Columbia Basin Tributary Habitat Improvement: A Framework for Research, Monitoring and Evaluation

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Bonneville Power Administration

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Executive Summary

Protection of Columbia River salmon and steelhead forms the heart of the largest ecosystem recovery effort in the nation, if not the world. Its foundation involves improvements at federal dams on the Columbia and Snake to assure that 96 percent of juvenile spring migrating fish and 93 percent of summer migrating fish pass each dam safely. Building on that foundation are hundreds of habitat protection and enhancement projects across a four-state region that further mitigate the impacts of the dams by improving spawning, rearing and migrating conditions for fish. All deliver on the commitments of the Biological Opinion for the Federal Columbia River Power System and the Columbia Basin Fish and Wildlife Program developed by the Northwest Power and Conservation Council.

A crucial element of the habitat improvement work throughout the tributaries of the Columbia and Snake rivers is an aggressive and well-organized framework for research, monitoring and evaluation, also known as RM&E. At its simplest, RM&E documents whether habitat projects, many funded by regional electric ratepayers, are completed as expected and deliver on their ecological goals. However, RM&E and associated analysis also go far beyond that to help identify the most effective types of restoration, improve its cost effectiveness and improve models that guide managers as they decide on future habitat improvement projects. This collection and analysis of information is vital to the BiOp's adaptive management mandate, which capitalizes on the latest science and research to inform management decisions and, ultimately, improve the effectiveness of actions on behalf of fish.

Continued research and monitoring is also essential to document the important relationship between habitat quality and fish survival. That relationship validates the BiOp's use of habitat improvements far from the federal dams to mitigate for the impacts of the dams on fish.

The strength of the RM&E program depends on the sum of its parts and how effectively they complement each other, which has been a focus of improvement. The RM&E program began under the 2000 FCRPS BiOp and further evolved through regional science reviews and pilot projects under a 2003 plan, subsequent BiOp remands and monitoring programs. This framework is an important step in describing its current structure and defining the components of the RM&E program for tributary habitat improvements, the benefits expected from those components and how the information will be analyzed and translated into useful information for managers. It also describes how the agencies carrying out the RM&E program are responding to recommendations from the Northwest Power and Conservation Council and the Independent Scientific Review Panel to improve the value of RM&E results. Because electric ratepayers fund RM&E, the agencies have a responsibility to make the most of the information by analyzing and applying the results effectively and making the results public and transparent.

RM&E results from the early years of the BiOp are revealing useful information about the effectiveness of different habitat improvements and demonstrating the connection between habitat restoration improves fish survival. This framework will improve the value of such information by focusing research where it is most needed and translating results into products that will best help decisionmakers and others understand the benefits of tributary habitat improvements for salmon and steelhead.

Acronyms and Abbreviations

AA	Action Agencies
AE	Action Effectiveness
AMIP	Adaptive Management Implementation Plan
AREMP	Aquatic-Riparian Effectiveness Monitoring Program
BiOp	Biological Opinion
BLM	Bureau of Land Management
Reclamation	Bureau of Reclamation
BPA	Bonneville Power Administration
CHaMP	Columbia Habitat Monitoring Program
Corps	U.S. Army Corps of Engineers
Council	Northwest Power and Conservation Council
ESA	Endangered Species Act
ESU	Evolutionarily Significant Unit
FCRPS	Federal Columbia River Power System
HCP	Habitat Conservation Plan
HCW	Habitat Collaboration Workgroup
ISAB	Independent Scientific Advisory Board
ISEMP	Integrated Status and Effectiveness Monitoring Program
ISRP	Independent Scientific Review Panel
MPG	Major Population Group
NMFS	National Marine Fisheries Service
NWFSC	Northwest Fisheries Science Center
OBMEP	Okanogan Basin Monitoring and Evaluation Program
PIBO	Pacfish/Infish Biological Opinion
PUD	Public Utility District
RM&E	Research, Monitoring, and Evaluation
RPA	Reasonable and Prudent Alternative
SPS	Salmonid Population Summary Database
USFS	U.S. Forest Service

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1. Introduction

The effort to protect and rebuild salmon and steelhead populations across the Columbia Basin represents a challenge of enormous magnitude, greatly exceeding most other ecosystem recovery initiatives in size and scale. But the scale of the effort and, in particular, its far-reaching habitat improvement component also presents a tremendous opportunity to learn much more about how restoration benefits fish and how to design, develop and apply habitat improvement actions to do the most good for fish, in the shortest amount of time, across the largest area.

How habitat improvement fits in

Habitat improvement adds to and builds on fundamental improvements at federal dams on the Columbia River and its tributaries designed to provide safe passage for 96 percent of spring migrating juvenile fish and 93 percent of summer migrating fish at each dam. The habitat actions further mitigate the impacts of the dams by boosting fish survival elsewhere. The successes are growing. Since 2005 the U.S. Army Corps of Engineers, Bureau of Reclamation and Bonneville Power Administration (known as the Action Agencies) in partnership with states, tribes, counties and others have reopened or improved accessibility of 1,590 miles of habitat for fish, more than the length of the Columbia and Willamette rivers combined. Fish populations also show improvement on a small and large scale, with more fish in rivers and the average abundance of natural-origin spawning adults increasing in 43 index populations.

Taking full advantage of that opportunity requires a strong Research, Monitoring and Evaluation (RM&E) program to track, study and draw lessons from the hundreds of projects completed and underway across the Columbia Basin. The RM&E program fulfills important obligations under the Columbia Basin Fish and Wildlife Program, which is primarily focused on habitat improvements to help mitigate for impacts of federal hydroelectric dams. It also is a required component of the NOAA Fisheries Biological Opinion for the Federal Columbia River Power System, not only to track progress under the BiOp but also to adaptively improve the value of habitat work by identifying the types of actions that most effectively meet its goals so that managers can focus resources accordingly.

The RM&E program covering habitat improvements in the tributaries of the Columbia River tracks the scope of the habitat improvements themselves. It includes interrelated components designed to answer basic management questions about the progress of individual habitat improvement actions as well as the larger-scale benefits of those actions for fish.

The current breadth of the RM&E program warrants a framework or structure that integrates those components so they build on each other to produce the most complete and useful information for managers. This report outlines the RM&E framework that surrounds and supports habitat improvements in the tributaries of the Columbia River system, describing:

- Each of the main components of the Action Agencies' RM&E program.
- How the components fit together into an integrated whole.
- The results of each RM&E component that will help inform and guide decisionmakers.
- How the RM&E program will become more focused and efficient with time.

Just as habitat improvement is advancing across the Columbia Basin on a scale and intensity rarely if ever attempted elsewhere, the RM&E program seeks to track the resulting progress at a remarkable degree of detail. It goes so far as to seek to document changes as fine as the percentage improvement in survival of juvenile salmon in a single stream. It is in fact a pioneering undertaking that, like the habitat improvement activities themselves, is designed to adapt and improve with the information it collects. This framework should support and promote those improvements so the program becomes more streamlined and focused on those components that best assist decisionmakers.

This framework remains a work in progress, subject to adjustment as research answers some questions and frees up funding and other resources to focus on remaining questions. BPA will continue to work with the Northwest Power and Conservation Council and other regional partners to streamline and focus tributary habitat work to ensure that it remains well coordinated and productive.

Funding for tributary habitat RM&E amounts to more than $20 million annually, with much of it provided by regional electric ratepayers through BPA. It therefore comes with a significant expectation of accountability that the funding will be applied as effectively as possible, will deliver constructive guidance that informs decisionmakers and will become more efficient over time as results reveal the most valuable and productive forms of RM&E. It also comes with an expectation of transparency and accessibility so the region can view and understand the same information.

2. Focus of RM&E: tributary habitat improvements

More than a century of land use practices and development have damaged and degraded tributary habitat across the Columbia River Basin that historically provided important spawning and rearing habitat for salmon and steelhead. Efforts to repair and improve that habitat have become an increasingly prominent part of salmon protection and recovery programs. The Columbia Basin Fish and Wildlife Program advanced habitat improvement as off-site mitigation for the impact of both federal and private dams on the Columbia River system. Biological opinions for the Federal Columbia River Power System further expanded the investment in tributary habitat, with the 2008/10 BiOp requiring improvements that would deliver specific improvements in fish survival.

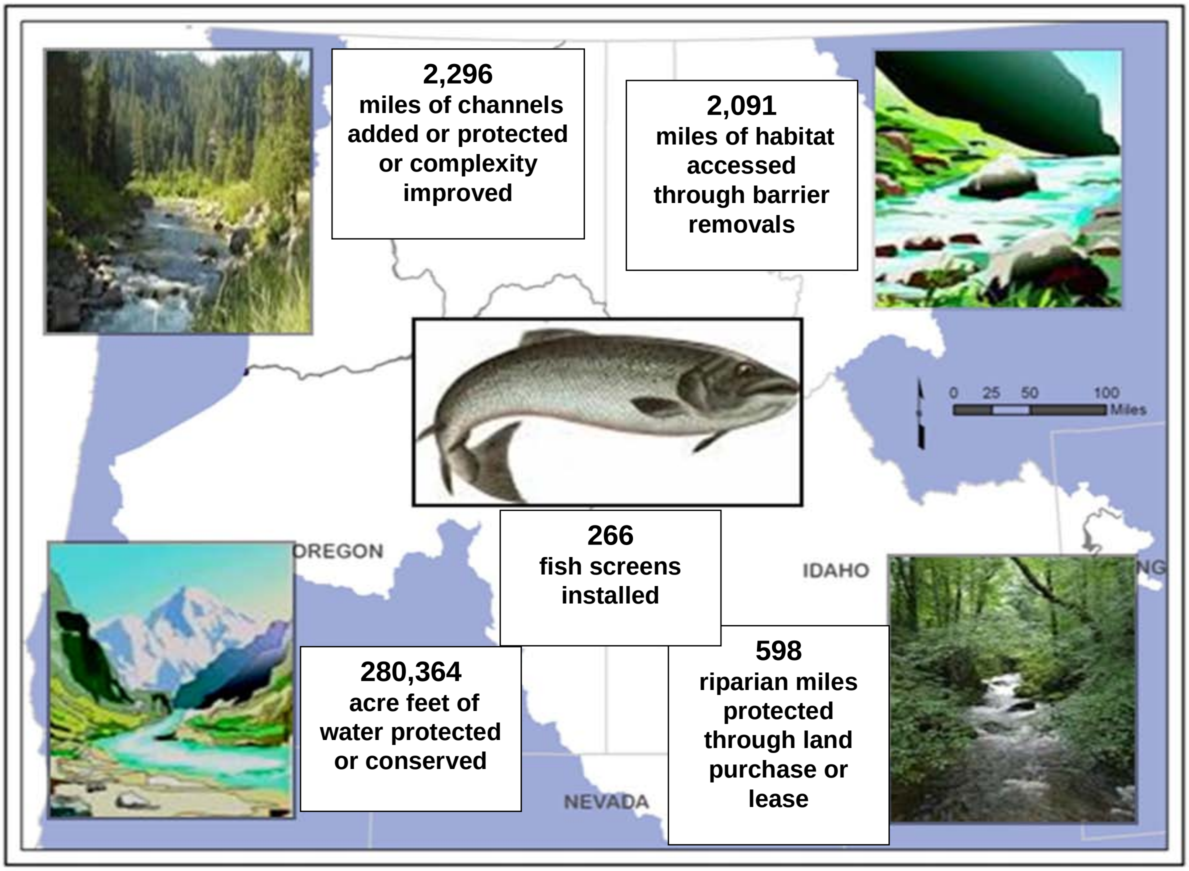


Figure 1. Action Agency funded habitat improvements, 2005-current.

Along with the expanded commitment to tributary improvements came an increased need for research, monitoring and evaluation to document, learn from and tailor the work. Managers must make habitat improvement decisions based on the best available science as to how to achieve the needed survival improvements; RM&E tests those decisions and evaluates the effectiveness of the habitat improvement to help managers make stronger and better informed decisions in the future. The current Tributary Habitat RM&E Program supports the Columbia Basin Fish and Wildlife Program while also specifically fulfilling the *Reasonable and Prudent Alternatives* (RPAs) required of Action Agencies by the 2008/10 FCRPS BiOp and 2010 Adaptive Management Implementation Plan (AMIP) (Table 1) . These tributary Habitat RM&E actions are implemented by federal, state, tribal and other partners and include actions funded under the Columbia Basin Fish Accords.

Table 1. Tributary Habitat RM&E requirements in the 2008/10 FCRPS BiOp and 2010 AMIP

Tributary Habitat RM&E Actions	
RPA Action 56: Status and Trends	**Monitor and Evaluate Tributary Habitat Conditions and Limiting Factors** • Quantify relationships between habitat conditions and fish productivity (Wenatchee, Methow, Entiat, Lemhi, S.F. Salmon, John Day) • Improve models for planning and implementation of habitat projects • Status and trend monitoring in the above basins and key ESA populations
RPA Action 57: Action Effectiveness	**Evaluate the Effectiveness of Tributary Habitat Actions** • Channel complexity and fish productivity in the Entiat Basin • Reduce entrainment and improved fish passage conditions in the Lemhi • Action effectiveness in Bridge Creek of the John Day • Project and watershed level assessments in the Wenatchee, Methow, and John Day basins
RPA Action 73: Implementation and Compliance	**Implementation and Compliance Monitoring** • Monitor the implementation of projects through standard procedures and requirements of contract oversight and management • Maintain habitat project tracking system.
AMIP Section III	**Enhance Research Monitoring and Evaluation** • Enhanced life-cycle monitoring (NOAA) • Additional adult status and trend monitoring • Additional juvenile status and trend monitoring • Additional habitat condition status and trend monitoring • Enhanced intensively monitored watershed (IMW) analysis • Climate change M&E (NOAA)

RM&E results will also inform Expert Panels created under the BiOp to assess the benefits that habitat projects provide for fish. The Expert Panels include biologists and other experts knowledgeable about the conditions of local watersheds. They combine their professional judgment with the best available science to independently examine habitat projects and estimate how much they are likely to change habitat conditions in ways that improve fish survival.

2.1 Refining and focusing RM&E

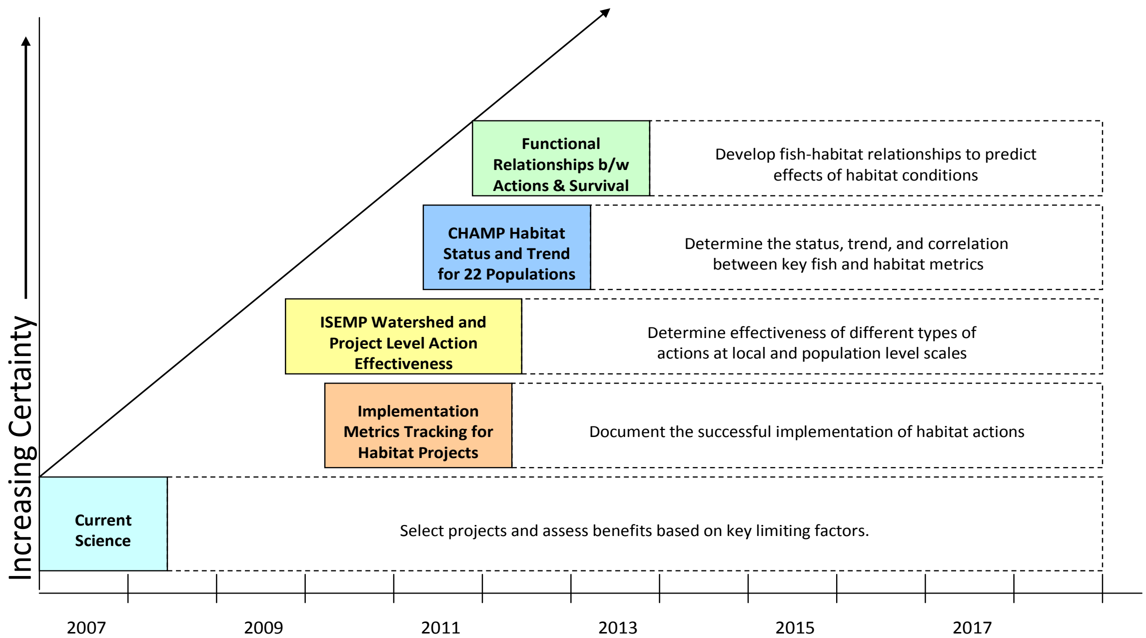
The extraordinary scale and reach of tributary habitat projects across the Columbia Basin warranted a similarly extensive RM&E program to track and learn from the results. The program grew quickly in response to the additional mandates of biological opinions starting with the 2000 FCRPS BiOp and all-H strategy, subsequent regional reviews and pilot projects under a 2003 RM&E plan, BiOp remands from 2004 through 2010 and monitoring programs and strategies. This framework is another step toward providing coordination and structure, but it is not the final step. The Action Agencies expect to annually review the value and utility of RM&E results to identify opportunities for improvement such as more effective sharing or analysis of data or consolidation of monitoring that provides duplicative results.

No matter how ambitious or well funded, no habitat improvement initiative could restore the Columbia Basin to its historical condition. Instead the Action Agencies seek to focus efforts and resources where they will make the most difference for fish. The larger the habitat program, the more important that it follows an informed and strategic approach that weighs the benefits of projects both individually and cumulatively. This is a challenge facing many large ecosystem restoration efforts.

“if we expect to restore populations of fish and other organisms that either migrate through large ecosystems or otherwise depend on large-scale ecosystem connectivity for their survival, we need to be strategic about our restoration investments and consider how many small projects may affect ecosystem function on the catchment scale,” a team of restoration scientists wrote in the journal Environmental Management (Kondolf et al, 2008) of major habitat improvement initiatives. “It took decades to cause the alterations, so it should not be surprising if restoration of highly altered river systems requires a long-term effort. The question becomes how to best allocate the (always limited) available resources strategically to achieve realistic restoration goals.”

The Columbia Basin RM&E program is designed to adapt and adjust over time, as the habitat improvement work will do. As our understanding of fish responses to various habitat protection and improvement actions increases, we expect to concentrate the Tributary Habitat RM&E program on remaining questions and uncertainties central to informed management decisions, consistent with the Council’s categorical review of RM&E. The focus will expand the understanding of fish benefits associated with habitat improvement actions and will improve the cost efficiency of both habitat improvement projects and the RM&E itself. The Council’s draft Monitoring, Evaluation, Research, Reporting and Data Access Framework recommends prioritizing monitoring and research according to the risk and uncertainty of an action, with riskier and less certain actions subject to more intensive monitoring. The approach also gives highest priority to information that can be gathered within a reasonable amount of time and that will strengthen management decisions as recommended in the MERR framework.

Science information improves over time



The building blocks of the RM&E program include complementary layers of research and analysis that will itself become more refined and focused over time to provide more detailed and accurate estimates of survival benefits. The improved estimates, in turn, will better inform the selection of habitat improvement projects.

The tributary RM&E Framework recognizes the unavoidable tradeoffs between the timely decisions necessary to deliver on habitat improvement commitments in the BiOp and the need for science to inform those decisions. The unprecedented scale and scope of tributary habitat improvements in the Columbia Basin means that some projects must proceed even amid some remaining uncertainty. In some cases the only way to build scientific confidence is to implement projects and monitor the results. For some management decisions, scientific certainty may not be necessary, desirable or even possible. For example, fish may be better served by a decision to use funds to protect more habitat rather than using the funds to study the environmental implications of habitat protection in depth.

Even the best available science can carry the inherent uncertainty that comes with natural variability, continuing development and land use changes, climate change and other factors. For instance fish populations show wide natural variations from year to year because of fluctuations in climate, precipitation, ocean conditions and other factors. Such variables can overwhelm or mask changes in fish populations resulting from habitat improvements. In some cases several years of monitoring may be necessary to distinguish habitat-related changes from other factors. In other cases, the benefits of habitat improvements may not be measurable with precision because of the cost, time and effort involved or because the impacts of trapping or tagging enough fish to document the change could offset the original benefits of the habitat treatment. The Action Agencies' goals are to minimize the impact of research on fish by, for instance, minimizing the number of fish, especially wild fish, that are injected with PIT tags for tracking purposes. The result may be that the full benefits of habitat improvements go underestimated despite the best efforts of researchers.

If habitat benefits cannot be measured directly, researchers may use a weight of evidence approach and correlation analysis to document the benefits of habitat protection and improvement projects. A weight of evidence approach combines expert experience, field observations and empirical data in a search for consistent signs of habitat benefits, while correlation analysis searches for relationships between environmental variables and fish health and survival.

Additional data over a longer time period or over a larger area often provides more definitive results and conclusions. Many organizations, including states and tribes, conduct research and monitoring on fish in the Columbia Basin. Where such information is compatible with and adds to data collected through the Action Agencies' RM&E Framework, it will be included in the relevant analyses. Standard and well documented regional monitoring protocols and data management are critical to effectively sharing information to support more robust and cost-effective assessments.

3. Structure of habitat RM&E

Tributary habitat RM&E must answer a series of questions that expand with the scale of the program, from the basic question of whether sponsors completed each individual habitat improvement project as expected to the much broader question of how projects within a watershed contribute to the survival improvements that support recovery of species. To do so, the various types of RM&E are structured in layers of increasing scope, from narrow, project-specific research and monitoring to more far-reaching landscape-level analysis. The advantage of the structure is that the more specific information collected through the more focused research and monitoring feeds into and strengthens the more far-reaching analyses, informing and improving management decisions at all levels.

Type of RM&E	Benefits for managers
Implementation and compliance	• Verifies that projects completed as planned and functioning as intended.
Habitat project action effectiveness	• Determines if project is meeting its environmental/biological objectives. • If not, why not? Answers can help make future projects more effective. • If so, helps identify actions that best address specific limiting factors. • Improves cost effectiveness of actions by tailoring them to conditions.
Multiple project action effectiveness	• Reveals collective benefits of habitat projects on a broader scale. • Documents relationships between habitat condition and fish survival. • Strengthens models that help estimate benefits of habitat actions. • Helps managers choose effective combinations of future actions.
Species level action effectiveness analysis	• Examines relationship between numbers of habitat actions and fish survival at a species scale. • Helps establish whether habitat restoration and protection moves species/ESU toward recovery.
Status and trends monitoring	• Reveals trends in fish numbers and habitat quality. Are they positive? • Identifies impairments and factors limiting fish populations. • Helps distinguish trends caused by natural factors such as climate or ocean conditions from trends caused by habitat degradation that can be addressed through enhancement actions. • Illuminates relationships between habitat quality and fish survival.

Four main levels of tributary habitat RM&E each examine important elements of restoration:

Implementation and compliance monitoring verifies that habitat actions have been completed and are still in place and functioning as intended. For example, if a culvert was replaced in 2009, compliance monitoring would show whether the new culvert was still effectively passing fish in 2012. This basic monitoring also includes limited, relatively short-term observations of how fish responded to the project through increased spawning or occupancy of habitat.

Action effectiveness monitoring occurs at two different spatial scales:

- ***Project level action effectiveness monitoring*** tracks the effects of individual habitat actions such as culvert replacements or riparian planting at the local scale. Results from similar projects such as barrier removals can be combined to assess the benefits of that kind of action.

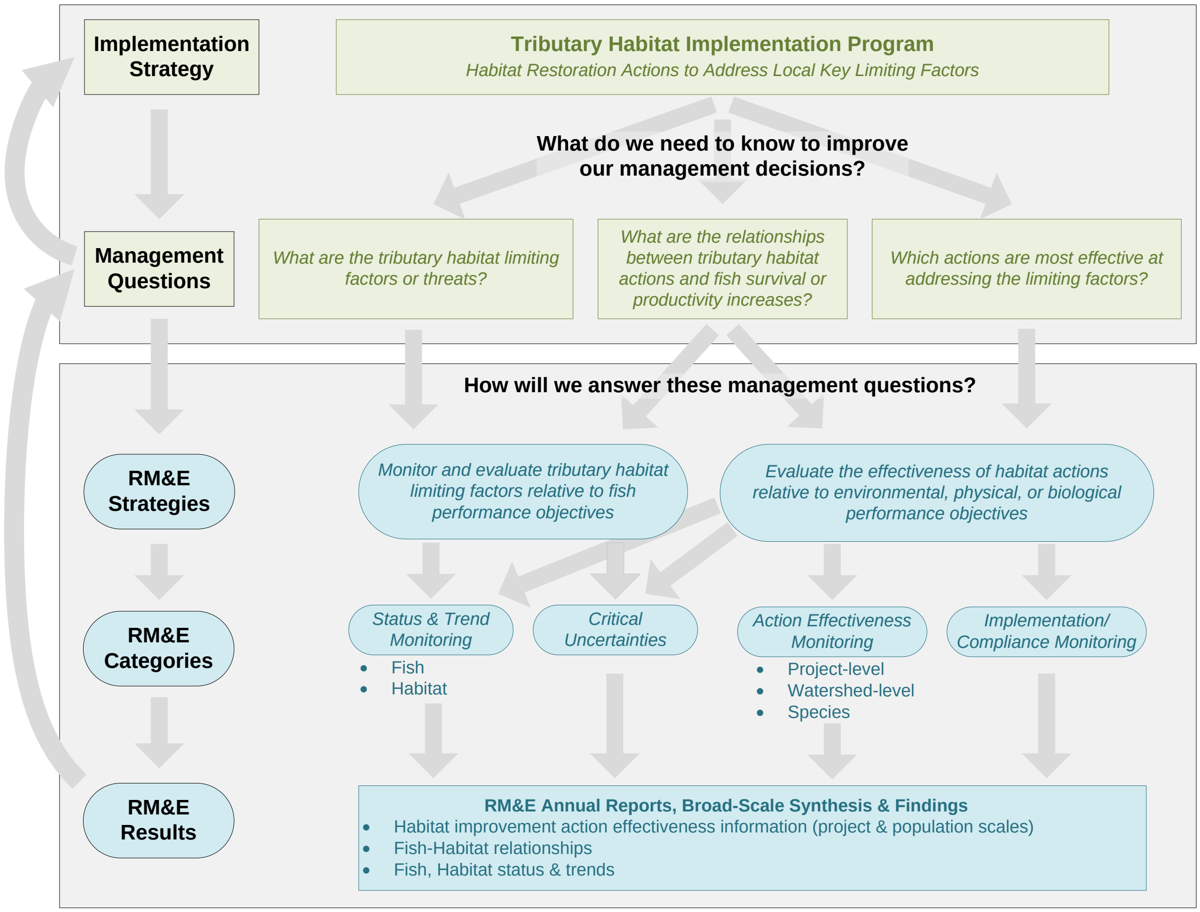
- ***Watershed (or population) action effectiveness monitoring*** determines how actions across a larger geographic area has collectively affected fish survival or productivity. Intensively Monitored Watersheds (IMWs) are an example of this kind of landscape action effectiveness monitoring that help discern relationships between habitat conditions and fish survival.

Status and trends monitoring tracks the status of fish populations and their habitat over a number of years. Managers look to status and trend information to determine if a particular limiting factor such as sediment in a spawning reach has improved, worsened or remained unchanged. Analyzing fish and habitat status and trends together reveals correlations between the two.

3.1 Answering the right questions

RM&E is more than mere data collection; it must produce useful and relevant information that improves management decisions. For example, status and trend monitoring can help identify factors that limit fish survival, as illustrated in the chart below. The Council and ISAB have called for improvements in the application and presentation of results to inform management decisions. The Action Agencies have developed a new annual report format and other requirements that will help fulfill that goal.

The Council and ISAB have also called for making more effective use of the combination of results from the variety of monitoring projects and programs underway in the Columbia Basin, often at different spatial scales. Several such programs are shown in the chart below. The Action Agencies are strengthening their approaches for combining, synthesizing and analyzing the combined results to produce more useful and definitive findings than any of the individual programs could provide on their own.



Links between Tributary Habitat Implementation Management Questions and RM&E categories. These categories of monitoring also apply to the estuary habitat program.

4. Implementation and Compliance Monitoring

This type of monitoring is generally the most basic and is a requirement for all habitat projects. Implementation monitoring describes the action, location and whether the action was completed as planned and collects basic observations of conditions before and afterwards. It does not require extensive environmental field data and is usually a low-cost monitoring activity. Compliance monitoring also assesses whether or not the project remained functional over the life of the monitoring.

Implementation and compliance monitoring involves a few steps. In the case of BPA projects, project sponsors report progress to BPA through online tracking systems. BPA staff then validates the progress through communication with sponsors and site visits. BPA is considering the option of using a third-party contractor to perform objective compliance monitoring. Results are integrated with NOAA's habitat improvement tracking system that covers the entire Northwest, for a regional picture of the progress and spatial extent of salmon habitat improvements.

How does Implementation and Compliance Monitoring benefit managers?

- Determines whether project was completed and functions as planned.
- Assesses whether project still functioning as intended.
- Documents conditions before and afterwards, noting changes.

5. Action Effectiveness Monitoring

Action effectiveness (AE) monitoring measures how effectively habitat improvements improve conditions and fish communities at the local level as well as at the watershed or population level.

Three types of AE monitoring and analysis inform the tributary habitat program:

1. Project (or local) monitoring, which evaluates the effects of types of habitat projects, such as barrier removals, floodplain improvement and fencing installations. Project-level fish effects are usually very local, within a reach or assessment unit of a stream and can be considered individually or collectively in categories.
2. Watershed (or population) monitoring, which evaluates groups of habitat projects in a larger geographic area.
3. Species-level analysis, which evaluates the effects of habitat improvement projects throughout the ESU/DPS for relationships to changes in fish survival.

5.1 Habitat project action effectiveness monitoring

Habitat project effectiveness monitoring tests the value of an investment in habitat improvement by examining how effectively a certain type of habitat action meets its environmental or biological objectives. An example is measuring the increase in juvenile rearing habitat following reconnection of a side channel that had been inaccessible to fish. The objectives of project action effectiveness monitoring are to:

(1) Determine which actions are most effective at addressing specific habitat impairments or limiting factors.

(2) Share those findings with resource managers throughout the region so they can pursue the most biologically- and cost-effective solutions for specific impairments.

(3) Document functional relationships between habitat quality and fish abundance or biomass.

Project sponsors generally designed their own project-level action effectiveness monitoring, which was then vetted through Council and ISRP review and implemented for the hundreds of BPA-funded habitat actions each year. However, BPA is currently working with the Council and other regional partners to develop a more standardized approach that applies consistent metrics to specific categories of habitat actions. These categories and metrics will be submitted to the ISRP for review (Table 4). This approach will better support the combined analysis of results from projects undertaken by different project sponsors across broader geographic areas to better inform policy decisions. Action effectiveness studies would then not be needed for each habitat project, but only for a representative sample. The number of project level studies required in each category is currently under statistical analysis to inform this programmatic approach.

Proposed F&W Program Project-Level Action Effectiveness Categories.

Action Categories	Sub Categories
Fish Passage*	Barriers* Entrainment*
In-stream Structures	Complexity Stabilization Large Engineered Structures Beaver Introductions
Off Channel Habitat	Side Channel Floodplain Wetland Improvement Confinement Reductions
Riparian Improvement	Fencing Planting Removal
Sediment Reduction/Addition	Roads Agricultural Spawning Gravel
Acquisition and Protection	
Flow Augmentation	Water Quality Barriers

*Indicates local fish response measured (no star indicates only environmental response measured).

To further strengthen results and the guidance they provide managers, BPA will also leverage other action effectiveness studies such as monitoring by Washington and Oregon.

The anticipated improvements in project action effectiveness monitoring will make it more cost-effective and increase the value and applicability of the results. They address Council and ISRP recommendations from the recent RM&E Categorical Review process.[1] A standardized approach to project-level AE monitoring and research is also underway in the Lower Columbia River Estuary (LCRE)

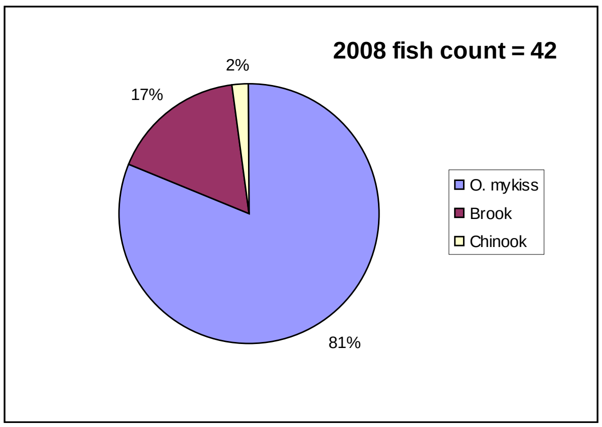
[1] http://www.nwcouncil.org/fw/budget/2010/rmeap/2011_06decision.pdf

and every effort will be made to keep the approaches consistent. For example, certain habitat action categories developed for tributary habitat may also apply to estuary projects.

Project level action effectiveness currently costs several million dollars annually. However, the cost should drop significantly as the Action Agencies’ programmatic approach takes hold and the streamlined program uses more coordinated syntheses of results. For example, if research and monitoring effectively measures and validates a certain type of habitat improvement, then further monitoring of that type can be scaled back and the funds and resources redirected to focus on remaining questions. Regular assessments will examine this question.

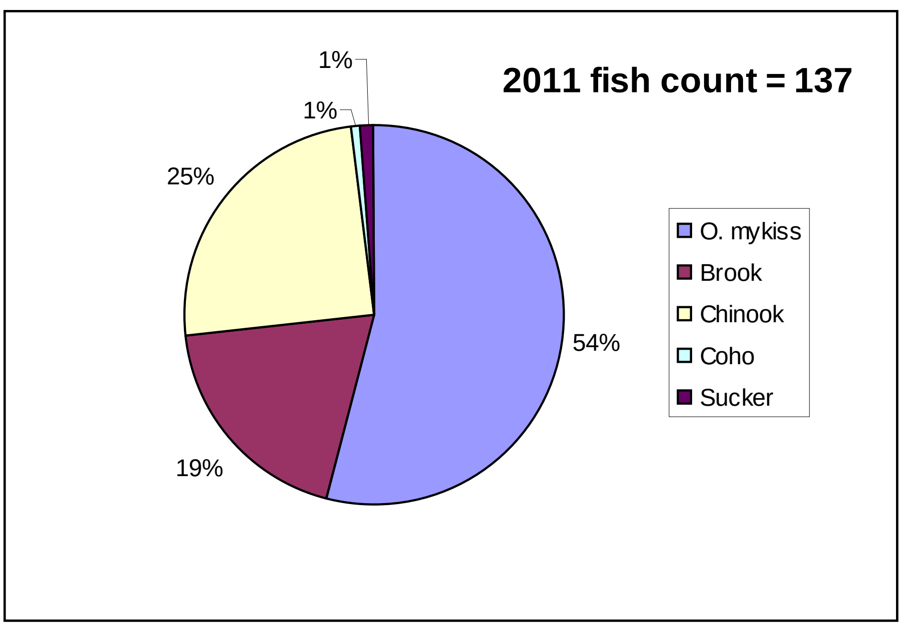
How does Habitat Project Level Action Effectiveness Monitoring help managers?

- Determines whether projects meet their environmental or biological objectives.
- Helps identify which project types best address certain key limiting factors for fish.
- Supports cost/benefit analyses of various project types, revealing most cost-effective actions.
- Reveals whether the number of fish and/or number of fish species increased after project.
- Provides data to strengthen models that estimate benefits of habitat improvements..



(From Reclamation Methow IMW monitoring report)

Fish abundance and diversity increased in a side channel of the Twisp River in Washington after a habitat project reopened it to river flows. ESA-listed spring chinook increased substantially.



5.2 Watershed Level Action Effectiveness Monitoring

Watershed level effectiveness monitoring for multiple projects examines the cumulative impacts of habitat projects at the watershed or population scale. Under this approach, in which habitat actions and follow-up monitoring are jointly planned and coordinated, with many or very large projects undertaken in a specific geographic area within a short time period with the goal of improving habitat conditions. If the projects are effective, increased number and size of fish should reflect the improvements. Watershed level action effectiveness monitoring aims to inform future decisions by:

- Determining if habitat improvement boosts fish survival or productivity.
- Identifying which habitat actions contributed most to the survival increase.
- Confirming relationships between habitat improvement and fish survival.

An important type of watershed level action effectiveness monitoring are intensively monitored watersheds (IMWs) – river basins where extensive monitoring tracks the response of fish populations to habitat improvements in comparison to areas with no such improvements. IMWs usually also include status monitoring and project level action effectiveness monitoring, which provide additional understanding of the environmental and biological mechanisms driving fish survival or productivity responses. Five IMWs are part of the Integrated Status and Effectiveness Monitoring Program (ISEMP) sponsored by BPA, while NOAA and the Bureau of Reclamation also fund additional IMWs. ISEMP, led by NOAA's Northwest Fisheries Science Center, provides for standardized methods to track fish populations and habitat conditions and has included installation of PIT tag detection systems throughout the region to gather information on juvenile fish abundance, survival, growth and escapement.

Intensively monitored watersheds in the Columbia Basin.

Watershed	Program	Lead	Funding
Asotin Creek	NOAA	NOAA	NOAA
Bridge Creek	ISEMP	NOAA	BPA
Entiat River	ISEMP	NOAA	BPA
John Day River	NOAA	NOAA	NOAA
Lemhi River	ISEMP	NOAA	BPA
Potlatch River	NOAA	NOAA	NOAA

South Fork Salmon	ISEMP	NOAA	BPA
Upper Middle Fork John Day River	ISEMP/ODFW	NOAA	BPA/NOAA
Methow River	Reclamation	Collaboration of local state, tribal and federal agencies	Reclamation
Grande Ronde River	CRITFC	CRITFC	BPA
Okanogan River	Okanogan Basin Monitoring and Evaluation Program	Colville Tribes	BPA

The annual cost of ISEMP has ranged from about $4 million to more than $6 million, including project level effectiveness and status monitoring and regional data management, although the cost is expected to decrease as monitoring programs become more focused and efficiencies are identified. For example, some research projects have begun to use more remote sensing data as a cost-effective alternative to the use of field crews to gather measurements on the ground.

One challenge of such large-scale, intensive monitoring is that definitive results may require years of research to tease apart the benefits of habitat improvements from the natural variations that constantly affect salmon populations. However, research in several IMWs has already produced initial evidence that habitat improvements do translate into survival benefits for salmon and the evidence that could be expected to become even stronger and clearer through the additional data that will come with time.

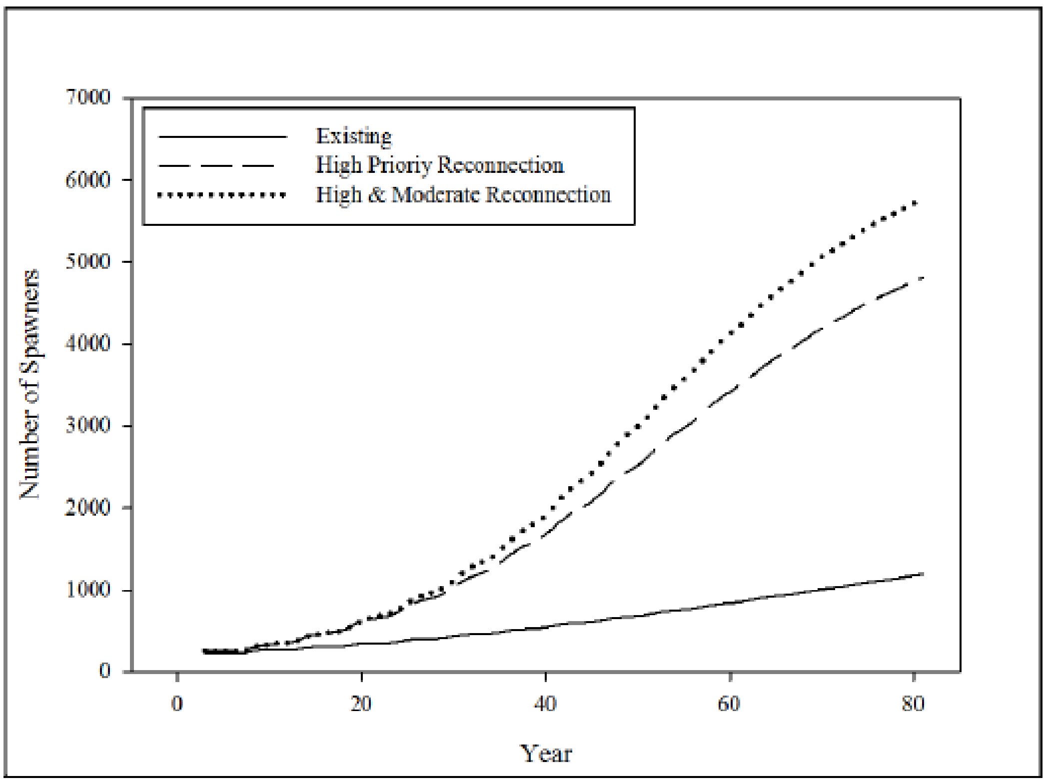
For further details on watershed level monitoring programs, see Appendix 3.

A crew installs a PIT tag antenna in the Lemhi River in Idaho, an intensively monitored watershed.

How does watershed level action effectiveness monitoring help managers?

- Identifies the extent of habitat improvement needed to improve fish populations on a landscape scale.
- Provides data to develop or improve models that predict benefits of habitat improvement.
- Reveals what combination of habitat improvements deliver greatest benefits for fish.
- Documents relationships between habitat quality and fish survival.

Modeling improvements



A model developed from multiple project monitoring on the Lemhi River IMW in Idaho estimates the benefits to fish, in number of additional spawners, of varied habitat improvement scenarios involving reconnection of historic habitat and water sources. When complete the model will also provide information on limiting factors, the relationship between habitat and fish survival and help managers

5.3 Species-Level Action Effectiveness Analysis

Species-Level AE analysis expands on watershed level monitoring by looking for associations between the number of habitat actions within a specific ESU/DPS and juvenile, adult or other life stage survival. For example, Paulsen and Fisher (2005) used correlation analysis to detect an association between the number of habitat improvement actions in the Snake River ESU and parr to smolt survival of spring/summer Chinook salmon. They determined that Snake River chinook populations from areas with higher intensities of habitat improvement actions had higher parr-to-smolt survival rates than Chinook from populations in areas with fewer habitat improvements. As information on the extent and intensity of different types of habitat improvement actions accumulate (from implementation and compliance monitoring), analyses can examine associations between extent and intensity of habitat improvement and fish survival.

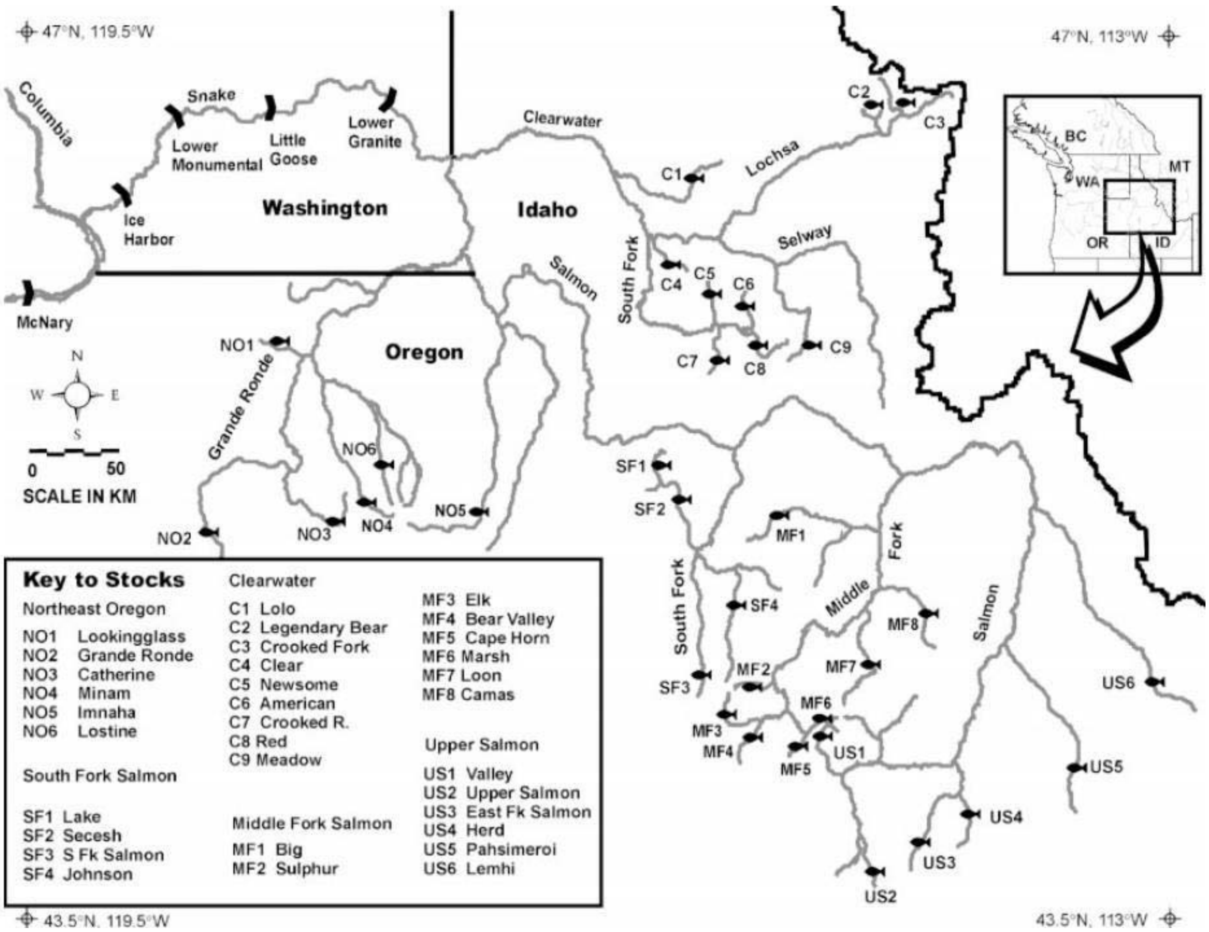
This type of monitoring is important because it provides information on the scale at which ESA listing and delisting occur. The objective of Species-level action effectiveness monitoring is to assess the intensity and extent of habitat improvement actions necessary to deliver lasting benefits for listed fish and, ultimately, to help assess the degree of habitat improvement needed to support recovery.

How does species level action effectiveness monitoring help managers?

Assesses the combined benefits of habitat projects on a species scale.

Helps focus resources on most effective habitat actions to support species recovery.

Assesses how habitat improvements support increased fish survival.



Fish symbols indicate locations where juvenile fish were tagged as part of research (Paulsen, 2005) examining the relationship between habitat improvement and fish survival. The study found a positive, significant relationship between survival and the number of habitat improvement actions undertaken.

6. Status and Trends Monitoring

Longer-term tracking of fish numbers and habitat condition in their own right is known as status and trends monitoring and is an important complement to action effectiveness monitoring of responses to certain habitat projects. Status and trends monitoring provides managers with current information on the status of fish populations and their habitat and reveals whether they are trending positively. This information is important in identifying relationships between habitat and fish at multiple life stages, which is critical for assessing the quality of habitat, identifying limiting factors and assessing the potential fish benefits associated with changes in specific habitat indicators.

6.1 Fish Population Status and Trend Monitoring

At its most basic, fish status and trends monitoring tracks the number of adult fish that spawn and the number of juvenile fish produced, often known as, “fish in/fish out.” This can be translated into egg-to-smolt survival given assumptions or measurements of the number of eggs produced per spawner and other factors. Over time, the data documents trends in the population as a whole.

One of the largest PIT tag detection antennas ever built stretches across the South Fork of the Salmon River. The antenna tracks PIT-tagged fish swimming past.

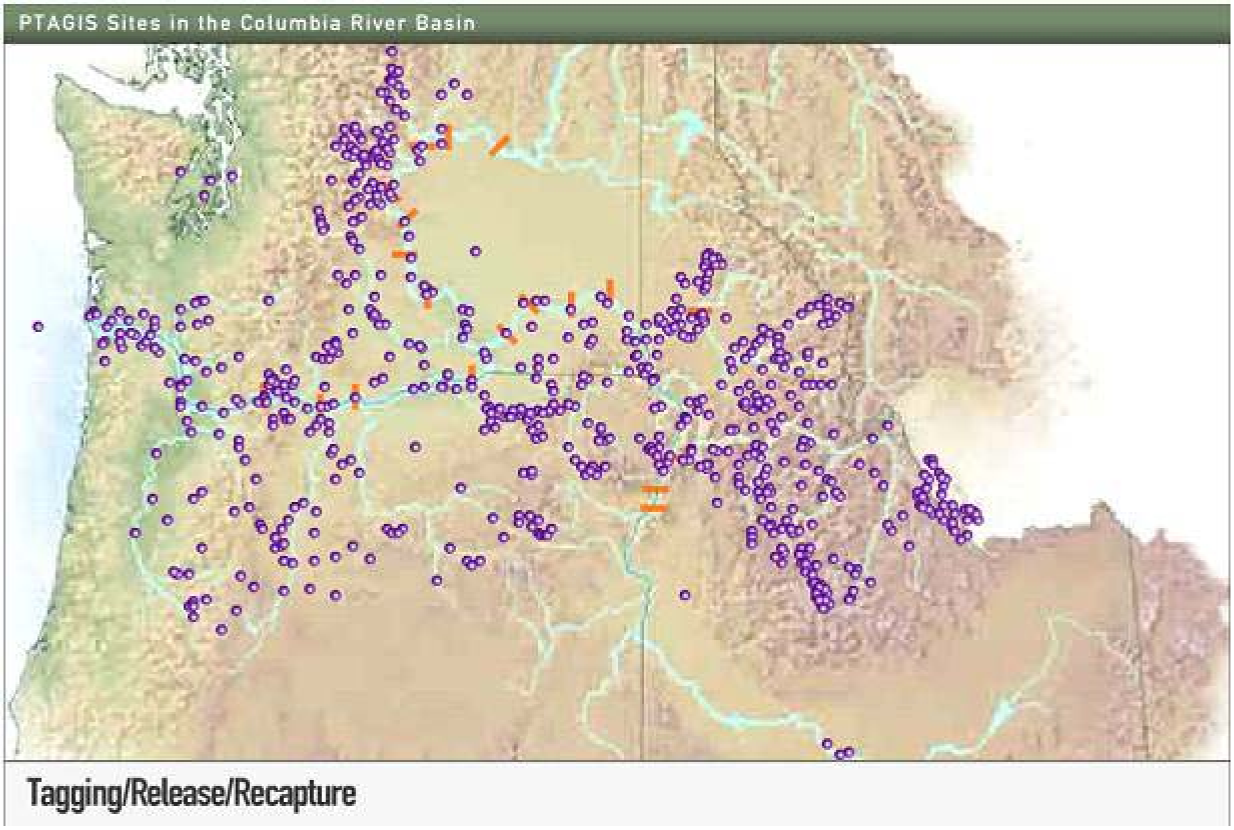
The main objectives of fish status and trend monitoring include:

- Measure and track total spawners (including both hatchery and natural-origin fish)
- Monitor egg-to-smolt survival, an indicator of whether the habitat can support successful rearing of juveniles.
- Count the natural-origin recruits (NORs) produced, which may also reflect how well the habitat supports successful rearing of juveniles.
- Track the number of returning adults per spawner, which reflects adult productivity
- Improve models or correlations of fish response to changes in habitat condition for use by managers and expert panels.

Fish population status and trend monitoring takes place over the long term and is not solely related to any particular program or the sole responsibility of the action agencies. Many organizations track fish numbers throughout the Columbia Basin and in many cases the resulting data are widely available for analysis on their own or in combination with data collected by others. In the Upper Columbia, for instance, a great deal of the fish-in/fish-out data are generated by the three public utility districts that operate hydropower projects on the Columbia River and hatcheries to help mitigate for those projects. Douglas County PUD, Chelan County PUD and Grant County PUD all gather data under their Habitat Conservation Plans (the counterpart to the Biological Opinion that applies to federal action agencies). These programs provide fish in/fish out data at the watershed and population scales.

PIT tag data collection sites for juvenile fish.

Adult fish data collection sites.



All sites where PIT-tagged fish are fitted with tags and released or recaptured, which may include dams and fish traps.

Fish status and trend data can be collected through different means depending on the scale and time frame involved. For instance, the ISEMP program described earlier originally used snorkel surveys to track fish numbers. More recently, ISEMP recommended the deployment of PIT tag technology as the preferred method to estimate fish status and trend data. The increasing deployment of automated PIT tag technology that remotely collects and transmits data to the regional PIT Tag Information System operated by the Pacific States Marine Fisheries Commission and funded by BPA may further improve and streamline fish status and trend monitoring. The expansive network of sites allows researchers to tap into the latest data from the expansive network of PIT tag simply by going online from their offices.

For full display and details of BPA-funded monitoring projects, see www.cbfish.org.

6.2 Habitat Status and Trend Monitoring

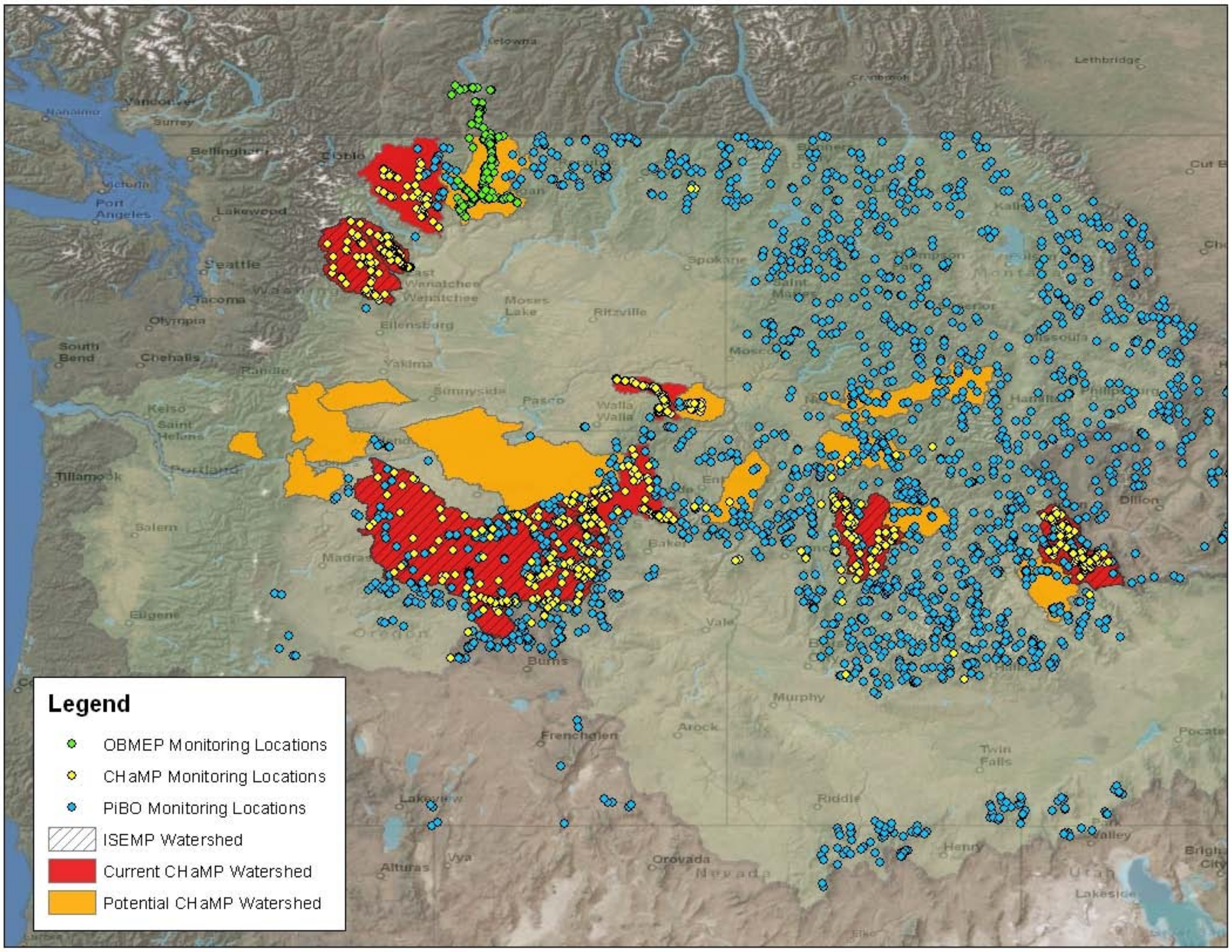
Habitat monitoring is the counterpart to fish population monitoring when it comes to status and trends. Habitat data documents physical, chemical, and biological components of salmonid habitats believed to influence egg-to-smolt survival or productivity at the population or watershed scale. Comparing the habitat and fish status and trends data can help demonstrate a relationship and, with sufficient data, produce or strengthen models that predict the response of fish populations to habitat improvements. Habitat status and trends data can also help expert panels identify habitat impairments and limiting factors that should be addressed through habitat improvements and can reveal whether habitat actions are in fact translating into positive trends in terms of habitat quality.

The primary objectives of tributary habitat status and trend monitoring include:

- Measuring and tracking the quality and quantity of salmon and steelhead habitat upstream of Bonneville Dam over time
- Identifying relationships between the metrics that influence the status of the population such as egg-to-smolt survival and habitat quality and quantity conditions.
- Develop useful data summaries and maps to assist the Expert Panels and other regional technical bodies in identifying habitat impairments and limiting factors.

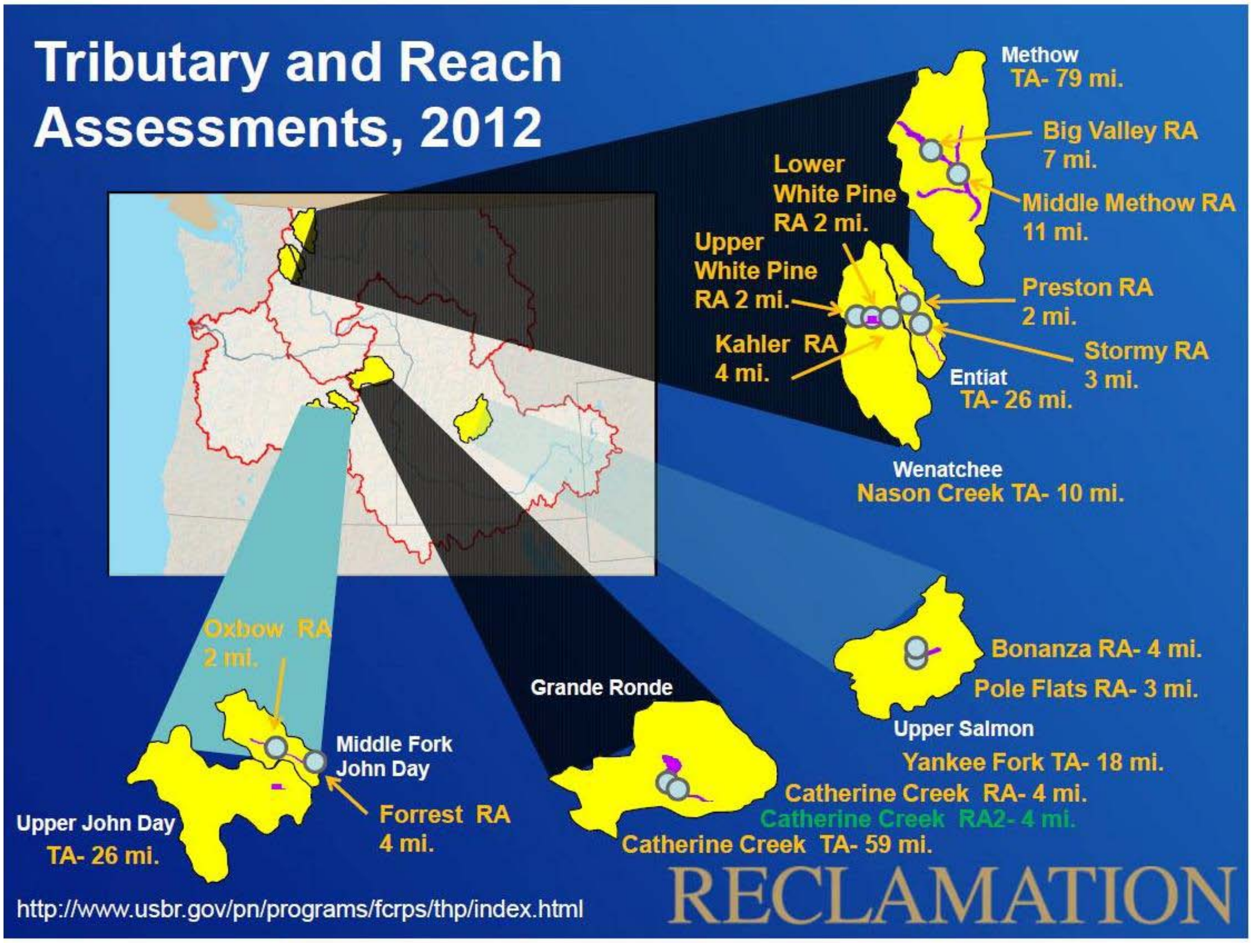
A leading example of habitat status and trends monitoring is the Columbia Habitat Monitoring Program, known as CHaMP. It is designed to detect changes in habitat over time and can be paired with population or watershed-scale fish data to look for relationships between the two. CHaMP grew out of the ISEMP and employs standardized data collection and analysis so data from many areas can be analyzed together, increasing the strength and definition of results. The 2011 CHaMP pilot year included 10 watersheds, including the Asotin watershed funded by NOAA's Pacific Coastal Salmon Recovery Fund (PCSRF) program and one sub-basin in California. Other watersheds are funded by the action agencies. In some cases where CHaMP and ISEMP overlap, CHaMP boosts coverage of IMWs with additional data. CHaMP metrics and their relationship to limiting factors are listed in the table in Appendix 2.

OBMEP, the Okanogan Basin Monitoring and Evaluation Program, resembles an IMW in that it tracks the status of fish populations and habitat within the Okanogan basin. It is a project of the Colville Tribes, funded by BPA, that also measures the response of fish to habitat improvements.



The combination of monitoring programs across the Columbia Basin leverage the power of data from hundreds of sites under different programs, as identified by the colored dots. Increasing standardization of data is helping make the data more compatible so researchers can use more of it to draw more reliable conclusions.

Another source of habitat status and trend data centered on federal lands is the U.S. Forest Service's long-running PIBO program, which was designed to monitor the results of the PACFISH/INFISH Biological Opinion and has consistently monitored an extensive series of sites. The PIBO program monitors fewer metrics than CHaMP with a longer rotation time between sites. A study examining the potential for better coordination between the two programs is underway.

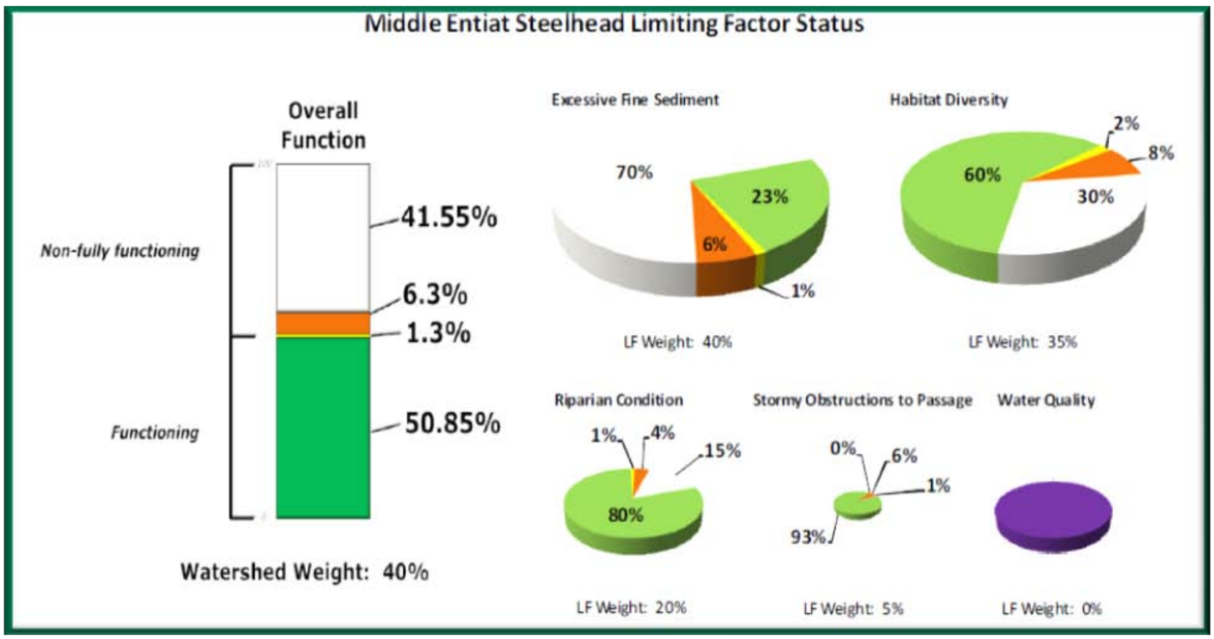


The U.S. Bureau of Reclamation has completed assessments of tributaries and reaches labeled in orange, while those in green are under way.

In addition, the U.S. Bureau of Reclamation has conducted a series of tributary and reach assessments to help focus improvement actions in the locations where they will best help fish. Reach assessments refine information in tributary assessments by examining and documenting the geological setting, channel morphology and other characteristics influencing habitat conditions. The assessments examine how habitat characteristics have changed over time, which helps identify habitat improvement actions that will address known limiting factors that are holding fish populations back and where such actions would be most successful given the characteristics of the river. Tributary and reach assessments are available through the subbasin links at www.usbr.gov/pn/programs/fcrps/thp/index.html.

How does status and trends monitoring help managers?

- Identifies limiting factors that should be targeted with habitat improvement actions.
- Assesses trends in natural-origin spawners to help determine if habitat can support them.
- Provides data to develop and strengthen models that predict fish responses to proposed habitat improvements and associated actions.
- Defines relationships between fish abundance and productivity, and habitat quality.



Charts developed from habitat status and trend monitoring document the limiting factors at work in the Middle Entiat Assessment Unit of the Entiat watershed. The pie charts depict the status of each limiting factor. The size of the pie charts represent the significance of that limiting factor for fish. The charts are color coded so that green represents the percent of potential function at the start of the 2010 FCRPS BiOp. The bar chart on the left summarizes the status of all the pie charts. So, for instance, the assessment unit stands at 50.85 percent of its fully functioning condition.

7. Pulling the pieces together

While each component of the RM&E framework evolved to address certain questions at certain scales, this framework brings them together under a common structure to make the most of their individual and combined value. The unprecedented scale of the habitat improvements underway and the RM&E to track and learn from them carries the risk that some projects may not proceed as expected or yield the predicted results. Even those instances hold value, however, as long as an effective RM&E program helps understand the reasons behind the outcome so that the experience can inform and improve future decisions. The combined lessons from many such individual instances will provide powerful guidance for managers and decisionmakers not only in terms of the most effective habitat improvements, but also how to apply them in the most effective places and at the most effective times.

The combined elements of the RM&E program, by examining the response of fish and habitat on multiple scales, maximize the opportunity to learn from each of the hundreds of habitat actions taking place across the basin using the best science available today. Monitoring of the chain reaction in which habitat actions change conditions for fish helps answer key management questions to support planning and adaptive management. The results will help identify the most enduring habitat actions that create the most lasting influence on fish populations. That, in turn, will help ensure that funding and other resources are allocated as effectively as possible, which benefits both fish and the electric ratepayers and others who provide the funding.

8. Improving the Action Agencies' RM&E Program

The importance of RM&E in documenting and tracking progress on behalf of the region's fish and wildlife populations and the large amount of federal and regional ratepayer funds devoted to it have led to appropriate scrutiny and accompanying recommendations for improvement. The Action Agencies appreciate the recommendations and have already adopted some of the recommendations and are in the process of pursuing others. The more effective, efficient and reliable the research and monitoring is, the better it will inform habitat improvement efforts and the more effective and efficient those will be in improving conditions for fish. This section of the report briefly describes recommendations for improvement in the RM&E program and how the action agencies are addressing them.

In addition, the RM&E program itself is fully designed and intended to be adaptive, adjusting and improving based on experience and lessons in terms of the approaches that deliver the most useful results. The Action Agencies will consistently assess their RM&E program and the results it provides for potential improvement. At any one time the RM&E framework should provide managers and others with data and analyses representing the best available science but will also strive to improve and advance that science over time to provide even more informative and useful results in the future.

Among the major recent recommendations from the Council and the ISRP and brief descriptions of how the Action Agencies are responding to them.

Develop a framework that clearly describes the components of the RM&E program. This description of the current RM&E framework, which has evolved over several years, contributes to this goal. A separate estuary framework document is also in development.

Standardize annual reporting by project sponsors. In 2012 BPA introduced a standard reporting template that all project sponsors will use to submit their annual reports. The more consistent format and timing will simplify analysis and synthesis of data, providing more useful and far-reaching results and guidance for decision-makers and managers. While the ISRP voiced some cautions, the Action Agencies believe they can be addressed by phasing in changes and considering lessons learned.

Standardize data collection. Traditionally project sponsors each developed their own monitoring approaches for their habitat improvement actions, resulting in varied studies that monitored different habitat conditions and tracked different metrics using different techniques. This often meant that the data and results were incompatible, unfortunately limiting their use. BPA continues to work toward program and region-wide standards for data collection and sharing. Project level implementation metrics are standardized under PISCES contract reporting. Methods for monitoring now require standard documentation using monitoringmethods.org. Advances continue through ongoing support for the Pacific Northwest Aquatic Monitoring Partnership tools for standard metadata (data documentation), monitoring designs and data exchange templates.

Consider using a single third party for monitoring. A pilot effort is underway in the Upper Columbia to evaluate a third-party monitoring program for implementation and compliance monitoring. If successful, the third-party approach could expand to include project level effectiveness monitoring.

Set realistic timeframes. The ISRP advised the Action Agencies to set realistic expectations for when useful results can be expected from the RM&E associated with habitat protection and improvement efforts. This is a particular challenge because while managers want useful results as soon as possible, habitat improvement may take year to show results and RM&E may take even longer to detect results. The Action Agencies are addressing this in a variety of ways. First, standardized measurements and reporting should produce clearer and more useful results sooner. Second, the scaled approach of the different elements of the RM&E Program should provide managers with detailed results on individual projects through project action effectiveness monitoring while also folding that information where possible into higher-level analysis that should provide timely, if less detailed, results at a larger scale. Because of the natural variables that influence habitat and fish populations on large scales, however, higher resolution results will require more data and more time. While much of the work outlined in this framework will continue through the term of the BiOp that ends in 2018, some streamlining is anticipated. Fish status monitoring and standardized action effectiveness monitoring of individual projects will likely be continued, other RM&E work will be re-evaluated.

Make data more accessible. BPA will improve the accessibility and management of fish and wildlife habitat data by implementing the elements of its data management strategy, "A Framework for the Fish and Wildlife Program Data Management: Issues and Policy Direction for Development of 2013 Data Management Strategies and Action Plan." This approach will help standardize methods and data exchange templates and integrate different data management systems so researchers can more easily access a wider range of data, much of it online. CHaMPMonitoring.org and the Status, Trend and Effectiveness Monitoring (STEM) database at NOAA's Northwest Fisheries Science Center will serve as central clearinghouses for BPA-funded data on habitat status and trends and action effectiveness. Regional fish status and trend data will be transferred to and accessible through the PTAGIS and StreamNet databases administered by the Pacific States Marine Fisheries Commission. In addition, development of the prototype Monitoring Explorer, an online mapping resource, through the website monitoringresources.org will help support expert panels and others in accessing BPA-funded and other types of data that will help identify key limiting factors.

Links to online data resources:

PTAGIS http://www.ptagis.org/

StreamNet website http://www.streamnet.org

NOAA Fisheries SPS database https://www.webapps.nwfsc.noaa.gov/apex/f?p=238:home:0

https://www.webapps.nwfsc.noaa.gov/apex_stem/f?p=168:1:2173217670742060

Monitoring Methods and Monitoring Explorer Tools http:www.monitoringresources.org

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10. Appendix 1: Project Level Action Effectiveness Example Report

Monitoring the Benefits of In-Stream Habitat Diversity

Entiat River, Chelan County, WA August, 2012

Introduction

The lower 16 miles of the Entiat River in north-central Washington State has seen a great deal of floodplain development and extensive channelization over the last 100 years. The increased concentration of flows in the main channel has in turn increased sediment transport rates, coarsened the bed, and incised the channel in many areas causing the river to abandon the surrounding floodplain. This project is in an area where the active channel has become straightened, confined, and armored, which has resulted in the loss of critical spawning, high flow refugia, and rearing habitat for several threatened and endangered salmonid species.

In September 2007, the Milne Diversion Project was completed to improve spawning and juvenile rearing habitat quantity and quality to the river by reintroducing site-scale habitat features and using natural stream processes. Located between river miles 2.8 – 3.0 the goal of the project is to establish habitat diversity **(Figure 1)**. Improved habitat diversity was envisioned to be accomplished through the addition of a variety of in-channel features, thereby increasing habitat complexity, increasing the availability of lost habitat types, and creating more dynamic habitats for three threatened and endangered species: Chinook salmon, steelhead, and bull trout. Features implemented in the project **(Photos 1 – 4)**:

- *Barbs* (two types: bank-height and low-height) to promote deposition of bed load material that may be beneficial for spawning activities,
- *Rootwads* to provide cover and refuge, and
- *Boulder clusters* strategically placed in the main channel to modify the local hydraulic conditions creating velocity, depth, and substrate diversity (pocket pool habitat) as well as providing energy dissipation.

In 2008, the Pacific Northwest Research Station through the U.S. Forest Service embarked on an effectiveness monitoring program focusing on the Milne Diversion Project. Since construction the team led by Polivka has obtained three years of monitoring data 2009 and through 2011. Effectiveness monitoring is on-going. Polivka (2012) has concluded from preliminary results that habitat with structures is more beneficial for spring Chinook salmon and steelhead.

This report summarizes the monitoring and evaluation of the project at the microhabitat-scale as presented by Polivka (2010, 2011 and 2012). The monitoring data derived from the Milne Diversion Project is inferred at the reach scale by considering treated and untreated habitats within multiple reaches. This smaller scale monitoring and evaluation work complements the larger scale monitoring and evaluation being conducted by the Integrated Status and Effectiveness Monitoring Program (ISEMP) for the Entiat Intensively Monitored Watershed (IMW).

Project at a Glance

Formal Project Name: Milne Diversion	
Project Type: In-stream Complexity	
Project Sponsor: Cascadia Conservation District for planning and Chelan County Natural Resources Dept for Construction	
Project Design: Bureau of Reclamation (Baconguis)	
Landowner(s): Milne and three Small families	
Partners: US Forest Service (Technical Assistance and Permitting), U.S. Fish and Wildlife (Project Development and Construction Oversight), and Bureau of Reclamation (Technical Assistance and Design)	**Reclamation Development Costs:** $153,000
Funding Source(s): Washington State Salmon Recovery Funding Board and the Tributary Fund	**Implementation Cost:** $97,000

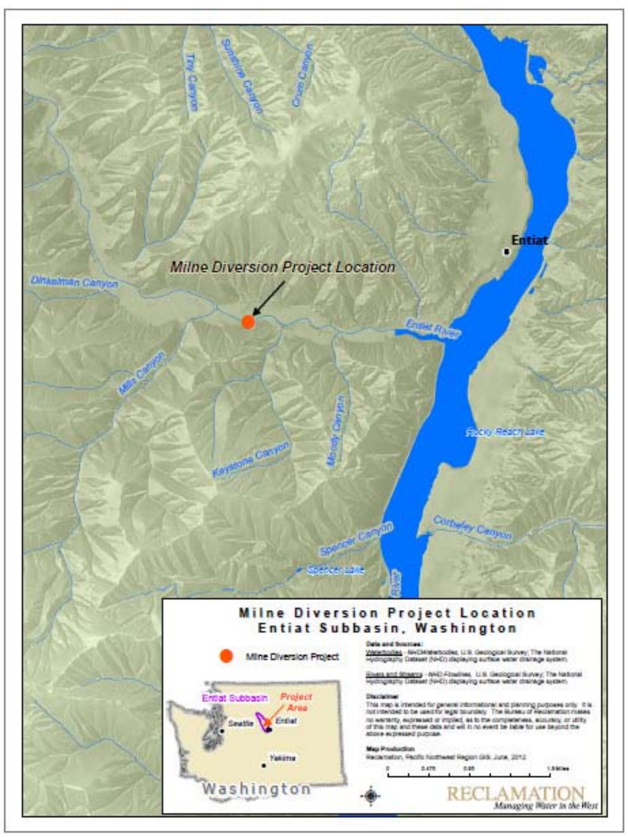

Figure 1. Location map of the Milne Diversion Project.

(1)

(2)

Photo 1. Two root wads keyed into the bank river right in the foreground and across the river on the left bank is a low-height diversion rock barb with sluice gate for a point of diversion at river mile 2.9. The river is moving to the east left to right.

Photo 2. Close up view of the same two root wads keyed into the bank river right from previous photo looking southwest down river with view around a bend in the river.


(3)

(4)

Photo 3. Low-height diversion rock barb on river left across from root wads shown in previous photos.

Photo 4. The view is southeast; entire view of site from previous photos showing adjacent orchard lands. Additionally contained downstream from previous structures is a boulder cluster (shown inside oval).

Methods for Monitoring and Evaluation

Monitoring and evaluation of the reintroduced in-stream habitat features is necessary to measure project success at meeting goals and forms the basis for adaptive management. Monitoring consists of both population size and individual growth and movement measurements within and among reaches. A paired reach scale monitoring design, one treatment and one control, is intended to complement the larger-scale effectiveness monitoring being conducted by ISEMP as part of the Entiat Intensively Monitored Watershed (IMW). Monitoring by the Polivka team is being conducted to evaluate and test hypotheses related to installed in-stream habitat features:

1) Fish growth and movement would show density dependence.
2) Density dependence would differ between the treated and control reaches.

The project entailed the installation of five rock barbs, one diversion barb structure with sluice-gate, thirteen large logs with root-wads, and six mid-channel boulder clusters with five boulders each. The diversion barb will be used to convey water to the irrigation ditch and replaces the push-up dam created annually by the orchardist. The Polivka team specifically focused on monitoring the effectiveness of a series of four engineered log jams and five rock barbs within the 400-foot stretch of the treated reach and several other pool locations within the upstream control reach.

To verify whether fish were using the newly reintroduced habitat features and to gather population data, the field crews surveyed the river using two methods (Polivka, 2010) **(Photo 5)**:

1) Snorkel surveys, and
2) Capturing, marking, and recapturing fish.

Ultimately, Chinook salmon and steelhead juvenile numbers were compared between microhabitats (pools) within each reach with and without added habitat features **(Photo 6)**.

ISEMP conducted snorkel surveys and sampling of several habitat metrics considered important for channel complexity at the Milne site in 2007 and 2008. Specific parameters collected to support the Entiat IMW at the Milne site beyond juvenile fish density included 1) Absolute thalweg depth; 2) Standard deviation about the thalweg depth; 3) Bankfull width-to-depth ratio; 4) Pools (expressed as the percent of the site length containing pools); 5) Substrate particle size expressed as D_{50}, and 6) Substrate particle size expressed as D_{84} (meaningful size range of spawning gravels).

Results, Interpretations, and Trends

Preliminary results from ISEMP indicate that fish densities increased at the Milne site; however, there were no appreciable differences in habitat metrics (Moberg and Ward, 2009). Of the six habitat metrics important for indicating changes to channel complexity sampled, several showed modest increases while the others very little. For example, microhabitat features at the Milne site did not create primary pool structures, but there were secondary pools created. Secondary pools are smaller than primary pools, which are defined as being wider than half the wetted channel width. Additionally, there was an increasing presence of larger substrate sizes evident from both large wood and rock placements. Conversely, conditions related to other metrics such as thalweg depth and bankfull width-to-depth ratio remained similar to control reach conditions.

Polivka (2011) has recognized from three seasons of monitoring a number of observations regarding increased fish density associated with structure placements within the Milne reach segment of the lower Entiat River. In 2009 the survey crew observed the density of juvenile Chinook and steelhead in microhabitat pools created by the structures (blue boxes, **Figure 2**), finding a higher density there in the early to mid summer (July-August) compared to microhabitats sampled at random in this and several other reaches. The comparison also held true for microhabitats sampled randomly within the same reach where the structures were located (see “Treated” in red, **Figure 2**).


(5)

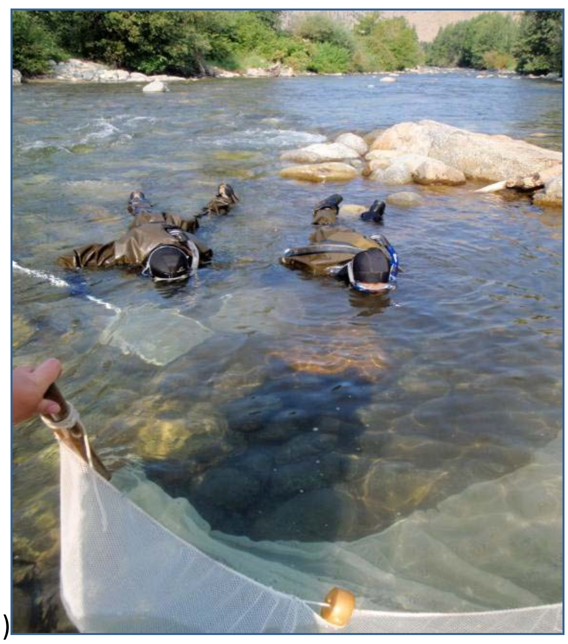
(6)

Photo 5. A rearing wild spring Chinook parr, viewed during a snorkel survey in a pool behind a rock barb during summer 2009.

Photo 6. A crew in summer 2009 capturing fish downstream from a low height rock barb for mark-recapture studies (see Figure 5 on page 8).

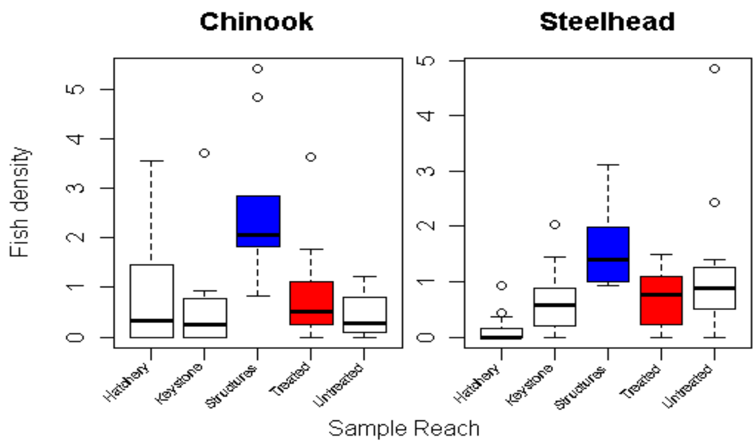

Figure 2. Fish density for Chinook salmon and steelhead in several sampled reaches in early 2009. Sampling was conducted using randomized selection of a standard set of microhabitats (N – 10-15) in each reach. The reach labeled "Treated" refers to censuses taken at random within the Milne diversion reach, in contrast with "Structures" which are non-random censuses taken at pools where the installed structures were located.

However, later in the summer of 2009, fish density was not strongly associated with pool structures (not shown). This likely reflects the sub-yearling Chinook parr migration toward over-wintering habitat downstream and overall highly variable habitat selection patterns by steelhead. Furthermore, random censuses in the "Treated" reach showed higher steelhead density than at structures in the same reach. Delayed sampling in 2010 and 2011, due to high flows resulting from El Niño and La Niña events, respectively, reflect results consistent with 2009. In the first of these censuses, Chinook were typically observed at higher density in treated pools, but not in later weeks. Steelhead density was higher in untreated microhabitats, similar to 2009, but was highly variable.

The elevated density of juvenile Chinook in treated microhabitats appears to be associated with the strong positive relationship with depth, a parameter that increased where structures were added **(Figure 3)**. Across the three study years, juvenile Chinook were consistently more abundant at habitats with structures in early season samples **(Figure 4)**. Juvenile steelhead were more frequently found in areas with added structures in 2009 and 2011, but not in 2010 **(Figure 4)**. There were no consistent relationships between physical habitat parameters such as depth or flow velocity and steelhead density (not shown).

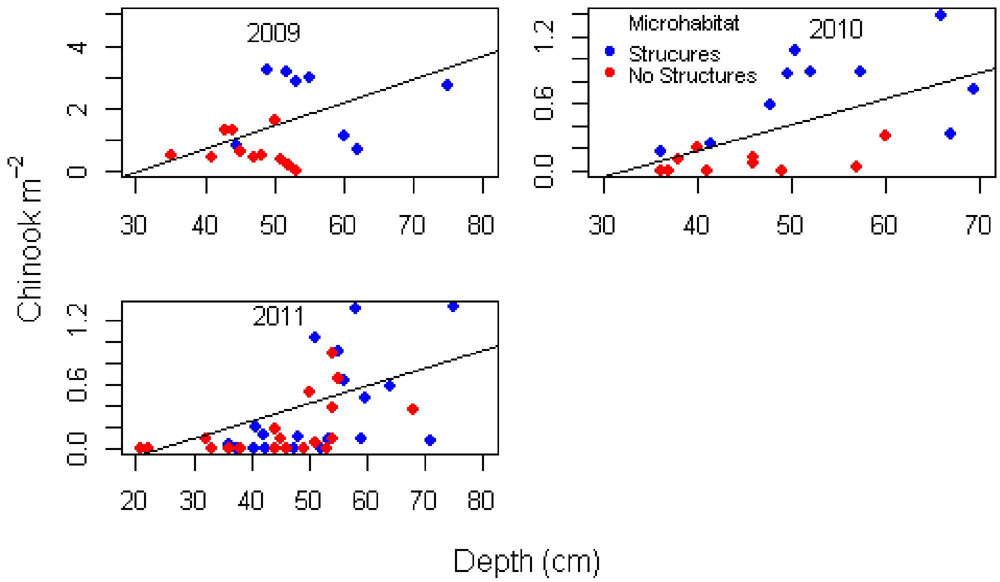

Figure 3. The association between pool depth and Chinook salmon density at microhabitats with or without structures in early season samples in each of three years of sampling.

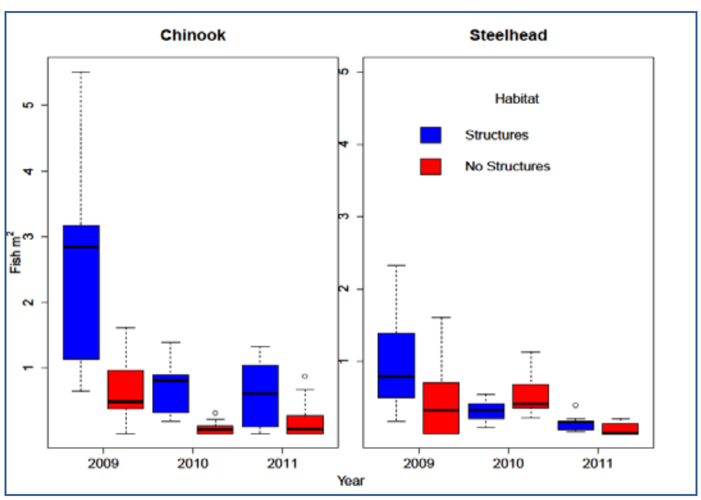

Figure 4. The early season (mid-July to early August) density of juvenile Chinook salmon and steelhead at microhabitat structures within the treated reach versus the control reach during three years of sampling.

Polivka (2011) took his investigation a step further in 2009 by examining behavior and growth in pools with and without treatment. His interest was to determine whether the observation of higher density at microhabitats with structures was truly a benefit to fish or whether this was an artifact of fish movement. In a short term (24 hr) mark-recapture study, both Chinook and steelhead tended to be recaptured in the same pools, where they were marked, more frequently when those pools were treated with structures compared with untreated microhabitats **(Figure 5)**. The higher affinity to microhabitat associated with the structure placement in the treated reach provides a short-term preference and appears highly beneficial for fish.

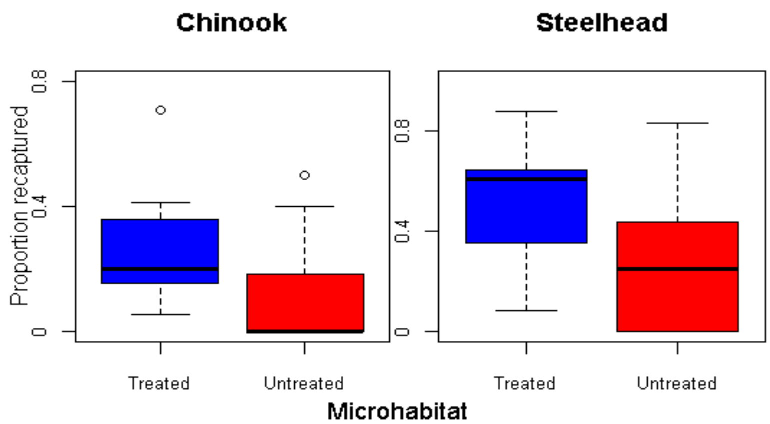

Figure 5. In 2009, fish were proportionally more often recaptured in habitat features within the treated reach of Milne than the control reach indicating a higher affinity for treated microhabitat features.

During both 2009 and 2010 field season, Polivka (2011) measured growth across the short season during which the survey crew were able to sample, mark and recapture both steelhead and Chinook. Due to the pattern of seasonal variation in fish density, in which Chinook density declines substantially during late August and early September, too few recaptures were obtained in both 2009 and 2010 to identify any difference in growth among Chinook. However, steelhead, despite being at lower density at structures than at untreated sites in 2010, had higher growth rates at the structures (2009 data are being analyzed). This strongly suggests that growth along with density could be used as an indicator for fish response to in-stream habitat restoration (Polivka, 2011). Growth patterns are still under analysis for data collected in both years.

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*** Karl Polivka, Ph. D, is a researcher for the Pacific Northwest Research Station, USDA Forest Service, Wenatchee, WA and the principal investigator whose work is referenced in this case study.**

11. Appendix 2: CHaMP Indicators and related limiting factors

Indicator	Metrics	Indicator Generation Process	Fish Response Category	Life Stage	Limiting Factor-Ecological Concern	Potential Project Category
Average Alkalinity	Site measurement of alkalinity	Estimated annually for entire survey frame with sampling design-based algorithm.	Survival	Parr to smolt	**Food** – Altered Primary Productivity	Plantings, Beaver Introduction, Channel Modification, Side Channel,
Average Conductivity	Site measurement of conductivity	Estimated annually for entire survey frame with sampling design-based algorithm.	Survival	Parr to smolt	**Water Quality** - pH/Oxygen	Plantings, Beaver Introduction, Channel Modification, Side Channel,
Average pH	Site measurement of pH	Estimated annually for entire survey frame with sampling design-based algorithm.	Survival	Parr to smolt	**Water Quality -** pH/Oxygen	Plantings, Beaver Introduction, Channel Modification, Side Channel,
Growth Potential	Site measurement of drift biomass and temperature	Estimated annually for entire survey frame with sampling design-based algorithm for the product of drift macroinvertebrate biomass and temperature	Growth	Parr to smolt	**Food -** Altered Prey Species Composition and Diversity **Channel Structure and Form** - Instream Structural Complexity	Instream complexity, Fertilization, Planting
Percent Below Summer Temperature Threshold	Year-round temperature logger data from sites	Model-based inference for all stream reaches in the watershed based on a continuous stream temperature model calibrated with site specific temperature logger data	Growth	Parr to smolt	**Water Quality -** Temperature	Planting, Channel Modification, Beaver Introduction
Percent Above Winter Temperature Threshold	Year-round temperature logger data from sites	Model-based inference for all stream reaches in the watershed based on a continuous stream temperature model calibrated with site specific temperature logger data	Growth	Parr to smolt	**Water Quality -** Temperature	Instream complexity
Velocity Heterogeneity	Modeled velocity heterogeneity at a site	Estimated annually for valley types nested in the survey frame with sampling design-based algorithm for variance Froude number across a site.	Growth	Parr to smolt	**Water Quantity –** Increased Water Quantity/Decreased Water Quantity/Altered Flow Timing	Channel Form, Flood plain, wetland creation

Embeddedness of Fast water Cobble	Average of site embeddedness measurements	Estimated annually for valley type nested in the survey frame with sampling design-based algorithm for riffle cobble embeddedness.	Survival	Eggs/Alevin	**Sediment Conditions -** Increased Sediment Quantity	Sediment Reduction, Planting
Pool Frequency	Site measurement of pool frequency	Estimated annually for valley type nested in the survey frame with sampling design-based algorithm for pool frequency.	Growth	Parr to smolt	**Channel Structure and Form** - Instream Structural Complexity	Instream Complexity, Channel Modification
Channel Complexity	Site measurements of depth, width, and thalweg sinuosity	Estimated annually for valley type nested in the survey frame with sampling design-based algorithm for variance in depth, variance in width, and variance in thalweg sinuosity.	Growth	Parr to smolt	**Channel Structure and Form** - Bed and Channel Form	Channel Modification
Channel Score	Site measurements of habitat unit volume, LWD, and substrate	Estimated annually for valley type nested in the survey frame with sampling design-based algorithm metrics necessary for RP100 calculations as used by PIBO, AREMP, and EMAP.	Growth	Parr to smolt	**Channel Structure and Form** - Instream Structural Complexity	Instream Complexity, Riparian
Residual Pool Volume	Site measurement of residual pool volume	Estimated annually for valley type nested in the survey frame with sampling design-based algorithm for residual depth of all pools as given by the site DEM.	Growth	Parr to smolt	**Channel Structure and Form** - Instream Structural Complexity	Instream Complexity,
Subsurface Fines	Site measurement of subsurface fines	Estimated annually for valley type nested in the survey frame with sampling design-based algorithm for subsurface fines.	Survival	Eggs/Alevin	**Sediment Conditions -** Increased Sediment Quantity	Sediment Reduction, Planting
Total Drift Biomass	Site measurement of total drift biomass	Estimated annually for valley type nested in the survey frame with sampling design based algorithm for total drift biomass.	Growth	Parr to smolt	**Food -** Altered Prey Species Composition and Diversity	Instream complexity, Fertilization, Planting
LWD Volume	Site measurement of LWD Volume	Estimated annually for valley type nested in the survey frame with sampling design-based algorithm for LWD volume.	Growth	Parr to smolt	**Channel Structure and Form** - Instream Structural Complexity	Instream Complexity, Riparian
Fish Cover	Site measurement of fish cover	Estimated annually for valley type nested in the survey frame with sampling design-based algorithm for habitat unit type and whole reach total fish cover.	Survival	Parr to smolt	**Habitat Quantity** - HQ-Competition	Instream Complexity,

Channel Unit Volume	Site measurement of volume (DEM, photos, site map) and channel unit type	Estimated annually for valley type nested in the survey frame with sampling design-based algorithm for habitat unit volume from site DEM and habitat unit delineation.	Growth	Parr to smolt	**Peripheral and Transitional Habitats** - Side Channel and Wetland Conditions & **Habitat Quantity** - HQ-Competition	Channel Modification
Channel Unit Complexity	Site measurements of habitat unit volume, LWD, and substrate	Estimated annually for valley type nested in the survey frame with sampling design-based algorithm for residual pool depth, subsurface fines and wood volume. A multivariate measure of habitat unit complexity, similar to DSM approach applied by AREMP and PIBO to habitat metrics to capture complexity.	Growth	Parr to smolt	**Channel Structure and Form** - Instream Structural Complexity	Instream Complexity, Side Channel
Riffle Particle Size (D16, D50, D84)	Site measurement of D50, D16, D84	Estimated annually for valley type nested in the survey frame with sampling design-based algorithm for D16, D50, and D84 from riffles.	Survival	Eggs/Alevin	**Sediment Conditions -** Increased Sediment Quantity; Decreased Sediment Quantity	Sediment Reduction, Gravel Placement
Riparian Structure	Site measurement of riparian structure	Estimated annually for post hoc stratified domains of historical riparian vegetation types in the survey frame with sampling design based algorithm for each riparian structure.	Growth	Parr to smolt	**Riparian Condition** - Riparian Condition	Planting, Fencing,
Solar Input	Site measurement of solar input	Estimated annually for valley type nested in the survey frame with sampling design-based algorithm for solar input.	Growth	Parr to smolt	**Water Quality –** Temperature, **Food** – Altered Primary Productivity	Planting, Channel Form

12. Appendix 3: Watershed Level Action Effectiveness Monitoring

Integrated Status and Effectiveness Monitoring Program (ISEMP)

ISEMP was first established in 2003 to develop a set of standardized methods to monitor both fish populations as well as changes in habitat condition. ISEMP developed the habitat status and trend monitoring techniques now used in the Columbia Habitat Monitoring Program (CHaMP) and continues to collect data on juvenile salmonids. For example, ISEMP's PIT tagging program provides estimates of juvenile abundance, survival, growth and escapement for Chinook and steelhead, with known and statistically verifiable estimates of uncertainty. This information on freshwater productivity will improve estimates of fish-habitat relationships basinwide.

ISEMP implements both population scale action effectiveness (AE) monitoring and status and trend monitoring for both fish and habitat in five intensively monitored watersheds (IMWs) throughout the Columbia Basin. Those watersheds include the Entiat and Wenatchee basins in the Upper Columbia, the John Day basin (including the Bridge Creek IMW), and the Salmon River Basin in Idaho (including both the South Fork Salmon and the Lemhi River basins) (see Figure 4). These areas were selected because they represent different eco-regions and geologic/geomorphic conditions within the Columbia Basin. They also include different ESUs and DPSs. For example, the Entiat and Wenatchee rivers are part of the Upper Columbia spring Chinook salmon ESU and Upper Columbia steelhead DPS. The John Day is part of the Middle Columbia River steelhead DPS, while the Lemhi and South Fork Salmon rivers are part of the Snake River spring/summer Chinook Salmon ESU and Snake River steelhead DPS.

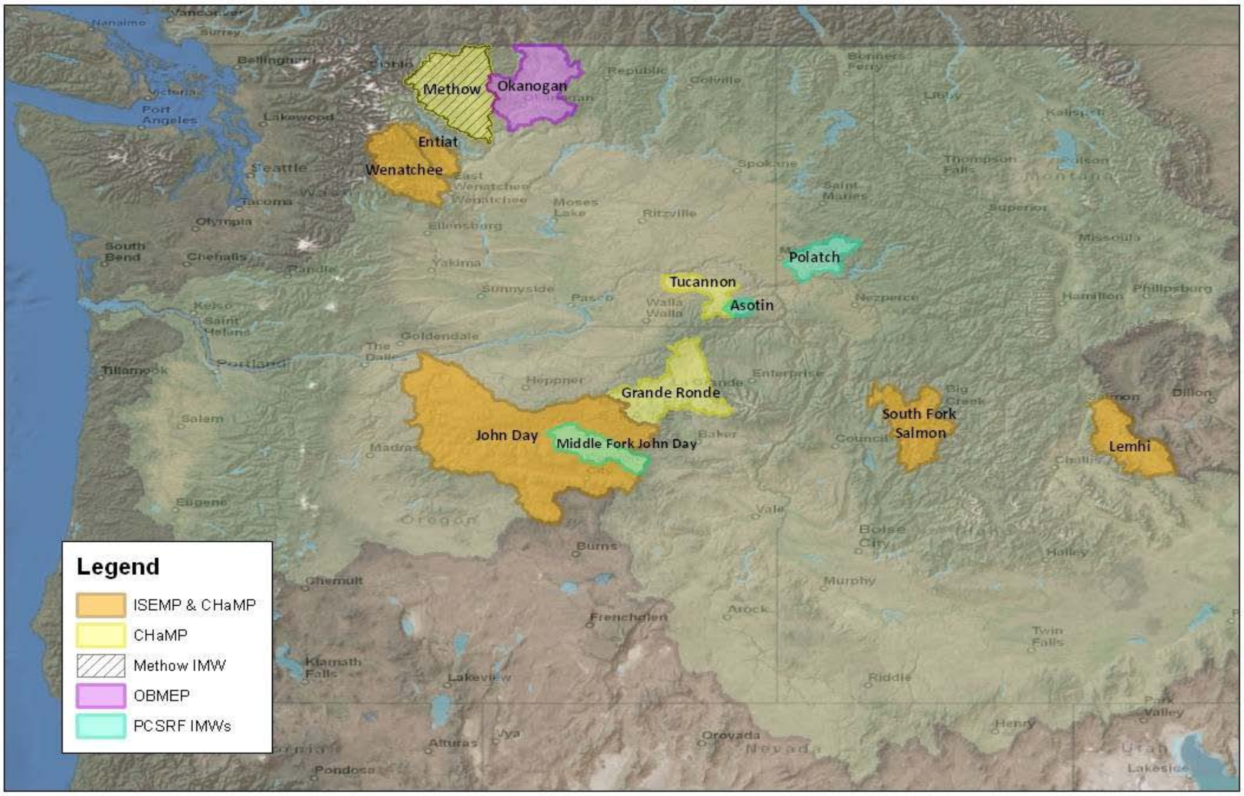

Figure 1. Columbia River sub-basins included in the Integrated Status and Effectiveness Monitoring Program (ISEMP), USBR Methow River IMW, Okanogan Basin Monitoring and Evaluation Program (OBMEP), and Pacific Coastal Salmon Recovery Fund (PCSRF) IMWs.

ISEMP is implemented by a multi-disciplinary/multi-agency team led by NOAA's Northwest Fisheries Science Center (NWFSC). It is designed to evaluate habitat actions and their effects on salmon and steelhead performance. This is accomplished by implementing both experimental and model-based approaches. For example, in the Entiat Basin, different types of habitat improvement actions are implemented in a series of steps according to a rigorous experimental design developed by ISEMP. This design allows researchers to evaluate the effect of suites of habitat improvement actions on fish performance at different spatial scales. In the Lemhi Basin, models are used to evaluate the effects of habitat improvement actions there. These models help to identify the mechanisms by which fish populations respond to habitat improvement actions. The Bridge Creek IMW, in the John Day basin, offers a unique opportunity to assess the effects of a single specific habitat improvement action, without the confounding effects of other habitat actions, on the performance of fish.

The fish-habitat relationships identified through ISEMP and other IMWs (e.g. Asotin Creek and the Germany, Mill, and Abernathy creeks) will help local watershed groups identify appropriate habitat actions and help expert panels evaluate the effects of actions on local habitat conditions.

One example of population scale AE monitoring undertaken by ISEMP is in the Lemhi watershed in Idaho. A Lemhi IMW in the Salmon River Basin is testing the effectiveness of reconnecting numerous small tributaries to the mainstem Lemhi River. While tributary reconnections are the major focus, the

Lemhi IMW also evaluates additional habitat actions including channel modifications, riparian fencing, diversion removals and screening, and side-channel development (ISEMP 2012).

ISEMP applied data since 2009 to a watershed production model to test whether the reconnection of tributaries to the mainstem Lemhi has been effective. In 2013, the model will contain data for one complete brood year of Chinook, but ISEMP has started to test the model and has also produced sample outputs that could inform management decisions in the near future. Figure 5 below shows a sample output that describes potential response curves for adult spawners given three reconnection scenarios (e.g. existing connections only, high priority reconnections only, or both high and moderate reconnections). While this model is not yet ready for use in decision making, this example, demonstrates its potential for projecting how various habitat actions will benefit fish. Other outputs derived from this model will include: identification of limiting factors, identification and comparison of effective project types, relating habitat improvements to survival improvements, identification of appropriate RM&E and evaluation of changes in habitat and fish populations.

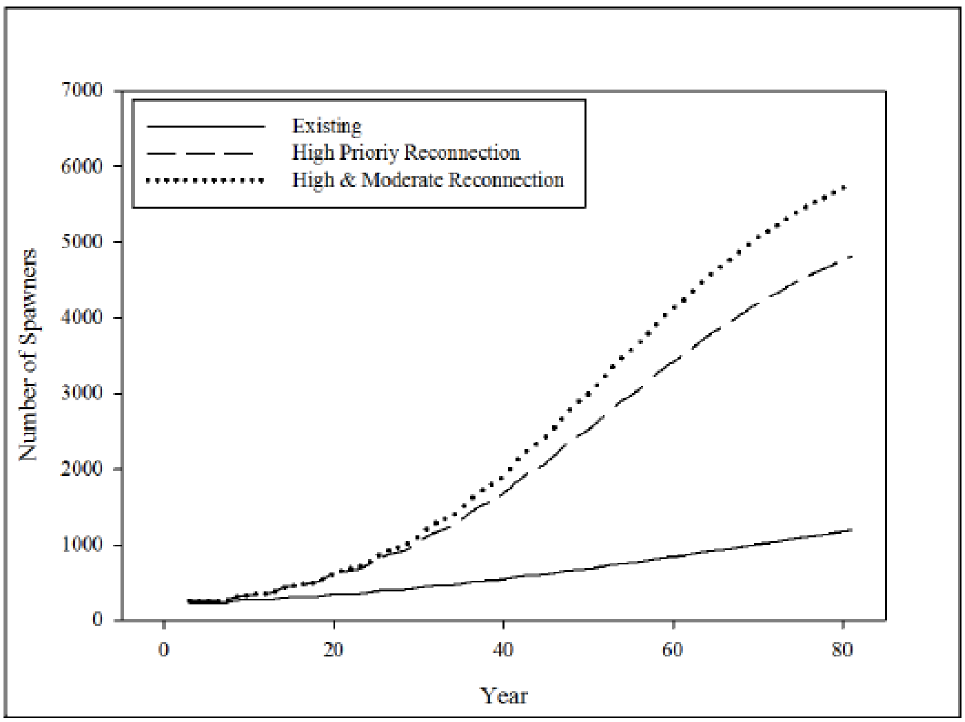

Figure 2. Number of spring/summer Chinook salmon adults returning to the Lemhi River given existing habitat, reconnection of high priority watersheds, and reconnection of high and moderate priority watersheds. (From ISEMP, 2012).

Reclamation's Methow River IMW

The Methow River IMW watershed is home to two ESA-listed populations of anadromous fish: endangered Upper Columbia River spring Chinook and threatened Upper Columbia River steelhead. The population of the Methow watershed is further divided into subpopulations in five distinct regions: the Upper Methow River above Winthrop, the Chewuch River at Winthrop, the middle Methow River between Winthrop and Twisp, the Twisp River, and the Lower Methow River below Twisp including three significant tributaries (Beaver Creek, Libby Creek and Gold Creek).

The Methow IMW partnership is a collaborative monitoring effort of the Upper Columbia River Salmon Recovery Board (UCSRB), the Washington Department of Fish and Wildlife (WDFW), the Douglas Public Utility District (DCPUD), the Yakama Nation (YN), the U.S. Fish and Wildlife Service (USFWS), the Northwest Fisheries Science Center (NWFSC), and the U.S. Forest Service (USFS), through Research, Monitoring and Evaluation (RME) agreements with the U.S. Geological Service - Columbia River Research Laboratory (USGS-CRRL) and the Cooperative Ecosystem Study Unit – University of Idaho Fish and Wildlife, College of Natural Resources (U of I).

Reclamation funded the development of models to propose and test hypotheses about how habitat projects affect fish survival and production. The models will be used to compare the effectiveness of a project or combinations of projects at varying spatial scales. A complimentary database project will track habitat and fish data before and after treatment.

Reclamation, USGS-CRRL and U of I developed an RME framework (Figure) to guide the collaboration among the Methow monitoring entities.

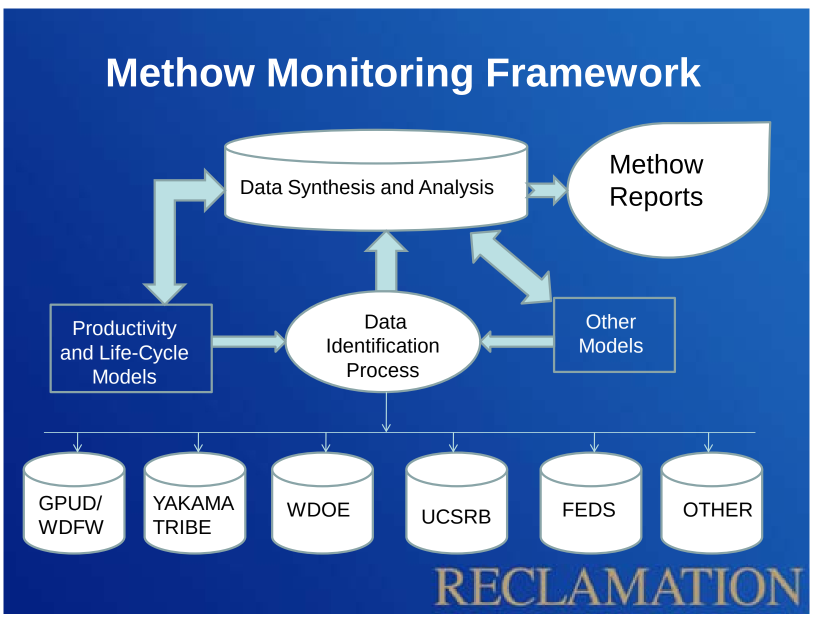

Figure 3: Reclamation Monitoring Framework in the Methow Basin

The primary model is the aquatic trophic productivity (ATP) model. It calculates how habitat influences the food available to fish and how the energy from food translates to fish survival and production. This model has been parameterized from literature values and from a recently completed Methow River trophic productivity study. The model will be used to predict fish production at several planned treatment sites. The monitoring partners are developing study designs for the treatment sites. CHaMP surveys will provide habitat data at the treatment sites. Additional habitat and fish data will be collected by other Methow monitoring partners. The model is approximately 50% complete. After a model assessment and recalibration period, the intent is to use CHaMP data and other project-level action effectiveness data to scale up production to the watershed level. The ATP model will be connected to a full life-cycle model to predict population changes through time.

We use the system dynamics software Stella@ (http://www.iseesystems.com/) to code the complex mechanistic interactions among habitat and fish populations in the ATP model. Stella@ supports mapping and modeling; simulation and analysis; and communication tools including text, graphs, tables and reports. The software is flexible and easy to learn. It supports full internal documentation in the stock and flow representations of the dynamical processes.

The core ATP model will be driven by separate 'actor' or treatment modules for each of the main Methow River habitat treatments (Figure). Each actor module will connect to the ATP model at the mechanistic points that are affected by the treatment type. Actor modules will be run independently or simultaneously to reflect combinations of treatments.

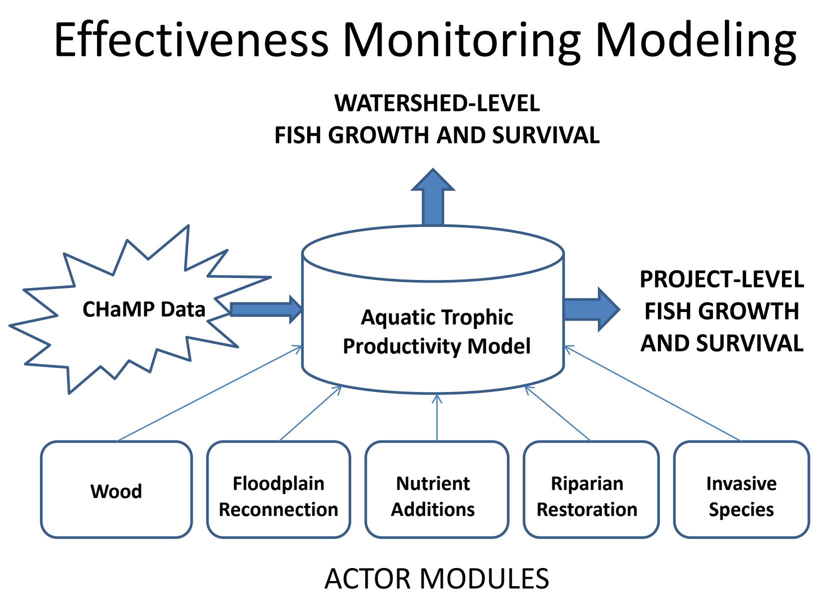

Figure 4: Reclamation Effectiveness Monitoring

Okanogan Basin Monitoring and Evaluation Program (OBMEP)

The OBMEP program[2], implemented by the Colville Tribes and funded by BPA, represents the long-term monitoring effort for habitat conditions and steelhead natural production in the Okanogan River Basin. Although the focus is primarily steelhead, the project also consolidates information related to sockeye and Chinook salmon. OBMEP is based on existing strategies (ISAB, Action Agencies/NOAA Fisheries, and WSRFB), guidance from the Monitoring Strategy for the Upper Columbia Basin (Hillman 2006), and was

[2] http://www.colvilletribes.com/obmep.php

called for in the Upper Columbia Salmon Recovery Plan along with the Okanogan sub-basin plan (Miller et al. 2011) due to very little monitoring data within this basin prior to this program. These data are now used to help inform reevaluating limiting factors, recovery plan adaptive management, action prioritization/selection, local fisheries management, and new action development.

The primary information collected can be placed into two categories. The first, biological data, includes: status and trends for summer steelhead adults (see Figure), fish community and macro invertebrate standing crop and juvenile steelhead out-migrants. The second category of information is salmonid habitat data that helps define existing conditions and changes over time. Additionally, habitat status data feeds the Ecosystem Diagnostic and Treatment (EDT) model which is used to understand and articulate the relationships between habitat and fish. The input parameters for EDT need further division to include information that varies across time (e.g. temperature, discharge/stage, dissolved oxygen) and habitat input parameters that vary across space (e.g. wetted and bankfull width, hydraulic and natural confinement). These habitat parameters are measured at 125 sites, with 50 sites visited annually and all sites visited every four years.

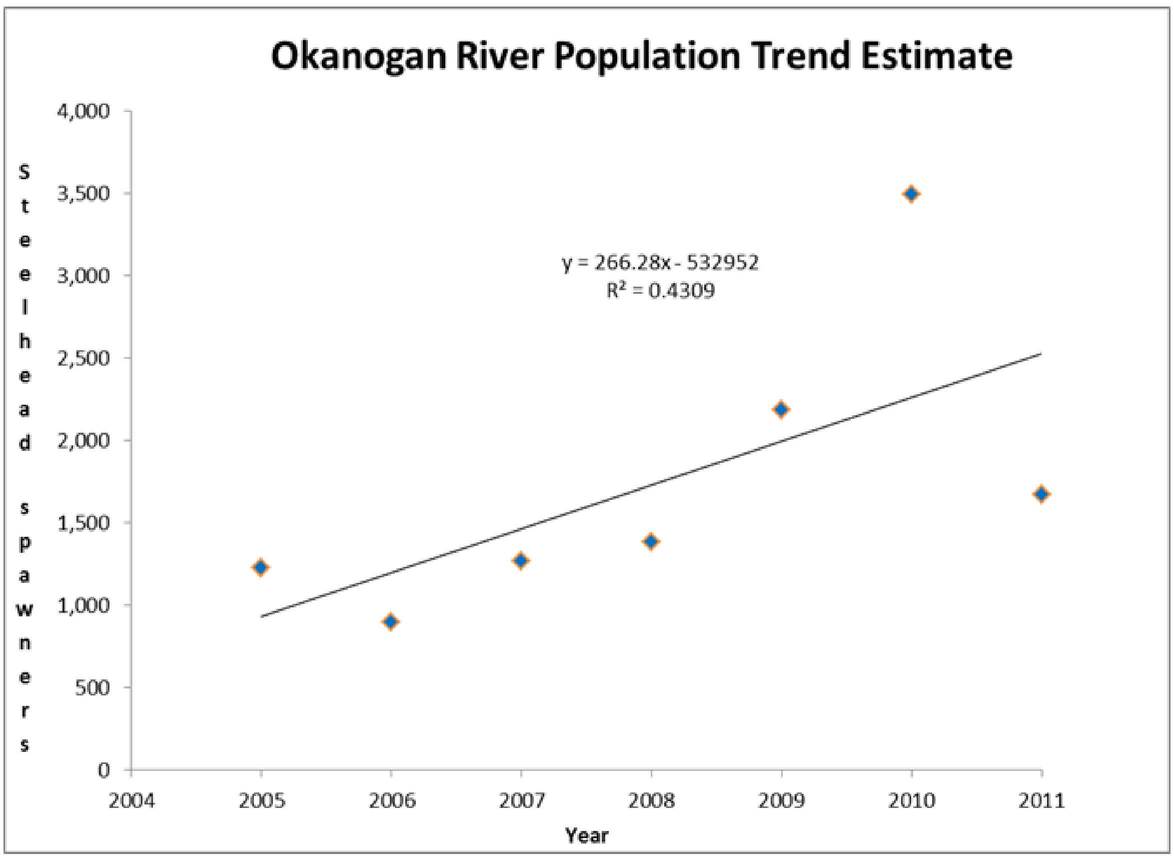

Figure 5: Population figures from 2005 through 2011 developed by OBMEP demonstrate an upward trend for summer steelhead in the Okanogan River basin.

Columbia River Inter-Tribal Fish Commission (CRITFC) IMW in the Grande Ronde

The Columbia River Inter-Tribal Fish Commission (CRITFC) leads a habitat action effectiveness monitoring program in the Upper Grande Ronde River and Catherine Creek basins (home to two threatened populations of the Grande Ronde MPG) that is designed to evaluate the effectiveness of aggregate habitat improvement actions. The Bonneville Power Administration funds this program to assess the effects of improvements to salmonid habitat on fish production. Fish data is obtained from Oregon Department of Fish & Wildlife (ODFW).

It includes three main objectives:

1. Assess status and trends in key limiting factors affecting ESA-listed spring Chinook using the CHaMP monitoring protocol, and additionally sampling subsurface sediment, benthic macroinvertebrates, and fish density and assemblage using a spatially balanced statistical design (GRTS). In addition, water temperature modeling and remote sensing of riparian condition at a stream network level will provide comprehensive status and trends for riparian condition and the water temperature regime. Additionally, because the team is assessing macroinvertebrates using the CHaMP protocol (drift sampling) and PNAMP protocol (benthic sampling; comparable with PIBO protocol), comparison of the two methodologies will help determine how these two factors relate to salmonid numbers and if one or both reflect juvenile salmonid habitat quality (e.g. as an indicator of food availability or a general indicator of water quality).

Snorkel surveys in the Okanogan Basin.

2. Evaluate the effectiveness of aggregate stream habitat improvement actions aimed at improving key limiting habitat factors (e.g. water temperature, spawning substrate condition).

3. Develop a life cycle model to help define the relationship between biotic responses of spring Chinook populations to current conditions and projected changes in stream habitat. In collaboration with other partners (NOAA, ODFW, and CTUIR), a quantitative modeling approach will be used to estimate the annual variation in recruitment and survival.

To date, this program has completed a preliminary water temperature model using water temperature and streamflow data to predict environmental conditions in the basin under different scenarios such as a changing climate. The CRITFC team extrapolates streamflow values to CHaMP sites that do not have streamflow gages by correlating the USGS gauged locations with local geologic characteristics. The team is still developing and incorporating the riparian improvement scenarios and expects to have a working model in 2014 that will project temperature blockages for salmonids and the frequency of low flows under different streamflow, air temperature, and habitat improvement scenarios.

In addition, the team is investigating the relationship between large woody debris and higher juvenile salmonid densities. This study seeks to identify the combined effect of pools and woody debris on summer juvenile salmonid rearing densities (an indicator of juvenile salmon habitat capacity), as well as the role of riparian canopies and other factors on local water temperatures. Results are reported annually in the CHaMP annual report and in an individual project report that is submitted to BPA.

NOAA-Funded IMWs

Other watershed-level AE monitoring programs are occurring with separate funding. For example, IMWs in Asotin Creek, John Day, Potlatch/Clearwater and the Germany, Mill, and Abernathy creeks all occur within the Columbia Basin. Although these are not funded by the Action Agencies, information generated from these IMWs will be integrated into the Action Agencies' monitoring program. Lessons learned from these IMWs will also be referenced in lessons learned from the Action Agencies' program.

Asotin IMW

The Snake River Salmon Recovery Board began funding an IMW in the Asotin Creek in 2007. The study design has undergone several changes since its inception but program is now in its fourth year of pre-project implementation. The Asotin IMW has used several habitat monitoring protocols and programs including PIBO in 2008 and 2009, and CHaMP in 2010 (draft protocol) and 2011. The focus of habitat rehabilitation work in this IMW centers on actions that improve the function of the riparian corridor along the stream.

As part of the pre-treatment monitoring in the Asotin, both adult and juvenile steelhead abundance has been tracked. Juvenile steelhead have been PIT tagged since 2008 as part of the IMW monitoring. The first habitat modifications were made in 2011 as a trial effort. Full implementation of the habitat improvement activities is scheduled to begin in 2012 with implementation and monitoring scheduled to continue through 2018. See Bennett *et al.* (2012) for a short summary of this IMW.

Upper Middle Fork John Day IMW

The Upper Middle Fork John Day IMW is a program including a broad partnership of federal, state, Tribal, university based, and private interests. Habitat improvement work was implemented in the Upper Middle Fork John Day IMW beginning in 2007. All habitat improvement projects in this IMW have at least one year of pre-treatment data. Like in the Asotin, a number of habitat monitoring protocols have been used in this IMW including PIBO protocols in 2008 and CHaMP protocols in 2011. Continuous monitoring of local fish populations has occurred since 2007 but previous periodic estimates as far back as 1990 have also been incorporated. Some status and trend results are already available and a full roll-up of effectiveness is projected to be available in 2017. See Abraham and Curry (2012) for more details.

Potlatch/Clearwater IMW

The Potlatch River Steelhead Monitoring and Evaluation (PRSME) project was initiated in 2005 using Pacific Coastal Salmon Recovery Funds (PCSRF). In 2008, the project was expanded into the upper

Potlatch River watershed using National Oceanic and Atmospheric Administration (NOAA) Fisheries Intensively Monitored Watershed (IMW) funds. The additional funds allowed work to occur simultaneously throughout the drainage (Bowersox and Biggs, 2012). Habitat monitoring has occurred in the basin since 2005 along with associated fish monitoring. Habitat improvement actions in this IMW are meant to address limiting factors such as: extreme flow variation, high summer water temperatures, lack of riparian habitat, high sediment loads, and low densities of in-stream structure. To date, most habitat improvement work has occurred outside of areas in the IMW, but significant habitat improvement efforts are being developed for implementation in 2012. A strong baseline data set is in place, providing a substantive basis for comparison once restoration actions occur within this IMW. Usable results are expected five to 10 years after implementation. See Bowersox and Biggs (2012) for more information.

Other IMWs outside of the geographic scope of this framework

In addition to the three IMWs described above, there are also several IMWs that occur in areas outside of the geographic scope of this paper. IMWs below Bonneville Dam (e.g. Germany, Mill, and Abernathy creeks) or in other areas of the Pacific Northwest (e.g. the Skagit River in Puget Sound) may still provide relevant and useful results that would be included in any analysis of habitat benefits for the Action Agencies 2013 Comprehensive Evaluation.

Action Agency Funded Habitat Status and Trend Monitoring Programs

Columbia Habitat Monitoring Program (CHaMP)

CHaMP is a fish-centric habitat quality monitoring program that is designed to detect changes in habitat over time (status and trend) or as a result of habitat actions (AE monitoring). CHaMP habitat data can also be paired with population or watershed-scale fish data and provide information on fish-habitat relationships. CHaMP began as a joint undertaking of federal, state, tribal, and private parties that was developed by sponsors of the ISEMP program and uses a standardized data collection and analysis protocol. While CHaMP monitoring covers environmental measurements and does not collect fish data, all CHaMP basins were intentionally located in areas with existing fish-in/fish-out data that can be combined with habitat monitoring data in their annual synthesis reports. The 2011 CHaMP pilot year included 10 watersheds[3] (see Figure 5) which includes the Asotin watershed in the mid-Columbia region that was funded by NOAA's PCSRF program as well as one sub-basin in California.

[3] Full expansion of CHaMP would encompass 18 watersheds.

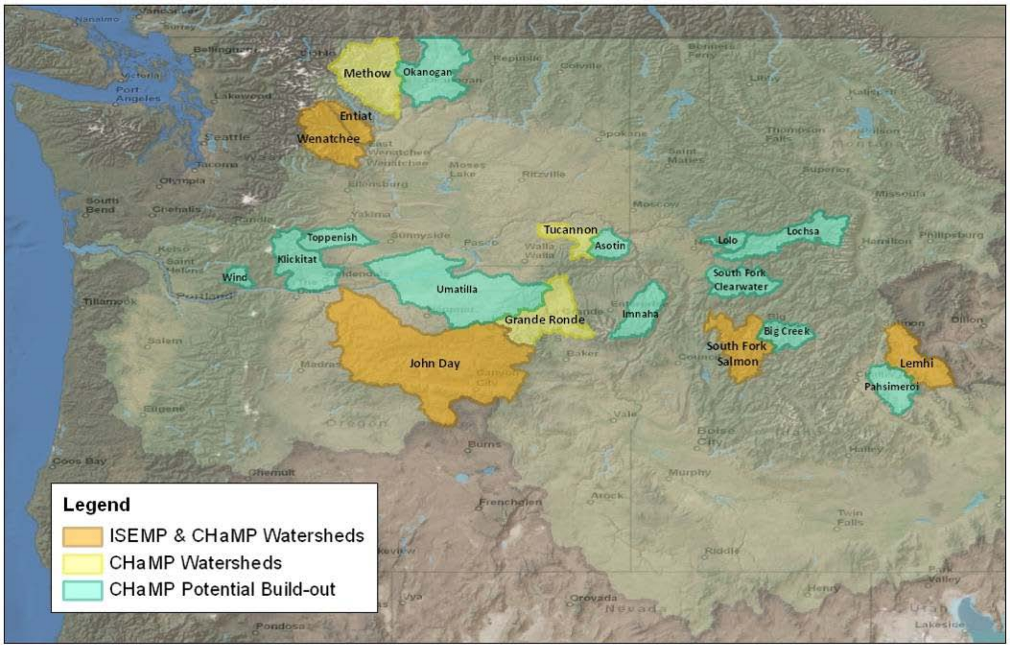

Figure 6. Basins currently included in the Columbia Habitat Monitoring Program (CHaMP) and those that may be included in the future.

In basins where CHaMP and ISEMP overlap, CHaMP monitoring supplements extra data collection sites to increase coverage for IMWs. As an example of the combined data sets collected by CHaMP and ISEMP, Table 5 shows that number of habitat samples collected in 2011.

Table 2. Summary of 2011 Sites surveyed with CHaMP protocol and tools

	CHaMP Sites	ISEMP IMW Sites	Total Sites Surveyed with CHaMP protocols and Tools
Methow	25		25
Entiat	16	60	76
Wenatchee	23		23
Tucannon	24		24
South Fork Salmon	25	8	33
Lemhi	25	17	42
John Day	50	9	59
Upper Grande Ronde	56		56
BPA-Funded Total	244	94	338

As mentioned above, the CHaMP program collects data on 78 different habitat parameters which are derived from 22 direct habitat measurements. Over time, the goal is to further narrow the number of measurements as the most important and telling metrics become evident. Some habitat measurements are measured directly using traditional methods, but others are derived from habitat measurements collected using professional surveying techniques. By intensely surveying a study site, the CHaMP program can develop detailed 3D models (called digital elevation models or DEMs) of each stream reach (see figure 6) that can be used for a wide variety of analysis techniques.

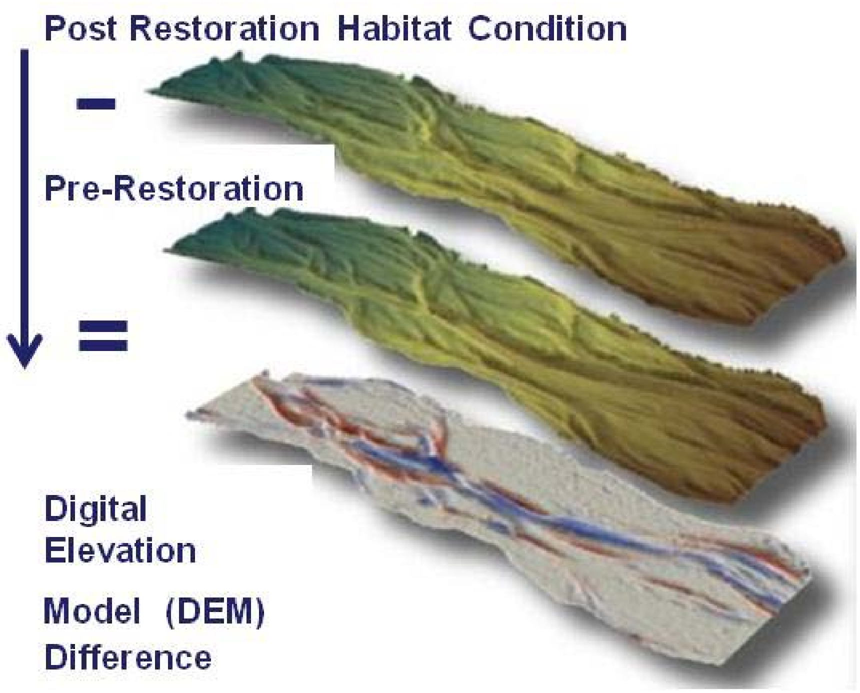

Figure 7. Example of Digital Elevation Models produced using the CHaMP protocol. Digital Elevation models taken before and after habitat improvement actions can be compared to see how the local habitat has changed (e.g. streambank measurements, such as erosion/deposition, average bankful width, number of pools). In this example, in the lower panel, red represents erosion and increased water depth and blue represents deposition, where water depth has decreased.

Examples of habitat status and trend information that can be generated from the CHaMP program are found in the program's annual report but selected examples are shown below. The CHaMP annual report and other background are available at www.champmonitoring.org, under "documents."

The habitat and fish correlations using habitat data collected by CHaMP, paired with fish data collected by ISEMP, are expected to provide high value results for both resource managers and local watershed groups that develop habitat improvement projects for review by the expert panels . Figure 7 is taken from the 2011 CHaMP report and shows the nine most important metrics for chinook salmon in the areas that CHaMP sampled. This chart based on only one year of data shows the relationships between the habitat metric (x-axis) and habitat quality (y-axis) and will change as more data is collected. The metrics themselves may also shift in the order of importance. While these relationships will evolve, these charts are an example of data that will be reported annually.

The habitat quality index on the y-axis reflects juvenile Chinook density, so these curves could be used by groups proposing habitat improvement actions to provide quantifiable goals for habitat improvement work. By proposing work to increase stream flow or pool volume past the threshold where juvenile abundance increases rapidly, habitat improvement work can target the most important limiting factors for Chinook at a level that should increase the success of a fish response.

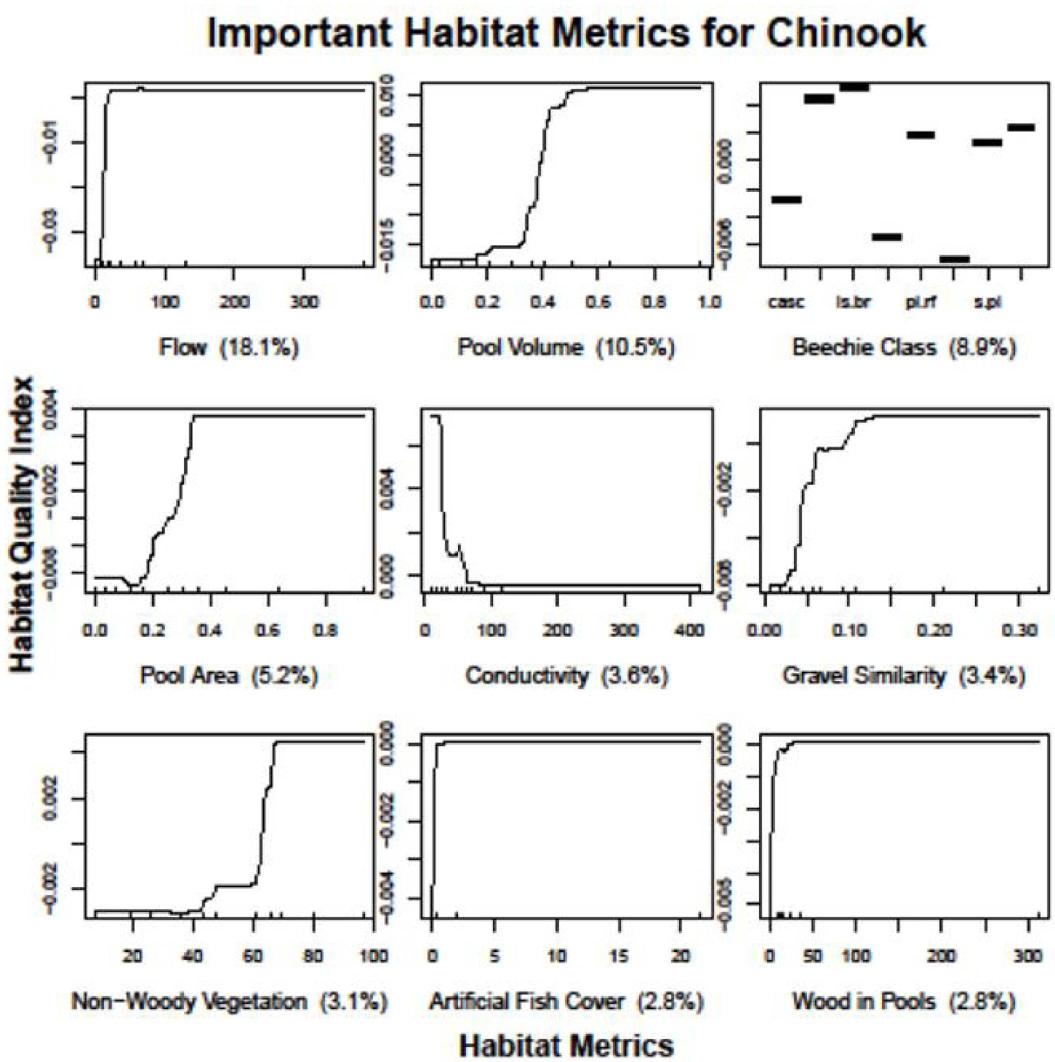

Figure 8. 2011 CHaMP Habitat Data combined with ISEMP Fish Data showing the response of fish density, as represented by the Habitat Quality Index, to nine of the nine most important habitat factors identified for that year. Such relationships will evolve further as more years of CHaMP data become available.

In addition to the example of habitat data shown above, CHaMP can also produce other tools that will be of great value to the Expert Panels as they evaluate the effectiveness of the AA's habitat improvement program. For example, the status and trend and AE monitoring data will help gauge how habitat has responded to the suite of habitat improvement projects in the watershed and evaluate whether restoration actions such as pools with large woody debris were effective and how environmental responses change over time. By adding the ISEMP and other programs' fish data, the fish-habitat relationships may also help predict what kind of fish abundances or densities could be expected with various suites of habitat improvement projects.

Bureau of Reclamation Tributary and Reach Assessments

Tributary and reach assessments produced by Reclamation include habitat condition information that can serve as baseline information for new habitat monitoring programs or supplement existing programs. These assessments evaluate geology, geomorphology, hydrology, hydrography, and vegetation conditions at a large (tributary) and refined (reach) scale to characterize how a dynamic river system operates within a channel and associated floodplain. These reports are used by resource managers to identify, prioritize, and implement sustainable habitat improvement projects that provide the greatest benefits to salmon and steelhead.

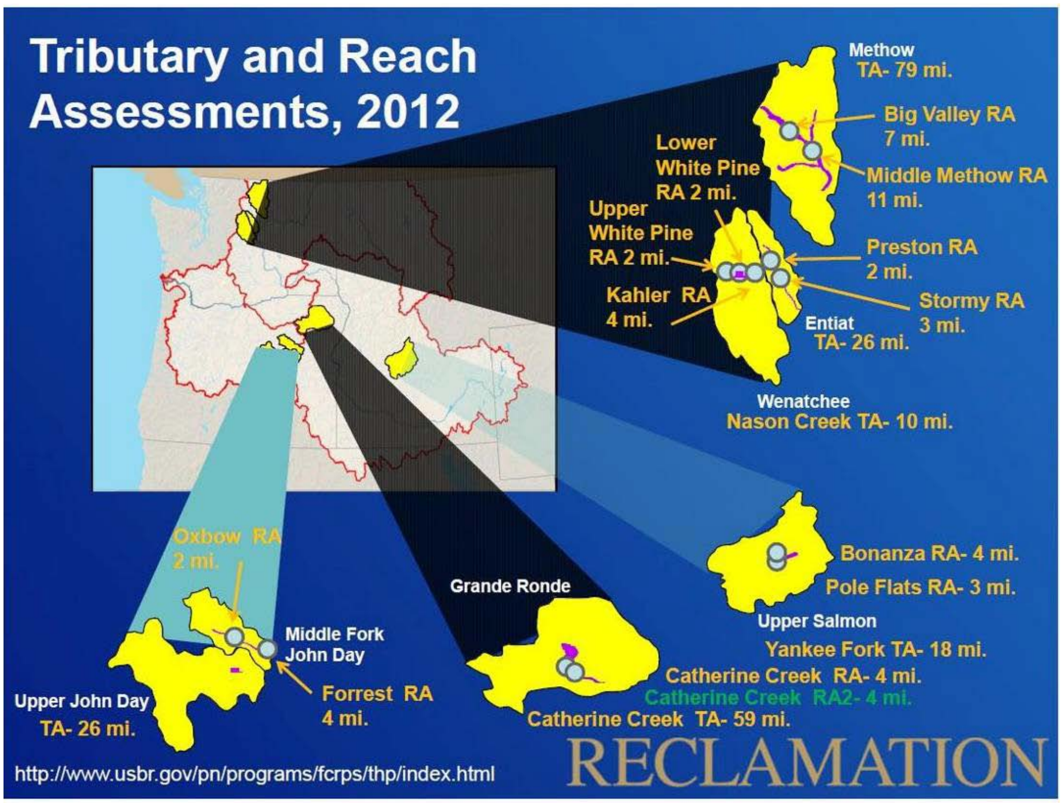

Figure 9. Locations of tributary and reach assessments produced by the Bureau of Reclamation. Orange names were completed and green names were in progress as of 2012.

Other Regional Habitat Status and Trend Monitoring Programs

USDA PIBO Monitoring Program

The PIBO program is implemented by the USDA's Forest Service (USFS) and Bureau of Land Management (BLM).[4] PIBO is a large-scale stream/riparian monitoring program intended to track conditions affecting

[4] http://www.fs.fed.us/biology/fishecology/emp/

fish on public lands in the Interior Columbia River Basin. PIBO is referenced under BLM's BiOp. PIBO receives funding from three regions of the Forest Service, two BLM state offices, and the US Environmental Protection Agency. PIBO's main program objectives are to:

1. inventory and monitor streams and riparian areas on federal lands of importance to fish in Upper Columbia River Basin;
2. determine if stream and riparian conditions are being maintained and/or improved;
3. Determine what effect federal management activities are having on stream habitat trends as related to fish populations.

In 2011, PIBO monitored 452 sites on federal lands using six measurements. Although PIBO and CHaMP both collect habitat status and trend data, the design is different because they have different goals.

Both programs have an extensive training program each year prior to the field season. The PIBO program was designed to monitor habitat in the upper reaches of streams that are typical of national forest lands and that are primarily affected by forestry activities (e.g., road construction, timber cutting and replanting, riparian buffer effectiveness, etc). In contrast, the CHaMP program was designed to monitor a stream types and associated habitat conditions in areas that range from upland forests to low-gradient lowland streams on both public as well as private lands. Because these two programs are both measuring habitat conditions used by Chinook salmon and steelhead, they collect some of the same measurements (e.g., water temperature, stream depth, etc.), but because they occupy different sections of the watersheds (with some overlap), and are designed to answer different questions, they also measure some habitat components that are unique to each program. Since there is overlap in some sub-basins, especially those with a large amount of USFS or BLM lands (e.g. Lemhi, Salmon, John Day), the CHaMP and PiBO programs are currently collaborating and investigating ways to better coordinate and use each other's data where possible. In 2012, the two programs identified several sites at which to perform side-by-side comparisons to determine the best way to collaborate and share data. By leveraging the two program's data sets where available, the federal agencies responsible for implementing PIBO and CHaMP will have a richer, more efficient source of information from which to make their management decisions.

After publication of the status and trend data of environmental conditions data collected by these programs local experts or technical teams may use this data or expert opinion to further document the limiting factors for specific salmonid populations at the Assessment Unit and eventually down to the reach level across the Columbia basin.

This is reflected in the width of the bar documented as Watershed Weight in Figure 10. Example of the Entiat Steelhead "Middle Entiat" Assessment Unit and Limiting Factor Documentation of priority limiting factors and Assessment Units will be further used to inform the solicitation of the most relevant restoration actions to achieve habitat improvement targets. Additional details regarding the colors associated with the charts are related to characterization of current condition, the potential for improvements and future actions ability to address limiting factors, which is further discussed in Section 8.

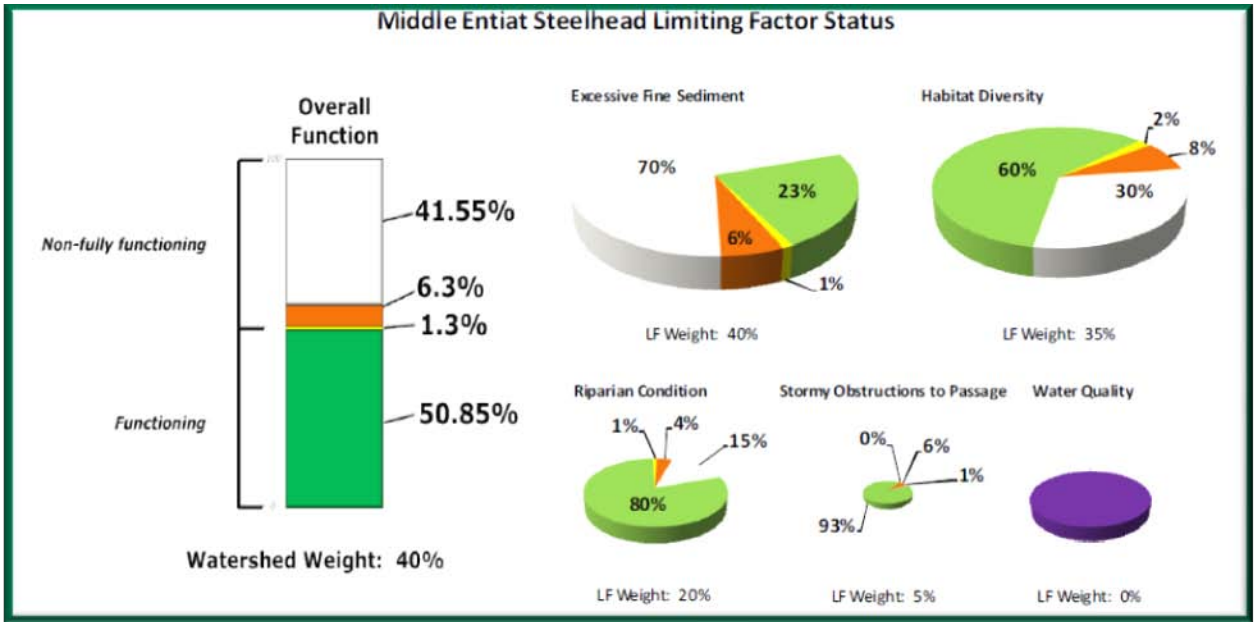

Figure 10. Example of the Entiat Steelhead "Middle Entiat" Assessment Unit and Limiting Factors weights

Other habitat status and trend monitoring programs also occur within and outside the FCRPS BiOp area. For example, the Washington Department of Ecology is implementing a habitat status and trend monitoring program in the state of Washington. Although this program is not funded by the Action Agencies, to the extent possible, information generated from these outside programs will be integrated into the Action Agencies' Tributary Habitat Monitoring Program going forward.