as intended. Habitat action effectiveness monitoring addresses stream habitat, water quality and flow, and watershed actions.

Stream habitat action effectiveness monitoring has many elements in common with habitat status and trend monitoring but generally addresses a much narrower set of objectives. For instance, where habitat status and trend monitoring might quantify the number of stream miles accessible to anadromous salmonids, action effectiveness monitoring might evaluate whether culvert replacement has effectively increased access to a given amount of suitable habitat.

Box 9-4. Questions addressed by habitat action effectiveness monitoring.

1. Have passage improvement actions increased access to significant amounts of suitable habitat for salmonids?
2 Have channel structure and bank stability improvement actions increased habitat quantity and quality for salmonids?
3. Have off-channel and side-channel improvement actions increased habitat quantity and quality for salmonids?
4. Have floodplain restoration actions increased habitat quantity and quality for salmonids?
5. Have water quality improvement actions increased habitat quantity and quality for salmonids?
6. Have water flow-related actions increased habitat quantity and quality for salmonids?
7. Have watershed actions increased watershed functions deemed beneficial to stream salmonid habitats?

Strategy

M.S33. Complete comprehensive assessments of habitat action effectiveness at 6-year intervals for the purpose of evaluating Recovery Plan progress.

Explanation: A 6-year assessment interval is identified by the Recovery Plan for the effectiveness of actions relative to baseline conditions and criteria. The assessment may involve annual collection and compilation of data and ongoing adaptive management based on results. The 6-year assessment is simply a formal checkpoint for evaluating progress and net effects in all areas.

M.S34. Monitor the effectiveness of habitat-related actions affecting the stream, water quantity and quality, and watershed conditions.

Explanation: The Recovery Plan identifies actions specific to each of these factors. Stream habitat related actions that address access to habitat blocked by artificial barriers, stream channel habitat structure and bank stability, off-channel and side-channel habitat, floodplain function and channel migration processes, and riparian conditions and functions. Water quantity and quality measures address limiting factors such as temperature, the adequacy of instream flows during critical periods, and the effects of regulated stream flows on critical habitat functions. Watershed measures address watershed conditions and hillslope processes (e.g. runoff and sediments) that affect stream habitats.

M.S35. Develop and maintain a comprehensive up-to-date inventory of habitat-related actions across the region.

Explanation: A comprehensive project inventory is a basic first step in accurately evaluating the significance of habitat actions intended to improve fish status and ameliorate habitat-related threats. Projects are being implemented by a tremendous variety of parties which makes it difficult to characterize the nature and extent of these activities. An inventory is one simple measure of the significance of the effort expended.

M.S36. Intensively monitor the effectiveness of a subset of representative habitat actions using a formal statistical research design.

Explanation: It is neither necessary nor feasible to conduct intensive scientific evaluations of the effectiveness of every habitat action. Resources are limited and benefits of monitoring to assure that actions are beneficial must be balanced with the costs of monitoring. Intensive effectiveness monitoring activities should be focused on a representative subset of actions. Effects of other similar actions may then be judged based on inference.

M.S37. Estimate and report the physical and biological effects and functional lifespan of every habitat-related project or program implemented in the region based on site-specific evaluations or by inference from similar project types elsewhere.

Explanation: While every habitat project need not be evaluated with a formal statistically-designed research project, every project should describe or estimate expected benefits as a required step in the proposal, design or implementation stage. This information will formalize considerations of assumed or expected benefits, highlight situations where basic effectiveness monitoring information is lacking and provide basic data to the regional habitat action inventory. This will force implementers to ask and answer what they intend to accomplish with any given project.

M.S38. Conduct habitat action effectiveness monitoring in close and complementary association with habitat status and trend monitoring.

Explanation: Habitat status and trend monitoring has many common elements with habitat action effectiveness monitoring. Wherever possible, action effectiveness monitoring should capitalize on information that is useful for multiple applications. Action effectiveness monitoring should also adopt comparable metrics and protocols where appropriate. It is not likely, however, that habitat status and trend monitoring will provide the fine scale habitat data needed to evaluate site-specific changes. Nor is it likely that action effectiveness habitat monitoring will always provide habitat data suitable that is representative of a broader region.

Indicators

Habitat action effectiveness indicators are identified for stream, water, and watershed characteristics in Table 9-15. Statistics describe the action, response, and functional lifespan of each project. Action descriptions may be qualitative or quantitative. Response descriptions may include physical or biological parameters. Lifespan of effect is of particular importance in evaluating short term vs. long term benefits. Response indicators for habitat action effectiveness monitoring have been categorized into three levels by the Washington Salmon Monitoring Oversight Committee (WSMOC 2002). Level 1 involves continued physical function as designed (e.g. did it survive high water?). Level 2 involves a physical response (e.g. did it provide the desired fish habitat condition?). Level 3 involves a biological response (e.g. were fish use and density affected as expected?)

Table 9-15. Example statistics describing habitat actions for use in effectiveness monitoring.

Feature	Factor	Example Project types	Descriptive statistics	Response Indicators			Protocol[1]
				Level I	Level II	Level III	
Stream	Access	Culverts, bridges, fishways, logjams, dam removal, debris removal	Number & type of improvements Affected stream length	Continued function as designed or placed	--	Species affected Fish use/density	MC-1
	Instream structure	Reconfiguration, deflectors, log & rock control structures, roughened channels, spawning gravel	Number & type of improvements Miles treated	Continued function as designed or placed	Pool frequency, stream width, substrate	Species affected Fish use/density	MC-2, MC-7
	Off-channel & side channel	Channel connectivity, channel or alcove construction	Number & type of improvements Effective area	Continued function as designed	Physical stream measurements	Species affected Fish use/density	MC-5
	Floodplain	Dike removal/setback, riprap removal, road removal/setback, landfill removal, wetland restoration	Number & type of improvements Effective area	Continued function as designed	Channel profile & capacity Pool frequency & depth	Species affected	MC-6
	Riparian	Planting, invasive plant removal or control, livestock exclusion	Number & type of improvements Stream length, width of zone Acres affected	Plant survival, plant reinvasion, fencing intact	Bank shading or erosion Canopy complexity	Species affected	MC-3, MC-4
Water	Quality	Point & non-point sources	Number & type of improvements	Continued function as designed	Temperature Contaminants	Species affected Fish use/density	
	Nutrients	Stream fertilization, carcasses or analogs	Area treated Volume of treatment	Continued function as designed		Species affected Fish use/density	
	Flow	Water lease or purchase, irrigation practice	Number & type of improvements Amount of flow (cfs) by time of year, water volume (acre ft.)	Continued function as designed	Stream flow	Species affected	
	Flow Regulation	Irrigation diversion dams, water treatment plants, pipes, ditches, head gates	Number & type of improvements	Continued function as designed	Stream flow	--	MC-8
Watershed	Condition	Sediment reduction, upland agriculture, upland vegetation,	Number & type of improvements Miles of affected road Acres affected	Continued function as designed	Stream, riparian, upland characteristics	Species affected Fish use/density	MC-10
	Protection		Affected area	Continued function as designed	Stream, riparian, upland characteristics	Fish & macro invertebrates	MC-10

[1] Report number reference for Washington Salmon Recovery Funding Board action effectiveness monitoring protocols (http://www.rco.wa.gov/srfb/docs.htm#strategy).

Sampling and Analytical Design

This Plan generally adopts habitat action effectiveness monitoring designs and protocols developed by the Washington Salmon Recovery Funding Board (SRFB). An overarching approach to habitat action effectiveness monitoring was described in Washington's comprehensive monitoring strategy and action plan for watershed health and salmon recovery (WSMOC 2002). Results of reach scale effectiveness monitoring activities are reported annually by the SRFB (WSSRFB 2007). Protocols for intensive habitat action effectiveness monitoring study designs have been developed by the SRFB for a variety of project types (Table 9-15).

This Plan identifies two levels of habitat action effectiveness evaluation design:

Intensive habitat action effectiveness monitoring involves a carefully designed and controlled scientific research design to describe physical and/or biological changes associated with a given project. It often employs a robust Before-and-After-Control-Impact (BACI) design. A BACI design samples the control and impact simultaneously at both locations at designated times before and after the impact has occurred (WSSRFB 2004). This design tests for changes at the area of impact relative to changes observed in a comparable control site where no impact occurs. This type of design is required when effects of external factors can confound before and after comparisons at the project site. An intensive sampling design for habitat action effectiveness typically involves repeated sampling over a period of years following project implementation. An intensive sampling regimen may also involve evaluations of project function as design (a level I response), physical effects of the project (a level II response), and biological effects (a level III response). Drawbacks of this design are the costs and years of data required. As a result, it is not feasible or desirable to implement an intensive action effectiveness monitoring effort for every project.

Extensive habitat action effectiveness monitoring based simply on level I indicators that describe whether a project continues to function as designed for a specified period. Continued function along with assumed physical and biological benefits provide a sound basis for assuming project effectiveness where more intensive monitoring has demonstrated effectiveness of comparable projects. Extensive monitoring can provide basic data on a large number of projects in a cost effective manner.

Implementation Actions

M.M18. Maintain current habitat effectiveness monitoring activities of all significant habitat protection and restoration programs.

Explanation: Current action effectiveness monitoring programs provide critical information regarding adequacy to address statutory listing factors.

M.M19. Develop and maintain a comprehensive up-to-date database inventory of habitat-related actions across the region.

Explanation: Actions are distributed among a wide spectrum of parties. Data is needed to provide basic information on the scale of habitat-related recovery action. The LCFRB is uniquely situated to implement this action.

M.M20. Formalize effectiveness monitoring activities for habitat-related actions by every implementing party by identifying expected benefits, describing criteria by which effectiveness will be monitored, and referencing the basis for estimated benefits.

Explanation: Some consideration of action effectiveness needs to be incorporated into every habitat protection and restoration action although every action does not require an intensive controlled pre and post project evaluation. Tasks and activities that address effectiveness monitoring should be a design element of every habitat-related project or program.

M.M21. Implement focused investigations of critical assumptions and uncertainties related to the effectiveness of representative types of habitat protection and restoration actions.

Explanation: Current assessments rely on a series of critical assumptions which affect the accuracy of those estimates. Intensive evaluations of representative actions will provide a basis for inference of similar actions throughout the basin.

9.5.2. Hydropower

Objectives

Hydropower action effectiveness monitoring is intended to determine if related fish protection, restoration, and mitigation actions reduce or limit effects on wild fish to levels consistent with the conservation and recovery of listed fish species while also achieving desired fish production benefits (Box 9-5). Construction and operation of a complex of tributary and mainstem dams and reservoirs for power generation, navigation, and flood control have fundamentally altered habitat conditions for fish and particularly anadromous fish throughout the Columbia River basin by the. Lower Columbia salmon, steelhead and trout are threatened by hydrosystem-related flow and water quality effects, obstructed and/or delayed passage; and ecological changes in impoundments. Dams in the Lewis, Cowlitz, and White Salmon subbasins have blocked access by anadromous fishes to large areas of productive habitat.

Box 9-5. Questions addressed by hydropower action effectiveness monitoring.

1. Are the target levels for juvenile and adult passage and survival though hydropower facilities consistent with recovery?
2. Are upstream and downstream habitat, water quantity, and water quality effects of hydropower facilities consistent with recovery?
3. Are fish reintroduction efforts into previously-blocked tributaries meeting population viability objectives identified in the Recovery Plan?
4. Are hydropower mitigation benefits for fish adequately meeting prescribed program objectives?

Strategy

M.S39. Complete comprehensive assessments of hydropower action effectiveness at 6-year intervals for the purpose of evaluating Recovery Plan progress.

Explanation: A 6-year assessment interval is identified by the Recovery Plan for the effectiveness of hydropower actions relative to baseline conditions and criteria. The assessment may involve annual collection and compilation of data and ongoing adaptive management based on results. The 6-year assessment is simply a formal checkpoint for evaluating progress and net effects in all areas.

M.S40. Evaluate hydropower action effectiveness for passage, habitat protection and restoration, reintroduction, and mitigation-related impacts on salmon and steelhead at all significant mainstem and tributary facilities that currently limit the viability of listed lower Columbia River populations.

Explanation: Hydropower facilities that affect Washington populations of lower Columbia River salmon include Bonneville Dam on the mainstem Columbia River, multi-dam complexes blocking the upper portions of the Cowlitz and Lewis systems to anadromous fish, and Condit Dam on The White Salmon River which also blocks anadromous passage. The Recovery Plan identifies significant actions for the benefit of listed populations involving each of these facilities.

M.S41. Monitor facility operations that potentially affect fish or fish habitat.

Explanation: This includes normal operations data on inflow, outflow, spill, turbine operations, bypass and fishway operations, etc.

M.S42. Conduct intensive annual monitoring and evaluation of juvenile and adult passage.

Explanation: Annual monitoring of fish passage is necessary to evaluate the effectiveness of current facilities. Both adult and juvenile passage need to be monitored.

M.S43. Monitor and evaluate effectiveness of hydro-related habitat measures based on downstream effects on stream habitat characteristics, water quantity, and water quality.

Explanation: Downstream habitat effects of hydro operations can significantly affect fish migration, spawning and rearing conditions either directly or indirectly via influences on habitat forming processes.

M.S44. Monitor effectiveness of adaptively-implemented reintroduction efforts above tributary facilities in the Cowlitz, Lewis, and White Salmon rivers based on net productivity.

Explanation: Recovery of several lower Columbia River species to meet criteria identified by the Technical Recovery Team cannot be achieved without restoring viable populations in several areas currently blocked to anadromous fish by hydropower facilities. Reintroduction efforts are planned or underway in the Cowlitz and Lewis rivers. The success of these reintroduction efforts will depend on achieving a net productivity measured in terms of net replacement rates. Condit Dam is scheduled for removal from the White Salmon River in 2010 and recovery in that system will likely involve a combination of reintroduction and natural recolonization.

M.S45. Monitor effectiveness of additional actions designed to mitigate hydropower impacts, where appropriate.

Explanation: In some cases, hydro actions involve mitigation for impacts through the implementation of other beneficial measures rather than direct remedies for the effects of facilities. The monitoring and evaluation program needs to include considerations of mitigation action effectiveness.

M.S46. Implement hydropower monitoring programs consistent with requirements of Federal Energy Regulatory Commission Licenses, Biological Opinions, and other plans and agreements.

Explanation: Monitoring and evaluation activities related to hydropower facilities are described, directed and governed by a variety of existing licenses, opinions, and agreements. The monitoring and evaluation strategy for hydropower action effectiveness relative to salmon recovery must be implemented in the context of the existing programs. It is expected that existing programs have fully addressed needs identified in the Recovery Plan or are in the process of revision to ensure the adequacy of existing programs relative to recovery needs.

Indicators

Hydropower indicators are identified for operations, passage, habitat, and reintroduction metrics (Table 9-16). Operations are simply project activities with the potential to affect fish. Passage includes both juveniles and adults. Habitat effects related to hydropower include water flow patterns, water quality, physical habitat features affected by flow and material recruitment processes. Reintroduction involves the rebuilding of viable populations in areas currently blocked from anadromous production. Mitigation refers to other activities designed to improve fish status affected by hydropower facilities.

Table 9-16. Attributes, metrics, and example statistics for potential use as indicators of hydropower effects.

Attribute	Related Metrics	Example
Operations	--	Facility activities that potentially affect fish
	Project-specific	Discharge, spill, turbine operations, gate/weir openings, bypass operations, fishway operations
Passage	--	Effective movement through hydropower facilities
	Collection efficiency	Proportion of t juvenile population that passes a facility
	Fish guidance efficiency	Proportion of juveniles diving toward turbine intakes that are guided into a bypass
	Fish passage efficiency	Proportion of juvenile migrants that pass a dam via non-turbine routes
	Passage survival	Proportion of the adult or juvenile population that survives passage of dam (may be net or route-related)
	Conversion rate	Proportion of adult population that passes a facility and associated reservoir
	Fallback rate	Proportion of adults that pass a dam but subsequently fall back downstream typically over the spillway
	Delay/travel time	Additional time required to negotiate artificial passage structures and other habitat impact. For juveniles can include reservoir passage (i.e. increased cross sectional area reduces velocity)
Habitat	--	Physical and environmental factors that limit fish
	Structure	Stream channel morphology, substrate, large woody debris
	Water quantity	Seasonal & annual discharge patterns & flood flows, seasonal minimum flows
	Water quality	Temperature, dissolved gas levels (seasonal averages, exceedence frequency)
Reintroduction	--	Restoration of viable populations upstream from facilities that currently block passage
	Productivity	Net production or replacement rate on a per adult basis (in part a function of passage)
	Viability	Abundance, productivity, spatial structure, diversity (see biological monitoring)
Mitigation	--	Beneficial actions implemented to indirectly address project effects
	Various	Project-specific including habitat protection & restoration, hatchery production, predator management, monitoring and research, information & education, etc.

Criteria

Hydro related monitoring criteria are detailed for each facility in operating documents including Federal Energy Regulatory Commission Licenses, Biological Opinions, and Settlement Agreements. The reader is referred to these documents for more details on project-specific criteria pertinent to salmon recovery.

Sampling and Analytical Design

The hydropower sampling design incorporates the following sampling and analytical design elements:

1. Routine monitoring and description of project operations on an hourly or daily basis as per current practice.

2. Systematic annual monitoring of juvenile and adult passage success based on mark-recapture and/or telemetry studies.
3. Systematic annual sampling of the abundance, productivity, distribution, and diversity of experimental reintroduced populations (see biological status and trend monitoring).
4. Focused empirical analyses of the efficacy of habitat actions (see habitat action effectiveness monitoring).
5. Hatchery and habitat monitoring programs consistent with mitigation objectives for each facility (see hatchery and habitat action effectiveness monitoring).

Applied research and analysis to evaluate critical assumptions, improve estimate precision, and refine assessment method and tools (see uncertainty and validation research).

Implementation Measures

M.M22. Maintain current monitoring and evaluation of adult and juvenile collection, passage, and survival rates at Bonneville Dam.

Explanation: Extensive monitoring programs are currently being implemented for Federal Columbia River Power System Facilities including Bonneville Dam. These programs are critical to limiting and improving passage success that limits the viability of upstream populations.

M.M23. Maintain current monitoring and evaluation of the relative abundance, distribution and dewatering of redds of chum (and fall Chinook from the unlisted Middle Columbia River population) in the Bonneville Dam tailrace.

Explanation: Bonneville Dam operations significantly affect habitat suitability downstream for spawning aggregations of chum of significant importance to salmon recovery. The importance of the chum population is elevated by the limited scope for improvement for the upper gorge chum population, which is even more limited by Bonneville reservoir.

M.M24. Continue to implement intensive monitoring and evaluation of reintroduction efforts for coho, spring Chinook and steelhead in the upper Cowlitz and Cispus rivers.

Explanation: These significant populations for recovery and effective reintroduction will depend on continuing facility refinements guided by monitoring and evaluation result.

M.M25. Implement intensive monitoring and evaluation of reintroduction efforts for coho, spring Chinook and steelhead in the upper Lewis River as per license direction and agreements.

Explanation: These significant populations for recovery and effective reintroduction will depend on continuing facility refinements guided by monitoring and evaluation result.

M.M26. Monitor the downstream channels of Mayfield (Cowlitz), the Sediment Retention Structure (Toutle), and Merwin (Lewis) dams for changes in flow, substrate, stream morphology, and water quality.

Explanation: Downstream habitat impacts of impoundment and operation can have significant long term effects on habitat suitability for salmonids due to changes in sediment and flow conditions.

M.M27. Implement focused investigations of critical assumptions and uncertainties in current hydro-related monitoring and evaluation efforts.

Explanation: Current assessments rely on a series of critical assumptions which affect the accuracy of those estimates.

9.5.3. Fisheries

Objectives

Harvest action effectiveness monitoring is intended to determine if fishery management regulatory processes and actions reduce or limit fishery-related mortality to levels consistent with the conservation and recovery of listed fish species while also providing significant and sustainable fishery opportunity and harvest (Box 9-6).

Fisheries that affect lower Columbia River salmon and steelhead are managed to optimize current and future fishing opportunity and harvest within the limitations and constraints of impact limits specified to protect weak, listed stock components. Fisheries do not generally target listed species but listed fish are incidentally caught in fisheries for hatchery and strong wild stocks.

Fishery action effectiveness evaluations are complicated because harvest is identified as both a threat and a goal in the Washington Lower Columbia Recovery Plan. Harvest acts as a threat through direct mortality of adult fish which decreases abundance and productivity, and can increase risks of extinction when the fishery impact is excessive. However, restoration of wild salmonids to sustainable, harvestable levels is also a recovery goal. Healthy, viable salmonid populations produce regular harvestable surpluses in excess of escapement needs for population sustainability. This program therefore includes monitoring and evaluation of both fishery impacts and benefits.

Box 9-6. Questions addressed by fishery action effectiveness monitoring.

1. Are fishery impacts on sensitive stocks effectively limited to prescribed levels?
2. Are prescribed fishing levels consistent with long term viability of listed stocks?
3. Are significant fishery opportunity and harvest being sustained by existing populations and management?

Strategy

M.S47. Complete comprehensive assessments of fishery action effectiveness at 6 year intervals as prescribed by the Recovery Plan.

Explanation: A 6 year assessment interval is identified by the Recovery Plan for evaluating the effectiveness of fishery actions relative to baseline conditions and criteria.

M.S48. Monitor annual impacts relative to prescribed limits for significant ocean and Columbia River sport and commercial fisheries on representative index groups for all species based on in-season data on fish numbers and fishery mortality collected using systematic statistical surveys of catch, catch composition, and harvest.

Explanation: Annual in-season monitoring is necessary to regulate direct and incidental fishing impacts within prescribed limits for each fishery while also optimizing fishery benefits in any given year. Fishery opportunity and effort is adjusted based on real time data on fish run strength, stock composition, and fishery success. Fisheries are managed based on index stocks representing sensitive species, life stage, and population groups.

M.S49. Periodically re-evaluate effects of prescribed fishery impact levels and strategies on long term viability of listed stocks based on risk assessments that consider recent stock abundance and productivity.

Explanation: Prescribed fishery impact limits are based on prior assessments of the effects of fishery-related mortality on spawning escapements of weak stock groups. Limits are ideally based on risk assessments that calculate the marginal change in low run size probability due to fishing. Risks are sensitive to fishing rates, variance in fishing rates, relationships between fishing rate and abundance, and stock abundance and productivity patterns. Periodic reassessments are needed to consider whether prescribed fishery limits remain consistent with long term viability based on current abundance and productivity information.

M.S50. Monitor annual fishery opportunity based on effort, harvest, and value in significant ocean, Columbia River, and tributary sport and commercial fisheries for all species.

Explanation: Monitoring of fishery statistics provides a basis for meeting sustainable use and value goals as well as the variety of escapement and allocation objectives consistent with optimum management of the fishable stocks and the fishery. These evaluations must consider the interaction in effects of protection measures for Columbia River stocks on fisheries directed on mixed stocks including fish originating in the upper Columbia and Snake rivers as well as Washington, Oregon, and Canadian systems outside the basin.

M.S51. Conduct annual evaluations of fishery assessment and management processes and tools based on post-season run reconstruction and analysis of forecast, in-season and actual information on fishery impacts and opportunities in order to optimize efficacy.

Explanation: Fishery assessment and management processes and tools are continually evolving based on recent experience and new data. Annual reporting of numbers is a long-standing practice although the depth and breadth of corresponding evaluations varies among fisheries. This strategy highlights the need to conduct systematic formal post season evaluations on an annual basis. These evaluations also provide the basis for adaptive preseason planning of the next year's fisheries.

M.S52. Systematically implement improvements in assessment methods, processes, and tools based on annual efficacy evaluations and directed investigations of critical uncertainties in current assessments and systems.

Explanation: This strategy includes focused effort on significant uncertainties in current assessment methods, processes, and tools. Specific examples are detailed under information gaps.

Indicators

Attributes & Metrics: Fishery indicators are identified for impact, effect, and benefit metrics (Table 9-17). Impact is defined as fishery-related mortality rate and is calculated as total harvest plus total indirect mortality divided by number of fish available. Indirect mortality includes catch-release mortality of fish that die following release due to the effects of handling in the fishery. In some fisheries, indirect mortality can also include drop-off mortality of fish that succumb prior to landing due to encounter with the fishing gear. Catch-release mortality is typically estimated as a fraction of the released component of the catch where the fraction has been based on directed studies. Catch composition apportions the catch in any mixed stock fishery among stocks of origin typically based on visual differences, recaptures of tagged fish or genetic information.

We define fishery effect in terms of the significance of fishing level to long term viability of the stock of interest. Significance to listed stocks is evaluated based on effects of fishing on extinction risk. This risk considers abundance and productivity of the limiting stocks as well as normal stock variation (process "error") and variance in fishery impacts due to fishing strategy and fishery implementation uncertainty (measurement "error").

Fishery benefit is defined based on effort, harvest, and value. Recreational fishery opportunities are typically assessed based on angler participation and success rates. Commercial opportunities are typically assessed based on harvested numbers or weight of fish and the economic value of that harvest.

Table 9-17. Attributes, metrics, and example statistics for use as indicators of fishery effects.

Attribute	Related Metrics	Example
Impact	--	Proportion of available population that is subject to fishery-related mortality. Typically includes harvest and release mortality
	Catch	Number of fish landed including those reduced to possession or released
	Harvest	Number of fish harvested (a portion of the total catch)
	Releases	Number of fish caught or encountered but not harvested. Can include releases of non-target species or stocks as well as fish that are encountered but not landed where the encounter is deemed significant (e.g. drop-off mortality).
	Catch composition	Species and stock of origin of fish caught, harvested, released, or encountered
	Run size	Number of fish available to fishery. Typically defined in terms of ocean recruits or Columbia River return
	Encounter rate	Proportion of available fish that are caught (includes harvested and released fish)
	Harvest mortality rate	Proportion of available fish that are harvested directly
	Non-harvest mortality rate	Proportion of available fish taken by catch and release or other encounter mortality
Effect	--	Significance of fishing level to long term viability of listed stocks
	Implementation uncertainty	Direction and variance in differences between planned and actual fishery impact rates due to forecast and in-season assessed uncertainties (affects risk)
	Risk	Marginal reduction in extinction risk due to fishery impacts on current and future spawner numbers (as propagated through the life cycle).
Benefit	--	Significance of fishery opportunity and harvest
	Effort	Measure of angler participation typically in terms of angler trips (recreational fishery) or fishery days, net days, number of participants (commercial)
	Harvest	Fish numbers or weight
	Value	Catch-per-unit-effort, ex-vessel value

Criteria: Criteria for fishery action effectiveness monitoring are identified in this program based on historical fishery impacts and current impact limits. Historical rates about the time of listing are a useful reference point for measuring decreases in impacts implemented to reduce near term extinction risks of listed stocks until sustainability is restored by a comprehensive suite of recovery actions. Current ESA impact limits have been adopted by Federal, State, and Tribal fishery managers to protect long term viability of listed stocks in the interim. Aggregate fishery impact rate allowances for wild salmon populations currently vary from 5% for lower Columbia River chum to 38% for lower Columbia River tule fall Chinook based on species-specific differences in productivity. Criteria for use in monitoring fishery action effectiveness are identified as benchmarks for each species in Chapter 6.

Sampling and Analytical Design

This design framework addresses freshwater and marine salmon fisheries in Oregon and Washington to which lower Columbia River salmon and steelhead are subject. These fisheries are already subject to a comprehensive monitoring framework designed and implemented by State, Federal, and Tribal fishery management partners operating under a series of interconnected jurisdictional and programmatic structures. Key sampling and analytical design elements of these programs include:

- Comprehensive accounting of effort, harvest, and impacts on listed stocks in all fisheries.
- Stratified statistical random sampling of major ocean and Columbia River sport, commercial, and Tribal ceremonial, subsistence, and commercial fisheries.
- Intensive effort, catch, and biological subsampling programs of significant commercial, and sport fisheries.
- Intensive in-season monitoring to estimate and regulate fisheries within prescribed limits.
- Comprehensive annual pre- and post-season analysis and reporting of monitoring information.

Regular validation research and analysis to evaluate critical assumptions, improve estimate precision, and refine assessment method and tools.

Program targets: This Plan identifies the following representative sampling program targets as a starting point for further consideration and discussion by the fishery management programs.

- Annual estimates of net fishery impacts on indicator stocks representative of limiting population in each listed lower Columbia River ESU.
- Minimum of 20% mark sample rate of the harvest in significant fisheries to estimate stock composition (this is the current target rate).
- Documentation of estimation precision for effort and harvest by stock in significant fisheries.
- Estimation precision of net fishery impacts for each ESU of not less than the greater of: a) 10% of the target impact rate with 80% confidence or b) an absolute impact of ± 2% with 80% confidence.

Identification and assessment of the magnitude of critical uncertainties in key assumptions of fishery estimates.

Implementation Measures

M.M28. Maintain current monitoring programs of annual harvest and harvest rates of representative index stocks in ocean, Columbia River mainstem, and tributary fisheries.

Explanation: Current fishery monitoring programs provide accurate and timely estimates of fishery effort, harvest, and impacts on listed stocks. This information is used to regulate fisheries within prescribed limits that optimize opportunity and value while also seeking to ensure escapements adequate to protect long term sustainability of the fishery and viability of affected stocks. This information also provides a sound basis for continuing evaluations of the effectiveness of fishery actions for regulating harvest at appropriate levels.

M.M29. Implement additional intensive biological monitoring of wild adult escapements of all species in order to improve the accuracy of fishery impact assessments.

Explanation: The accuracy of current fishery impact assessments is constrained by the quality of the available wild escapement data. This is particularly true for wild lower Columbia River coho.

M.M30. Evaluate and expand where appropriate current Chinook and coho wild index stock marking efforts to provide an adequate basis for stock identification and fishery impact estimation.

Explanation: Current wild index stock identification methods are not adequate for accurate estimation of fishery impacts on wild salmon in Columbia River fisheries.

M.M31. Implement focused investigations of critical assumptions and uncertainties in current fishery monitoring and evaluation efforts (to include efficacy of selective fisheries).

Explanation: Current fishery assessments rely on a series of critical assumptions which affect the accuracy of those estimates. With the widespread advent of mark-selective fisheries, assumptions regarding indirect mortality are among the more proximate concerns.

M.M32. Develop and implement a comprehensive annual assessment and report of fishery impact, effect, and opportunity information for each listed ESU (to include assessments of the accuracy of impact estimates and effects on ESU viability).

Explanation: Current fishery information is reported piecemeal for fisheries spread over a wide area of overlapping jurisdictions. Fishery effects on listed stocks are identified in semi-annual biological assessments of each fishery but comprehensive assessments are generally not available for net fishery effects on listed fish.

9.5.4. Hatchery

Objectives

Hatchery action effectiveness monitoring is intended to determine if hatchery management actions reduce or limit effects on wild fish to levels consistent with the conservation and recovery of listed fish species while also achieving desired fish production benefits (Box 9-7). Hatcheries released over 50 million salmon and steelhead per year in Washington lower Columbia River subbasins around the time of first listing. Many of these fish are released to mitigate for loss of habitat resulting from the Columbia River hydrosystem and widespread habitat development. Hatcheries provide valuable mitigation and conservation benefits but may also cause significant adverse impacts if not prudently and properly employed. Risks to wild fish include genetic deterioration, reduced fitness and survival, ecological effects such as competition or predation, facility effects on passage and water quality, mixed stock fishery effects, and confounding the accuracy of wild population status estimates.

Box 9-7. Questions addressed by hatchery action effectiveness monitoring.

1. Are hatchery impacts on sensitive stocks effectively limited to prescribed levels?
2. Is hatchery performance consistent with objective benefits and risks identified for each program?
3. Are hatchery practices consistent with objectives identified for each program?

Strategy

M.S53. Complete comprehensive assessments of hatchery action effectiveness at 6 year intervals as prescribed by the Recovery Plan.

Explanation: A 6-year assessment interval is identified by the Recovery Plan for the effectiveness of hatchery actions relative to baseline conditions and criteria.

M.S54. Intensively monitor potential hatchery threats to wild population status for every salmon and steelhead hatchery program.

Explanation: Hatchery influences are pervasive on many lower Columbia River salmon and steelhead populations. Hatchery effects have been identified as a significant threat to the status of these listed species.

M.S55. Monitor the potential impacts of hatcheries on the status of wild populations based on the annual incidence of natural spawning by hatchery fish and the contribution of natural origin fish to the hatchery brood stock.

Explanation: Annual monitoring is necessary to regulate hatchery impacts within prescribed limits for each natural population. While the net effect of hatchery-origin fish spawning in the wild on wild fish is unknown, it is clearly related to the relative frequency of naturally-spawning hatchery fish and natural-origin fish in the hatchery broodstock.

M.S56. Monitor hatchery performance and practices in order to evaluate program benefits relative to associated risks and activities related to both risks and benefits.

Explanation: Detailed hatchery production and return statistics provide a systematic quantitative basis for the evaluation of benefits associated with risks and corresponding hatchery actions. Production and return data are routinely collected by all hatcheries for use in program planning and evaluation relative to various production and mitigation goals. This same information will be useful in evaluations of conservation objectives or limitations associated with hatchery programs.

Indicators

Hatchery indicators are identified for impact, performance, and practice metrics (Table 9-18). Impact is defined in terms of hatchery contributions to naturally-spawning populations. Performance refers to hatchery production levels that are related to both hatchery benefits and risks. Practice refers to hatchery activities that affect impact and performance.

Table 9-18. Attributes, metrics, and example statistics for use as indicators of hatchery effects.

Attribute	Related Metrics	Example
Impact	--	Significance of hatchery interaction with natural populations
	Hatchery-origin spawners (pHOS)	Proportion hatchery-origin spawners in local natural population
	Out-of-basin strays	Proportion of total return that is observed in natural spawning areas outside the basin of origin
	Proportion natural influence (PNI)	Index of local hatchery effect (product of proportion of hatchery origin spawners and proportion of natural origin brood stock
Performance	--	Description of hatchery effectiveness
	Smolt-adult survival	Proportion of release surviving to return
	Fishery contribution	Number of hatchery-origin fish harvested in fisheries (by fishery)
	Hatchery return	Number of adults returning to hatchery collection facilities
	Age composition (adults)	Proportion by age of hatchery return
	Size at age (adults)	Average & range of length at age
	Migration & Spawn Timing	Temporal distribution of hatchery return relative to natural population
Practice	--	Description of hatchery activities related to hatchery effectiveness & effect on natural populations
	Brood stock no.	Number of broodstock spawned
	Brood stock origin (pNOB)	Proportion natural-origin fish incorporated into brood stock
	Egg take	Total number of eggs collected
	Release number	Total number of fish released
	Release size	Size at release (typically #/lb)
	Release practice	Acclimation type, release site, etc.
	Mark rate	Proportion of release marked by fin clip and coded wire tag

Criteria: Hatchery action effectiveness criteria are program specific and based on changes relative to historical base periods as well as specific objectives identified in Hatchery Genetic Management Plans (HGMPs) adopted for each program. Thus, generic criteria for evaluating hatchery performance are not included herein. HGMPs are developed and revised based on ESA consultations for the operation of specific programs. Reference values for evaluation of reductions in hatchery impacts to each wild population are also identified by the Recovery Plan consistent with the recovery priority of each population.

Sampling and Analytical Design

The hatchery effectiveness sampling design incorporates the following sampling and analytical design elements:

1. Systematic annual sampling of hatchery contributions to natural populations of every significant salmon and steelhead population targeted for protection or improvement to moderate or higher levels of viability (see biological status monitoring).
2. Systematic annual sampling of broodstock and production information in every hatchery program.
3. Fishery sampling programs adequate to estimate the contribution each hatchery program to the harvest (see fishery action effectiveness monitoring).

4. Applied research and analysis to evaluate critical assumptions, improve estimate precision, and refine assessment method and tools (see uncertainty and validation research).

Methods: Hatchery monitoring activities include a number of common elements:

Escapement monitoring is conducted to collect random samples of spawning escapements for hatchery marks or tags. This information is needed to estimate the proportion of hatchery fish in natural spawning populations, a critical piece of hatchery action effectiveness monitoring.

Broodstock sampling includes detailed count data on fish returning to hatchery collection facilities and also typically involve regular and systematic subsampling of the hatchery return for biological data.

Production inventory involves collecting detailed count data on numbers, sizes and marks of fish released and as well as a variety of other production statistics (egg take).

Fishery sampling provides information of hatchery contributions which is a critical component of evaluations of the hatchery benefits associated with risks to listed wild populations.

Index stock marks and tags of hatchery fish are used to distinguish naturally-spawning hatchery-origin fish and to identify stock composition in mixed-stock commercial and sport fisheries in the ocean and Columbia River mainstem.

Run reconstructions are detailed analyses of fish numbers by stock or population based on estimates of harvest and escapement. They involve summary and synthesis of all of the information described above. This information is used for a wide variety of hatchery evaluation, fishery management, and biological status assessment purposes.

Program targets: This Plan identifies the following representative sampling program targets as a starting point for further consideration and discussion by the fishery management programs:

- Estimation precision of hatchery origin spawners for each primary and contributing population of not less than an absolute impact of ± 5% with 80% confidence.
- Estimation precision for hatchery production numbers of ± 10% with 80% confidence
- Minimum of 20% mark sample rate of the harvest in significant fisheries to estimate stock composition (this is the current target rate).

Implementation Actions

M.M33. Maintain current monitoring programs for performance and practice of every hatchery.

Explanation: Current hatchery monitoring programs collect extensive information on production and returns. This information is used to guide and optimize hatchery operations. This information also provides a sound basis for continuing evaluations of the effectiveness of hatchery actions relative to objective benefits of each program.

M.M34. Implement additional biological monitoring of adult escapements of all species in order to accurately assess levels of hatchery contribution to natural production.

Explanation: Information on hatchery fractions in natural populations is widely collected but is incomplete, particularly for natural populations of coho. The accuracy of current hatchery impact assessments is constrained by the quality of the available escapement data. In part this is related to historic difficulties in distinguishing hatchery and wild fish. The advent of 100% adipose marking of hatchery fish is expected to greatly facilitate assessment of the proportion of hatchery origin spawners.

M.M35. Develop and implement a comprehensive regular assessment and report of hatchery impact, performance, and practice for all lower Columbia hatchery programs for use in periodic recovery action effectiveness assessments.

Explanation: Current hatchery information is collected by all programs and maintained by the respective operating agency (WDFW, ODFW, USFWS, Tribes). Various reporting protocols are followed by the various parties but regular comprehensive summaries that address the evaluation needs relative to ESA and recovery Plan implementation are not available. NMFS currently completes periodic status assessment reviews that would include assessments of both biological status and threat factors including hatcheries.

M.M36. Implement collaborative research to resolve critical uncertainties regarding hatchery-wild interactions to guide assessments of hatchery effects. (See Research)

Explanation: Hatchery risks and benefits remain a source of continuing controversy with significant uncertainty in whether significant production hatchery influences are consistent with salmon recovery and if conservation hatchery programs may be an effective tool for recovery in some circumstances. Further research is needed to clarify the nature and magnitude of effects and to guide development of appropriate remedies.

9.5.5. Ecological Interactions

Objectives

Ecological interactions refer to the relationships of salmon and steelhead with other elements of the ecosystem. Limiting factors include interactions with non-native species, effects of salmon on system productivity (e.g. nutrient cycling), and native predators of salmon. Each of these factors can be exacerbated by human activities either by direct actions or indirect effects of habitat alteration. Ecological action effectiveness monitoring is intended to determine if current management activities are adequate to address current or developing threats involving new species invasions and potentially manageable predation. Several significant ecological elements are subject to detailed monitoring programs already in place and this chapter briefly summarizes those efforts and refers to the detailed plans for further information.

Strategy

M.S57. Complete comprehensive assessments of ecological interaction action effectiveness at 6-year intervals for the purpose of evaluating Recovery Plan progress.

Explanation: A 6-year assessment interval is identified by the Recovery Plan for the effectiveness of actions relative to baseline conditions and criteria. The assessment may involve annual collection and compilation of data and ongoing adaptive management based on results. The 6-year assessment is simply a formal checkpoint for evaluating progress and net effects in all areas.

M.S58. Evaluate effectiveness of actions to address ecological interactions involving non-native species introductions and predation effects that currently limit or could grow to limit the viability of listed lower Columbia River populations.

Explanation: The Recovery Plan identifies significant actions for the benefit of listed populations involving these categories.

M.S59. Implement a periodic systematic monitoring program for aquatic nonindigenous species of plants, invertebrates, and fishes in the Columbia River mainstem and estuary.

Explanation: Recovery Plan measures include regulatory, control and education measures for the prevention of exotic species invasions. Effective treatment of this threat will involve early detection of invasion. Without a systematic sampling program involving both periodic surveys in at risk areas and adaptive sampling to response to newly-identified problems, emerging problems may not be recognized in time to be effectively addressed. This Plan does not envision a large scale intensive statistical sampling program for all elements of the ecosystem owing to the expense and limited direct benefit of such an effort to salmon recovery. Rather, it envisions a surgical and focused systematic effort aimed at identifying emerging threats. Significant problems may then be candidates for more focused monitoring or research efforts specific to the nature of the particular problem.

M.S60. Monitor the status of existing introduced species, including shad, based on current information and identify appropriate refinements in critical uncertainty research regarding the potential significance of this threat.

Explanation: Current fish sampling programs provide periodic information assumed to suffice for identifying significant changes that could alter the significance of existing threats. For instance, ladder counts of American shad at Columbia River mainstem dams provide extensive annual data on numbers and distribution throughout the system. Similarly, systematic angler surveys provide information on the occurrence of introduced sport fish species in the catch. The significance of a number of these potential threats is unclear and has been identified as a critical uncertainty that warrants future research. Additional monitoring needs in this area may be identified as a result of additional research.

M.S61. Conduct intensive annual monitoring and evaluation of the effectiveness of measures to manage predation in the Columbia River mainstem and estuary by northern pikeminnow, marine mammals and piscivorous birds.

Explanation: This includes the effectiveness of measures to discourage concentrated predation by pinnipeds in areas of salmon vulnerability downstream from Bonneville Dam, reduce predation by northern pikeminnow by exploitation in the sport reward fishery, and to redistribute Caspian Terns and other bird species from concentrated nesting areas of the estuary where predation on juvenile salmonids is significant. Note that assessments of the significance and trends of these factors are addressed by dedicated research projects identified in that section of this Plan.

Indicators

Ecological indicators are identified for monitoring of non-native species and predation (Table 9-19). The examples below include metrics currently in use by existing monitoring and evaluation programs for aquatic nonindigenous species (Sytsma et al. 2004), avian predators (Collis et al. 2006), pikeminnow predators (Porter 2006), and pinnipeds (Stansell 2004; Wright et al. 2007).

Table 9-19. Attributes, metrics, and example statistics for use as indicators of ecological interactions.

Category	Focus	Attribute	Example
Non-native species	Invasive exotics	Occurrence	Presence/absence, density or distribution by species
	Shad	Numbers	Daily ladder counts in Columbia mainstem dams
Predators	Avian (Terns & cormorants)	Abundance	Numbers or index counts of nests & nesting adults
		Productivity	Nesting success/fledge rates, rate of population change
		Distribution	Nesting distribution
		Diet composition	% salmonids
		Predation rates	Minimum estimates based on PIT tag recoveries
	Fish (pikeminnow)	Angler participation	Numbers of sport reward participants
		Harvest	Number of pikeminnow harvested by sport reward anglers
		Exploitation rate	Proportion of population harvested annual by anglers
		Size & age structure	% of pikeminnow tagged and harvested by size over time
	Pinnipeds (seals & sea lions)	Abundance	Index numbers / observation frequency
		Distribution	Relative abundance near Bonneville & downstream
		Diet	Species composition by time and area
		Predation rate	Number of salmonids eaten near Bonneville Dam relative to dam count

Monitoring criteria are program specific and based on changes relative to historical base periods as well as specific objectives identified in related action plans.

Sampling and Analytical Design

The ecological effectiveness sampling design incorporates the following sampling and analytical design elements:

1. A combination of systematic periodic and opportunistic sampling for invasive plants, invertebrates, and fishes at index sites in the estuary and mainstem.
2. Intensive systematic annual sampling of avian predators and predation in the estuary.
3. Intensive systematic annual sampling of the northern pikeminnow population and sport reward fishery for pikeminnow in the lower Columbia mainstem and estuary.
4. Systematic annual sampling of pinniped numbers and predation.

Applied research and analysis to evaluate critical assumptions, improve estimate precision, and refine assessment method and tools (see uncertainty and validation research).

Methods employed for current action effectiveness monitoring programs related to ecological factors are summarized below.

Aquatic Nonindigenous Species: A comprehensive literature review and field survey of exotic species in the lower Columbia River was completed in 2001-2004 (Sytsma et al. 2004). This survey describes baseline conditions and establishes effective protocols for any future monitoring efforts. A variety of sampling projects have been conducted prior to 2004 but a systematic periodic sampling program has not been established.

Avian predation has been systematically monitored in the Columbia River estuary since 1997 to: 1) evaluate the effectiveness of efforts to reduce impacts on juvenile salmonids by relocating nesting colonies of Caspian tern, 2) assess potential management options to reduce predation by double-crested cormorant, and 3) monitor colonies of other piscivorous waterbirds (Collis et al. 2007). Terns and cormorants have been identified as a significant mortality factor on juvenile salmonid migrants. Efforts are underway to reduce tern predation by relocating nesting colonies to estuary islands closer to the ocean where alternative food sources result in less salmonid mortality. The effectiveness of this action is being evaluated by monitoring the abundance, distribution, productivity and diet of nesting colonies. Similar actions are being contemplated for cormorants based on results from the ongoing research and monitoring program.

Pikeminnow predation: Large-sized northern pikeminnow are significant predators on juvenile salmonids. A northern pikeminnow management program has been underway in the Columbia River mainstem since 1990 (Porter 2006) to reduce survival to large sizes of pikeminnow that account for the majority of the predation losses. The effectiveness of this program is based on trends in angler participation, catch rate, harvest, annual exploitation rates, and size structure of the predator population. Angler effort, harvest and biological information is collected at participant registration stations. A sample of pikeminnow are caught, marked, and released prior to each fishing season in order to estimate exploitation rates from tag recoveries by anglers. Biological data includes size and age (estimated from bony structures).

Marine mammal monitoring efforts in the lower Columbia mainstem and estuary have been implemented and expanded in recent years in response to growing numbers of California sea lions, Steller sea lions, and harbor seals throughout the lower river and increasing seasonal concentrations of sea lions and observations of predation in the tailrace of Bonneville Dam (NOAA 2007). Monitoring efforts include systematic observations of pinniped numbers and salmonids eaten by pinnipeds in the Bonneville Dam tailrace. Beginning in 2005, a hazing program was implemented to deter predation on vulnerable salmon and steelhead in the dam tailrace (Wright et al. 2007).

Implementation Measures

M.M37. Monitor occurrences of new exotic aquatic fishes, invertebrates or plants based on a dedicated sampling program in indicator sites and incidental observations during other biological status monitoring, anecdotal reports, and follow-up sampling where appropriate.

Explanation: The objective of this activity is to proactively identify emerging threats while there is still a possibility of containment. This will involve development of a program that does not currently exist.

M.M38. Continue to monitor abundance of American shad based on Bonneville Dam counts.

Explanation: Dam counts continue to provide an inventory of status and trends in shad abundance and will identify any significant changes in numbers or population dynamics. They will provide a direct indicator of the response to any shad management actions that might be contemplated based on results of research on the significance of any interaction with salmonids.

M.M39. Monitor annual angler participation, harvest, and exploitation rate in northern pikeminnow management program in Columbia River mainstem.

Explanation: Continued monitoring is needed to determine whether program is achieving desired 10-20% annual exploitation rates intended to reduce pikeminnow predation on juvenile salmonids by 50%. In involves monitoring of anglers registered, numbers and sizes of fish caught, and the annual percentage of tagged fish caught.

M.M40. Conduct periodic censuses of the abundance, distribution, and diet of avian predator including Caspian terns and Cormorants.

Explanation: This monitoring is needed to determine if management measures limit avian predator numbers and distribution achieve the desired effects.

M.M41. Conduct periodic censuses of the abundance, distribution, and diet of marine mammals throughout the lower Columbia River mainstem and near Bonneville Dam and evaluate response to hazing, exclusion, and other management measures as implement.

Explanation: Monitoring of marine mammal status and behavior will determine the trend in this increasing mortality factor as well as the effectiveness of management measures.

9.5.6. Mainstem/Estuary

Mainstem/Estuary action effectiveness monitoring is intended to identify trends and effects of protection, restoration, and management actions affecting habitat conditions critical to salmon migration and rearing. Estuary and lower Columbia mainstem habitats play an important but poorly understood role in the anadromous fish life cycle. Large scale changes in river flow, water circulation, sediment transport, and floodplain and wetland destruction or isolation have altered habitat conditions and processes important to migratory and resident fish and wildlife. Hydro flow regulation, channel alternations, and floodplain development and diking have all contributed to these habitat changes. Estuary conditions and actions affect all salmon ESUs in the Columbia River basin and are treated in a comprehensive estuary recovery plan module (NOAA 2006) and a dedicated research, monitoring, and evaluation program. The Estuary MR&E program identified by Johnson et al. (2006) meets the status monitoring, action effectiveness monitoring, and uncertainties research needs of the Washington Lower Columbia Recovery Plan. Key elements are summarized below and the reader is referred to the regional plan for further detail.

Objectives

Measure the effects of individual habitat restoration actions at project sites relative to reference sites and evaluate post-restoration trajectories based on project-specific goals and objectives (termed effectiveness monitoring in the estuary plan).

Estimate the collective effects of habitat conservation and restoration projects in terms of cause-and-effect relationships between ecosystem controlling factors, structures, and processes affecting salmon habitat and performance (termed validation monitoring in the estuary plan).

Indicators

The framework organizing action effectiveness research is built on an estuary conceptual that relates stressors, controlling factors, ecosystem structures, ecosystem processes and ecosystem functions. Monitoring indicators corresponding to these factors are identified in the following table (Table 9-20).

Table 9-20. Indicators identified for application to estuary action effectiveness monitoring.

Category	Monitored indicators
Flow regulation	Water discharge
Passage/Flow Barriers	Passage barriers
Invasive Species	Species composition, abundance, spatial distribution
Watershed conditions	Discharge, water velocity/temp., sediment budget, large woody debris
Geology sediments	Accretion rates, contaminants, Redox potential, soil composition
Hydrodynamics	Ground water level, surface water elevation, water velocity
Bathymetry/Topography	Bathymetry, floodplain topography
Water quality	Dissolved oxygen, nutrients, pH, salinity
Temperature	Temperature
Landscape features	Ecosystem structures map, area restored, large woody debris
Tidal Channel Morphology	Edge/Density/Sinuosity
Vegetation cover	Percent cover by species
Food web	Foraging success, predation index, prey availability
Salmonid preference	Abundance, age/size structure, distribution, growth rate, migration pathways, residence time, species composition

Implementation Measures

The estuary research, monitoring, and evaluation program identifies two measures specific to action effectiveness research/monitoring in addition to a suite of measures for estuary status and trend monitoring, estuary uncertainties research, and estuary implementation compliance monitoring.

Estuary action effectiveness measures are:

M.M42. New and ongoing estuary projects should consider applying monitoring protocols in the plan.

M.M43. Develop an analytical model to quantify and evaluate the cumulative effects of multiple hydrologic reconnection restoration projects.

9.6. Uncertainty and Validation Research

Uncertainty and validation research targets specific issues that constrain effective Recovery and Watershed Plan implementation. Research includes evaluations of cause and effect relationships between fish and limiting factors, actions that address specific threats related to limiting factors, and testing of assumptions about population trends, land use trends, and flow and water quality conditions. Incomplete understanding of biological systems and of the human impact upon those systems results in uncertainty about the outcomes of the actions identified in the Recovery and Watershed Plans. These plans support the careful consideration of uncertainty by explicitly identifying assumptions and working hypotheses, incorporating safety factors into recovery scenarios, conducting validation research and studies to explore uncertainty, and adjusting implementation actions when appropriate. Research provides focused information on a variety of questions and often involves some type of intensive sampling program to determine if the initial plan assumptions are valid. Research can be costly, often evolves as a series of questions are answered, and ends when its purposes it met. Research can provide very specific and detailed information on key monitoring subjects, and results are often incorporated into long term monitoring programs in the form of sampling protocols, expansion factors or bias corrections, or estimates of precision and accuracy.

9.6.1. Objectives

The objective of uncertainty and validation research is to characterize unknown ecological relationships and critically examine cause and effect relationships between fish, limiting factors/threats, watershed processes, and actions that address specific factors/threats. These critical uncertainties constrain our ability to identify or evaluate the effects of specific actions.

9.6.2. Implementation Measures

M.M44. Conduct research of salmonid status and population viability to evaluate critical assumptions, reduce uncertainty, and guide Recovery Plan implementation.

Explanation: Research questions related to salmonid status and population viability aim to validate recovery goals and evaluate other assumptions made regarding population viability and risk. In addition, the program should consider ways to improve understanding of ocean conditions and climatic impacts on salmon population viability.

M.M45. Conduct research on stream habitat and watershed health to evaluate critical assumptions, reduce uncertainty, and guide Recovery Plan implementation.

Explanation: Research questions related to stream habitat and watershed health should aim to validate assumptions made regarding impacts on salmon populations, including a feedback loop to inform EDT analysis and prioritization of habitat actions. Other research needs include better understanding of foodweb relationships, impacts of reduced instream flow and changes in water quality.

M.M46. Conduct research on hydropower operations and impacts to evaluate critical assumptions, reduce uncertainty, and guide Recovery Plan implementation.

Explanation: Research questions related to hydropower operations should aim to validate assumptions made regarding impacts of hydropower operations on salmonid status and viability. Efforts should investigate relationships between changes in flow regime and habitat conditions, as well as reintroduction measures above hydropower systems.

M.M47. Conduct research on fisheries impacts to evaluate critical assumptions, reduce uncertainty, and guide Recovery Plan implementation.

Explanation: Research questions related to fisheries should aim to validate assumptions made regarding impacts of fisheries on salmonid status and viability as well as evaluate potential alternative methods and fisheries management measures. Efforts might include evaluating innovative techniques (gear, time and area management), incidental mortality, and appropriateness of indicator stocks.

M.M48. Conduct research on hatchery impacts to evaluate critical assumptions, reduce uncertainty, and guide Recovery Plan implementation.

Explanation: Research questions related to hatcheries should aim to validate assumptions made regarding impacts of hatcheries on salmonid status and viability. Efforts might include improving understanding of interactions between hatchery and wild fish, including potential predation, competition, disease concerns, and negative effects on productivity. In addition, this measure should address evaluating appropriate source stocks for reintroduction and supplementation programs.

M.M49. Conduct research on ecological interactions to evaluate critical assumptions, reduce uncertainty, and guide Recovery Plan implementation.

Explanation: Research questions related to ecological interactions should aim to validate assumptions made regarding impacts of various interactions on salmonid status and viability. Efforts might include improving understanding of impacts of native and non-native species on salmon populations, as well as impacts of altered nutrient cycling.

M.M50. Conduct research on mainstem and estuary conditions to evaluate critical assumptions, reduce uncertainty, and guide Recovery Plan implementation.

Explanation: Research questions related to mainstem and estuary conditions should aim to validate assumptions made regarding mainstem and estuary habitat and its impact on salmonid status and viability. Efforts should include improving the understanding of the role of the estuary for various life history strategies, improving understanding of distribution and timing of salmonid use of the estuary, restoration method validation, impacts of the altered hydrologic regime on habitat conditions, and impacts of altered water quality.

9.6.3. Research Needs

Research needs were identified by a review of the literature and plans related to salmon status and recovery. Sources are referenced where a research need was specifically identified in a particular plan or report. Needs are listed by category.

Salmonid Status and Population Viability

1. Validate recovery goals and preliminary estimates of persistence probabilities based on life cycle analyses and long term data sets.
2. Empirically evaluate assumptions regarding the significance of Allee effects and depensation at small population sizes associated with quasi-extinction risk estimates.
3. Identify relationships and co-variation between marine and freshwater survival and productivity patterns for salmon.
4. Identify long term trends in global factors affecting salmon production including climate and ocean conditions.

5. Adapt and apply new genetic stock identification methods to population status assessments.
6. Climate change: How will different scenarios of climate change affect ecosystem dynamics, habitat characteristics, and ultimately population condition across all life stages? (NOAA 2007)
7. Natural cycles: How can the effects of poor ocean conditions related to the Pacific Decadal Oscillation (PDO) or El Niño Southern Oscillation (ENSO) be quantified and managed for in the future? (NOAA 2007)

Stream Habitat and Watershed Health

1. Apply monitoring feedback loops to inform EDT analysis and improve estimates of fish productivity and capacity based on habitat and fish productivity data.
2. Determine relative short term and long term tradeoffs in the benefits of site-specific and process based actions.
3. What are the quantitative relationships between tributary in-stream flow and juvenile rearing and out-migrant survival? (NOAA 2007)
4. What is the uncertainty associated with various models (EDT, Shiraz) used for evaluating limiting factors? (NOAA 2007)
5. What is the relationship of habitat type and quality to a quantitative fish productivity level? (NOAA 2007)
6. Which habitats are most important in determining juvenile and adult migration patterns and potential for increases in viability? (NOAA 2007)
7. How are genotypic variations related to habitat use? (NOAA 2007)
8. How can the use of ongoing PIT tagging and other tagging and marking studies and data be used to determine origin and estuarine habitat use patterns of different stocks? (NOAA 2007)
9. How can action effectiveness be linked to changes in population and ESU status and viability (multiple scales)? (NOAA 2007)
10. What is the effect of toxic contaminants on salmonid fitness and survival in the Columbia River estuary and ocean? (NOAA 2007)
11. What effect do invasive species have on salmon, and how can those effects be controlled? (NOAA 2007)
12. What are the relationships between micro- and macro-detrital inputs, transport, and end-points? (NOAA 2007)
13. How have historical changes in estuary morphology and hydrology affected habitat availability and ecosystem processes? (NOAA 2007)
14. What is the relationship between future ground water supply development and instream flows? (WRIA 25/26 and 27/28 Detailed Implementation Plans, Table 12)
15. What are the relationships between forest harvest rates, maturation of forests, and instream flows and water quality? (WRIA 25/26 and 27/28 Detailed Implementation Plans, Table 12)
16. What are the relationships between trends in agricultural lands, road densities, urban and rural development, and instream flows and water quality? (WRIA 25/26 and 27/28 Detailed Implementation Plans, Table 12)
17. How do observed trends in urban, rural, and industrial sectors relate to water demand predictions? (WRIA 25/26 and 27/28 Detailed Implementation Plans, Table 12)
18. How has development of groundwater supplies impacted instream flows in priority streams? (WRIA 25/26 and 27/28 Detailed Implementation Plans, Table 12)

19. Based on instream flow monitoring, how have instream flows responded to target flow, programmatic, and other actions designed to improve the flow regime? (WRIA 25/26 and 27/28 Detailed Implementation Plans, Table 12)
20. How do observed instream flow responses relate to modeled responses? (WRIA 25/26 and 27/28 Detailed Implementation Plans, Table 12)

Hydropower

1. Determine feasibility of re-establishing self-sustaining anadromous populations upstream of hydropower facilities in the Lewis, Cowlitz and Tilton systems.
2. Determine effects of flow on habitat in the estuary & lower mainstem.
3. How do uncertainties in estimates of delayed mortality affect conclusions regarding population status and viability? (all ESUs) (NOAA 2007)
4. Pre-spawning mortality (all ESUs)? (NOAA 2007)

Fisheries

1. Evaluate innovative techniques (e.g., terminal fisheries and tangle nets) to improve access to harvestable stocks and reduce undesirable direct and indirect impacts to wild populations.
2. Evaluate appropriateness of stocks used in weak stock management.
3. How do uncertainties in exploitation rate estimates affect evaluations of the effects of harvest on VSP and population status? (NOAA 2007)
4. How does uncertainty surrounding the use of indicator (hatchery) stocks to infer fishery mortality on natural-origin fish affect conclusions regarding population status and viability? (NOAA 2007)
5. Are there gaps in quantitative data available for analyses of fishery impacts at relevant units (e.g., by population, MPG, or ESU) and if so, how does this affect the certainty of concluding the status of the population and ESU? (NOAA 2007)
6. How have distributions (instead of point estimates) of parameter estimates been used to improve our understanding of how harvest effects impact populations, and how our management is working to reduce negative impacts? (NOAA 2007)
7. Is the accuracy of estimates of incidental mortality related to bycatch in non-target fisheries and from specific gear types in catch and release fisheries known, and how does that affect our management? (NOAA 2007)

Hatcheries

1. Develop a strategy for assessing the interactions between hatchery and wild fish.
2. Determine relative performance of hatchery and wild fish in wild in relation to broodstock divergence and hatchery practices.
3. Experimentally determine net effects of positive and negative hatchery effects on wild populations.
4. Experimentally evaluate the efficacy of hatchery program integration, segregation, and supplementation.
5. Determine hatchery effects on disease and predation on wild fish.
6. How do uncertainties in estimates of reproductive success of hatchery and natural-origin fish spawning affect evaluations of the effect of hatchery practices on population status and viability? (NOAA 2007)

7. How do surplus hatchery-origin fish on the spawning grounds affect the productivity and genetic integrity of the natural population? (NOAA 2007)
8. What are the short- and long-term effects of hatchery fish intervention on the status of viability attributes of natural-origin populations within the sub-basins as well as within the migratory corridors? (NOAA 2007)
9. Is early spawn time of hatchery steelhead stocks a successful management tool for segregating hatchery and natural fish? (NOAA 2007)
10. How effective are fish culture techniques, such as acclimation, in segregating hatchery fish from natural populations? (NOAA 2007)
11. What is the significance of ecological interaction between hatchery and wild fish (including predation by steelhead and coho on chum salmon for instance)?

Ecological Interactions

1. Experimentally evaluate nutrient enrichment benefits and risks using fish from hatcheries or suitable analogs.
2. Determine the interactions and effects of shad on salmonids.
3. Is predation by marine mammals a significant factor limiting the status of some populations, and if so, how can it be managed? (NOAA 2007)
4. What is the rate of infection of disease in the natural population? (NOAA 2007)
5. How is the rate of transmission of disease affected by anthropogenic impacts on physical and biological processes? (NOAA 2007)

Mainstem/Estuary

A monitoring, research, and evaluation (MR&E) plan for the Columbia River estuary and plume was recently developed (Johnson et al. 2003) for the purpose of fulfilling certain requirements of Reasonable and Prudent Alternatives of the 2000 Biological Opinion on the Operation of the Federal Columbia River Power System (NMFS 2000). Research needs were identified in that process at a 2003 workshop. The following research needs were identified at that workshop:

1. Move from a collection of available conceptual frameworks to an integrative implementation framework, where we combine what we have learned in the various conceptual frameworks to identify the most important areas for restoration actions, and what are the most likely avenues for success.
2. Implement selected restoration projects as experiments, so that we can learn as we go.
3. Implement pre- and post-restoration project monitoring programs, to increase the learning.
4. "Mining" of existing, underutilized data to minimize the risk of collecting redundant or unnecessary data, and to compare with current and projected conditions.
5. Make more use of ongoing PIT tagging and other tagging and marking studies and data to determine origin and estuarine habitat use patterns of different stocks.
6. Collect additional shallow water bathymetry data for refining the hydrodynamic modeling, and identifying/evaluating potential opportunities for specific restoration projects.
7. Determine operational and hydrologic constraints for the FCRPS, so that we have a better understanding of feasibility and effectiveness of modifying operations.

8. Identify and implement off-site mitigation projects in Columbia River estuary tributaries.
9. Establish a data and information sharing network so that all researchers have ready and up-to-date access.
10. Increased genetic research to identify genotypic variations in habitat use.
11. Understanding salmonid estuarine ecology, including food web dynamics.
12. Understanding sediment transport and deposition processes in the estuary.
13. Understanding juvenile and adult migration patterns.
14. Identifying restoration approaches for wetlands and developing means for predicting their future state after project implementation.
15. Improve our understanding of the linkages between physical and biological processes to the point that we can predict changes in survival and production in response to selected restoration measures.
16. Improve our understanding of the effect of toxic contaminants on salmonid fitness and survival in the CRE and ocean.
17. Improve our understanding of the effect of invasive species on restoration projects and salmon and of the feasibility to eradicate or control them.
18. Improve our understanding of the role between micro- and macro-detrital inputs, transport, and end-points.
19. Improve our understanding of the biological meaning and significance of the Estuarine Turbidity Maximum relative to restoration actions.
20. Identify end-points where FCRPS BO RPA action items are individually and collectively considered to be satisfied, so that the regulatory impetus is withdrawn.
21. Increase our understanding of how historical changes in the estuary morphology and hydrology have affected habitat availability and processes.
22. What are the effects of flow on habitat in the estuary and lower mainstem? (NOAA 2007)

9.7. Data & Reporting

Implementation Measures

M.M51. Conduct a data management needs assessment and use it to develop a data management plan.

Explanation: Additional assessments are needed to coordinate with complementary data management activities throughout the region. For example, the Pacific Northwest Aquatic Monitoring Partnership (PNAMP) is developing a forum for coordinating state, federal, and tribal aquatic habitat and salmonid monitoring programs. Although it is still under development with uncertain funding for the future, it will likely compliment the needs of the lower Columbia MR&E program and thus warrant continued attention.

M.M52. Maintain consistent regionally-standardized datasets and archive in regional data storage and management facilities (e.g., Pacific State Marine Fisheries Commission StreamNet, Washington Department of Fish and Wildlife SSHIAP, NMFS's biological datasets).

Explanation: Existing infrastructures will be used to archive relevant data and metadata generated through monitoring and research activities. Data will be compiled and subject to rigorous quality assurance/quality control protocols by the collecting agency. Collecting agencies will be responsible for maintaining databases and providing access upon request. Information will be also distributed to multiple archives to maximize accessibility.

M.M53. Produce and distribute regular progress and completion reports for monitoring and research activities.

Explanation: Regular reporting is essential in making new information available to technical/scientific staff, decision-makers, stakeholders, and the public. It is likely that much of the routine reporting will be conducted electronically.

M.M54. Closely coordinate Washington lower Columbia River monitoring, research, and evaluation efforts with similar efforts throughout the basin, including prioritization of activities and standardization of data methods.

Explanation: Other MR&E efforts are underway at local and regional scales across the Pacific Northwest. Coordination of Washington lower Columbia River efforts will provide synergistic benefits. For instance, many critical uncertainties are common among different areas and need not be addressed in each area. Standardization of data methods will greatly enhance comparative and interpretative power of monitoring and research activities.