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2010 ANALYSIS WORKSHOP SYNTHESIS REPORT

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Upper Columbia Regional Technical Team 2010 Analysis Workshop Synthesis Report

November 8, 2010 (Publication Date)

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This document is a summary of a workshop held by the Upper Columbia Regional Technical Team on January 12-13, 2010 in Wenatchee, WA as part of the Upper Columbia Salmon Recovery Board's adaptive management process for salmon and steelhead recovery in the Upper Columbia. It was adopted by the Upper Columbia Regional Technical Team on October 13, 2010

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The document can be obtained online at: www.ucsrb.com

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Letter of Welcome from UCRTT and UCSRB Chairs

November 8, 2010

Dear Conference Participants and Interested Persons:

Welcome to the first Upper Columbia Habitat Adaptive Management 2010 Science Conference! This forum represents a key milestone in the adaptive management cycle for the *Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan* (2007). Although the Conference is a one day event, it is part of an ongoing process. Planning for the Conference and the Upper Columbia Regional Technical Team 2010 Analysis Workshop that preceded it began more than two years ago. The Conference reflects an unprecedented level of collaborative agreement among partners from tribal, federal, state, county entities, and non-governmental organizations.

Even before the federal government formally adopted the Recovery Plan, the Upper Columbia Salmon Recovery Board (UCSRB), the Upper Columbia Regional Technical Team (UCRTT), and project partners established a habitat adaptive management framework (see inside back cover), built an implementation infrastructure for the Recovery Plan, and hired a Data Steward to manage project data. The Data Steward also assists the UCRTT in the process of identifying data gaps, conducting analyses, and translating information into recommendations for actions. These and many other steps laid the groundwork for this Adaptive Management Science Conference.

Collectively, we have completed a tremendous amount of work and made significant progress towards achieving our recovery goals. And even though the tasks we have completed place us on the cutting edge of salmon recovery efforts, we still lack many of the answers we seek. You will find a consistent theme throughout the UCRTT 2010 Analysis Workshop Synthesis Report; in nearly every case, we have made significant progress to lay the ground work to answer key management questions, but more work lies ahead. The complexity of our challenge means that answers are interlinked across project elements. For example, in the Habitat Status and Trend chapter you will see that issues surrounding efficiency in monitoring methodology must be resolved before key management questions can be answered.

We have prepared the analyses and recommendations in this document for the project implementers, policy makers, Watershed Action Teams, and the general public as a part of our iterative reporting process. Though we are not yet able to answer all the key management questions, the UCSRB and UCRTT believe this product is an important step along the road to recovery. Bridging the moats that separate the realms of policy, implementation, management, and science is critical to improve the implementation of the Recovery Plan, and to return salmon to healthy and sustainable populations.

This conference provides an important opportunity for us to turn to participants and stakeholders and ask for your help in continuing to support the locally led collaborative process that is the foundation of salmon recovery in the Upper Columbia region. For ways to get involved in salmon recovery visit www.ucsrb.com/get-involved.asp. We appreciate your participation and look forward to your feedback at the Adaptive Management Science Workshop in Wenatchee on 16 November 2010. We welcome your interest and hope that you will work with us to successfully implement the *Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan*.

Sincerely,

Casey Baldwin
UCRTT Chair

William Towey
UCSRB Chair (2010)

Overview

The status of spring Chinook salmon and steelhead in the Upper Columbia region is a study in contrast between dire straits and hopeful community action. In 2010, three years after the Upper Columbia Salmon Recovery Board published one of the first recovery plans written for threatened or endangered salmonids in the Northwest, the biological news remains grim. In contrast, the efficient and concerted efforts of community groups such as landowners, watershed action teams, and state, federal and tribal officials offer hope that good news is on its way.

Endangered Populations

The bad news is that populations of salmon and steelhead throughout the West Coast have been declining for at least 100 years. Since listing under the Endangered Species Act (ESA) began in the early 1990's, 28 populations of salmon and steelhead throughout the West Coast have been listed as being either threatened or endangered with extinction. Upper Columbia spring Chinook joined the ranks of this list in 1999 (only four other populations are currently listed as endangered) and Upper Columbia steelhead in 1997, although steelhead have since been upgraded to threatened in 2009.

The reasons for the declines of these fish are numerous and, when not attributable to certain natural causes, are often attributed to four major areas of human impact, including the effects of fishing harvest, hydropower development and operation, hatchery influence, and reductions in habitat quality. Addressing and ameliorating the human-caused impacts to these populations has been the focus of natural resource management in the past several decades. Often these efforts have been driven by state and federal mandates. In the Upper Columbia, however, recovery planning efforts have also been locally driven and supported by federal, state, and tribal entities. This is where the good news starts.

Locally Guided Recovery Efforts

Some of the first actions under the ESA in the Upper Columbia were undertaken by the federal government and had nearly disastrous repercussions. Actions seen by some as heavy handed stirred communities and for a time threatened our chances of working together to help salmon and steelhead populations. Fortunately, leaders in county and tribal governments, assisted by local landowners and cooperating agencies, guided the high energy into concerted local action, rallying the region around locally led salmon recovery.

In 1999, the Upper Columbia Salmon Recovery Board (UCSRB) held its first meeting and established that the new direction toward salmon recovery would be a local process, founded on strong partnerships, so that salmon recovery efforts would realize their conservation and economic goals. Stakeholders have been motivated into active citizen committees, watershed action teams, a trans-subbasin team, a technical team, and other collaborative groups that are working toward salmon recovery.

By 2007, the UCSRB published the *Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan*. In many ways this was a pioneering document, particularly because it is one of the first recovery plans ever federally adopted for salmon and steelhead in the Columbia Basin and was drafted by a local body.

An important feature of the Recovery Plan has been its incorporation of the adaptive management process. The adaptive management process uses the scientific method of "learning by doing," and then adapting accordingly, and is an extremely useful tool for moving toward recovery when uncertainty exists regarding the threats to the species, the species' life history, or the effectiveness of various management actions.

Three-year cycles of action, monitoring, analysis, and feedback define the adaptive management process as undertaken in the Upper Columbia. 2010 is the occasion for the first-ever check-in on this adaptive management process and on January 12-13, 2010, the UCRTT, a local consortium of natural resource scientists who have been advising the Board since 1999, held the first Upper Columbia Regional Technical Team Analysis Workshop. At this workshop, fisheries biologists, researchers, and environmental scientists from around the region reported the latest scientific evidence pertaining to the status and trends in Upper Columbia salmon and steelhead populations. Other scientists described efforts to understand the threats to these fish as well as the benefits accruing to them from habitat recovery actions undertaken during the last 10 years. Since the workshop, the UCRTT has been deliberating the workshop findings and has been guiding the development of this synthesis report.

This document attempts to capture the key findings from the workshop and UCRTT synthesis, and present them in a way that will help interested stakeholders better understand the threats to our salmon and steelhead populations and how our recovery efforts are working toward future good news. The recommendations presented in this report are to assist policy makers, managers, project sponsors, and others to better adaptively manage decisions and project actions to move the region closer to the recovery objectives as defined in the Upper Columbia Recovery Plan. The following are a summary of the key analysis points and recommendations from each chapter of this report:

Chapter 1: Status of VSP for Each Population and the ESA — Fish Status and Trend

- Populations of spring Chinook and steelhead in the Upper Columbia remain at high risk for abundance, productivity and diversity measures. There have been observable changes in status at scales smaller than the ESU but the duration of those changes has not been long enough to affect risk levels at the ESU scale.

- Smolt traps operate annually in all the subbasins, providing an opportunity to evaluate juvenile productivity trends in the future.
- The UCRTT recommends that a working definition of a "trend" should be developed so that future measurable changes in status can be related to something tangible.
- The productivity of spring Chinook and steelhead in all subbasins is at low levels and is the same or lower than five years ago.
- The UCRTT recommends that status data from the Canadian portions of the Okanogan steelhead population be included in the overall status assessment.

Chapter 2: Implementation, Limiting Factors, and Threats

- Coordinated, broad-scale tracking of project implementation is a challenge. Implementation monitoring should be provided for all habitat actions in the Upper Columbia. Efforts are anticipated to improve with a newly funded implementation monitoring project and recent updates to the Habitat Work Schedule project tracking tool for the Upper Columbia region.
- In regards to habitat projects, actions that increase juvenile survival and growth should be the highest priority for improving VSP status.
- Watershed Action Teams should focus on implementing high priority actions and project funders should direct funds toward high priority projects.
- Not all past actions have been focused on the primary limiting factors, although many actions were implemented before the Recovery Plan was in place and priorities were less clear.
- Impairments and threats to habitat are being ameliorated in one category in particular: human-caused barriers that block access to fish habitat in the Wenatchee and Entiat have been, with a few notable exceptions, removed as threats. Similarly, passage projects in the Okanogan are in progress to ameliorate barriers to accessing habitat.

Chapter 3: Habitat Status and Trend

- Ways to interpret, summarize, and report the large number of habitat attributes that are being monitored need to be developed.
- Changes in habitat status have been detected at small scales (trends were demonstrated at the project level, reach level, and at larger scales) but more time and more data are needed to make a determination for habitat at the population and ESU scale.
- The UCRTT recommends that data collected by monitoring programs like ISEMP and OBMEP be further used in the adaptive management process. The UCRTT and the UCSRB staff should work with these monitoring programs to develop a process for reporting the results for all relevant metrics so adaptive management planners can make use of those results.

Chapter 4: Habitat Action Effectiveness

- There are many success stories from around the world of effective habitat restoration actions and some of these global results are being born out in local studies as well.
- It can be difficult to link habitat conditions to survival changes, leading to uncertainty in the effectiveness of the actions.
- The UCRTT recommends that the preferred sequence of actions is to protect high-quality habitats, and restore connectivity and watershed processes before implementing instream habitat improvement projects.
- The UCRTT recommends that the highest priority actions are those that improve viable salmonid population status by increasing juvenile salmonid survival and growth.
- Actions that have a short life span and which do not restore ecosystem processes are likely to be less effective in the long term.

Chapter 5: Data Gaps and Research Needs

- The MaDMC has completed an assessment of data gaps in the Upper Columbia, which includes criteria for prioritizing data gaps. Many of the high priority data gaps will be receiving funding. The MaDMC will continue to keep the data gap prioritization matrix updated.
- Across the ESU there is a need for consistency and efficiency in genetic analysis. Patterns of genetic diversity are a high risk factor for these ESUs.
- A reference condition for genetic variation for steelhead and spring Chinook in the Upper Columbia is needed so that we can determine what the goal is and how to track progress.
- More information about the effectiveness of restoration actions is needed. This means we need more effectiveness monitoring studies and/or larger sample sizes.
- More juvenile life history studies are needed to determine which factors drive fish survival and growth and whether growth and survival can be attributed to spatial location and life history type.

Status of VSP by Population and ESU
FIsh Status and Trend

Summary of Results by Key Management Questions

The following key management questions are aimed at assessing our current knowledge of fish population status compared to the recovery criteria. Providing answers to the key management questions will help establish if the fish populations are increasing or decreasing and which Viable Salmonid Population (VSP) parameters need the most improvement. This knowledge could lead to a stronger focus on specific VSP parameters that would help future restoration actions be more efficient in contributing to recovery. Two papers were presented in this session: an update on the ICTRT Status Assessment from NOAA-Fisheries and a presentation on the genetic variation of steelhead/rainbow trout (Oncorhynchus mykiss) in tributaries to the Lower Methow Basin. A third paper on juvenile productivity was added after the workshop to provide an assessment of the current efforts to monitor outmigrating juvenile salmon (smolts), an important aspect of understanding the contribution of recovery efforts within the Upper Columbia watersheds.

In general, the status of fish populations has not really changed in a meaningful way in the short time period since the adoption of the recovery plan. There have been some improvements to certain population characteristics, such as spring Chinook abundance, but the change is not large enough to alter previous conclusions. In other cases, such as with Okanogan steelhead, some important habitat restoration actions have occurred (i.e. water quantity improvements to Salmon Creek) that have removed the "threat" that was a major part of the cause of the high extinction risk. Overall, more time and more restoration actions are needed before we would expect to see a meaningful trend towards the recovery criteria.

Is the status of the population/ESU/DPS improving?

Salmon and steelhead are managed with respect to the ESA in groups of populations (e.g. populations from the Wenatchee, Entiat, Methow, and Okanogan subbasins) that are known as Evolutionary Significant Units (e.g. Upper Columbia spring Chinook salmon) or Distinct Population Segments (e.g. Upper Columbia steelhead). In this document, we use ESU as an abbreviation for both of these similar management terms. Ultimately, decisions regarding the status of fish with respect to the ESA are made at the ESU level. However, fish are monitored at much smaller spatial scales (spawning areas within populations) and the status of these "building blocks" can be rolled up into conclusions at the broader scales. Likewise, there are multiple recovery criteria that are monitored to evaluate four different VSP parameters including abundance, productivity, spatial structure, and diversity. This Key Management Question seeks to answer the very broad question regarding what the status of the fish populations are when we roll up all the pieces and come to an overall conclusion. Unfortunately, after updating the status assessments with more recent data it was apparent that the status of populations of spring Chinook and steelhead in the Upper Columbia remain at high risk when compared to the recovery criteria as measured by the VSP parameters. There have been observable changes in status at spatial scales smaller than the ESU but the magnitude and duration of those changes has not been enough to change the overall conclusion. At the population and sub-population scales, certain habitat actions have been implemented that have reduced impairments or threats so that the fish population now has the opportunity to respond. Changes in status are expected to follow after a sufficient response time. In order to demonstrate a population response and change in status, sufficient time is also needed by monitoring programs to measure and assemble the necessary data.

Is the abundance of naturally produced adult fish trending to the recovery criteria for each population?

The abundance of adult spring Chinook improved slightly in the Wenatchee and Methow in the past five years but has stayed the same for spring Chinook in the Entiat. The abundance of adult steelhead in all four subbasins is higher than five years ago, but still far from achieving the recovery criteria. These current trends in the data have little adaptive management significance given that fish populations are still so far from safe recovery levels and that the trends are based on such a short time span. In fact, the apparent increase in abundance may be due, in part, to a statistical artifact. Because fish abundance varies considerably from year to year, the official measure of abundance in the recovery plan involves taking a kind of average of each year's abundance over the past 12 years (known as the 12 year geometric mean). In the current analysis of abundance, several years of very low abundance (from the mid-1990s) are no longer included in the 12 year geometric mean thereby showing an increase in the abundance of Upper Columbia spring Chinook and steelhead.

The recovery plan specifies a set of recovery criteria, which are targets for certain aspects of each fish population, that must be met in order for these populations to be removed from the Endangered Species list. However, the Key Management Question includes a statement about "trending" towards the recovery criteria. Unfortunately, there are no legal, mathematical, statistical, or biological definitions of what "trending to the recovery criteria" means. The UCRTT recommends that a working definition of a "trend" should be developed so that future measurable changes in status can be related to something tangible.

There are a number of reasons why it is not surprising that we have not detected obvious trends in salmon or steelhead abundance. First, scientific measurements contain uncertainties and are never exact. In this case, measurement uncertainties prevent us from assigning formal statistical or biological significance to the changes in abundance that we observed. Also from a statistical viewpoint, the five-year data set is too short to be definitive about trends; more data are needed. Then there is the matter of the amount of habitat work that was completed in the past five years since adoption of the Recovery Plan. Although many projects have been completed, in total they do not add up to a large enough shift in the fish habitat of the Upper Columbia to make enough difference to be detected by the monitoring programs at a notable level of statistical significance. Furthermore, there is a five-year lag time between action implementation and the earliest possible time an effect could show up in the adult population because the life cycle of a salmon takes 4 to 6 years to complete. Finally, methodologies for enumerating adult steelhead need improvement especially for the Entiat population where uncertainties in adult steelhead population estimates are too great to make firm conclusions.

Is juvenile productivity of naturally produced fish increasing within each population?

Juvenile salmon that are migrating to the ocean (smolts) are captured in smolt traps, which operate annually in all the subbasins, providing an opportunity to evaluate juvenile productivity trends in the future. One method of evaluating the success of salmon while in their freshwater habitat is to track the number of smolts produced per nest (redd) that is built (smolts/redd). Data necessary to calculate the smolt/redd metric is being collected in all of the Upper Columbia subbasins, however, most data sets are of short duration and are not yet being reported. Therefore, we cannot answer this Key Management Question across the Upper Columbia at this time. The Chiwawa River and Monitor (Lower Wenatchee River Mainstem) are the exceptions where long-term data sets on smolts per redd are available and are reported. Since 1991, the long term trend in smolts/redd for the Chiwawa River has been stable, including some very high productivity years during the very low abundance conditions present in the mid-1990s.

There is much about the juvenile life history of spring Chinook salmon and steelhead that we do not understand. Which factors determine fish survival and growth? Can growth and survival differences be attributed to spatial location and life history type? Unfortunately, smolt productivity data sets are still too short to answer these questions and require more data in order to make meaningful trend analyses. The Chiwawa is the one exception where enough data has been collected to make conclusions about trends. Since the Chiwawa River has received very little habitat restoration and is less disturbed than other watersheds, it may be a good watershed for comparison with areas where a lot of habitat actions are occurring (e.g. Nason Creek, etc.). However, uncertainties exist regarding comparisons between watersheds because of inherent differences in the productivity of these watershed due to the effects of local geology and hydrology and the effects of hatchery programs.

More work is needed in order to standardize the analyses and reporting of smolt traps across the Upper Columbia. Detailed statistical analyses will be required in order to understand the accuracy and precision of the smolt productivity estimates.

Is the population productivity of naturally produced fish trending to the recovery criteria for each population?

Productivity is a measure of the number of offspring produced per parent spawner. For this Key Management Question, the VSP parameter for recovery criteria is the number of adult offspring produced per spawning parent. In order for a population to be stable or increasing it must, on average, have greater than one returning adult for each fish that spawned in the previous generation. This “whole life cycle” productivity integrates survival across a 4 to 6 year time-span and a broad geographic area including each subbasin in the Upper Columbia, the Columbia River mainstem downstream to the estuary (including 7-9 hydroelectric projects), as well as the Pacific Ocean. The status update concluded that the productivity of spring Chinook and steelhead in all four subbasins remains at low levels and has not improved from the status assessment five years ago.

Studies from other areas in the Pacific Northwest, as well as in the Wenatchee River, have shown that hatchery programs can affect population abundance, productivity, and genetic diversity. Although studies are underway in the Wenatchee and planned in the Methow, it is not yet clear how much hatchery programs influence population productivity in the Upper Columbia. Likewise, if improvements in productivity are detected in the future it may be difficult to determine if the change occurred due to improvements in hatchery practices or due to improvements to habitat conditions.

Is the spatial structure of the populations trending to the recovery criteria for each population?

A fish population’s spatial structure is how individual fish are distributed throughout their population boundaries (range) and how they are utilizing the habitat that is available. When major spawning areas are cutoff by things like roads, dams, and excessive water withdrawals, the population loses productive capacity, resilience to catastrophic events, and the ability to expand during high abundance years. Fortunately, at the time the Recovery Plan was written spring Chinook populations in the Upper Columbia were at “low risk” for the criteria for spatial structure in the Wenatchee, Entiat and Methow due to relatively good access to spawning and rearing areas throughout these populations. The current status update concluded that they remain at low risk.

Similarly, the populations of steelhead in the Wenatchee, Entiat and Methow were at “low risk” for the spatial structure metrics and the current status update concluded that they remain at low risk. In the previous assessment as part of the Recovery Plan, the steelhead population in the Okanogan was rated at “high risk” due to problems with spatial structure related to disconnected spawning areas in Salmon and Omak creeks. However, recent flow restoration efforts to provide seasonal flows in Salmon Creek have allowed in-migration of adult steelhead and outmigration of juvenile steelhead, thereby reducing the threat to spatial structure. With more time and ongoing monitoring it is expected that there will be a trend towards the recovery criteria for the spatial structure metrics.

The federally adopted Recovery Plan excluded the Canadian portion of the Okanogan steelhead population for jurisdictional reasons, not biological reasons. The UCRTT recommends that status data from the Canadian portions of the Okanogan steelhead population should be incorporated into the overall status assessment that has until now focused on the portion of the Okanogan subbasin within the U.S. The abundance and productivity benchmarks to use are the ICTRT minimum threshold of 1,000 fish and the respective productivity on the viability curve. For spatial structure, major and minor spawning areas within Canada need to be identified/delineated and then monitored to complement similar monitoring in the U.S. portion of the Okanogan.

Is the phenotypic and genotypic diversity of the population trending to the recovery criteria for each population?

The genotypic diversity (DNA, genes, alleles, etc.) and the phenotypic diversity (age structure, size structure, migration timing, etc.) are important aspects of a population's viability that are often overshadowed by more obvious characteristics such as abundance (the number of returning adult salmon). Populations of spring Chinook and steelhead in all four subbasins remains at "high risk" due to aspects of population diversity. This is largely due to a persistent homogenization from previous and ongoing fish management efforts and from a large abundance of hatchery-origin spawners. Efforts are underway in several watersheds to reduce the proportion of hatchery fish on the spawning grounds which should help improve the status of this metric in the future.

The presentation by Weigel suggests that there may be more diversity in the Upper Columbia steelhead populations than previous assessments indicated, although no trend information may be inferred by her work. In order to better understand the status and trends in genetic diversity and to understand how Weigel's findings fit into the recovery process, the UCRTT recommends that a spatially balanced genetic sampling program for Chinook salmon and steelhead should be established throughout the Upper Columbia that can be repeated at intervals.

The assessment of diversity criteria in the Entiat spring Chinook population should improve in the next generation since the Entiat National Fish Hatchery has recently stopped releasing spring Chinook that originated from populations outside of the Upper Columbia. Although this management action will result in a relatively quick (1 to 4 years) change to the spawner composition metric, the change to genetic diversity will be much slower. It is expected to take at least several salmon generations for local adaptation to cause changes in the population's genetic structure.

The remainder of the chapter consists of articles reporting the contents of presentations given either during the UCRTT Analysis Workshop held on January 12 and 13, 2010 or during the deliberations of the UCRTT that followed:

Updates to the ICTRT Status Assessment

Tom Cooney, Casey Baldwin, and Michelle McClure

Michelle and Tom are biologists with NOAA Fisheries and Casey is the RTT chair and a biologist with WDFW in Wenatchee.

A new assessment of the status of Upper Columbia salmon and steelhead populations was completed in 2008 by the Interior Columbia Technical Recovery Team (ICTRT). This update includes five more years of data since the information that was used in the Recovery Plan.

In the past five years, the abundance of adult spring Chinook improved slightly in the Wenatchee and Methow but has stayed the same for spring Chinook in the Entiat. The abundance of adult steelhead in all four subbasins is higher than five years ago.

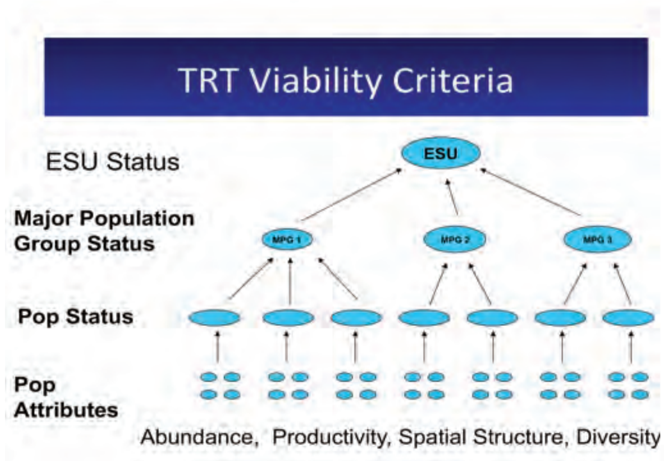

Figure 1. Fish abundance, productivity, spatial structure, and diversity are the four VSP criteria that make up population status, major population group status and ultimately ESU status.

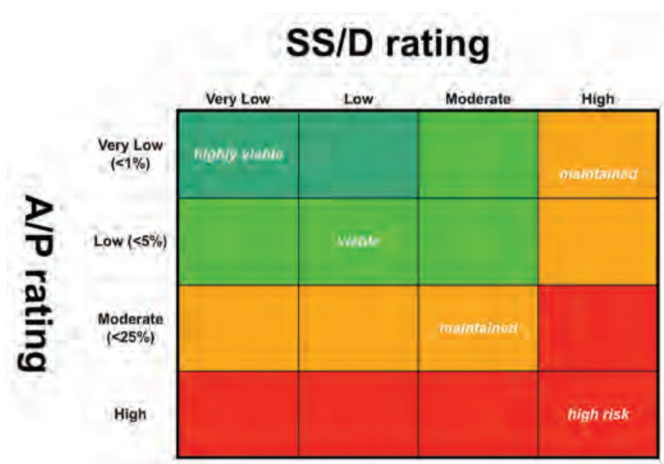

Figure 2. By combining VSP ratings in a matrix like the one above, the ICTRT can assess the viability of populations across all VSP criteria. All spring Chinook and steelhead populations in the Upper Columbia are in the lower right box.

The productivity of spring Chinook and steelhead in all four subbasins is at low levels and is the same or lower than five years ago.

Spring Chinook populations are at "low risk" for most of the spatial structure criteria in the Wenatchee, Entiat, and Methow due to relatively good access to restored and historic spawning and rearing areas throughout those populations.

The population of steelhead in the Wenatchee, Entiat and Methow are at "low risk" for many spatial structure metrics, whereas the population in the Okanogan remains at "high risk" due to problems with both spatial structure and diversity.

Populations of spring Chinook and steelhead in all four subbasins remain at "high risk" due to aspects of population diversity.

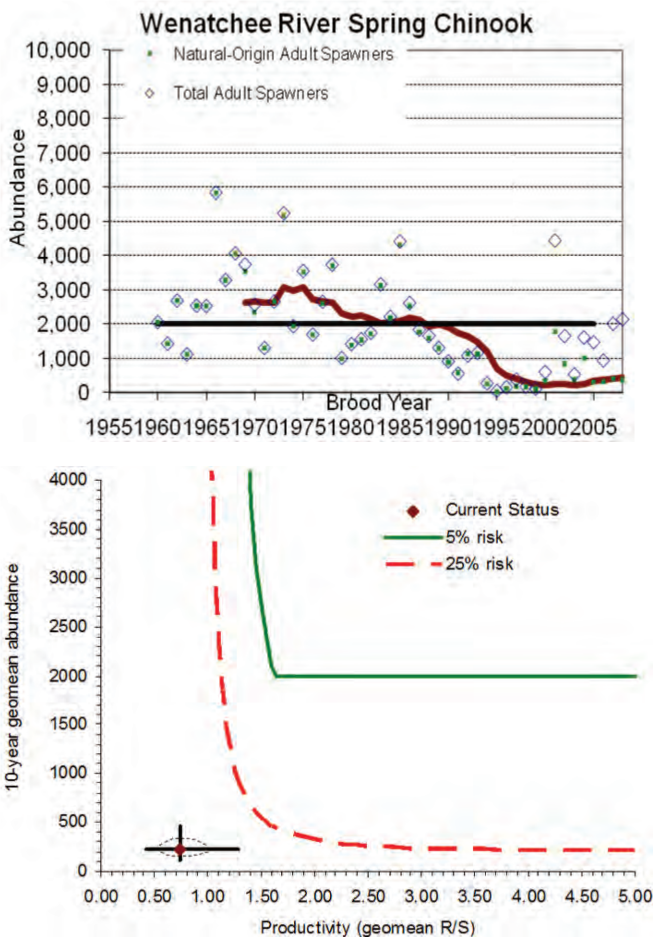

Figure 3. The population size of natural-origin Wenatchee River spring Chinook (left top figure, green dots) has been well below the minimum abundance threshold of 2,000 for at least the last 20 years, with only a slight increase in the past five years. This is also the case if hatchery fish are counted in the total adult spawning population although the past five years have seen a larger increase in hatchery returns than was observed for natural-origin fish. If the levels of natural-origin abundance is compared with productivity (left bottom figure), we see that Wenatchee River spring Chinook has greater than a 25% risk of extinction. For these reasons, Wenatchee Spring Chinook population is at a high risk of extinction based on current abundance and productivity.

Methods and Results

Population risk ratings are based on abundance and productivity (AP) and spatial structure and diversity (SS-D) measures that are combined into four categories of risk: Highly Viable, Viable, Maintained and At Risk. Populations are assigned to a category based on a combined evaluation of AP and SS-D, with consideration for uncertainty.

Abundance and Productivity

Abundance should be high enough that in combination with intrinsic productivity, declines to critically low levels would be unlikely assuming recent patterns of environmental variability, compensatory processes provide resilience to the effects of

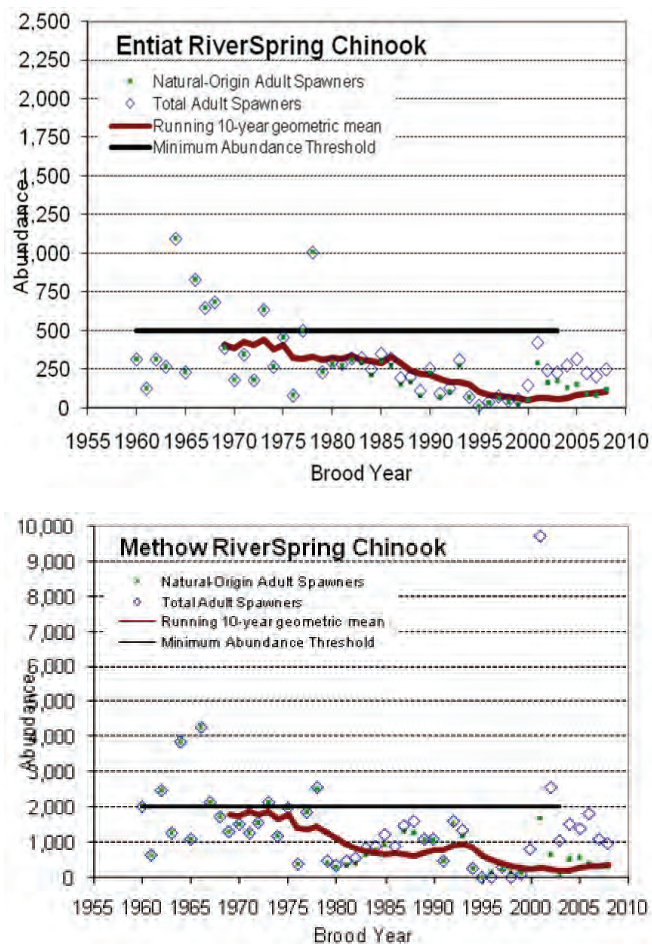

Figure 4. The population size of natural-origin Entiat River spring Chinook (right top figure, green dots) has also been well below the minimum abundance threshold (500 fish in the Entiat, 2,000 in the Methow) for several decades as has the Methow population (right bottom figure). In both subbasins, there has been a slight increase in the past several years but this is relative to very poor population sizes in the late 1990s. Higher numbers of hatchery fish in the past several years have helped to inflate the total adult spawner abundance in both subbasins. Like the Wenatchee, both Methow and Entiat populations of spring Chinook have greater than a 25% risk of extinction (no figures available). For these reasons, both Entiat and Methow spring Chinook populations are at a high risk of extinction based on current abundance and productivity.

Subbasin	Spring Chinook		Steelhead	
	2003	2009	2006	2010
Wenatchee	0.93	0.63	0.84	0.87
Entiat	1.04	1.08	0.48	0.55
Methow	0.80	0.45	0.32	0.32
Okanogan	-	-	0.15	0.15

Table 1. Upper Columbia spring Chinook and steelhead intrinsic potential: 20-year geometric mean.

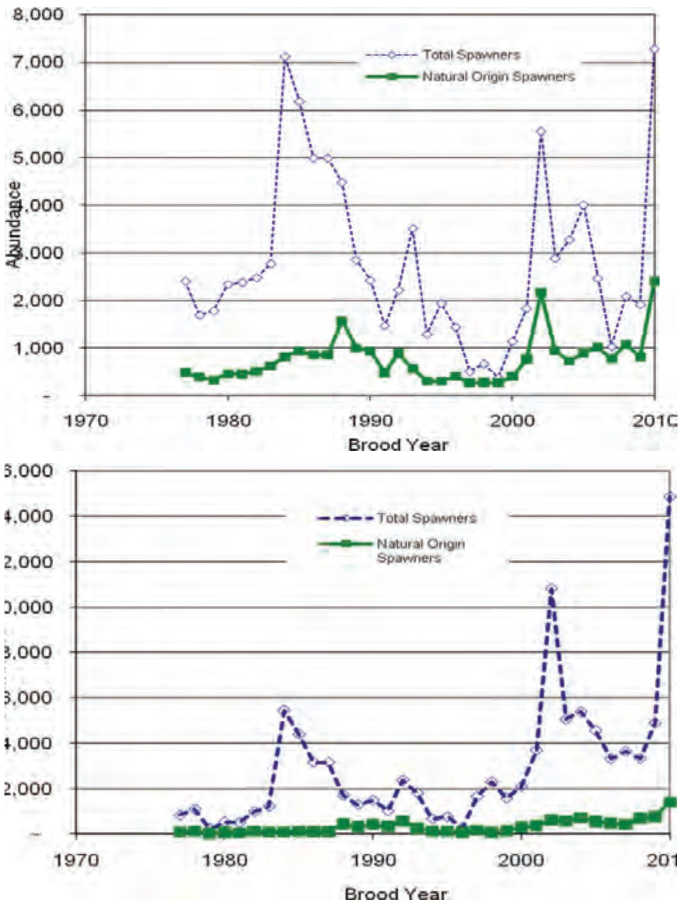

Figure 5. The population size of natural-origin steelhead in the Wenatchee (left top figure, green dots) has been fluctuating near the minimum abundance threshold of 1,000 for at least the last several years with a couple relatively high years since 2000. The natural-origin steelhead population in the Methow also has been near the minimum abundance threshold of 1,000 and has increase slightly in the last few years (left bottom figure). These low levels of abundance, combined with the low productivity (see Table 1), put both of these populations at high risk of extinction.

short-term perturbations, and subpopulation structure is maintained (e.g., multiple spawning patches, etc). In addition, status estimates should consider statistical uncertainties. Population size thresholds are set since populations with fewer than 500 individuals are at higher risk for inbreeding depression and a variety of other genetic and demographic concerns. Increased thresholds for larger populations promote the full range of AP objectives, avoid alee affects, ensure compensatory processes, and provide for spawning in multiple sub-areas. In the Upper Columbia, spring Chinook AP estimations are based on spawner abundance from redd counts by index surveys of major spawning areas plus supplemental counts which are expanded to the area. Fish per redd (shift to age-based) data is also used, as well as hatchery/wild data from carcass surveys stratified by major area, and spawner age composition data from carcass surveys stratified by major spawning area (natural origin).

Upper Columbia steelhead AP estimation methods use spawner data from dam count differences and radio tracking distributions, accounting for harvest and losses, apportioning hatchery and wild returns to basins separately, but combining at basin level and using age structure data from Priest Rapids sampling and the Wells broodstock program.

Spatial Structure and Diversity

In support of spatially mediated processes we are measuring whether or not a significant portion of the landscape is occupied, whether gaps within and between populations are bigger or smaller than they were historically, and whether the range of the population is truncated in comparison with historical conditions. In addition, we consider whether there have been

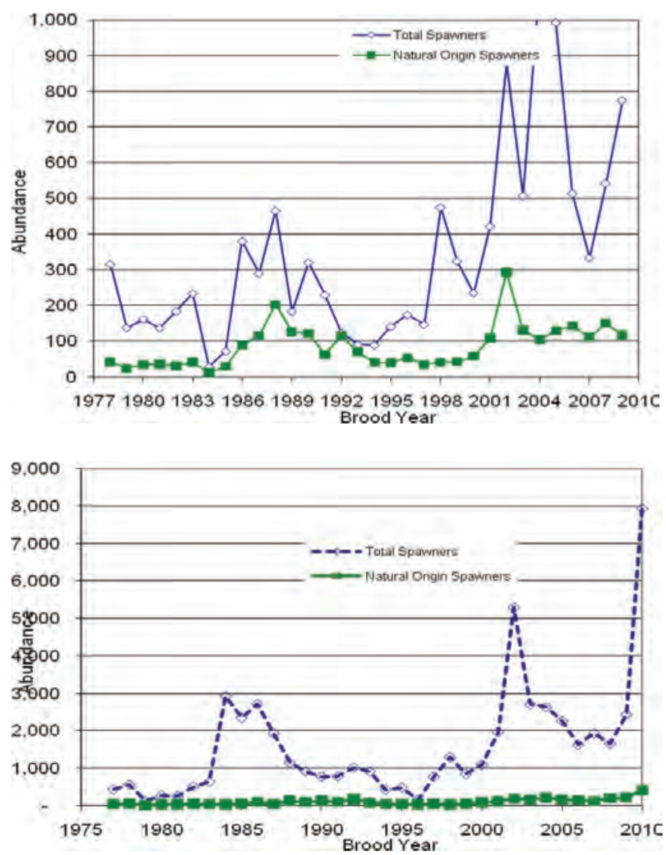

Figure 6. The population size of natural-origin steelhead in the Entiat (rigt top figure, green dots) has been well below the minimum abundance threshold of 500 for decades. The natural-origin steelhead population in the Okanogan also has been near the minimum abundance threshold of 500 and has increase slightly in the last few years (right bottom figure). These low levels of abundance, combined with the low productivity (see Table 1), put both of these populations at high risk of extinction.

observable changes in genetic, phenotypic or life history variation. Whether hatchery fish are a significant component of the spawners (*modifiers), whether the range of habitats occupied is different in comparison with the historical range, and whether human actions affecting are a portion of the population differentially (i.e., selection). The SS-D metrics are integrated as shown in Table 2.

To see the full 2008 status assessment updates for Upper Columbia spring Chinook populations, go to this web link:

http://www.nwfsc.noaa.gov/trt/col/trt_upper_columbia_chinook_mpg.cfm

The productivity of all three Upper Columbia populations of spring Chinook has been low and continued to decrease between the most recent assessments (from 2003 to 2009). For example, the intrinsic productivity of Methow spring Chinook was 0.45 in 2009, which means that for every 100 spawners in one generation only 45 adults would return in the next generation. This is an alarming situation and is why the UCRTT is focused on restoration actions that would increase productivity.

The productivity of the four Upper Columbia steelhead populations improved slightly between the most recent assessments (from 2006 to 2010) but is still dire. With productivity values much less than 1.0, Upper Columbia steelhead populations remain at high risk of extinction.

There has been no appreciable change in the risk levels for spatial structure and diversity for any of the spring Chinook or steelhead populations in the Upper Columbia since the Recovery Plan was written.

Goal	Mechanism	Factor	Metrics
A. Allowing natural rates and levels of spatially-mediated processes (Spatial Structures).	1. Maintain natural distribution of spawning areas	a. Number and spatial arrangement of spawning areas.	Number of MaSAs, distribution of MaSAs, and quantity of habitat outside MaSAs.
		b. Spatial extent or range of population	Proportion of historical range occupied and presence/absence of spawners in MaSAs.
		c. Increase or decrease of gaps or continuities between spawning areas	Change in occupancy of MaSAs that affects connectivity within the population
B. Maintaining natural levels of variation (Diversity).	1. Maintain natural patterns of phenotypic and genotypic expression	a. Major life history strategies	Distribution of major life history expression within a population.
		b. Phenotypic variation	Reduction in variability of traits, shift in mean calue of trait, loff of traits.
		c. Genetic Variation	Analysis addressing within and between population genetic variation.
	2. Maintain natural patterns of gene flow	a. Spawner composition	(1) Proportion of natural spawners that are unnatural out-of-ESU spawners.
			(2) Proportion of natural spawners that are unnatural out-of-MPG spawners.
			(3) Proportion of hatchery origin natural spawners derived from a within-MPG brood stock program, or within-population (not best practices) program.
			(4) Proportion of hatchery origin natural spawners derived from a local (within-population) broodstock program using best management practices.
	3. Maintain occupancy in a natural veriety of available habitat types	a. Distribution of population across habitat types	Change in occupancy across ecoregion types.
	4. Maintain integrity of natural systems	a. Selective change in natural processes or impacts	Ongoing anthropogenic activities inducing selective mortality or habitat change within or out of population boundary.

Table 2. Integrating spatial structure and diversity metrics.

Metric	Risk Assessment Scores				
	Metric	Factor	Mechanism	Goal	Population
A.1.a	H (-1)	H (-1)	High Risk (Mean-.1)	High Risk	High Risk
A.1.b	H (-1)	H (-1)			
A.1.c	H (-1)	H (-1)			
B.1.a	VL (2)	VL (2)	High Risk	High Risk	
B.1.b	M (0)	M (0)			
B.1.c	H (-1)	H (-1)			
B.2.a(1)	L (1)	High Risk (-1)	High Risk (-1)		
B.2.a(2)	NA				
B.2.a(3)	H (-1)				
B.2.a(4)	NA				
B.3.a	L (1)	L (1)	L (1)		
B.4.a	L (1)	L (1)	L (1)		

Table 3. Okanogan steelhead spatial structure and diversity.

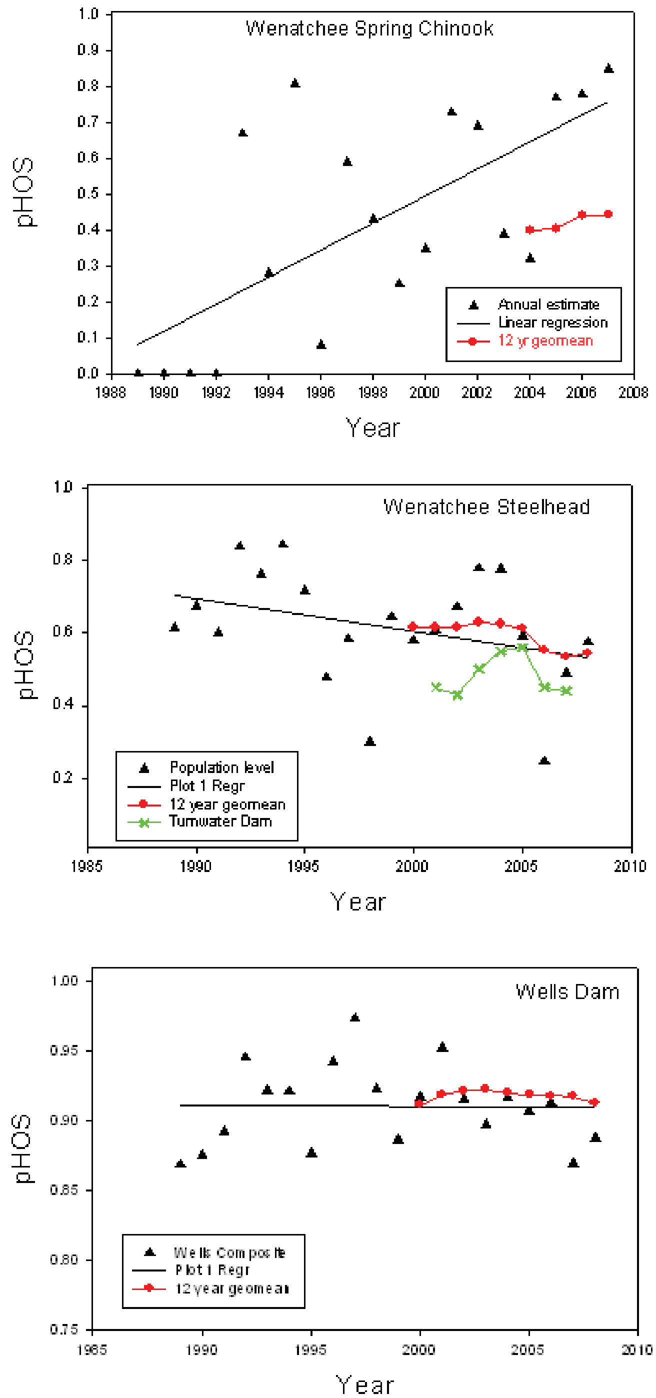

Figure 7. The proportion of hatchery-origin spawners within sampled spawning populations, including: (top) spring Chinook salmon in the Wenatchee subbasin, (middle) steelhead in the Wenatchee subbasin and a subsample at Tumwater Dam, and (bottom) steelhead adults sampled at Wells Dam which include fish returning to the at least the Okanogan and Methow subbasins. The black regression line and the red geometric mean line are both ways of looking at trends in the data. The high proportion (more than 90 percent) of hatchery fish within the population of adult steelhead passing Wells Dam is the leading factor for determining that steelhead from the Methow and Okanogan subbasins are at high risk for diversity metrics.

Adaptive Management Recommendations

Species status is expected to change slowly, given the complex and vast environment that affects salmon survival. Additional restoration actions and more time for the population to respond are needed before we would expect to see a trend towards recovery criteria.

Status data from the Canadian portions of the Okanogan steelhead population should be incorporated into the overall status assessment that has until now focused on the portion of the Okanogan subbasin within the U.S. The abundance and productivity benchmarks to use are the ICTRT minimum threshold of 1000 fish and the respective productivity on the viability curve. For spatial structure, major and minor spawning areas within Canada need to be identified/delineated and then monitored to complement similar monitoring in the U.S. portion of the Okanogan.

A working definition of what a "trend" is, relative to NOAA recovery criteria, should be developed so that future changes in status can be compared to a tangible guideline.

Spring Chinook remain at "low risk" for the Goal A spatial structure metrics (Table 2) in all three populations because of a favorable population structure and distribution. Steelhead in the Wenatchee, Methow, and Entiat subbasins also remain at "low risk" for these metrics. However, steelhead populations in the Okanogan subbasins are still rated at "high risk" for the spatial structure and diversity metric because of problems with both spatial structure and diversity (Table 3).

The Methow remains at high risk for diversity metrics due to the high proportion of hatchery fish passing Wells Dam, the mixing of Methow and Okanogan fish in the broodstock, the release of smolts into the Methow that could have originated from Okanogan parents, and the threat that the Wenatchee strays pose. The Okanogan population of steelhead is also affected by some of the same threats as the Methow and is further hampered by unoccupied areas in the Salmon Creek and Omak Creek major spawning areas. Habitat restoration actions (flow and passage) now allow steelhead to access Salmon Creek and spawning has been documented in recent years. Based on the ICTRT criteria, however, it will take many years of a demonstrated population response in order to change the risk level for the metric.

The guidelines in Table 2 show how spatial structure and diversity metrics are integrated and Table 3 shows an example from Okanogan steelhead. Okanogan steelhead are at high-risk for all three spatial structure metrics (e.g., A.1.a, which we see in Table 3 means the number and spatial arrangement of spawning sites) as well as two of the 9 diversity metrics. Either one of these risk levels leads to a rating of "high-risk" for the integrated spatial structure/diversity metric.

Spawner Composition Trends

The large proportion of hatchery fish on the spawning grounds is a particular threat to the diversity of salmon and steelhead in the Upper Columbia as shown in the B.1 metrics in Table 2. As illustrated with the red lines in Figure 7, the proportion of hatchery fish (pHOS) is high, particularly for steelhead and even more so for steelhead that migrate to habitat above Wells Dam (e.g. the Methow and Okanogan). The proportion of hatchery spawners has changed little in the past several years since the drafting of the Recovery Plan.

Although high proportions of hatchery spawners have been a high risk factor for spring Chinook in the Entiat in the past, the Entiat National Fish Hatchery has stopped releasing out-of-ESU origin spring Chinook. Starting in 2010, the risk level for B.2.a.(1) "out of ESU spawners" should decline to moderate or low risk. Hopefully, subsequent generations will show a divergent trend in genotype, leading to a lower risk score for B.1.c.

Juvenile Productivity of Naturally Produced Fish by Population

Upper Columbia Regional Technical Team

Introduction

The key management question "Is juvenile productivity of naturally produced fish increasing within each population?" was not addressed with a presentation during the workshop; however, given its relevance to evaluation of progress in the recovery plan we thought it was important to include in the synthesis report. UCRTT discussions after the workshop led to the agreement to cover a couple of basic pieces of information related to juvenile fish productivity: 1) are we collecting the right data to answer it in the future? and 2) what does some of that data look like?

Juvenile fish monitoring is an important component of the Upper Columbia Monitoring Strategy (Hillman 2006) and is occurring in each of the four major subbasins that host the seven ESA listed populations of salmon and steelhead in the Upper Columbia. Additionally, smolt abundance and smolts/redd are important monitoring metrics called for in the Recovery Plan (UCSRB 2007). The Recovery Plan recognizes that full life cycle survival and productivity are critical components that determine population viability. However, because out-of-basin effects can vary greatly and are sometimes difficult to quantify, the Recovery Plan suggests that monitoring juvenile productivity (i.e. smolts/redd) will assist in determining whether habitat restoration and preservation projects are achieving their intended goals. By compartmentalizing survival into two components of the life history (egg-smolt and smolt to adult), a better understanding of freshwater productivity can be achieved. Likewise, management options could be implemented that would assist in addressing the factors that limit juvenile productivity. For example, if the majority of feasible habitat restoration options have been implemented in a subwatershed and smolt productivity (smolts/redd) is relatively high then efforts could be shifted to other areas. Using this approach, the juvenile productivity measures can be a contributing factor in deciding when enough habitat actions have been implemented in each subbasin/population.

Adaptive Management Recommendations

Agreement on statistical methods and/or biological indicators is needed to determine the definition of trend with respect to this and other juvenile fish data in order to definitively answer the key management question.

A statistical analysis of a comparison between traps within, and among subbasins is needed. Duration (years), variance, and autocorrelation (not shown on any of the graphs) will be important considerations in these analyses.

More habitat actions need to be completed before we would expect to see a Major Spawning Area or population-level response in juvenile productivity.

UCRTT Deliberations

The juvenile productivity metric requires additional development. For example, it may need to be standardized to address density dependence effects when fish population abundance increases. Also, it is important to use smolts (or parr) as the juvenile indicator rather than emigrants since smolts (actual smolts or yearlings produced in the Chiwawa) show strong density dependence, as do parr. This means that parr and smolt survival decreases with stock size. Analyses based on Chiwawa subyearling emigrants and subyearling plus yearling emigrants show no density dependence. The data from the Chiwawa suggest that the survival bottleneck occurs between the fry and parr stage.

There is less certainty that this metric will work for steelhead, since smolt traps and redd surveys are not as efficient as they are with spring Chinook. Other biological indicators may need to evaluated, such as snorkel survey densities for parr.

Tributaries with low trap efficiencies may have too much variance to have confidence in this type of evaluation. Again, other juvenile survival metrics may need to be evaluated for use in certain areas.

Watershed/River	Operator	Years of operation	Estimate total smolt production	Smolts / redd	Source/comments
White River	YN	2007-present (2)	Yes	Yes	Data are reported to GPUD
Nason Creek	YN	2004-present (7)	Yes	Yes	Data are reported to BPA and ISEMP
Chiwawa R	WDFW	1991-present (19)	Yes	Yes	CPUD Hathery M&E report
Lake Wenatchee Trap	WDFW	1997-present (14)	Yes	No	Only valid for Sockeye, CPUD Hatchery M&E report
Monitor (lower Wenatchee)	WDFW	2000-present (11)	Yes	Yes	WDFW database, CPUD Hatchery M&E report does n ot report smolt production from the Monitor trap
Lower Entiat	USFWS	2007-present (lower trap)	Yes?	Yes?	ISEMP is planning to estimate production after 5 yrs
Lower Methow	WDFW	2002-present (9)	Yes	Yes	Only reported through 2007 (WDFW annual report to DPUD)
Twisp	WDFW	2002-present (9)	Yes	Yes	OBMEP annual reports; high uncertainty on the total production estimates due to low trap efficiency
Lower Okanogan	CCT	2006-present (4)	Yes	No	OBMEP annual reports; high uncertainty on the total production estimates due to low trap efficiency
Omak Creek	CCT	2007-present (4)	No	No	Unpublished data available through the Colville Tribes

Table 1. Smolt trap locations and supporting information for Upper Columbia subbasins.

Methods

The Upper Columbia Monitoring Strategy calls for determining the abundance, distribution, and size of parr as well as the number, size, and genetics of smolts. Various methods are employed to monitor these indicators including snorkel surveys, smolt traps, and PIT tags. Generally, snorkel surveys provide distribution and size of parr and PIT tag studies provide distribution, migration timing, and survival to fixed points such as detection arrays at the mouth of tributary and at Columbia River dams. Smolt traps are operating in each of the basins and provide an opportunity to install PIT tags, obtain a tissue sample, measure phenotypic characteristics, and estimate total smolt emigration. When combined with age class information and the respective adult escapement or redd surveys the total smolt production estimates allow for calculation of smolts/redd (or smolts/spawner). This metric encompasses survival from egg to smolt and therefore integrates across multiple juvenile life stages.

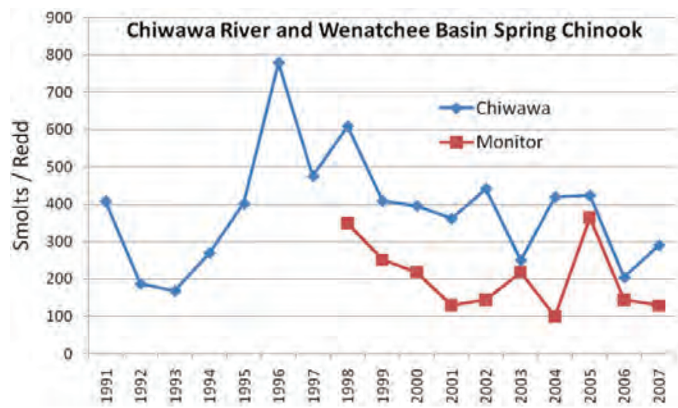

Figure 1. Smolts per redd for spring Chinook each year for two smolt trap locations in the Wenatchee Subbasin. Chiwawa data was taken from the Chelan PUD hatchery monitoring annual report (CPUD 2009), and the estimates at Monitor were provided by Todd Miller from an unpublished WDFW database.

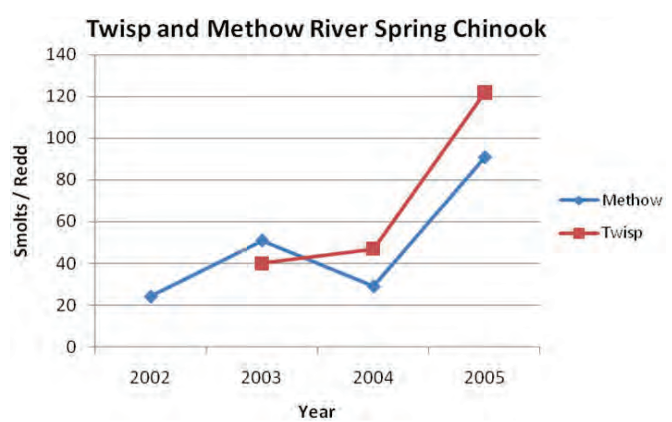

Figure 2. Smolts per redd for spring Chinook each year for two smolt trap locations in the Methow Subbasin. Data were taken from the most recent finalized annual report (2007) for the hatchery evaluation efforts funded under the Douglas PUD programs (Snow et al. 2008).

Currently, there are 10 smolt traps operating in the Upper Columbia region, including a trap at the lower end of each population (Table 1). Having a trap at the lower end of each population allows for the opportunity to evaluate population level productivity status and trend, if appropriate expansions can be made. Having smolt traps in sub-watersheds allows for comparisons between Major Spawning Areas, comparing Major Spawning Areas to the population as a whole, and potentially comparing Major Spawning Area or population estimates to reference watersheds.

Results and Discussion

The smolt trap survey in the Chiwawa River Basin provides the longest term data set in the Upper Columbia, with 19 years of operation (Table 1). Annual status as well as longer term trends can be evaluated from data sets of this length. For example, the density dependent response in juvenile productivity is suggested by the much higher smolts/redd observed during the low adult escapement years of the mid-late 1990s (Figure 1). Data sets for most other smolt traps are not long enough to evaluate long-term trends or have confidence that the mean across years shows the year-to-year environmental variability that is natural and expected (Table 1). The Chiwawa River has received very little habitat restoration and is considered highly functional habitat, so it may be a good reference watershed, if the contribution of hatchery origin fish spawning in the wild can be accounted for.

When picking a reference stream, it is important that inherent differences in productivity due to watershed specific climate, geology, geomorphology, and hydrology are understood. Analyses still need to be conducted to determine exactly how to use and compare the juvenile productivity data between subbasins. For example, it is reasonable to assume, based on an examination of the graph to conclude that the Wenatchee Subbasin as a whole is not as productive as the Chiwawa River, since every year the population level estimate from the Monitor smolt trap is less than the Chiwawa River estimate (Figure 1). A statistical analysis of a comparison between traps within and among subbasins is needed (Figure 2). Duration (years), variance, and autocorrelation (not shown on any of the graphs) will be important considerations in these comparisons. Likewise, additional information is needed to determine the definition of trend with respect to this and other juvenile fish data in order to definitively answer the key management question. However, given the length of time and quantity of habitat restoration actions that are planned and the long-term commitments in place to continue smolt monitoring, it is likely that this will prove to be a useful measure for increases in habitat productivity in the future.

Genetic Variation in Oncorhynchus mykiss in Tributaries to the Lower Methow Basin

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Background

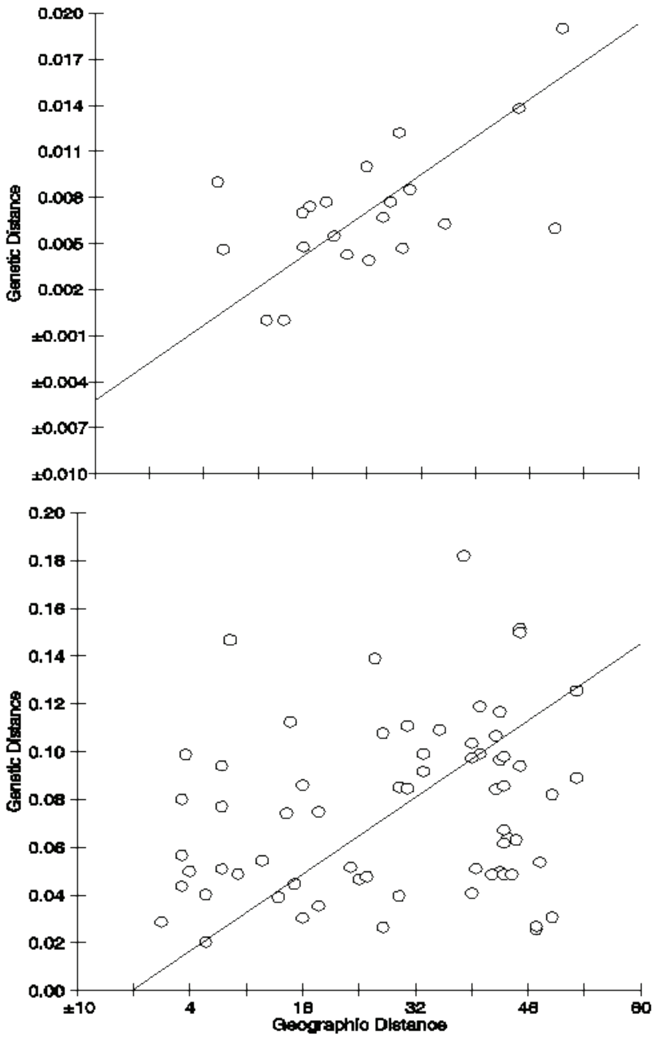
Genetic processes such as selection, mutation, and drift interact with various behavioral and environmental factors to promote reproductive opportunities for individuals in a landscape. Genetic differentiation is determined by population isolation. Salmonids are known to exhibit several isolating mechanisms such as: life history variation separated spatially and temporally, homing to natal streams, and assortative mating.

Oncorhynchus mykiss exhibit sympatric life history strategies: resident/fluvial and anadromous. Studies have shown some inter-breeding between these life history types, and plasticity in their derivation (such as resident fish parenting anadromous offspring). Hatchery fish are present in the Methow Basin, and introgression between the wild and hatchery populations is thought to occur. However, hatchery fish have much lower relative fitness in natural environments. For example, wild (W) female steelhead were found to produce about 20 times the smolts than hatchery (H) females in a study in Forks Creek, Washington (McLean et al. 2004). In addition, the cross and direction can determine the relative survival to age 1 with WxH having 58%, HxW 30%, and HxH 14% of the relative survival of WxW offspring (Miller et al. 2004).

The purpose of this study was to: describe genetic diversity and genetic differentiation in O. mykiss from 3 natal tributaries (Beaver, Libby and Gold creeks) in the lower Methow Basin, and explore the relative contribution of environmental and biological attributes. The null hypothesis tested was that O. mykiss populations in the study area were panmictic (or no detectable population differentiation). The alternative hypotheses was that population differentiation was detectable and was related to life history and/or habitat attributes.

Methods

Juvenile and adult trout were collected from 19 sites in the study area during 2004 and 2005 using electrofishing. Genetic material were collected and PIT tag interrogation data were used to determine the dominant life history strategy at each site. Trout were considered to exhibit anadromous migration patterns when PIT tags were detected at John Day/McNary dams or downstream on the lower Columbia River. Anadromous sites had >3%, and resident sites <1%, of the proportion of total tags deployed detected on the Columbia River or estuary. Stream distances between sites were calculated using the distance tool in ArcView GIS software.



Figures 1 and 2. Mantel test for isolation by distance for anadromous sites (top) and for resident sites (lower) in the lower Methow tributaries. The test is significant ($p < 0.05$) with an $R^2 = 0.35$ for anadromous sites, not significant ($p > 0.05$) and $R^2 = 0.05$ for resident sites.

DNA was extracted and amplified using standardized protocols and loci for the Columbia Basin O. mykiss (Stephenson et al. 2009). Sixteen microsatellite loci were used. The later 5 loci provided some differentiation between O. mykiss and O. clarki. Putative full siblings were identified and removed using ML Relate set to 10,000 permutations (Kalinowski et al. 2006). A Bonferroni correction was used for all multiple comparisons. Exact tests for Hardy Weinberg and linkage disequilibrium were performed using Genepop set to default values (Raymond and Rousset 1997). Genetic diversity indices (heterozygosity and allelic richness) were calculated using HP Rare (Kalinowski et al. 2005). Genetic differentiation was measured using pairwise Fst values and exact tests were calculated using Genepop set to default values. Isolation by distance, examining whether there is increased genetic differentiation with geographic distance, was tested with a Mantel test using IBD Web Service (Bohanak et al. 2002). Arlequin was used to partition variation using AMOVAs (Excoffier et al. 2005).

UCRTT Deliberations

Weigel et al. have demonstrated that populations of Oncorhynchus mykiss are more diverse in the Methow Subbasin, and presumably in the Upper Columbia, than had been previously understood. The limited geographic scope of this study does not give us a complete estimate of status that is of most interest to recovery assessment and would not provide much of a baseline against which to elucidate trends . These findings recall the question of what are the normative processes and conditions against which the spatial structure and diversity (SS/D) metrics should be compared? A spatially-balanced sampling program for steelhead throughout the Upper Columbia should be initiated to give us much better insight into the status and trends related to SS/D. Existing genetic monitoring programs that focus on the comparison between hatchery vs. natural populations are powerful and need to be included in any future genetic monitoring program. However, additional investigation would be required to 1) develop a reference condition or an idea about what is the desired condition for SS/D, 2) describe the status and trends in SS/D for steelhead for the entire ESU, and 3) elucidate the contribution of rainbow trout production and diversity to steelhead, something that recent studies suggest may be significant.

	Basin	Life History
	(B, L, G)	(A, R)
Among group	0.40%	0.10%
Among pop. within group	3.90%	4.10%
Within Pop.	95.70%	95.80%

Table 1. The amount of variation at the basin scale (Beaver, Libby, Gold) to life history (anadromous vs. resident) (AMOVA).

Results

A total of 693 trout were collected from 19 sites. Suspected full siblings detected at each site ranged from 0 to 62% (average 23%), with more full siblings detected at resident sites. After removing all but one suspected full sibling from each site, 590 trout from 19 sites were used for the subsequent analyses. Sample sizes ranged from 7 to 55 (average 28). Of the 19 sites, 6 were anadromous, 6 were resident, 4 were resident O. m. with O. m. x O. c. hybridization present, and 2 were anadromous O. m. with O. m. and O. c. hybridization present. Three additional sites in Beaver Creek have not been analyzed yet.

Four sites had one locus each out of Hardy Weinberg Equilibrium and 7 of 2,280 comparisons showed significant linkage disequilibrium. There was no pattern to these loci or sites. Sample-wide pairwise Fst values ranged from 0 to 0.18 across all the sites. Pairwise Fst values ranged from 0 to 0.019 across the anadromous sites with about half the sites significantly different ($p < 0.003$). Generally, adjacent sites tended not to be significantly different. The Mantel test showed significant isolation by distance for all the pairwise site comparisons in the study area with an $R^2 = 0.18$. However, when we separated the data set by life history type, anadromous sites showed a stronger ($R^2 = 0.35$) and significant isolation by distance relationship, whereas resident sites did not (Figures 1 and 2). The AMOVA indicated that >95% of the genetic variation is at the individual level, and a small proportion is at the basin or life history level (<0.5%). Basin explained four times the variation in the genetic data than life history, additional indication that genetic diversity is related to distance or other landscape variables more so than life history (Table 1).

	# sites	# anad sites	# loci	He (Ho)	AR	Fst	Sig IBD
Methow B, L, G	19	8	16	0.67-0.83	4.53-6.88	0-0.18	Y anad N resid
Klickitat (Narum et al 2008)	20	7	13	0.46-0.82	2.8-9.0	0-0.377	Y anad N resid
Grande Ronde (Narum et al 2006)	4	4	20	(0.76-0.81)	11.2-12.4	0.005-0.016	
Walla Walla (Narum et al 2004)	14	12	6	0.8, 0.78	14.5, 13.7	0.001-0.018	
Snake (Neilsen et al 2009)	79	75	11	0.55-0.73	4.1-6.2	0.003-0.05*	Y
Skeena, Nass, Dean – Canada BC (Heath et al. 2001)	10	10	6	0.75-0.85		Avg 0.04*	Y
Kamchatka - Russia (McPhee et al. 2007)	7	5	10	0.24-0.54	1.9-9.8	0-0.19	Y

Table 2. Comparison of *O. mykiss* data from Beaver, Libby and Gold creeks genetic diversity and differentiation measures and isolation by distance to other studies in the Columbia Basin, British Columbia, Canada, and Kamchatka, Russia. Asterisk indicates data that were pooled by subbasin and are not a direct site level comparison to the values reported in this study.

Adaptive Management Recommendations

A spatially balanced genetic sampling program for Chinook salmon and steelhead should be established throughout the Upper Columbia that can be repeated at intervals to understand the status and trends in genetic diversity. This program would be particularly useful if it was designed 1) to monitor the influences of hatchery impacts to population genetic structure, 2) to help understand what the desired condition for SS/D might be, and 3) elucidated the contribution of rainbow trout production and diversity to steelhead, something that recent studies suggest may be significant.

Status data from the Canadian portions of the Okanogan steelhead population should be incorporated into the overall status assessment that has until now focused on the portion of the Okanogan subbasin within the U.S. Included within this assessment should be the identification, delineation, and monitoring of major and minor spawning areas within Canada. Likewise, the Canadian portions of the Okanogan should be included within a spatially balanced genetic sampling program (see above point).

Discussion

The genetic diversity measures (heterozygosity, allelic richness), genetic differentiation measure (Fst), AMOVA and isolation by distance results from the lower Methow tributaries are similar to other studies documented in various Columbia Basin tributaries, British Columbia, Canada, and Kamchatka, Russia (Table 2). Our study is most similar in sample intensity, genotypic data and spatial extent to the Klickitat Basin, Washington study (Narum et al. 2008), aside from some low heterozygosity, allelic richness and higher Fst values that were likely the influence of more isolated resident populations sampled in the Klickitat study. The Klickitat populations were shown to have no detectable hatchery introgression thought to be due to little reproductive overlap between the native steelhead and stocked Skamania steelhead in the basin (Narum et al. 2006).

The O. mykiss sampled from the Grande Ronde basin in Oregon had higher genetic diversity (heterozygosity and allelic richness), but similar genetic differentiation (Fst) values (Narum et al. 2006). This study only compared data from two wild and two hatchery populations. Hatchery populations could be increasing these genetic diversity values due to brood management practices such as random mating. The Walla Walla basin, Snake River basin and British Columbia basins (Narum et al. 2004, Neilsen et al. 2009, Heath et al. 2001) have similar genetic results to our study. The Kamchatka populations show lower levels of heterozygosity and allelic richness, but similar levels of genetic differentiation to our study (McPhee et al. 2007).

Several of the populations tested in the Snake River basin (Neilsen et al. 2009) showed introgression between O. m. and O. c. from other studies (Weigel et al. 2002), indicating that this is not a phenomenon limited to the Methow Basin study. In conclusion, spatial genetic diversity in O. mykiss in the lower Methow tributaries is present, and most sites were significantly different. Spatial genetic diversity and differentiation is generally similar to other O. mykiss studies. Basin explained more genetic variation than life history, and isolation by distance was significant for anadromous sites, but not resident sites.

Summary of Results by Key Management Questions

Efforts to recover salmon and steelhead are addressing threats from four major areas of human impact including the effects of fishing harvest, hydropower development and operation, hatchery influences, and reductions in habitat quality. The focus of this document is on the efforts to recover salmon and steelhead in the Upper Columbia through the implementation of habitat restoration and protection actions. These are actions that are designed to protect and improve environmental conditions within the Upper Columbia that affect fish habitat and that limit the recovery of salmon or steelhead populations.

Project sponsors in the Upper Columbia are implementing habitat projects and getting them done according to the schedule developed through the recovery planning process. However, a standardized approach to project implementation monitoring is still lacking, impacting the quality of information recorded in the implementation tracking database used in the Upper Columbia, Habitat Work Schedule. Efforts are underway to implement a standardized implementation monitoring project for all recovery actions in the Upper Columba Region. At the same time, the Habitat Work Schedule to track the implementation of these projects has been improved. Standardized implementation monitoring and the improved Habitat Work Schedule will allow managers to assess if we are implementing the correct actions in future adaptive management cycles.

It remains uncertain whether habitat restoration actions being implemented in the Upper Columbia will actually lead to improvements in salmonid populations. This is due, in part, to the past practice of directing projects to fix threats and impairments in habitat rather than designing projects that ameliorate ecological limiting factors. Recent practices are emphasizing the need for the project design processes to focus more on ecological limiting factors. However, as described in more detail below, the concept of ecological limiting factors is difficult to apply in real-world management scenarios. Some research presented in this volume (for example Connolly et al.) suggests some restoration actions in the Upper Columbia (e.g. the removal of barriers on Beaver Creek) has indeed increased steelhead productivity in one tributary to the Methow River. In general, more work needs to be done to understand whether ecological limiting factors are being ameliorated by habitat restoration actions. The UCRTT made recommendations regarding habitat restoration action implementation. A principle recommendation was that Watershed Action Teams should continue to increase the focus on implementing high priority actions and that project funders should direct funds toward high priority projects. The highest priority, the UCRTT noted, is to implement habitat restoration actions that increase juvenile survival and growth because these actions would have the best chance for improving the biological criteria necessary for recovery. Additionally, the UCRTT provided the guidance that actions that have a short life span and that do not restore ecosystem processes are likely to be less effective in the long term.

The UCRTT also recommended that project planners and those auditing the progress of action implementation should evaluate projects on the basis of whether a project will remedy an ecological limiting factor. The UCRTT endorsed the use of the Habitat Work Schedule tool and recommended that analysis of project information continue to more fully answer these key management questions.

Were actions implemented according to the implementation schedule? How many actions of each type and tier were implemented? Did the number of actions implemented meet the target number identified in the implementation schedule or adaptive management plan (Appendix Q)?

Project sponsors in the Upper Columbia have been implementing habitat projects. Based on available information in the Habitat Work Schedule, at least 163 projects have been implemented in the Upper Columbia during the past decade by a variety of groups and agencies. Before the official start of the recovery process in 2007, however, no one group or agency was responsible for tracking the details of all of these projects in a coordinated way that would allow information about these projects to be summarized across the Upper Columbia with a high level of confidence. As a result, detailed information about many of these projects, like their type, priority level, and whether they met recovery targets, was not available at the time of the UCRTT Analysis Workshop in January 2010.

Fortunately, the UCSRB and partners are now focused on consolidating and organizing information about all of the habitat actions in the Upper Columbia, using the Habitat Work Schedule. This tool was demonstrated at the UCRTT Analysis Workshop and some simple answers to the key management questions were presented but detailed and consistent answers will take more time to develop, and will be reported in the future. The UCRTT endorsed the use of the Habitat Work Schedule tool and recommended that analysis of project information continue to more fully answer these key management questions.

The beginning of the recovery process in 2007 also initiated a change in the focus of habitat actions and a better understanding of the reasons for doing this work. The recovery process emphasizes implementing restoration and protection actions that will help improve salmon and steelhead populations to an eventual point of recovery while, in the past, projects were done to address threats and impairments in habitat that were not always "limiting" the recovery of populations. Using the Habitat Work Schedule, we learned that past actions did not always focus on the primary limiting factors: in fact about half of the 163 projects done in the past 10 years addressed problems not identified in the UCRTT Biological Strategy as "limiting factors." We suspect an unknown portion of these projects may have addressed limiting factors and that the method of reporting did not capture it. Also, 114 recommendations in the Biological Strategy, including 40 high priority recommendations, were not addressed by even a single project. UCRTT members suspect this may be due, in part, to the complexity of developing projects that restore ecological function. Projects that restore ecological functions require intensive coordination among multiple landowners, funding entities, and project sponsors, and are very difficult and expensive to design and implement.

These results suggest that Watershed Action Teams should continue to emphasize implementing high priority actions, such as projects that restore ecological functions, and that project funders should direct funds toward these project types. The highest priority, the UCRTT noted, is to implement habitat restoration and protection actions that increase juvenile survival and growth because these actions would have the best chance for improving the biological criteria necessary for recovery.

What type of actions were implemented?

A wide variety of habitat restoration actions were implemented. The largest category, close to a third of all actions, included restoration of habitat complexity and habitat quality, most often through the installation of instream structures or other modifications to the channel. Fixing fish passage barriers accounted for another one quarter of all the projects completed. Habitat protection was another category with many projects.

Have we done things to address habitat limiting factors?

Habitat actions are being done to address limiting factors but quantifying these accomplishments in time for the January 2010 Workshop was not possible due to a lack of standardized implementation monitoring and reporting of results. Continued analysis with the Habitat Work Schedule tool will help us better answer this question in the near future.

Terminology, it turns out, is another reason why it is difficult to answer this question but, even worse, incorrect use of the scientific term "limiting factor" could have a major effect on the likelihood of success (and cost) of recovery efforts. In ecological terms, a limiting factor is an aspect of the environment that limits the recovery of a salmon or steelhead population. It should not be confused with "threats," "degradations," and "habitat impairments" or other management terms that were often used in the past to identify and plan actions. A project may address a "threat" or "degradation" but still not address a factor that truly limits the recovery of salmon or steelhead populations.

The UCRTT recommends that project planners and those auditing the progress of action implementation should evaluate projects on the basis of whether a project will remedy an ecological limiting factors. To do this properly, we need to strengthen our understanding of the actual ecological limiting factors operating in the Upper Columbia. The long term goal would be to develop our understanding of limiting factors enough so that restoration and protection targets with predictable affects on salmon and steelhead population parameters could be identified. On the other hand, the UCRTT cautions that implementation targets should not become such a focus that other limiting factors are overlooked.

Analysis by Baldwin and White (this volume) suggests that about half of the 163 projects done in the past 10 years addressed problems not identified in the UCRTT Biological Strategy as "limiting factors."

Are we planning the right things to address habitat limiting factors?

In response to the recovery plan, the UCRTT, UCSRB, and project sponsors have been developing mechanisms to ensure that we are planning and implementing the right actions. Before the recovery plan was completed, projects were not as focused on priority limiting factors as they are now. Since then, a crosswalk mechanism has been established that helps to make sure that projects are directed toward the appropriate limiting factors. Also, the Habitat Work Schedule will improve our ability to track and manage progress in restoration action implementation.

The UCRTT recommends that the Implementation Schedule be reviewed to ensure that it meets the priorities of the UCRTT Biological Strategy and the UCRTT encourages the Board to only support projects that are consistent with these priorities. The UCRTT also recommends that projects be clustered rather than spread over wide areas. Although some uncertainty exists regarding the importance of clustering, such approaches in the Entiat Intensively Monitored Watershed program and the M2 project in the Methow may help answer this uncertainty. Clustering projects is consistent with the UCRTT reach-based approach recommended in the Biological Strategy.

The UCRTT was concerned that a perceived "use it or lose it" approach to project funding may allow low priority projects to receive funding. The UCRTT encourages the Board to develop ways to manage project funding to ensure that it gets spent on high priority projects. For example, perhaps unused project funds could be banked for future rounds or used for project development.

Are the limiting factors associated with habitat being ameliorated such that they do not limit the desired status of the population?

Impairments and threats to habitat are being ameliorated in one category in particular: human-caused barriers that block access to fish habitat in the Wenatchee and Entiat have been, with a few notable exceptions, removed as threats. Similarly, several passage projects in the Okanogan are in progress to ameliorate barriers to accessing habitat. It remains uncertain whether fixing these degradations and threats means that the ecological limiting factor has been removed, and assuming that is has, whether changes in fish population parameters result. Research by Connolly et al. (this volume) suggests that removal of barriers on Beaver Creek has indeed increased steelhead productivity within that tributary.

In its 2008 Barrier Prioritization Framework, the UCRTT recommended that an explicit evaluation be conducted of the remaining access barriers in the Methow in relation to VSP, and recommended that the Icicle Creek boulder field be assessed for human-caused passage limitations. Currently, there are no chronic access impairments associated with structures that cause a high level of concern for steelhead or spring Chinook in the Methow.

Little was presented at the Analysis Workshop regarding ecological limiting factors or regarding threats and impairments other than access to spawning habitat. It is hard to characterize progress towards the goal of ameliorating limiting factors without having targets or criteria for the interpretation of habitat metrics and without a better understanding of how the ecological concept of limiting factors applies to management questions. There are several ways of interpreting habitat data or fish metrics that need more development. Answering this question may be impossible for a suite of scientific reasons (e.g., measurement precision is too low, it is exceedingly hard to implement adequate monitoring designs to answer limiting factors questions in the real world) and the fact that limiting factors in a diverse ecosystem is easy to talk about but difficult to measure (see chapters on Habitat Status and Trend and Habitat Action Effectiveness, this volume).

The remainder of the chapter consists of articles reporting the contents of presentations given either during the UCRTT Analysis Workshop held on January 12 and 13, 2010 or during the deliberations of the UCRTT that followed:

Summary of Completed Habitat Actions in each Subbasin over the Last 10 Years

Derek Van Marter

Derek is the Associate Director of the UCSRB.

The *Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan* includes an Implementation Schedule of salmon recovery actions. The intent of the Implementation Schedule is to provide a framework for prioritizing, sequencing, and tracking the completion of hundreds of recovery actions over time that are identified in the Recovery Plan. However, managing the Implementation Schedule on paper over a period of 10-30 years would be prohibitively cumbersome. In 2009, the UCSRB adopted the use of the Habitat Work Schedule (HWS) to help track recovery action implementation. This online database functions as the Implementation Schedule for the Recovery Plan, and now allows for the efficient and interactive management of recovery actions, providing stakeholders in the Upper Columbia a real-time opportunity to interact with different phases of any project.

With the help of the HWS, for the first time, the UCSRB and UCRTT have the ability to look at trends in historic implementation, and compare those trends with certain milestones in the development and implementation of the Recovery Plan. However, we recognize some data are missing from the HWS or may be inaccurate. Both of these deficiencies may diminish the reliability of this analysis. Future work will standardize data entry and facilitate the collection of better information about the magnitude and quality of projects.

An analysis of completed projects in the HWS yields 163 projects across six broad categories: fish passage (e.g. barrier removal, culvert replacement), instream (e.g. adding stream complexity), instream flow, protection, riparian (e.g. plantings), and sediment. A look at the number and types of projects implemented over time suggests the presence of several patterns. While instream flow, instream, and riparian projects have always been a constant part of habitat restoration in the Upper Columbia, there appear to be several distinct periods of project implementation associated with particular events (Figure 1).

The data appear to show a period of particular focus on fish passage projects immediately after listing in the late 1990s (Figure 1). This initial focus on fish passage projects was followed by a period largely dominated by protection projects, during a time when progress was being made on the development of sub-

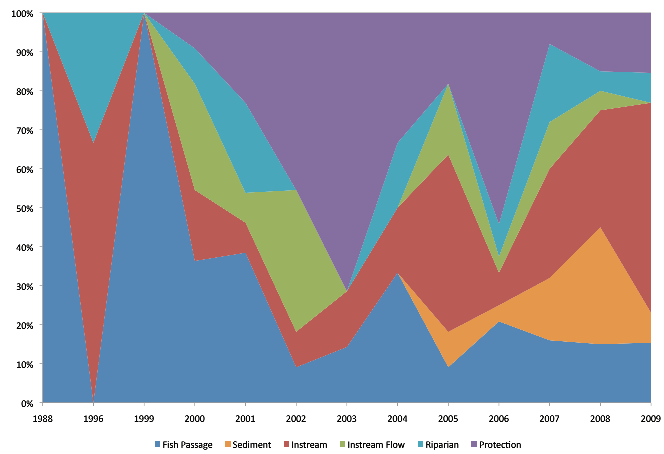


Figure 1. Annual salmon recovery projects in the Upper Columbia percent by project type. Periods of particular focus are clearly visible: first on fish passage projects, then on protection projects, and most recently as a diversified mix. Data are from the Habitat Work Schedule (uc.ekosystem.us).

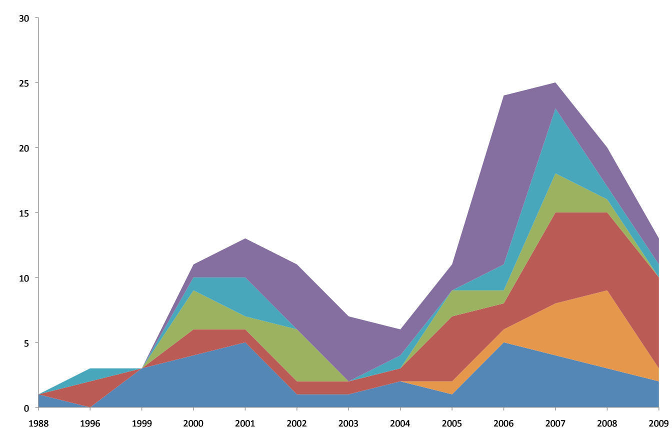


Figure 2. Count of annual salmon recovery projects in the Upper Columbia by project type. Distinct increases in total project count appear to be associated with listing in the late 1990s, and formal adoption of the Recovery Plan in 2007. Data are from the Habitat Work Schedule (uc.ekosystem.us).

basin plans and the Recovery Plan. A final period appears to start around the time the Recovery Plan was being finalized and adopted, and is characterized by a balanced portfolio of project types centered around efforts to implement instream projects, while fish passage and protection continue to serve an important role. In addition to the changes in focus over time, distinct increases in the number of projects completed appear to be associated with listing in the late 1990s, and again after adoption of the Recovery Plan in 2007 (Figure 2).

There are interesting points to tease out of the data within each subbasin. For example, the primary focus in the early years in the Methow was on fish passage (60%). More recently, the majority of projects fall into protection (70%) and instream projects (30%). In the Wenatchee, the more recent focus has been on fish passage (30%), instream (50%), and riparian (20%) categories, with a few protection projects; earlier the focus was on instream (50%) and riparian (40%) projects. Similarly, the Entiat sub-basin has shifted its priorities over the last decade from protection to instream work. Finally, the Okanogan, early and now, have maintained a focus on fish passage (80%), and more recently on sediment (20%).

Some of the change in focus on different project types over time may be related to a refinement of planning science in the Upper Columbia, and an increased understanding of limiting factors and actions necessary to address them (Figure 3). We know more about project implementation than ever before. Now, action can be targeted, in some places, to specific reach segments. Watershed and subbasin plans early in the decade identified strategies and projects to improve habitat conditions. The Recovery Plan incorporated and added to those plans with additional information, analysis, and planning. In 2008, the UCRTT updated its Biological Strategy, which outlines key limiting factors and project priorities for Upper Columbia watersheds. The Biological Strategy was refined later that year into a Summary of Priority Reaches and Actions that summarized the priority biological areas across the Upper Columbia by assessment unit, limiting factor and potential actions. This summary has led to geomorphic reach assessments completed by the Yakama "Nation and Bureau of Reclamation. These areas are now the primary focus of implementation and based on collaborative partnerships to affect change within an entire reach based on those factors limiting fish production.

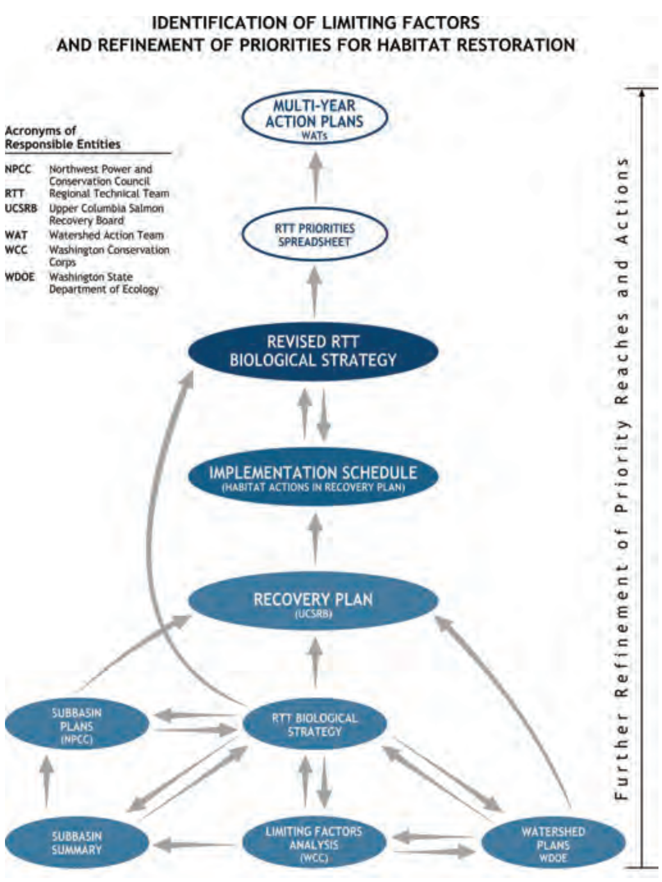


Figure 3. Increased understanding of limiting factors, and continuing refinement of planning science, from watershed and subbasin plans to the Recovery Plan and Biological Strategy, have allowed the focused development of Implementation Schedules and Multi-Year Action Plans, and increasingly more targeted project implementation over the last decade.

A Comparison of Project Implementation with Factors Limiting VSP Parameters in Each Subbasin

Casey Baldwin and James White

Casey is the Chair of the UCRTT and a fish biologist with the WDFW and James is the Data Steward for the UCSRB in Wenatchee, WA.

Limiting Factors

The term "limiting factor" is often used in several contexts, and can be confusing if not used consistently. In many cases, particularly related to habitat restoration, "limiting factor" is often used to describe human-induced degradation of habitat. There is generally an assumption that the human-induced degradation is limiting the survival of one or more life stages of the target species. However, in cases where the human-induced habitat degradation does not prevent the status of the population from improving then it is not a limiting factor and would be a low priority for restoration.

The definition of limiting factor can be generalized to any biological process. If we restrict it to population ecology, then a limiting factor is an aspect of the environment that controls the growth of a population of organisms in an ecosystem. The growth of a population is controlled or limited by that essential environmental factor or combination of factors present in the least favorable amount. The limiting factor may not be continuously existing condition but may occur only at some critical period of time.

Habitat actions often begin with a habitat assessment. An assessment often identifies a degraded habitat condition and, subsequently, a project is developed to ameliorate the degradation.

There is a generally untested assumption that the improved condition will fix the habitat and benefit the target species. However, if the degraded habitat condition is not affecting a process that limits the population (e.g. the life stage affected by the habitat is not limited by the particular degradation) then very little fish benefits may accrue due to the restoration action.

An alternative approach is to ensure that habitat actions are designed/located to benefit the population in a way that targets where the greatest improvements in VSP status are needed. For example, if a population is at low risk for spatial structure characteristics but high risk for productivity then it would not make sense to restore passage to historic habitat that is highly degraded (i.e. less productive than the habitat fish would have spawned in if the barrier had not been removed). In this example, restoring passage might decrease the spatial structure risk but it would potentially increase the productivity risk.

Limiting Factor — General Definition

A limiting factor is an aspect of the environment that controls a biological process.

Limiting Factor — Salmon Recovery

A limiting factor is an aspect of the environment that controls the growth of a salmon or steelhead population.

Limiting Factor — Two Examples

From health sciences: "A patient's health won't benefit from reduced dietary cholesterol if he is bleeding to death from a gunshot wound." The limiting factor is the gunshot wound.

From salmon recovery: "A fish population's status won't benefit from improved access to habitat if the habitat lacks the structure and food necessary for survival and growth." The limiting factor is the impaired habitat qualities.

Can Habitat Actions Help?

Status assessments performed for the Recovery Plan were analyzed for this presentation. The analysis indicates that those VSP parameters which are limiting populations, and which can be influenced by habitat actions, are the parameters that must be addressed first by habitat actions. Specifically, habitat actions that increase juvenile survival (e.g., smolts/redd) and growth are the highest priority for improving VSP status in all Upper Columbia populations.

Abundance and Productivity—All populations were at high risk for abundance and productivity with intrinsic productivity estimates less than 1 return per spawner. Improvements to habitat quality can increase egg to smolt survival thereby increasing the juvenile productivity of the population. Although there is no guarantee that improved juvenile productivity will result in higher spawner abundance, because factors outside the natal rearing tributaries may limit the production of spawners, juvenile productivity is the parameter most likely to be influenced by habitat actions in the subbasins of the Upper Columbia.

Diversity—All Upper Columbia populations of steelhead and spring Chinook are at high risk for diversity. However, in most cases diversity risk metrics that are responsible for the high risk ratings are not controlled by habitat conditions but, rather, are more directly influenced by the side-effects of hatchery production. For example, high risk factors for all populations include the high proportion of hatchery fish on the spawning grounds and the lack of genotypic variation. Therefore, implementation of habitat actions is not likely to lead to direct changes in the risk level of the genetic diversity metrics.

Spatial Structure—For most Upper Columbia populations, spatial structure metrics are at low to moderate risk, thereby not limiting the population from achieving its desired status. The one exception was for Okanogan steelhead, where the population has not had full access to several important major spawning areas in Salmon and Omak creeks. A water quantity project in Salmon Creek allowed steelhead access to the middle reaches in 2009, but efforts to get steelhead over Mission Falls in Omak Creek have not been successful so far.

Adaptive Management Recommendations

- The UCRTT recommends that project planners and those auditing the progress of action implementation should evaluate projects on the basis of ecological limiting factors, in particular, a limiting factor is an aspect of the environment that controls the growth of a population of salmon/steelhead. More effort needs to be made to describe the limiting factors in terms of life stage survival limitations of the populations, rather than just the human induced degradation or threats that might be contributing to reduced survival. These are not mere rhetorical distinction: properly focusing on ecological limiting factors, rather than perceived threats and limitations, could substantially improve likelihood of success (and reduce the cost) of recovery efforts.
- Our understanding of the actual ecological limiting factors operating in the Upper Columbia should be developed to a point, perhaps, where life stage survival limitations of the population could be identified (although this goal is far-reaching and will not be achieved in the near term). On the other hand, the UCRTT cautions that implementation targets or thresholds should not become such a focus that other limiting factors are overlooked.
- The highest priority for improving the status of all populations, when productivity is less than 1.0, is to increase productivity. Actions that increase juvenile survival (e.g., smolts/redd) and growth are the highest priority for improving VSP status. For example, efforts to gain and maintain access to the middle reaches of Salmon Creek and upper Omak Creek should continue and are critical to achieving a viable population of steelhead in the Okanogan.
- Accurate and comprehensive data entry into the Habitat Work Schedule is a critical step in tracking implementation progress in the future.
- The Habitat Work Schedule should be used to compare the history of implemented projects in watersheds with UCRTT recommendations, particularly focusing on high priority actions. The results of this comparison should be used to adjust implementation schedules so that actions addressing identified limiting factors are planned.

Two important technical documents were produced by the UCRTT in the first adaptive management cycle since the Recovery Plan was completed:

The Biological Strategy was Revised in 2008

The Biological Strategy is a document which outlines a strategy for the protection and restoration of salmonid habitat in the Upper Columbia region. Prepared by the UCRTT, originally in 2000 and updated in 2002 and 2003, it was revised in 2008 to better conform with Recovery Plan products and to accomplish four objectives:

- Address the Viable Salmonid Population (VSP) characteristics in a manner consistent with the Recovery Plan and technical guidance from the Interior Columbia Technical Recovery Team.
- Update the technical appendices with new information regarding restoration strategies and priorities.
- Provide revised technical scoring criteria for habitat restoration, protection and assessment projects submitted for funding through various sources.
- Update the critical uncertainties section.

The intent of the document is to provide support and guidance on implementing the Recovery Plan, which includes actions for bull trout and other habitat restoration activities. This document should serve as a technical foundation to set regional priorities for habitat protection and restoration, based on available information and the professional judgment of fisheries biologists familiar with the region.

A copy of the most recent Biological Strategy can be found at: http://www.ucsrb.com/resources.asp.

Prioritization Matrix was Developed in 2009

Another important technical product developed by the UCRTT in support of the Recovery Plan is the "Summary of Priority Reaches and Actions, "also known as the "Prioritization Matrix." This spreadsheet was developed at the request of the UCSRB, to recommend the most biologically important reaches and actions that could be taken for salmon recovery in the Upper Columbia.

The UCRTT's objective with the Prioritization Matrix was to create a concise product, with more specific guidance than is found in the Biological Strategy, that would help to guide the Watershed Action Teams (WATs) in their task of updating the implementation schedules and developing mid-range work plans. Priority levels were determined based on the professional judgment of the UCRTT. In addition to the actions and reaches described in Prioritization Matrix, many other actions and reaches have been identified for habitat improvements which may also make important contributions to recovery. However, the UCRTT believes that the habitat related actions outlined in the Prioritization Matrix are the highest priority for maintaining and restoring the viability of listed salmonid populations in the Upper Columbia Region.

The spreadsheet tables accompanying this memo do not provide a complete picture of threats and limiting factors that the action types and specific actions are intended to address. The background information for why particular reaches and actions are important can be found in appendix G of the Salmon Recovery Plan (UCSRB 2007), UCRTT Biological Strategy (UCRTT 2008), USBR Tributary and Reach Assessments, the Detailed Implementation Plan for the Entiat Water Resource Inventory Area (WRIA) 46, and other documents.

Are We Doing the Right Actions?

This investigation compared the number of habitat actions to aid salmonid recovery that have been implemented in the Upper Columbia during the last 10 years with priorities and recommendations made by the UCRTT in the 2008 version of the Biological Strategy. This comparison was done for each of 39 assessment units throughout the Upper Columbia.

During the last 10 years, 163 restoration actions have been completed in the Upper Columbia. Meanwhile, the UCRTT's Biological Strategy has made 281 recommendations regarding ways to protect and restore habitat in the Upper Columbia. About half of the 163 projects addressed human degradations not prioritized in the UCRTT Biological Strategy.

Of the 281 recommendations from the Biological Strategy, 114 (41%) were not addressed by a completed habitat action. Also, some recommendations that were addressed with one or more actions may not have been completely addressed: additional actions may be necessary. Since the recommendations had varying levels of priority, we compared the list of 114 recommendations with the UCRTT priorities spreadsheet, which was a recent refinement in subbasin-level priorities. This comparison revealed that 40 of the 114 (35%) were considered high priority actions, indicating that there was still considerable opportunity to address important habitat degradations in the Upper Columbia.

Within each assessment unit, the number of projects of each project type were compared to the identified degradations. Although useful for syncing efforts in individual assessment units, this comparison was difficult to make in a presentation format due to the large number of assessment units and degradations. It was also limited in that it did not capture the relative importance of the recommended degradations within each assessment unit.

UCRTT Barrier Prioritization Framework and its Application in the Wenatchee and Entiat Subbasins

Casey Baldwin

Casey is the Chair of the UCRTT and a fish biologist with the WDFW.

Background

The Upper Columbia Regional Technical Team (UCRTT) has provided technical review of habitat restoration projects proposed for funding from various entities including the Salmon Recovery Funding Board (SRFB), the Community Salmon Fund (CSF), and the HCP Tributary Funds of the Mid-Columbia Public Utility Districts. Past project review sessions revealed uncertainty regarding which culverts/diversions were considered a priority for repair based on their potential biological benefit. Additionally, Chelan County Natural Resource Department (CCNRD) has asked the UCRTT for direction on culvert-replacement priorities for funding from the Bonneville Power Administration (BPA) through the Northwest Power Planning Council's Fish and Wildlife Program. These processes clarified the need for a standardized and systematic approach to prioritizing barrier-correction projects throughout the Upper Columbia. The UCRTT started this effort in 2006 and developed a draft document describing a prioritization method using the Wenatchee Subbasin as an example. In January of 2008, the CCNRD requested that the UCRTT finalize the barrier-prioritization framework and complete our evaluation of the priority level of known artificial barriers in the anadromous zone of the Wenatchee and Entiat watersheds.

Various projects and agencies have evaluated barriers to fish migration through conducting inventories and estimating the severity of the obstruction and the habitat quality and quantity above the barrier (USFS district and Forest level barrier assessments; WDFW 2000; Schmidt and Canning 2005; Schmidt 2006; Harza 2000; PWI 2003; Arterburn et al. 2007). None of these efforts were inclusive of all life stages for the three listed species (spring Chinook, steelhead, and bull trout) throughout their entire range in the Upper Columbia Recovery Region. Therefore, there is no single assessment available to quantitatively determine the biological benefit and prioritization of barrier-correction projects in the Upper Columbia Region. Additionally, the Recovery Plan (UCSRB 2007) calls for the repair of all man-made barriers in the anadromous zone, but provides no prioritization or timelines for completion of repairs, nor does it place barrier corrections within the context of overall habitat-restoration priorities. Thus, it is unclear which barrier-correction projects should proceed in the near term versus those that can/should follow other higher priority actions.

Our goal was to develop a framework that uses a wide variety of available information to develop prioritized lists of culverts/obstructions for correction throughout the Upper Columbia salmon recovery region. To accomplish this goal we first needed to derive a method to determine the relative biological benefit of repairing or replacing culverts or diversions that would combine existing regional inventories and assessments, incorporate the Viable Salmonid Population (VSP) guidelines from the Interior Columbia Technical Recovery Team as well as the Recovery Plan (ICTRT 2007; UCSRB 2007).

Methods

Obstructions on larger streams (4th to 6th order, using Strahler 1:100k classification) were prioritized separately from smaller (1st to 3rd order) streams. Any obstruction on a 4th to 6th order stream that prevents or inhibits a measurable level of passage and access to historic spawning or rearing habitat in the Upper Columbia was automatically considered high priority for restoration.

Prioritizing obstructions on small streams was based on:

- Broad-scale prioritization implications for contributing to VSP attributes;
- Fine-scale/local consideration;
- Information that did not fit into either one of those categories; and
- Special case information that fit these categories but should supersede attempts to standardize and quantify the information that went into each category.

Adaptive Management Recommendations

- Moderate and low priority barriers should be corrected, but not right away. Other factors besides these barriers may limit the population and need to be addressed first. Also, in some cases, other action types and actions in other watersheds need to be addressed before these moderate and low priority barriers are corrected.
- The UCRTT Barrier Prioritization Framework should be applied to the Okanogan and Methow subbasins.
- The Icicle Creek boulder field needs an assessment to determine if there is a man-caused passage limitation for steelhead and bull trout. With the exception of Icicle Creek, passage barriers should not be considered a "primary limiting factor" for anadromous salmonids in the Wenatchee and Entiat populations.
- In the Wenatchee and Entiat, despite some gains that could be made to capacity, the habitat above many of the moderate to low priority barriers is degraded such that there are potential decreases in productivity.
- Inventories should be updated and periodically re-evaluated for priorities

UCRTT Deliberations

Some qualitative aspects of the Barrier Prioritization Framework could be analyzed quantitatively.

The broad-scale analysis incorporated the spatial structure and diversity guidance from the ICTRT by evaluating whether each tributary was a part of a major or minor spawning area for each of the three listed species (UCSRB 2007; ICTRT 2007) including spring Chinook, steelhead, and bull trout. Three tiers were created using a point system where major spawning areas scored two points, minor spawning area scored one point, and subwatersheds not within the boundaries of a major or minor spawning area got zero points. Total points were summed across each subwatershed; the highest priority (Tier 1) consisted of subwatersheds that scored from four to six points, Tier 2 subwatersheds had two to three points, and Tier 3 subwatershed had zero or one point.

Two additional "high priority" filters were then applied. A barrier was considered high priority for correction if (1) access to the blocked habitat would, by itself, improve the population risk-level for spatial structure or diversity or (2) the barrier blocked a quantity of habitat that was necessary for the population to reach VSP abundance thresholds, unless habitat above the barrier was degraded to the point that productivity (smolts/redd or egg-to-smolt survival) of the population might decline if access was provided without first conducting habitat restoration. While this second point is quantitative in nature, this filter was applied qualitatively using professional judgment. We also reserved the option of reducing the priority if needed.

A finer scale analysis was needed to refine priorities within major spawning areas or between spawning areas with similar priority levels. To accomplish this, we considered the number of listed species that would utilize the habitat upstream of the barrier at two different life stages (adult spawning and juvenile rearing). We also factored in the quantity and quality of habitat above the barrier by estimating the linear distance of stream above the barrier and whether it was low gradient (<4%), high gradient (>4%), or substantially degraded. The 4% break was based on a broad-scale analysis by the ICTRT that showed considerable increases in redd density in stream gradients less than 4%.

We recognized that using the area (length x width), rather than linear distance, would have been a more accurate method for evaluating the quantity of habitat for spawning and rearing above the barrier. However, several factors lead us to conclude that linear distance would be adequate for the purposes of this framework. First, there was a lack of data on stream widths for many small streams. Second, the assessment was limited to small-order streams so the variability in stream widths was minimized. Additionally, there was uncertainty regarding the end point of potential distribution in many cases so estimating area, rather than linear distance, would increase the error in these estimates exponentially.

Finally, we determined that seasonal spawning and rearing in intermittent streams should get some consideration, if there is adequate rearing habitat in upstream or downstream perennial reaches (particularly for steelhead because they spawn and migrate during spring runoff). In many cases, there is/will be no data for the presence, density, or probability of successful rearing in the areas upstream of a barrier. For these cases, we recommend evaluation of the flow, habitat conditions, and fish presence before finalizing the prioritization or proceeding with correcting the potential obstruction.

Stream segments with less than 4% gradient above the barrier were rated as high, moderate, or low priority according to the species use and linear distance matrix in Table 1, assuming there was low to moderate levels of habitat degradation upstream of the barrier. Stream segments with greater than 4% gradient above the barrier, or less than 4% gradient but with moderate levels of habitat degradation were rated as moderate or low priority according to the species use and linear distance matrix in Table 2.

In North Central Washington, the US Forest Service staff completed an analysis of subwatershed conditions (6th HUC) for the Okanogan-Wenatchee and Colville National Forests to be used for upcoming Forest Plan revision. The percentage of roads in a sub-watershed within the riparian area was used to evaluate channel constriction.

Streams at 3% gradient and lower were weighted as 75% of the score for constriction, and streams above 3% gradient accounted for 25% of the score. Road percentages above 5% for a sub-watershed received a -1 value. Sub-watersheds with no roads within 30m of a stream received a score of +1. The values were used to rank riparian road constriction from highest to lowest for 297 subwatersheds on the two National Forests. The closer a constriction score came to a value of -1, the greater the assumed intensity of previous anthropogenic activities and the greater the assumed degradation of aquatic habitat (Reiss et al. 2008).

The UCRTT used this analysis to inform our barrier-prioritization process by assuming that any stream falling in the lowest quartile (25%) for riparian roads was highly degraded. This translated to a USFS riparian road score of –0.11 or lower. This cutoff point provided an important consideration in our process of determining the value of providing full fish passage to each area. However, we recognize that levels of degradation are on a continuum and habitat condition and road location in relation to the stream channel vary throughout a watershed. Therefore, we modified our priority recommendations on a case-by-case basis depending on the locations of obstructions in the watershed relative to the roads.

Results and Discussion

Various projects and agencies have evaluated barriers to fish migration through conducting inventories and estimating the severity of the obstruction and the habitat quality and quantity above the barrier. None of these efforts were inclusive of all life stages for the three listed species (spring Chinook, steelhead, and bull trout) throughout their entire range in the Upper Columbia Recovery Region. The Salmon Recovery Plan calls for the repair of all man-made barriers in the anadromous zone, but provides no prioritization or timelines for completion of repairs, nor does it place barrier corrections within the context of overall habitat-restoration priorities. Thus, it is unclear which barrier-correction projects should precede in the near term versus those that can/should follow other higher priority actions.

The UCRTT developed a framework that uses a wide variety of available information to develop prioritized lists of culverts/obstructions for correction throughout the Upper Columbia Recovery Region. Our method considers the relative biological benefit of repairing or replacing culverts or diversions by combining existing regional inventories and assessments and incorporating the VSP guidelines from the ICTRT as well as the Salmon Recovery Plan.

We applied this framework to 112 culvert barriers with 21 complexes (two or more culverts on one stream) in the Wenatchee and Entiat watersheds and determined that three (one culvert complex and two singles) were high priority. Three blockages had potential to be high priority but were labeled "need more information" due to either sequencing issues with other limiting factors or uncertainty regarding the details of the obstruction. Finally, all six of the blockages that ranked as moderate priority under the small stream prioritization matrix were downgraded to low priority in the overall ranking due primarily to high levels of habitat degradation (i.e. other primary limiting factors) upstream of the barriers.

Barrier Removal in Omak Creek

Rhonda Dasher

Rhonda is a fish biologist with the Colville Confederated Tribes.

Background

The Colville Tribes and their partners have been addressing passage barriers and working to re-establish connectivity throughout the Omak Creek assessment unit. Both of these actions were

Figure 1. Looking down Omak Creek in the Okanagan Basin pre-construction when passage was blocked by boulders in the spring of 2009.

Figure 2. Looking down Omak Creek post-construction:. The structure is in place and just has to have the geotextile cloth added.

prescribed by the Recovery Plan and are likely critical for the recovery of steelhead in the Upper Columbia, since Omak Creek is one of only two major spawning areas in the U.S. portion of the Okanogan which must support significant numbers of naturally produced adult steelhead in order for the Upper Columbia ESU to be reclassified as "recovered."

Methods

Beginning with a catastrophic failure of a road culvert in lower Omak Creek in 1999, the Colville Tribes have been improving fish passage in a phased approach.

In 2000, documented access to spawning habitat by adult steelhead was provided in the lower 5.1 miles of Omak Creek by a channel reconstruction project at the site of the failed road culvert. Since this project was effected, steelhead and spring Chinook salmon have been observed spawning in lower Omak Creek.

Adaptive Management Recommendations

The UCRTT supports and encourages actions that promote and maintain access to the middle reaches of Salmon Creek and upper Omak Creek by steelhead. Providing access to these habitat is critical to achieving a viable population of steelhead in the Okanogan.

After this repair was completed, the next significant barrier to fish passage was Mission Falls, which has been impaired since the 1930s when railroad construction blocked fish passage in the stream with boulders and other debris. Some of these large boulders were removed from Omak Creek in 2000.

By 2005, when no definitive proof of fish passage at Mission Falls had been found, even after three years of focused monitoring, three pool structures were installed that would facilitate fish passage within the Falls.

High water in 2006 flushed more debris into these pools, threatening their efficacy, while some remaining large boulders were observed to impede fish passage in 2007.

Consequently, more work was conducted in 2008 and 2009. The remaining boulders and other debris were removed from the critical areas of Mission Falls, additional engineering assessments were completed, and another structure was built to facilitate fish passage. Furthermore, following a complete assessment of Mission Falls, any remaining passage issues were completed by NCRCS in February 2010. More structures may be designed to help with any additional passage issues that might be identified.

Next Steps

Monitoring continues to take place. Once adequate fish passage at Mission Falls is documented, attention will shift to other parts of Omak Creek and its tributaries upstream of the Falls.

Habitat Status and Trend

Summary of Results by Key Management Questions

Upper Columbia spring Chinook salmon and steelhead cannot be considered “recovered” until, in part, an evaluation demonstrates that the status of their habitat and the threats to their habitat are improved to a point that these fish are no longer in danger of extinction or are not likely to become endangered in the foreseeable future. For this reason, it is very important to develop a keen understanding of the status of salmon and steelhead habitat in the Upper Columbia. Similarly, we need to understand what changes are taking place in salmon and steelhead habitat so that we know if the threats to survival are being reduced.

There are natural processes in watersheds that form fish habitat and these processes are necessary for the long-term survival of fish. These processes form the basis for evaluating the status of fish habitat and can be thought of affecting habitat conditions in seven distinct categories. These categories include water quality, habitat access, habitat quality, channel condition, riparian condition, stream flows, and watershed condition.

The Key Management Questions pertaining to habitat status and trend treat each of these seven conditions separately. However, monitoring fish habitat for the purposes of evaluating “recovery” is a relatively new endeavor and answers to all seven of these Key Management Questions are basically the same at this point in time. Therefore, the UCRTT has decided to combine answers for all seven habitat status and trend questions into a single set of answers.

Is the status of the habitat improving?

- *Is water quality increasing, decreasing, or remaining stable within the distribution of the populations in the Upper Columbia region?*
- *Is habitat access or connectivity increasing, decreasing, or remaining stable within the distribution of the populations in the Upper Columbia region?*
- *Is habitat quality increasing, decreasing, or remaining stable within the distribution of the populations in the Upper Columbia region?*
- *Is channel condition increasing, decreasing, or remaining stable within the distribution of the populations in the Upper Columbia region?*
- *Is riparian condition increasing, decreasing, or remaining stable within the distribution of the populations in the Upper Columbia region?*
- *Are stream flows increasing, decreasing, or remaining stable within the distribution of the populations in the Upper Columbia region?*
- *Is watershed condition increasing, decreasing, or remaining stable within the distribution of the populations in the Upper Columbia region?*

Changes in habitat status have been detected at small scales (trends were demonstrated at the project level, reach level, and at larger scales) but more time and more data are needed to make a determination of habitat trends at the population and ESU scale. For example, at the project, scale the Colville Tribes (this volume) showed favorable trends in water temperature in a reach where riparian planting occurred. At the reach scale, at the watershed scale, and at the subbasin scale, Jordan et al (this volume) showed significant trends in certain Wenatchee subbasin habitat metrics. However, a simple, clear-cut answer regarding Wenatchee habitat trends could not be presented because the trends that were observed behaved differently at each of these three scales and were different for each habitat metric that was examined. Additional work is required to summarize these complex results. At the scale of the entire Interior Columbia Basin, Al-Chokhachy et al (this volume) found significant increases in the condition of streams at managed sites on U.S. Forest Service lands while conditions decreased at un-managed reference sites.

In order to detect biologically significant changes in fish habitat, monitoring programs need to collect the right type of information for a long period of time (many years) before significant trends will be apparent. Habitat monitoring programs in the Upper Columbia have been collecting the right information for the past five to six years in most places. In 2010, habitat monitoring data collection began to include non-federal lands in the Methow, the last area of the Upper Columbia to receive adequate habitat monitoring. However, regardless of location and the fact that the necessary information is being collected, not enough time has elapsed to truly make strong conclusions about trends in habitat conditions.

Currently, there is no easy way to summarize and report the large number of habitat attributes that are measured under habitat status and trend monitoring programs. For example, there are several habitat attributes that make up “habitat quality” but there is no single, composite metric that describes the somewhat ambiguous “habitat quality” indicator. The Colville Tribes are interpreting habitat data by using the Ecosystem Diagnostic Tool to amalgamate habitat attributes into estimated fish metrics. This is a laudable approach because it puts complex, and sometimes ambiguous, habitat data into fish terms that are easier, and perhaps more relevant, for managers to understand. However, possible pitfalls with this approach need to be avoided. In particular, the habitat attributes that are used in the tool need to be identified and reported so that scientists and managers can better understand the input to the tool. Furthermore, the output from the tool can also be interpreted in many ways so developing a transparent way to report and interpret the data to managers remains an important goal. There are at least three possible ways of interpreting habitat data or fish metrics that need more development including indices of biotic integrity, decision making models, and/or comparisons to “reference conditions.”

The PIBO monitoring work typified the complexity that is found in fish habitat data. Although some trends were observed in the ten years of U.S. Forest Service habitat data, they were not consistent across locations or metrics. The UCRTT recommends that the PIBO data be analyzed with variance decomposition like that performed by Jordan et al. (this volume), which may aid in the interpretation of these results.

Currently, data being generated by monitoring programs in the Upper Columbia do not explicitly inform the adaptive management process. The UCRTT recommends that data collected by monitoring programs like ISEMP and OBMEP be used in the adaptive management process. The UCRTT and the UCSRB staff should work with these monitoring programs to develop a process for reporting the results for all relevant metrics so adaptive management planners can make use of those results. The data reporting structures need to be established in ways that apply the appropriate time and space scales to each Key Management Question.

Finally, Key Management Questions may need to be revised and managers need to be ready for complicated answers. Fish habitat is the manifestation of complicated landscape and river processes. These physical characteristics are themselves complicated and require many different metrics to be adequately described. As fish habitat data sets are being assembled and analyzed, we are learning more about the meaning and characteristics of the data and fish habitat in particular. In some cases, we are finding that Key Management Questions are phrased in ways (e.g. oversimplified, focused too narrowly, etc.) that will eventually stand in the way of better understanding how well fish habitat and populations are recovering in the Upper Columbia. The UCRTT recommends that the Key Management Questions for habitat status and trend be revisited and, if necessary, revised once we have more information from the emerging analyses related to habitat status and trend monitoring.

The remainder of the chapter consists of articles reporting the contents of presentations given either during the UCRTT Analysis Workshop held on January 12 and 13, 2010 or during the deliberations of the UCRTT that followed:

Water Temperature Status and Trends in the Okanogan

Rebekka Lindskogg, David Zhou, and Brent Phillips

The authors work for Summit Environmental Consultants, Inc. Rebekka is an Information Manager, David is a Data Systems Manager, and Brent is a Fisheries and Wildlife Ecologist.

Background

Electronic data loggers have been deployed at many sites throughout the Okanogan River basin to collect hourly data throughout the year. Reporting and quality assurance and control has been achieved by the use of multiple queries, decision support matrices, and lengthy iterative discussions within a developing data auditing rule set. After cleansing the data, automated report queries allow information to be displayed in a concise manner at various spatial and temporal scales. These reports link complex temperature data to salmonid biology.

Project Objectives

Since 2006, collaboration between Summit Environmental Consultants Ltd and the Confederated Tribes of the Colville Reservation has been funded by Bonneville Power Administration through the Okanogan Basin Monitoring and Evaluation Program (OBMEP) to evaluate temperature data collected throughout the Okanogan River basin.

The objectives of this project are to:

- Develop a Data Auditing Rule set.
- Automate spatial and temporal analyses routines.
- Produce a report for the Okanogan River basin.

Temperature Data Set

There are 91 stations with data loggers that collect hourly temperature data throughout the Okanogan basin. Temperature is monitored each year at 31 annual panel sites and another 60 rotating panel sites are sampled once every 5 years. The OBMEP database has over 750,000 temperature records. We identified and removed data anomalies during quality assurance testing of the data, for example, loggers collecting air instead of water temperatures, malfunctioning loggers, incorrect set up of loggers, etc.

Methods

Automated reports were developed in several steps:

1. A Biologist/Data Manager Exchange Workshop was held to develop the concept of the automated reports;

2. The data auditing procedures and the candidate rule set were defined and include:

    - Maximum Diel Variation
    - Temporal Analyses
    - Comparisons with flow data and air temperatures
    - Reference stations
    - Hourly incremental changes
    - Daily average – smooth moving average
    - Thresholds to discard entire data set.

    We then completed an iterative analysis of these candidate rules to select a final set, and to decipher what order to apply them. The iterative analysis involved multiple queries and decision support matrices to examine the effect that implementation of each rule would have on the data. We completed this analysis on a subset of the data, representing four annual site test cases. The finalized Data Auditing Rule Set with order of implementation is:

    - All temperatures below zero will be changed to equal zero;
    - Exclude the first and last days of each data series;

Prepared for:

Annual Stations Water Temperature by Station

Prepared by: SUMMIT ENVIRONMENTAL CONSULTANTS LTD.

Station ID: *OBMEP-388* **Location:** *Bonaparte Creek*

Panel: *Annual* **Tributary or Mainstem:** *Sp/Migrate*

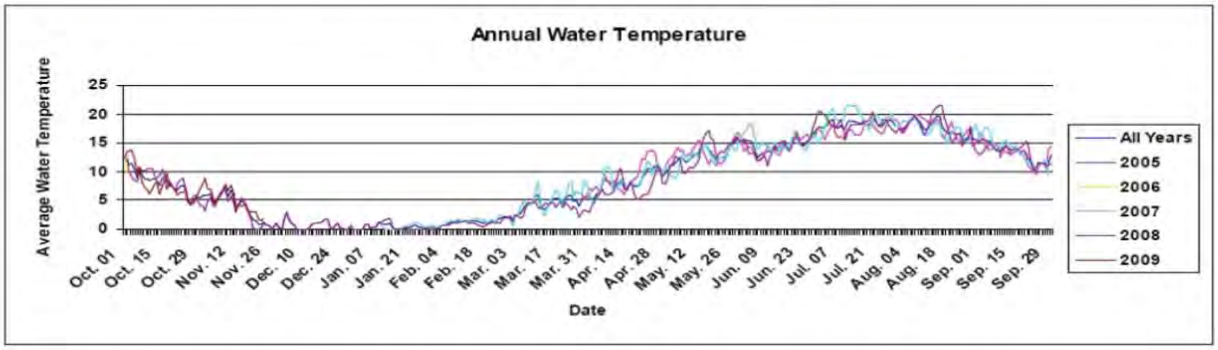
Reach Code: *B1*

Status

WATER YEAR	FIRST DATE	LAST DATE
2005	Mar	Sep
2006	Oct	Oct
2007	Jan	Sep
2008	Oct	Sep
2009	Oct	Nov

Watershed Baseline Ancilliary
Water Quality Parameters
Average All Years

pH:	7.96 pH	SP_Cond:	3.42 ms/cm
DO_MGL:	11.29 mg/L	DO%:	99 %
Salinity:	1.93 pps	Turbidity:	31.64 ntu



Prepared for:

Annual Stations Water Temperature by Station

Prepared by: SUMMIT ENVIRONMENTAL CONSULTANTS LTD.

Station ID: *OBMEP-361* **Location:** *Omak Creek*

Panel: *Annual* **Tributary or Mainstem:** *Sp/Migrate*

Reach Code: *OMAK UPPER*

Trend

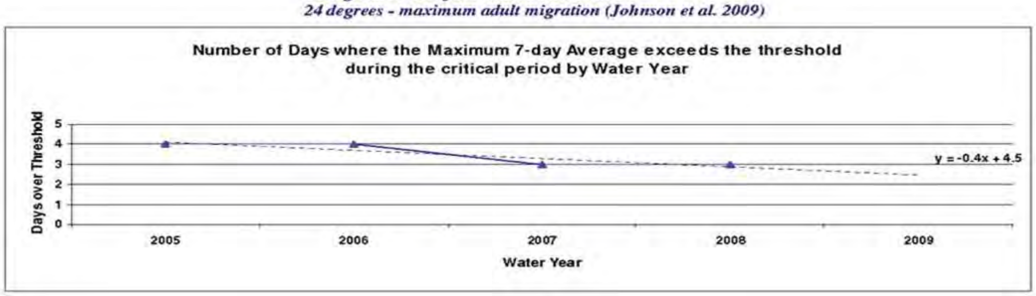
Note: considers year round data by Water Year

Water Year	Max WT-7 day Pd	Avg WT-7 day Pd	Max WT	> 16 (Days)*	> 18 (Days)*	> 24 (Days)*	Max. Diel Var.
2005	23.91	19.2	24.72	73	46		9.59
2006	25.94	9.37	27.71	64	36		8.78
2007	24.31	10.03	25.42	71	42		8.68
2008	23.61	9.11	24.68	59	39		8.2
2009	12.48	9.15	13.5				3.465

** Based on daily average temperatures*

Threshold: >18 Degrees **Critical Period:** April 1 - June 30

Biological importance of thresholds: *16 degrees - State Water Quality (Core Summer Salmonid Habitat; DOE)*
18 degrees - LC50 for summer Steelhead
24 degrees - maximum adult migration (Johnson et al. 2009)



Figures 1 and 2. Examples of automated reports produced for two annual sites (Bonaparte Creek (OBMEP-388) and Omak Creek (OBMEP-361)).

- Exclude data records from any measurement with an hourly increment > 5°C until temperature recovers at least 3°C. Exclude data for the entire day if there are any remaining results > 30°C.

3. Automated reporting and document preparation will be prepared upon completion of the data audit.

Preliminary Results

Currently the auditing and automated reporting has only been completed for two annual sites (Bonaparte Creek (OBMEP-388) and Omak Creek (OBMEP-361); and one panel Site (Ninemile Creek Watershed)). A status and trend analysis was completed for the annual sites. The status page graphs daily averages by water year, and includes averages for water quality parameters. The trend page shows several different ways of describing temperature exceedances in the data (i.e., maximum water temperature within a 7-day period, maximum diel variance), plus it graphs the number of days within the sensitive period with average water temperatures above the threshold. The panel sites are grouped by watershed and the reporting includes a location map, followed by status pages for each year that combines the individual stations. As with the annual sites, the panel site status page graphs daily averages by water year and includes averages for water quality parameters. The automated reporting outputs for these sites are attached to this document.

Next Steps

The next steps for this project are to:

1. Finalize development of the auditing routines for the entire database;

2. Run the automated reports for all annual and panel sites;

3. Support the CCT staff with final document preparation for reporting for the Okanogan River basin;

4. Standardize temperature status and trend reporting within the Okanogan River basin and beyond.

Habitat Status and Trends from the Wenatchee ISEMP

Chris Jordan

Chris is the ISEMP Principal Investigator and works for the Northwest Fisheries Science Center, National Oceanic and Atmospheric Administration, Corvallis, OR.

R & D to Assist Management

The ISEMP's mission is to research and develop appropriate monitoring techniques to answer the types of questions relevant

Adaptive Management Recommendations

- Regional monitoring programs (e.g. ISEMP, OBMEP et al.) are collecting a lot of data that could be used in the adaptive management process. The UCSRB staff should work with these programs to develop a process for reporting the results for all relevant metrics so adaptive management planners can make use of those results. Key Management Questions may need to be revised in light of the relevant metrics reported by these monitoring programs. Multi-metric indices of watershed health and/or decision-support models may need to be developed in order to better interpret complex status/trend data.
- Now that subtleties are being uncovered in actual data, scientists need to work with managers to make sure that data reporting structures are established in a way that the appropriate time and space scales are being applied to particular questions.
- Biological responses to habitat trends need to be analyzed and reported at the proper spatial scale and should be reported at each significant scale.

The Hierarchical Model

ISEMP's status/trend monitoring design is based on a hierarchical model (Figure 1) that presupposes that habitat data behaves differently at the site level, the watershed level and the subbasin level (it also includes a factor for fish zones in case habitat influences on fish differ by fish community type). Figures 3 and 4 show how different trends can be detected at all three of these different scales .

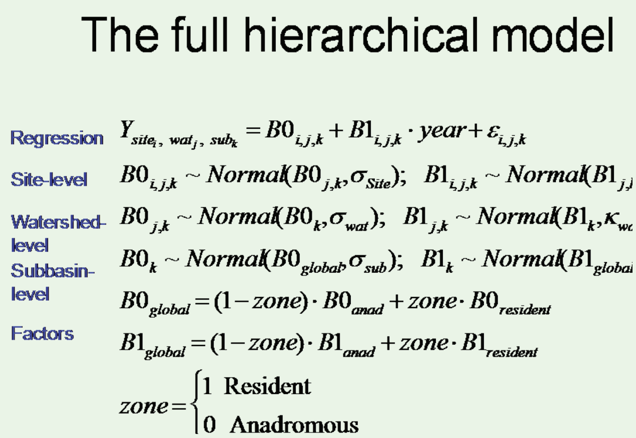


Figure 1. ISEMP is using a hierarchical model to better understand the complexity of habitat data collected in the Wenatchee and Entiat. This model accounts for variation in the data at three levels (the site, watershed, and subbasin) as well as in the anadromous and resident fish zones.

Bayesian Methodology

The hierarchical model (investigating three spatial scales) was fit to habitat metric data from the Wenatchee Subbasin from 2004-2009 using the WinBUGS (Bayesian inference using Gibbs sampling; Lunn, Best, and Speigelhalter 2000) software. The resulting output (e.g. Figures 2 and 3) depicts the actual distribution of the modeled parameters (not necessarily normally distributed as in other methodologies; in this case the slope of the trend line).

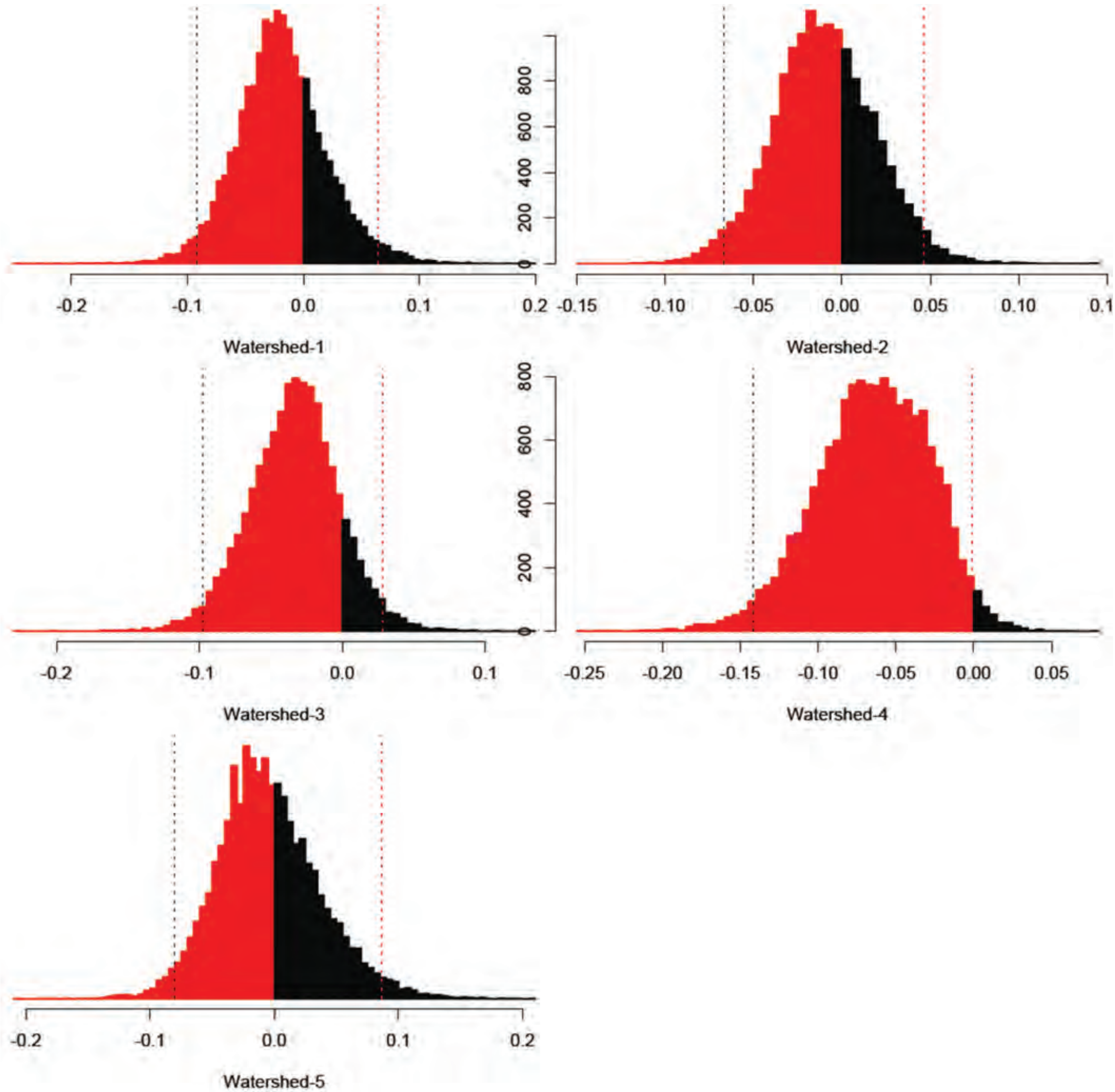


Figure 2. Trends in the average embeddedness (measured at 25 annually-visited sites in the Wenatchee) vary between watersheds independently of trends at the subbasin or site scale. The x-axis is the slope of the trend line for each watershed within the Wenatchee Subbasin. The histogram represents the distribution of the estimated slope parameter. Units on the y-axis are arbitrary weightings whose absolute scale depends on the shape of the distribution.

Here we see that embeddedness at Watershed 4 is clearly trending down (most of the values are red and are less than 0, indicating a downward trend) while Watershed 5 has little trend (close to half of the data are black/greater than 0)

This answers, in part, a question that was asked by the model's design, namely, is there spatial structure within the trend data; is there a difference in performance of the model at the watershed scale versus the subbasin or site scale? The answer is clearly yes. At the subbasin scale (not illustrated) the trend has a significant negative slope while we see in this figure that there are also trends (independent of the subbasin trend) at the watershed scale. While embeddedness is trending downward in all watersheds, a downward trend is most pronounced in watersheds 4 and 3 but is less pronounced in the watersheds 1, 2, and 5.

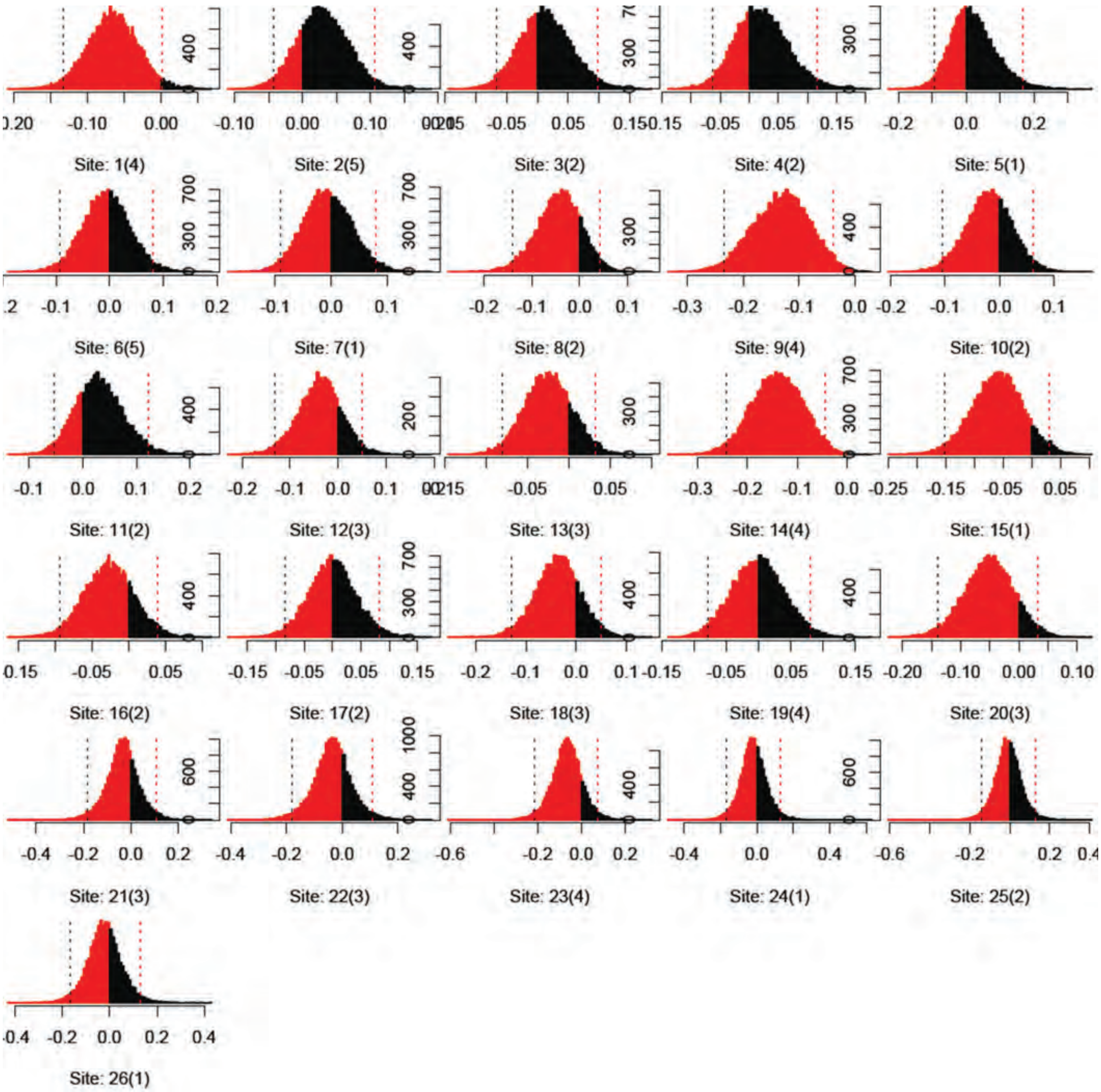


Figure 3. Trends in the average embeddedness (measured at 25 annually visited sites in the Wenatchee) vary between sites independently of trends at the watershed or subbasin scale. The x-axis is the slope of the trend line for each watershed within the Wenatchee Subbasin. The histogram represents the distribution of the estimated slope parameter. Units on the y-axis are arbitrary weightings whose absolute scale depends on the shape of the distribution.

Here we see that trends in embeddedness vary among sites at this finer spatial scale. Embeddedness is trending upward at some sites (e.g., sites 2, 3, 4, and 11), is trending downward at other sites (e.g., 1, 9, 14, 15, and 20), and shows relatively little trend at the other sites.

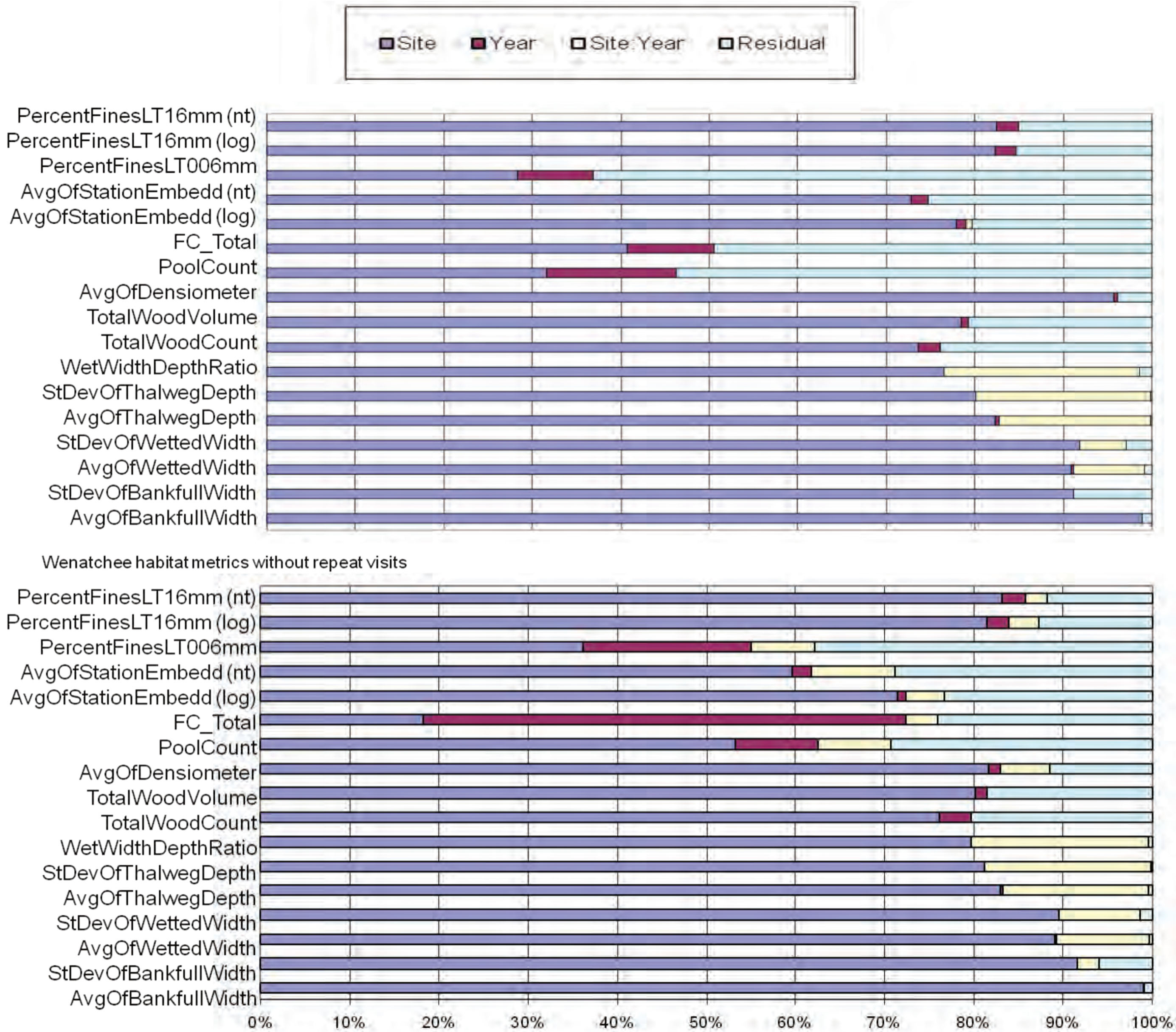


Figure 4. Sources of variation in habitat metrics collected in the Wenatchee subbasin with and without repeat visits.

to the managers of salmonids in the Upper Columbia and the rest of the region. Funded by Bonneville Power Administration and sponsored by NOAA Fisheries since 2003, this program has had a strong influence on how data for status/trend and effectiveness monitoring is being collected throughout the Upper Columbia, particularly in the Wenatchee, Entiat, and, more recently, the Methow. The Regional Technical Team (UCRTT) provides formal technical oversight of ISEMP in the Upper Columbia , helping to ensure that ISEMP's work is relevant to the Upper Columbia's key management questions.

The Right Question

To better design monitoring in the Upper Columbia, ISEMP's first step is to translate key management questions into the relevant and corresponding scientific questions.

Managers would like to know:

- What is the status of the fish populations and the habitat that they depend on?
- What effects are habitat actions having on recovering salmonid populations?

But, the scientists must first ask:

- Are the monitoring programs generating repeatable, useful fish and habitat metrics?
- At what spatial scale are the metrics meaningful?
- At what temporal scale do the metrics change?
- What are we measuring the status of? The mean, variance, and/or distribution of these metrics?
- What are we measuring the trend of? Temporal or spatial information?
- What does watershed condition mean?

Asking the right questions is a basic aspect of scientific monitoring, that, perhaps surprisingly, requires immediate and dedicated attention as the region shifts to include recovery implementation within the more traditional management goals such as harvest, hatchery, and hydropower management.

A Walk Through Real Variation

It has taken several years for ISEMP to amass a sufficient quantity of data for exploring the basic scientific questions necessary to understand what can, and cannot, be said in terms of recovery-related management questions. While the process still needs to unfold before managers' most important questions can be answered, the following examples show how ISEMP is uncovering the complexity within the data.

This presentation uses real habitat monitoring data to illustrate some of the challenges inherent in the exercise of interpreting variability in observed data. In particular, it describes how variance in habitat metrics among sites changes when incorporating the temporal scale through repeat sampling, and how variation at different spatial scales influences trend detections.

Decomposing Variance

Variance decomposition is helpful for understanding if a metric is useful for status (where comparisons between sites is important) or trend detection (where we want to compare data from one year to the next). Metrics in Figure 4 with large "site" variability (e.g., the bottom row, Average of Bankfull Width) indicate metrics with good spatial resolution. Metrics with relatively large "year" variability (e.g., Fish Count and Pool Count in the top graph) suggest these metrics may be useful for trend detection.

For each metric, we see that the amount of unexplained variability (the light blue or "residual" variability) is greater in the top graph than in the bottom graph. This is because the addition of data from the repeat visits in 2009 allows us to extract additional information that otherwise would be unexplained.

For example, in the top graph (sixth row, "FC_Total"), we see that differences between sampling sites accounts for just over 40% of the variation in total Fish Cover. About 10% of the variance is explained by variation between sampling years. In this form, this metric would be better at showing differences in habitat condition at the spatial scale (between sites) but less good at elucidating the temporal scale, or trend, information across years. Unfortunately, nearly 50% of the variation is "residual" and cannot be explained which suggests this metric is relatively less useful than other metrics with lower residual scores. It has a low "signal to noise" ratio.

However, for the same metric in the bottom graph, we see that the addition of data from repeat visits reduces the unexplained residual variance to less than 25%, thereby improving the signal-to-noise ratio and improving the utility of the metric. In particular, the metric's ability to sense year-to-year differences, useful for trend detection, is improved to about 55% while a site:year term is added as well.

The use of repeat sampling appears critical to explaining at least some residual variance and understanding how certain metrics may be useful for status and trend detection.

UCRTT Deliberations

Statistically significant and independent trends at three different scales (the subbasin scale, the watershed scale, and the site scale) can be seen in many habitat metrics. A hypothetical example was developed (see Figure 5 a-c) to illustrate this point and the management ramifications of significant/independent trends at multiple scales.

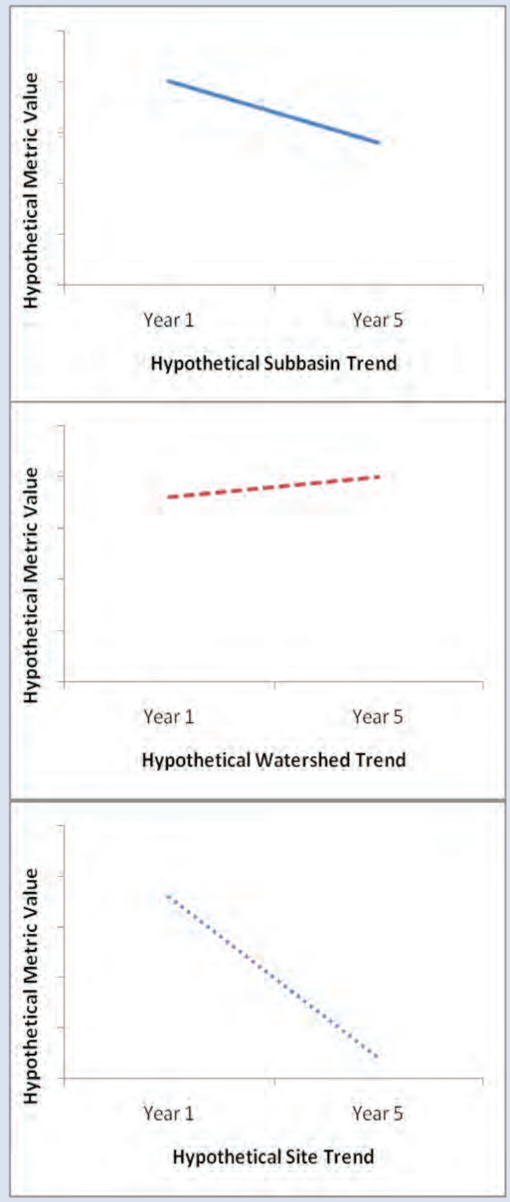


Figure 5 a-c. An example of statistically significant, yet independent, trends at three spatial scales for a hypothetical habitat metric. These relationships were demonstrated by Jordan with actual data in subsequent figures.

The phenomenon of observed statistically significant, yet independent, trends at multiple scales suggests that additional care must be taken in the analysis and reporting of habitat (and presumably fish) trends. Answers to Key Management Questions (and the preceding analysis and data reporting) need to account for the appropriate spatial scales

Conclusions

This brief look at two example habitat metrics (Figures 2 and 3) indicates that the spatial scale at which key management questions are asked will influence the trends that can be reported, with results perhaps varying widely between one scale and another. Similarly, incorporating the temporal component into spatial data will give us a different picture on the relative status of one site (or watershed or subbasin) versus another site.

Now that some of these subtleties are being uncovered in actual data, scientists need to work with managers to make sure that data reporting structures are established in a way that the appropriate time and space scales are being applied to particular questions. For example, it might not be sufficient to report a trend for a subbasin when trends could be quite different for habitat supporting one or another major population group. Likewise, comparisons between control site and treatment sites may give widely different results if the temporal scale is not considered.

There are other questions that will need to be answered before subbasin-scale monitoring data will be ready for answering the key management questions. For example, we need to better coconnect what we know about habitat metrics and our management questions. We need to better understand which habitat metrics (and which metric trends) are biologically relevant. Do indicators based on single habitat metrics mean anything and, if not, how do we integrate multiple metrics in order to answer key management questions? Finally, the question of how do fish relate to habitat status and trends is perhaps the most relevant question and one of the hardest challenges left as we ask increasingly complex questions of already complex monitoring data in order to understand salmon recovery.

Okanogan Basin Habitat Status and Trends: Summer/Fall Chinook

Chip McConnaha and Jesse Schwartz

Chip is a Fisheries Ecologist with ICF International and Jesse is a Senior Ecologist and Analyst at ICF International.

OBMEP Creates a Monitoring Framework for the Okanogan

The goals of the Okanagan Basin habitat status and trend monitoring is to create a framework for evaluating status and trends in Okanogan stream habitat, to provide a basis for future evaluation of habitat and restoration actions, and apply OBMEP data to critical restoration decisions.

Objectives of this Study

- Update the 2004 subbasin planning data set, focusing initially on summer/fall Chinook;
- Adjust the template estimate to address new information;
- Develop a status and trends reporting system, and
- Compare the template, 2004 and 2008 outputs, using that system.

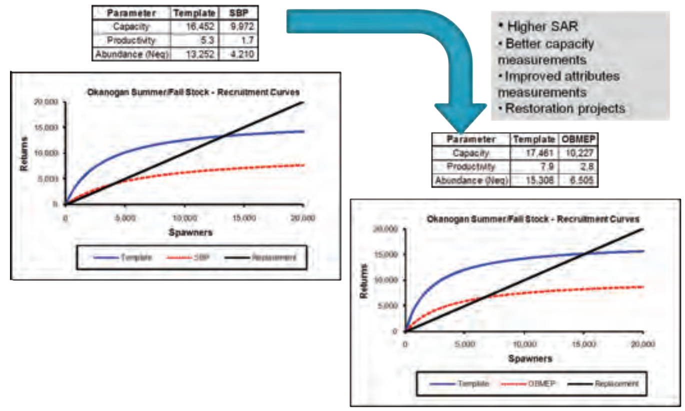


Figure 1. EDT was used to estimate the overall habitat potential for summer/fall Chinook in the Okanagan Basin.

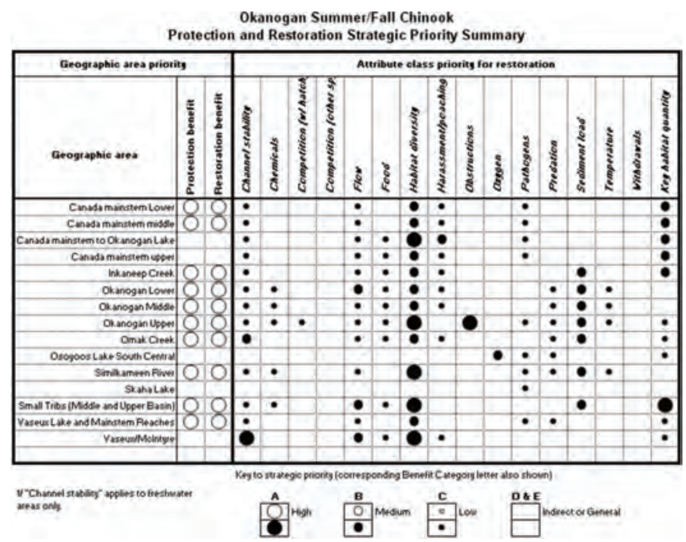


Figure 2. A summary of a protection and restoration strategy priorities for Okanagan summer/fall Chinook using OBMEP data and an EDT analysis. The OBMEP data indicates reach-level limiting factors for summer/fall Chinook.

Methods

The status and trends framework was constructed in EDT using 2008 habitat status data from OBMEP. The field data was post-processed for EDT attributes and we rectified the Subbasin Planning (SBP) Stream Reach dataset with the OBMEP data. We then developed the Okanogan summer/fall Chinook population and revised the EDT system to allow for multiple patient datasets to analyze habitat trends over time (EDT3 – Q1 2010).

Results

The Okanogan status & trends dataset provides a basis for tracking habitat change and restoration potential and for prioritizing habitat restoration/protection decisions while EDT provides a system to “make sense” out of habitat monitoring data. The OBMEP data indicated significant differences in habitat relative to the SBP data but it should be noted that change from 2004 to 2008 largely represents data improvements rather than habitat change.

Conclusions

We recommend that the status/trends framework is used to link the Tribe’s goals to habitat restoration/protection needs in the Okanogan and that OBEMP habitat data is linked to the Hatchery Master planning to create overall management framework. Future work should include:

- A refining of the analysis to look at other species and improve life history characterization;
- Developing a process for regular updating of EDT framework to reflect known habitat change, restoration actions, and degradation or development;
- A post-facto analysis of pre-2008 restoration projects should be developed to evaluate their potential;
- Linking the habitat analysis to hatchery evaluation and analysis;
- Refining the analysis to include SAR & harvest assumptions, fitness effects due to hatchery, life history patterns, spawner distribution, and pre-spawning holding;
- Applying analysis to steelhead and spring Chinook; and
- Deploy a production version of EDT3 to implement status and trends reporting.

PIBO Habitat Status and Trends

Robert Al-Chokhachy, Eric Archer, and Brett B. Roper

The authors are researchers with the U.S. Forest Service in Logan, UT.

Background

Habitat degradation is one of the major factors affecting the declines of salmonids in the Columbia River Basin. Evaluating the effects of land-management activities on the status and trend of instream salmonid habitat is particularly necessary in light of the listing of numerous species under the ESA. To meet this need the PIBO Effectiveness Monitoring Project has implemented a habitat monitoring program since 2001 at more than 1,200 sites within the Interior Columbia River Basin. This program follows a probabilistic, 5-year rotating panel sampling design. Most sites are sampled every 5 years; however, 50 ‘sentinel’ sites have been sampled annually since 2001 to quantify temporal variability in stream habitat. To date, 750 sites within reference (i.e., minimally-managed) and managed (i.e., experiencing a variety of land-management activities) watersheds have been repeat-sampled. Field data related to the physical habitat and riparian condition of streams, temperature data, and macroinvertebrate data are collected at each site.

We are currently using PIBO field data to answer critical questions related to habitat status and trend and ultimately salmonid recovery within the Upper Columbia River Basin.

PIBO Explores Status and Trends Science

The status of physical habitat is being characterized annually, with specific comparisons between reference-site data and sites experiencing different levels of management activities. The

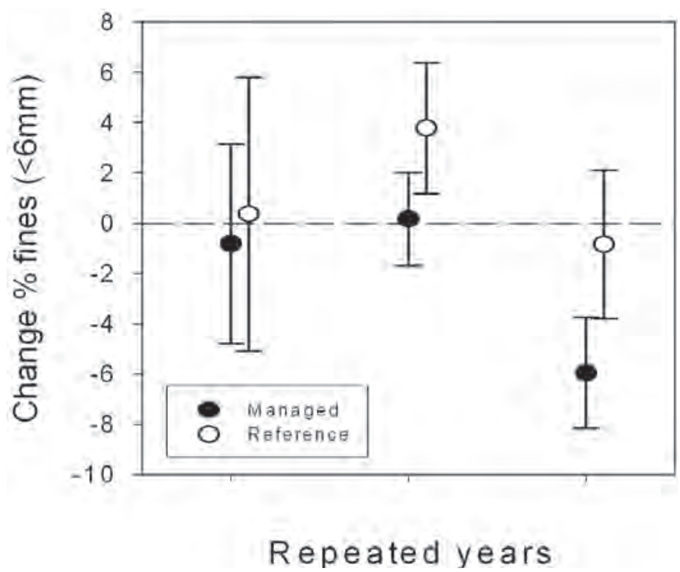


Figure 1. Change in percent fine sediment (< 6mm) in reference (hollow) and managed (solid) sites in the PIBO study area for sites repeat-sampled during 5-year rotations.

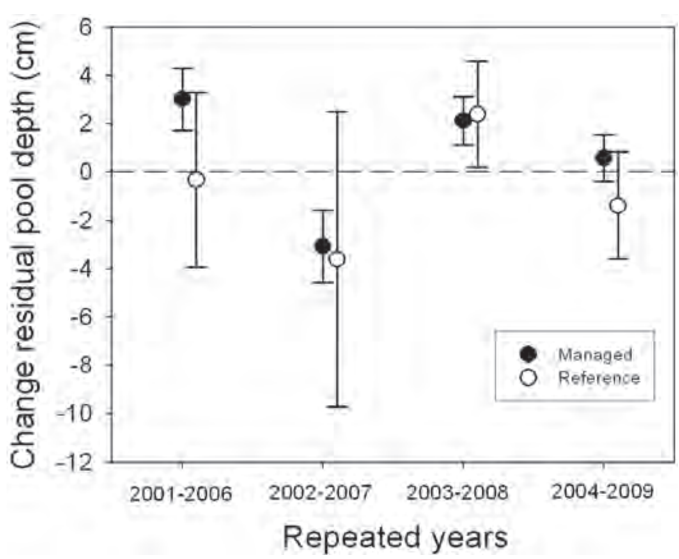


Figure 2. Change in residual pool depth (cm) in reference (hollow) and managed (solid) sites in the PIBO study area for sites repeat-sampled during 5-year rotations.

UCRTT Deliberations

- Variance decomposition like that performed by Jordan (this volume) may be appropriate in this case to help interpret these results.
- Need to include habitat status and trend sites outside the federal lands.

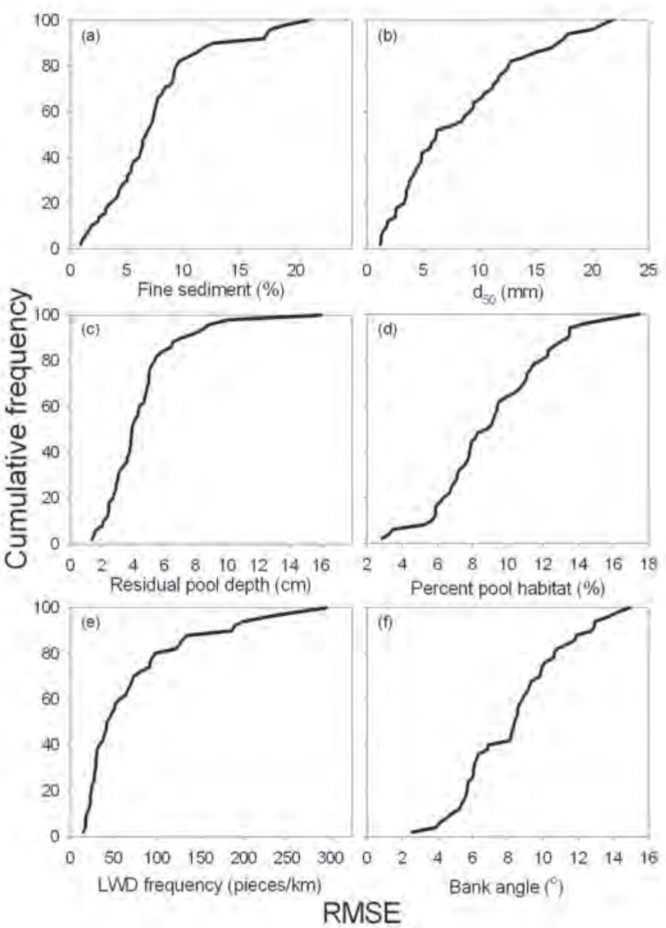


Figure 3. The cumulative frequency of sites (n = 50) with root-mean-square-errors (RMSE; as measures of temporal variability) for % fine sediment (a), d50 (b), residual pool depth (c), percent pool habitat (d), LWD frequency (e), and bank angle (f).

status and trends in physical habitat condition are analyzed by specific geographic regions and across a gradient of land-use practices and watershed characteristics, including landscape characteristics, natural disturbances, and management intensity.

A multi-metric physical habitat index of integrity has been developed to evaluate the overall condition of physical habitat and to minimize the difficulties of quantifying physical habitat status on an individual-attribute basis. Sentinel-site data elucidates the magnitude of temporal variability at given sites, what characteristics lead to greater levels of variability, and how this temporal variability can affect inferences made following habitat restoration efforts. In addition, models have been developed describing the biotic integrity of sites using macroinvertebrates within an observed/expected approach.

The condition of physical habitat, macroinvertebrate data, and stream temperature data are being integrated within a Bayesian approach for an overall assessment of watershed condition. These 'bottom-up' results are compared with "top-down" assessments that use landscape GIS data.

Sediment and Pool Depths Varied by Management Category and Year

Two attributes, percent fine sediment (< 6mm) and residual pool depth, were compared across different management categories and different years. Fine sediment levels were generally stable or decreasing at managed sites and stable or increasing at reference sites (Figure 1). Residual pool depths were variable across years. In most years, residual pool depth was either stable or increasing at managed sites and generally stable at reference sites (Figure 2). However, at sites initially sampled in 2002 and repeat-sampled in 2007, residual pool depth decreased significantly at both reference and managed sites.

Components of variability in habitat attributes were quantified and compared at sentinel-sites: observed differences in temporal variability across sites confounds physical habitat change detection through time. Site-to-site variability is the largest component of variability which highlights the importance of repeat-sampling at specific sites in physical habitat trend evaluation. The variability attributed to year-effects is minimal which is expected given the broad spatial distribution of PIBO sentinel sites. The amount of temporal variability in stream habitat attributes across sites is high (Figure 3). These results illustrate how differences in temporal variability can impact the statistical power to detect changes in physical habitat through time. Site-to-site differences in temporal variability have significant impacts on the power to detect change and highlight the need to quantify the amount of temporal variability in situ at a given monitoring site.

Physical Habitat Index Helps Interpretations

An index of physical habitat condition was developed for headwater streams using 8 physical stream habitat metrics collected

Managed Watersheds:

Subject to a variety of activities including road building and maintenance, timber harvest, livestock grazing, mining, and motorized recreation.

PIBO Reference Watersheds

- Include wilderness areas and watersheds with a low level of management activities,
- No permitted livestock grazing occurred in the last 30 years,
- Minimal (< 10%) timber harvest has occurred,
- Minimal road densities (0.5 km/km2) exist at the watershed scale,
- No roads within the proximate (1 km) riparian buffer, and
- No evidence of historic mining within riparian areas.

at reference sites from 2003 to 2007. This multimetric tool, that controls for natural variability and geoclimatic differences among sites, can provide managers with an easily-interpretable tool to monitor the status of the overall condition of physical habitat (Al-Chokhachy et al. In press). For example, with inherent differences in physical habitat attributes among sites controlled through the use of multiple linear regression analyses incorporating landscape and climatic covariates, physical habitat condition at 217 reference and 934 managed streams in the Interior Columbia River and Upper Missouri River Basins were scored (ranging from 0 to 100) and evaluated. The index of physical habitat condition in reference sites (mean = 47.1, SE = 1.4) was significantly higher than for managed sites (mean = 30.4, SE = 0.7): indices of habitat condition were more frequently low at managed sites and more frequently high at reference sites.

Field Assessments Disagree With GIS-Models

Our understanding of the impacts of land-management and disturbance on the condition of streams is largely theoretical. However, little agreement regarding the condition of watersheds was found in a comparison of a Bayesian combination of three field-based metrics, including the index of physical habitat condition, an assessment of biotic condition based on macroinvertebrates, and stream temperature, with a Bayesian combination of GIS-based metrics which included two land-management characteristics: road density at the catchment scale and the percent of catchments grazed by livestock. These results highlight the need to formally evaluate GIS-based watershed models (e.g., with validations using field-based assessments) and the need to incorporate uncertainty into these models.

Habitat Action Effectiveness

Summary of Results by Key Management Questions

The UCRTT Analysis Workshop featured several researchers who described results from the Upper Columbia and beyond who are trying to answer the general question "does habitat restoration work?" A global summary of the effectiveness of habitat restoration actions was provided by Roni (this volume). There are many success stories from around the world of effective habitat restoration actions. Roni noted successes in many areas: "livestock exclusion has shown the most promising results" in riparian restoration, "dam removal has shown promise for improving habitat diversity;" and "the placement of structures appears to be successful at increasing local fish abundance" to cite just a few examples.

Some of these global results are being borne out in local studies as well. For example, the replacement of irrigation diversion dams with rock vortex weirs (see Connolly et al., this volume) was shown to have improved steelhead access to Beaver Creek with consequent increases in juvenile production. Likewise, in the Entiat, small-scale instream structures appeared to benefit juvenile fish (see Polivka, this volume). Furthermore, Gross and O'Neal (this volume) described improvements to fish habitat from floodplain reconstruction.

The science of action effectiveness can often be hampered due to designs with limited sample size, short duration, and limited spatial scale, as Roni found in his global review. Also, he clearly pointed out that "results are highly variable among species, life stages and [project] types." These hindrances also crop up in studies conducted in the Upper Columbia. For these reasons, the UCRTT recommends conducting more effectiveness monitoring studies and/or increasing the sample sizes within such studies. In conjunction with more formal effectiveness monitoring, the UCRTT also supports current efforts to compile the results of implementation monitoring and make these results available for use in the adaptive management process (See Chapter 2).

In light of these uncertainties, however, ecological principles espoused by Roni make clear that restoration actions can be done effectively within certain guidelines. Therefore, the UCRTT recommends that project implementation follow a preferred sequence of actions similar to Roni's Figure 4 (this volume). For the Upper Columbia region, the UCRTT recommends that the preferred sequence of actions is to protect high-quality habitats, and restore connectivity and watershed processes before implementing instream habitat improvement projects.

Which actions could be suggested as most important to managers and funding entities?

The UCRTT recommends that the highest priority restoration actions are those that improve viable salmonid population status by increasing juvenile salmonid survival and growth. Within this category of actions, the reconnection of isolated habitats through passage barrier removal and side channel reconstruction, instream habitat improvement, and floodplain rehabilitation are all examples of actions that have proven effective for improving habitat and providing benefits to juvenile fish. For example, the replacement of irrigation diversion dams with rock vortex weirs (see Connolly et al., this volume) was shown to have improved steelhead access to Beaver Creek with consequent increases in juvenile production. Likewise, in the Entiat, small-scale instream structures appeared to benefit juvenile fish (see Polivka, this volume). Furthermore, Gross and O'Neal (this volume) described improvements to fish habitat from floodplain reconstruction. Finally, Roni (this volume) summarized many project types that increase juvenile salmonid survival and growth that may be appropriate in certain situations in the Upper Columbia.

On the other hand, actions that have a short life span and that do not restore ecosystem processes are likely to be less effective in the long term. These types of projects often treat symptoms instead of the causes of degradation. The particular kind of action to be implemented depends on local conditions. For example, several factors in the Entiat River combine to suggest that the approach of improving fish habitat through the use of instream structures, while not a "process based" solution, is perhaps the only viable approach to improving habitat conditions in the lower Entiat where the history of large-scale degradation of habitat and historical land use patterns limit the feasibility of other approaches. However, this solution is unique to the lower Entiat and would not be applicable where process-based actions may be implemented or where larger more robust populations have more options. The implementation of instream structures will eventually need to be repeated and require a continuous cycle of human-engineered solutions that are not sustainable whereas process-based restoration allows for natural processes to build and maintain suitable habitat in perpetuity.

The UCRTT recommends that project implementation follow a preferred sequence of actions similar to Roni's Figure 4 (this volume). This is because there is little benefit in spending money on instream fixes if an upstream degradation would continue to negate the effectiveness of the work. However, in some cases, it might be more important to fix watershed processes before fixing fish passage barriers because providing fish with access to poor habitat could decrease overall productivity if the fish are lured away from spawning in good quality habitat elsewhere in the watershed. In other words, one factor may be temporarily a lower priority if another limiting factor is having a more pronounced negative effect on fish populations. Like many aspects of restoration planning, specific local conditions need to be considered in all cases and "exceptions to the rule" may apply even to this preferred sequence of actions.

In Roni's review of a wide variety of project types, it is clear that some types work better than others. While certain project types should not be categorically ruled out, some types of instream structure techniques have fallen out of favor or can be shown by geomorphic analysis to be ineffective in specific locations. Instream structure techniques, in particular, should be undertaken with careful consideration of scale, watershed conditions, watershed processes, and local conditions and should be coupled with rigorous monitoring programs.

There is a significant amount of uncertainty around the effectiveness of habitat actions in large part because of difficulties in monitoring. The track record of action effectiveness science is poor: Roni's (2008) review of 345 effectiveness studies concludes that "firm conclusions . . . were difficult to make" due to limited designs, short duration, and limited scope. Following habitat restoration, there has been relatively little post-treatment monitoring, studies often did not cover a sufficient spatial/temporal scale, and monitoring metrics have not been consistently studied or reported. This scientific feedback is even more frustrating for people "who learn from their mistakes" because published studies tend to report success stories and are less likely to report failures.

Other uncertainties around the effectiveness of habitat actions stem from localized ecological realities, so results that apply to one project may not be relevant to another. Finally, it can be difficult to link habitat conditions to changes in fish survival thereby obscuring our understanding of the causes and effects that are important to salmon recovery.

Did the project type affect the environmental parameters (physical/chemical variables) that were the target of the action?

Action effectiveness monitoring is the direct measurement of the effect of a project on the physical environment. Action effectiveness monitoring can demonstrate that the environmental parameters targeted by the action have been affected, particularly in the short term. For example, Connolly et al. (this volume) handily demonstrated that converting water diversion dams to rock vortex weirs afforded better access for fish to Beaver Creek. However, long-term and subbasin-wide effects are harder to demonstrate and require a long-term funding and reporting commitment. For example, Jordan et al. (this volume) showed that the effects of implementing a large suite of restoration actions in the lower Entiat River will only be understood with a rigorously-designed, intensively monitored watershed approach.

Action effectiveness monitoring is routinely suggested and often conducted in the Upper Columbia. However, effectiveness monitoring results have not been published or disseminated. The UCRTT supports current efforts to compile the results of effectiveness monitoring and make these results available for use in the adaptive management process.

Did the project type affect environmental and biological parameters at a reach or habitat scale?

Roni (this volume) reviewed projects from around the world that made physical and biological changes at the habitat scale. Presentations by local researchers including Gross and O'Neal, Connolly et al., and Polivka (this volume), also demonstrated changes in physical conditions and biological parameters at the habitat unit scale as well as responses in local fish abundance. However, the biological or statistical significance of changes in local fish abundance is largely undetermined at this time. One common concern, born out in the scientific literature, is that changes in local fish abundance may merely reflect attraction of fish from one location to another instead of the desired absolute increase in fish abundance throughout the system. The solution to this uncertainty, the UCRTT recommends, is to conduct more effectiveness monitoring studies and/or increase the sample sizes within such studies.

Did the project type affect the biological parameters at a population scale? Did multiple action types affect the biological parameters at a population scale?

These are the overarching questions for the whole science of habitat action effectiveness monitoring and whether individual projects, or suites of many projects, affect the overall status of fish populations is yet to be determined. Studies are underway in the Upper Columbia to evaluate the effects and responses to selected restoration projects at the reach and subbasin scale. For example, intensive monitoring work is being done in conjunction with the Methow M2 project at the reach scale and the Entiat IMW at the reach and subbasin scales. However, conclusive results will likely not be available for many years. In the case of the Entiat IMW, the effectiveness monitoring work is operating under a ten-year experimental design.

In most cases, it is not realistic to expect one project type to have a large population-scale effect when there may be more than one limiting factor suppressing a fish population. Of course, there are exceptions to this observation in cases where limiting factors are particularly obvious. Two proven examples include the restoration of fish access to Beaver Creek through the removal of fish barriers and the restoration of fish access to Salmon Creek by providing instream flow.

A final note of caution was raised at the Analysis Workshop. Efforts to improve hatchery programs in the Upper Columbia are also occurring concurrent to the implementation of habitat restoration actions under the recovery plan. These changes in hatchery practices are also expected to influence biological parameters of Upper Columbia fish populations. Changes resulting from new hatchery practices may confound habitat action effectiveness monitoring studies at the population scale if these overlapping changes simultaneously affect the productivity and abundance of target fish populations.

The remainder of the chapter consists of articles reporting the contents of presentations given either during the UCRTT Analysis Workshop held on January 12 and 13, 2010 or during the deliberations of the UCRTT that followed:

Effectiveness of Common Habitat Restoration Techniques: Results From Recent Reviews and Meta-Analysis

Phil Roni

Phil is Watershed Program Manager with the Northwest Fisheries Science Center, National Marine Fisheries Service, Seattle, WA.

Background

The degradation of inland aquatic habitats caused by decades of human activities has led to worldwide efforts to rehabilitate freshwater habitats for fisheries and aquatic resources. We reviewed published evaluations of stream rehabilitation techniques from throughout the world, including studies on road improvement, riparian rehabilitation, floodplain connectivity and rehabilitation, instream habitat improvement, nutrient addition, and other, less-common techniques. We summarize current knowledge about the effectiveness of these techniques for improving physical habitat and water quality and increasing fish and biotic production. Despite locating 345 studies on effectiveness of stream rehabilitation, firm conclusions about many specific techniques were difficult to make because of the limited information provided on physical habitat, water quality, and biota and because of the short duration and limited scope of most published evaluations. Reconnection of isolated habitats, floodplain rehabilitation, and instream habitat improvement have, however, proven effective for improving habitat and increasing local fish abundance under many circumstances. Techniques such as riparian rehabilitation, road improvements (sediment reduction), dam removal, and restoration of natural flood regimes have shown promise for restoring natural processes that create and maintain habitats, but no long-term studies documenting their success have yet been published. Our review demonstrates that the failure of many rehabilitation projects to achieve objectives is attributable to inadequate assessment of historic conditions and factors limiting biotic production; poor understanding of watershed-scale processes that influence localized projects; and monitoring at inappropriate spatial and temporal scales. We suggest an interim approach to sequencing rehabilitation projects that partially addresses these needs through protecting high-quality habitats and restoring connectivity and watershed processes before implementing instream habitat improvement projects.

Methods

Our review of 345 scientific papers on the effectiveness of various habitat rehabilitation techniques was global or international in extent, but the vast majority of the literature was from the USA, Canada, and western Europe. We acknowledge that the published literature may be biased towards reporting positive results.

Results and Discussion

Many historical and recent papers have emphasized the paucity of information on the success of stream and watershed rehabilitation projects and the need for monitoring and evaluation. Although only a small fraction of the billions of dollars spent annually on stream and watershed rehabilitation is allocated to monitoring, most categories of techniques were in need of more thorough evaluation while other specific techniques (e.g., placement of boulders and wood in streams) have received considerable attention. Moreover, some techniques, such as placement of instream habitat improvement and reconnection of isolated habitats, have demonstrated benefits to fishes, whereas little or no information was available on the effects of road improvements and riparian rehabilitation techniques on fishes.

Road Improvements

Roads affect sediment delivery and hydrology and efforts are underway to limit the impacts of forest and urban roads on streams and their biota. Road improvements were the most poorly evaluated category of techniques. With the exception of studies on fish colonization after road crossing removal or upgrade, little biological monitoring was reported. However, techniques such as traffic reduction, road resurfacing, and road removal or abandonment appeared to be successful at reducing erosion and landslides and improving hydrology associated with roads in forested areas. The one technique related to road improvement that has demonstrated a direct benefit to fisheries resources is the replacement of culverts or other stream crossings that prevent migration. The success of stream crossing removal or replacement appears to depend on the ability to transport sediment, restore other watershed processes, and provide year-round fish access.

Riparian Rehabilitation

Common techniques for restoring riparian areas and improving

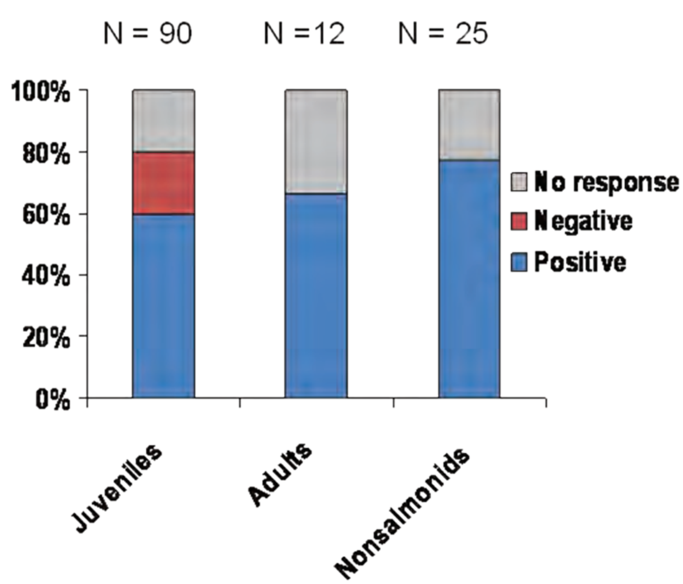


Figure 1. The effectiveness of rehabilitation projects varies by fish age class.

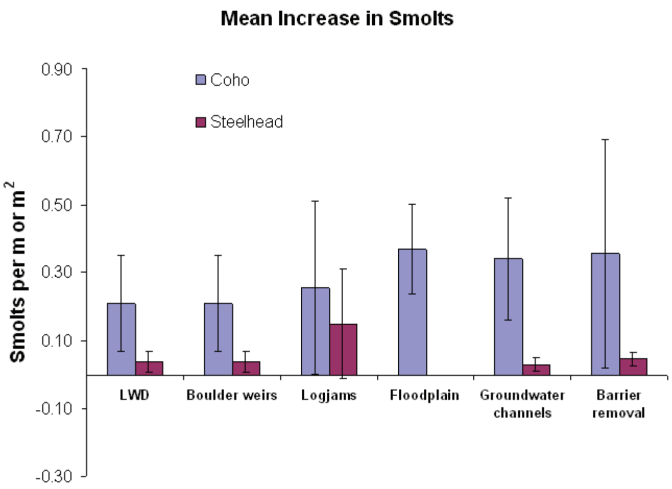


Figure 2. The increase in abundance of smolts varies by treatment type.

instream habitat have demonstrated benefits for riparian vegetation. The level of information on riparian silviculture treatments, such as planting and thinning, is particularly scarce, and few studies have examined instream factors or biota after riparian treatment. Passive restoration of riparian areas may be effective if the disturbance can be removed and if invasive species do not compete with native vegetation. The most extensive published information on riparian rehabilitation effectiveness at improving streams focuses on the various fencing and grazing strategies. The complete exclusion of livestock through removal or fencing has shown the most promising results in terms of vegetation, bank, and instream characteristics. Rest–rotation and other grazing systems have shown promise under proper management and under certain physical, morphological, and climatic conditions. Responses of the stream channel and biota to grazing and riparian silviculture treatments tend to lag behind vegetation recovery; thus, long-term, well-designed monitoring is required to detect any changes. The responses of instream conditions and biota to various riparian treatments were often influenced by upstream conditions, and it was often difficult to distinguish between failure of a particular technique and failure to consider broader processes during project implementation. Results were further confounded by a lack of consideration of geology, channel type, climate, exotic species, site preparation, native ungulates, effective control of grazing intensity and duration, size of the exclusion or buffer zone, and upstream processes or impacts. These are clearly important factors to consider when implementing a riparian rehabilitation project and associated monitoring program.

Floodplain Connectivity

This category of techniques is very diverse, and many of the techniques (e.g., levee setbacks and dam removal) have only recently been implemented on a broad scale. Floodplain rehabilitation is a relatively new science, and long-term studies documenting biological effectiveness are not currently available. In addition, the goals typically encompass broad ecological and cultural objectives. Thus, evaluation of a purely fisheries response to a project is difficult. It is clear that most techniques evaluated to date can lead to improvements in physical, hydrologic, and other natural processes; provide additional slow-water habitats; and provide additional habitat for fishes. However, adequate long-term studies documenting such improvements are rare or have not been published. Reconnection of isolated floodplain habitats is probably the most thoroughly evaluated floodplain technique, and several studies demonstrate its effectiveness at providing habitat for salmonid and non-salmonid fishes. Dam removal has also shown promise for improving habitat diversity, providing habitats for various fishes, and increasing species diversity. Levee removal, channel remeandering, and construction of floodplain habitats have produced positive results both physically and for biota, but long-term data on the success of these techniques are not yet available. Many factors influence the physical and biological effectiveness of projects, including habitat complexity, depth, wood volume, connectivity with the main channel, channel incision, flow volume, flow source, exotic species, project size, upstream flow regulation, and upstream water quality. Dam removal may produce some short-term negative impacts (e.g., increases in fine sediment or decreases in water quality) downstream or in former reservoir reaches, but such effects depend on the level and contents of sediments stored in the reservoir, whether attempts are made to remove or stabilize them, and the time period examined. In the absence of dam removal, restoration of natural flood regimes appears to improve restoration processes, reconnect habitats, and restore flood-dependent biota. Beaver reintroduction into their native habitat is another potentially important technique for restoring natural floodplain processes. As was the case for most techniques, long-term, broad-scale studies evaluating the success of various floodplain techniques were not located.

Instream Habitat Structures

The majority of published evaluations of rehabilitation were on instream habitat enhancement projects or instream structures. When implemented properly, these techniques can produce dramatic improvements in physical habitat and biota, particularly

Figure 3. Riparian plantings are commonly used to restore the riparian corridors, reduce erosion, and increase bank stability.

for salmonid fishes. However, given (1) the variability in results for various species and structure types, (2) the limited number of statistically rigorous studies, (3) the response differences among species or life stages, and (4) the cost of instream habitat improvement projects, it is apparent that such projects should be undertaken with careful consideration of scale, watershed conditions, and watershed processes and should be coupled with rigorous monitoring programs. Several books are dedicated to the appropriate application and design of instream habitat rehabilitation, and these books should be consulted. The success of instream habitat enhancement projects is often tied to larger, watershed-scale issues, such as water quality, hydrology, sediment transport, stream gradient, riparian conditions, and upslope conditions. For many years, the need for a broader-scale perspective in implementing instream projects has been acknowledged. The potential benefits of most instream structures will be short lived (< 10 years) unless coupled with riparian planting or other process-based restoration activities that can lead to long-term recovery of deficient processes.

While placement of instream structures appears to be successful at increasing local fish abundance, particularly that of salmonids, results are highly variable among species, life stages, and structure types and little positive benefit has been documented for non-salmonids. The most successful projects are those that create large changes in physical habitat and mimic natural processes. Considerable information exists on fish response to instream rehabilitation, but most of these studies occurred on short stream reaches and documented only localized changes in abundance. Though most instream projects occur at a site or reach scale, these projects may produce or affect physical habitat and fish production responses in downstream reaches, in adjacent habitats, or throughout a watershed. Thus, changes in one stream reach may affect salmonid abundance in adjacent stream reaches. Assessment of biotic and physical responses at a watershed scale is arguably more important (and more difficult) than examining reach-scale responses, such as changes in local fish abundance.

Nutrient Addition

The addition of inorganic and organic nutrients to oligotrophic streams can lead to increases in growth and production of algae and zooplankton and, in some cases, fish growth. Obviously, this technique is not appropriate in many areas where nitrogen and phosphorus levels are either naturally high or elevated due to human activities (e.g., agriculture runoff and wastewater discharge). The drawback of nutrient addition is that continued application or an increase in natural nutrient delivery (recovery of depressed anadromous fish runs) is needed to maintain elevated production. However, little work has been done to quantify the duration for which benefits persist after nutrient addition ceases. There are many factors that must be evaluated prior to nutrient enrichment; these include baseline nutrient status (i.e., the nutrients that are limiting productivity) and the species composition of plankton, algae, macroinvertebrates, and fishes (top-down versus bottom- up control). The success of nutrient enrichment projects depends on an understanding of these factors and on the treatment of only those streams that are deficient in nutrients.

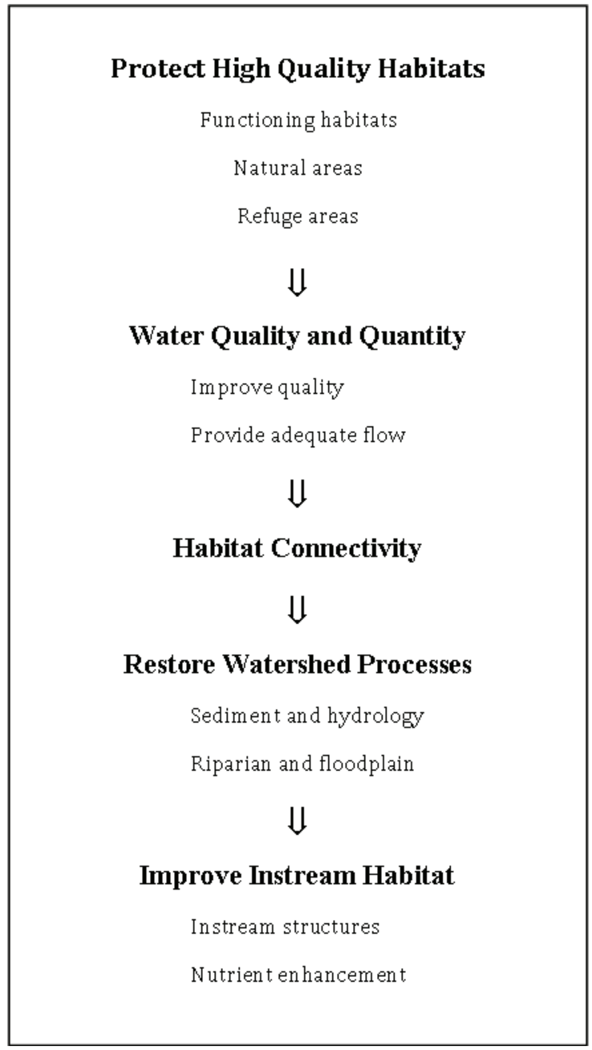


Figure 4. Sequencing stream rehabilitation projects in this order, after considering other factors (e.g., project cost, species of interest, cost–benefit ratio,economic, social, and political), will provide for the best long-term success.

Implications for Planning and Prioritization

Despite the broad range of rehabilitation techniques examined, several common factors appear to limit the success of projects. Water quality, water quantity, erosion, and sedimentation prevent many projects from achieving full biological potential. These factors were particularly common among riparian, floodplain connectivity, and instream habitat projects. Each factor limiting project success results from a lack of understanding of the physical and ecological context of the project, which clearly reinforces the point made by numerous authors that broader watershed processes must be considered when planning projects. Unfortunately, many studies of restoration effectiveness also do not consider factors outside of their study area, making it difficult to improve project planning and design and thus to avoid future failures. Avoidance of the common causes of project failure requires a clear process for using watershed assessments to identify and prioritize projects. However, many restoration groups do not yet have comprehensive watershed assessments and instead select restoration projects opportunistically. In such cases, a sequence of habitat rehabilitation methods based on project effectiveness, watershed processes, and longevity of actions can be used to help maximize project success. Based on this global review of the literature on restoration effectiveness, we recommend a broadly applicable approach for sequencing stream and watershed restoration projects in the absence of watershed assessments (Figure 4). In this sequence, factors that most often limit the biological success of restoration projects are addressed first, and projects addressing other habitat factors are implemented later. Because poor water quality and low water quantity can prevent biological recovery in response to all other project types, major water quality and quantity issues should be addressed prior to considering other habitat rehabilitation actions. This should be followed by addressing key processes, such as sediment delivery and riparian conditions, which often limit success of instream rehabilitation efforts. After addressing these processes and overriding factors that potentially limit the effectiveness of structural habitat manipulations, one can consider issues of connectivity and habitat structure. If these issues are not addressed, either sequentially or simultaneously, then project failures similar to those reported in the existing literature are likely.

Implications for Monitoring and Evaluation

Similar to considering watershed processes when implementing rehabilitation, the need for rigorous monitoring and evaluation has been noted for many decades. Our extensive review of the literature on this topic demonstrates that despite the numerous published evaluations on effectiveness of habitat rehabilitation actions, there are three major needs related to monitoring and evaluation: (1) the need for long-term evaluation, (2) the need for watershed or broad-scale monitoring, and (3) the need for a consistent set of metrics for evaluation of project success. First, the monitoring duration or length in most of these studies was not more than a few years (average = 3.4 years; range = 1–24 years). There were, however, several retrospective post-treatment studies that collected only a few years of data but included projects that had been implemented more than 10 years before. Most of these evaluations were at a reach scale or even an individual habitat scale, and monitoring at the population, watershed, or basin scale is needed to understand the implications of a single project or a suite of projects. Finally, it was difficult to compare effectiveness among projects within even a specific project type because of differences in metrics used. Compatible physical and biological metrics within and across projects are needed to allow comparison of success among techniques. The immediate challenge for future monitoring and evaluation is to address these shortcomings of duration, scale, and metrics.

Summary and Conclusions

Our review of 345 papers on effectiveness of stream rehabilitation techniques indicates that some techniques, such as reconnection of isolated habitats, rehabilitation of floodplains, and placement of instream structures, have proven to be effective for improving habitat and increasing local fish abundance under many circumstances. Techniques for restoring the natural processes that create and maintain habitats, such as riparian rehabilitation, sediment reduction methods (road improvements), dam removal, and restoration of floods, have also produced encouraging results, but it may take years or decades before a change in fish or other biota is evident, and little or no long-term monitoring of these techniques has been conducted. Our review emphasizes the need for adequate assessment of watershed processes and factors limiting biotic production, consideration of upstream or watershed-scale factors that influence the outcome of reach-scale or localized rehabilitation projects, and monitoring and evaluation of adequate temporal and spatial scales. Key research and monitoring priorities include examination of most techniques in areas other than the USA and Canada, where most research has occurred. Additional research on instream habitat enhancement structures is needed in other parts of the

Figure 5. The effects of removing or reducing grazing by fencing or a rest-rotation management program on streams. Photos on the left are before, photos on the right after. Top photos are from Mount Vernon Creek, Wisconsin, U.S.A., and show results 20 years after grazing was excluded form the stream. Photos on the bottom are from Cartron Stream, Ireland and show restoration of the stream three years are fencing excluded cattle from the stream. Photos courtesy of Ray White and Martin O'Grady.

world, but such techniques have been extensively examined in the western and Midwestern USA and in Canada. Examination of the effectiveness of riparian, road, and floodplain rehabilitation techniques in restoring watershed processes (i.e., delivery of wood, water, and sediment) and biota is needed in all geographic areas. Finally, few studies have conducted examinations at a sufficiently broad scale for determining effects of individual or multiple projects on an entire watershed or fish population. This is clearly one of the most pressing research needs and is probably attainable with recent technological advances in remote sensing and fish tagging.

Relevant Literature

This presentation was based largely on a paper by Roni et al. (2008, Global Review of Physical and Biological Effectiveness of stream habitat rehabilitation techniques) which contains a list of references regarding stream restoration techniques. More information can be found in Roni et al. (2008) and Smokorowski and Pratt (2007, Effect of a change in physical structure and cover on fish and fish habitat – a review and meta-analysis) and Stewart et al. (2009, Effectiveness of engineered in-stream structure mitigation measures to increase salmonid abundance). This summary of Roni's presentation omits literature citations that can be found in Roni et al. (2008).

Salmon Recovery Funding Board Reach-Scale Habitat Effectiveness Monitoring Results in the Upper Columbia

Tricia Gross and Jennifer O'Neal

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Background

Reach–scale effectiveness monitoring has been conducted throughout Washington on behalf of the Washington State Salmon Recovery Funding Board (SRFB) since 2004. In the Upper Columbia Basin, 10 individual projects in six different monitoring categories are included as part of that ongoing effort. Preliminary results indicate that significant changes are being detected in many of the project categories across the state. Project-specific changes have also been detected at many of the sites in the Upper Columbia. Through this process, lessons have also been learned that can be used to better direct salmon recovery efforts in the region.

Monitoring Approach

The SRFB Reach-Scale Effectiveness Monitoring Program currently includes nine monitoring categories that are being actively monitored throughout the state. Descriptions of those categories and detailed protocols for monitoring each are available in Crawford (2008 a-h) and Crawford and Arnett (2008). They can also be found on the Washington Recreation and Conservation Office (RCO) website, under the Monitoring Protocols section, at http://www.rco.wa.gov/monitoring/protocols.shtml.

Monitoring Category	Indicators Tested
Fish Passage	Passage Structure Juvenile Fish Abundance Adult Abundance
In-Stream Habitat	Quantifying In-stream Structures Juvenile Salmonid Abundance Stream Morphology Substrate Large Woody Debris Slope Measurements Riparian Vegetation Structure Shading
Riparian Planting	Quantifying Riparian Plantings Survivorship Riparian Vegetation Structure Shading Actively Eroding Streambanks
Livestock Exclusion	Livestock Presence Riparian Vegetation Structure Shading Actively Eroding Streambanks
Constrained Channel	Stream Morphology Slope Measurements Bankfull Channel Capacity Flood Prone Width
Channel Connectivity	Stream Morphology Channel Connectivity Slope Measurements Riparian Vegetation Structure Shading Juvenile Salmonid Abundance
Spawning Gravel	Gravel Present After Placement Substrate Adult Abundance
Diversion Screening	NOAA Diversion Screening Criteria
Habitat Protection *Freshwater Indicators*	Stream Morphology Substrate Large Woody Debris Slope Measurements Riparian Vegetation Structure Shading Actively Eroding Stream Banks Fish Species Assemblages Macroinvertebrate Assemblages Upland Plants

Table 1. Indicators for each monitoring category

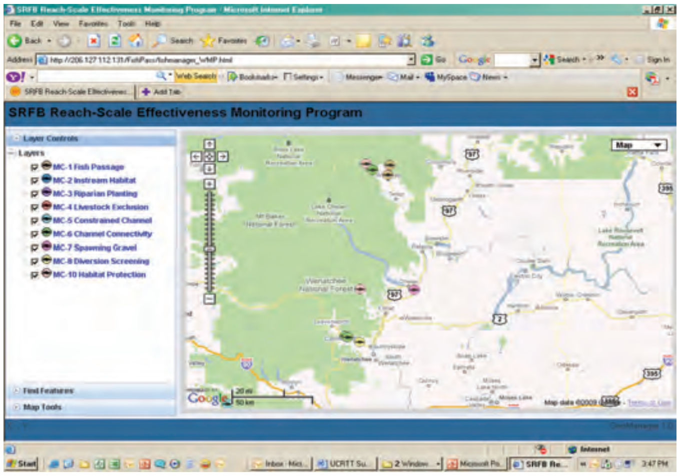

Figure 1. Upper Columbia monitoring sites as depicted in the SRFB web-based reporting tool.

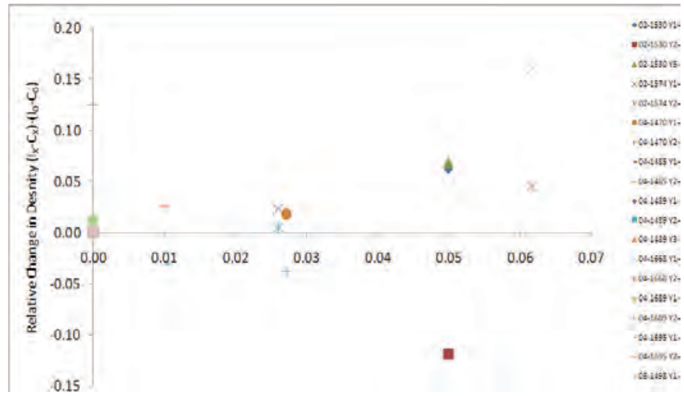

Figure 2. Change in juvenile coho salmon reach-scale densities (fish/m2) versus juvenile coho salmon densities in the downstream control reach in Year 0.

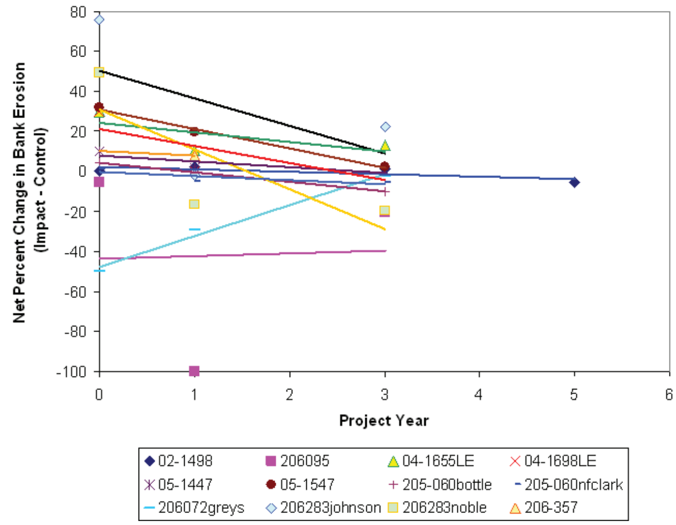

Figure 3. Net percent change in Bank Erosion at twelve Livestock Exclusion Projectsbased reporting tool.

Using a standard set of protocols to monitor each project category allows the collection of comparable and compatible data. The data can be used to do the following:

- Determine the most successful types of projects for affecting specific parameters
- Document lessons learned through project implementation
- Improve project planning and design
- Prioritize funding to target those project types that have been proven more effective.

Of the nine project categories, seven of them use a Before After Control Impact (BACI) design. BACI design project categories include Fish Passage, In-Stream Habitat, Riparian Planting, Livestock Exclusion, Constrained Channel, Channel Connectivity, and Spawning Gravel. For projects in those categories, monitoring is conducted at a control site and an impact site. Monitoring is conducted prior to project implementation (Year 0) and subsequent years of monitoring are conducted following completion of the project. The number of years that a project category is monitored following implementation varies by category based on the indicators that are being measured. Monitoring is also conducted for Diversion Screening Projects, which are assessed based on a function without a control. Additionally, Habitat Protection Projects are monitored, which do not have a control reach and the monitoring goal is to track changes in ecological health through time.

The indicators monitored and the decision criteria for each category are detailed in the monitoring protocols (Crawford (2008 a-h) and Crawford and Arnett (2008)). The monitoring protocols also contain equipment lists and information regarding statistical analysis of the data collected. Table 1 includes a brief description of the monitoring parameters for each monitoring category.

Monitoring of most BACI project sites require two days of field time and a team of two to four field staff, with a day each in the control and impact reach. For projects that require juvenile fish monitoring, a team of two conducts the snorkel or electrofishing survey, while another team of two collects habitat data. For

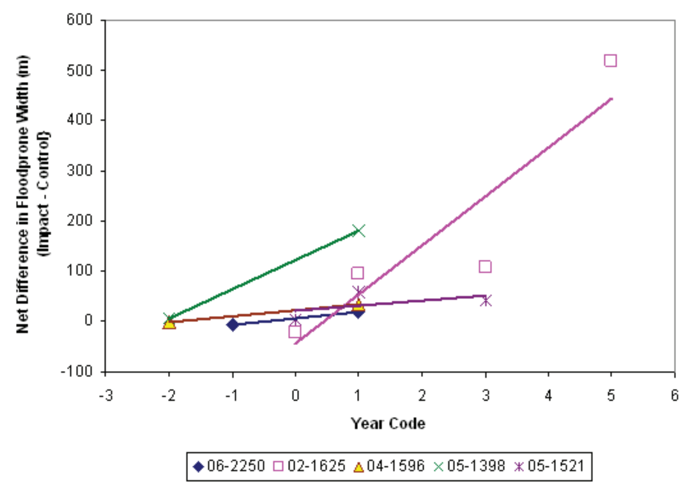

Figure 4. Net Increase in Flood prone Width for five Constrained Channel Projectsbased reporting tool.

project categories that do not require juvenile fish monitoring, two field staff can generally conduct the entire survey. Diversion screening projects only require a team of two and one day of monitoring. Habitat Protection sites require a team of four, with two field staff monitoring fish and macroinvertebrates, while two others collect habitat data. Depending on the size of the project area, monitoring of these projects may be completed in one to two days. Estuarine sites typically only require a team of two to collect all of the data.

Reporting

Following each sampling season, the data are summarized and statistical analyses are conducted. Specifics regarding data analysis are provided in the protocol descriptions. Each year, an annual report is developed to present the findings of the current year and all previous years of data collection. Monitoring reports can be found on the RCO website, under Project Effectiveness Monitoring (Tetra Tech EC, Inc. reports), at http://www.rco.wa.gov/doc_pages/other_pubs.shtml#monitoring.

The 2009 annual report includes a web – based reporting tool that was developed to allow easy access to the data and project information (http://206.127.112.131/FishPass/fishmanager_CMP.html) (Figure 1). The web-based application allows you to view information about each project, including project background, location information, summary statistics, and project photos. In 2010, this information will be integrated into the Lead Entity Habitat Work Schedule (HWS). This will provide a single location for project sponsors, lead entities, agencies, and others to access SRFB data and results.

Project Category Results

The project category results presented below describe analyses of data from all projects and all years of data.

Fish Passage Project Results

Data from Fish Passage Projects show statistically significant increases in juvenile coho densities upstream of passage structures after project implementation. Improvements for adult coho and redds, Chinook juveniles, and steelhead parr have not been shown to be statistically significant. Additionally, our data show that detecting an increase in juvenile fish density above a barrier is dependent on having sufficient juvenile density downstream of the barrier prior to project implementation (Figure 2). Without sufficient initial density, the probability that juveniles will move above the barrier and be detected by monitoring is very low. Juvenile densities of 0.04 fish/m2 or greater below the barrier seem to show detectable responses in the impact reach. We also found that Fish Passage Projects should be monitored for a minimum of two years because first year results often did not reflect improvement observed in later years of monitoring.

Project Name	Category	Years Monitored	Notes
Fulton Dam Barrier Removal	Fish Passage	2	Not a complete barrier
Chewuch Dam Barrier Removal	Fish Passage	3	Not a complete barrier
Fender Mill Floodplain Restoration	Constrained Channel	0	Never was implemented
Dryden Fish Enhancement	Channel Connectivity	3	
Gagnon CMZ Off-Channel Project	Channel Connectivity	3	
Beebe Creek Channel Reconfiguration	Spawning Gravel	3	
Jones-Shotwell Screen and Diversion	Diversion Screening	2	
Methow Critical Riparian Habitat Acquisition	Habitat Protection	2	
Entiat River	Habitat Acquisition	2	

Table 2. Monitoring sites in the Upper Columbia region in the SRFB Reach-Scale Effectiveness Monitoring Program.

In-Stream Habitat Project Results

Statistically significant increases in mean vertical pool profile area have been detected for In-Stream Habitat Projects (p-value = 0.0015, α = 0.10). This indicator is used to evaluate the availability of thermal refuge for salmonids. No significant changes were observed for the other variables identified in Table 1.

Livestock Exclusion Project Results

Livestock Exclusion Projects have been shown to significantly decrease bank erosion (Figure 3). These results were detected in the first year after implementation through a coordinated monitoring program between Washington and Oregon. Since all projects in this category were monitored using a standard protocol, data could be shared to increase sample size and statistical power. Other variables, canopy density and riparian vegetation structure, did not show significant changes.

Riparian Planting Project Results

Although not statistically significant, noteworthy increases in bank erosion have been observed at Riparian Planting Projects. This indicates a need for further investigation of project implementation conditions. We found that existing erosion at the project sites was causing project sponsors to set back their plantings from the bank to allow time for them to mature and prevent loss. Additionally, in some cases, invasive species needed to be removed before planting, which resulted in short-term increases in erosion. Canopy cover and riparian vegetation structure have not yet shown significant changes for this project type.

Constrained Channel Project Results

Significant increases have been detected in flood prone width across all Constrained Channel Project sites (Figure 4). This indicates that removal or setback of levees is effective as increasing off-channel habitat.

Other Project Categories

Channel Connectivity Projects are also monitored as part of this program. No significant improvements were documented in this category; however, average improvements for coho juveniles were shown. Diversion Screening Projects, as a category, have been found to function as designed; however, long-term success of Diversion Screening Projects also depends on continued maintenance.

Determining the effectiveness of Habitat Protection Projects is difficult in the first 5 years of monitoring. More effective monitoring approaches over the long term may include aerial photo analysis and collection of land use data to determine the relative contribution of the parcel to the habitat in the watershed. Additionally, if acquisitions can be made in areas where natural channel processes are currently limited and acquiring and reconnecting the land would create off-channel or floodplain habitat or LWD recruitment, these changes could be monitored through time to document the specific effectiveness of the acquisition to improve habitat. At the two Habitat Protection Projects monitored in the Upper Columbia, Methow Critical Riparian Habitat Acquisition and Entiat River Habitat Acquisition, both showed very little change in river habitat conditions in the first 5 years of monitoring.

Upper Columbia Monitoring Sites

Nine projects in six categories are currently being monitored in the Upper Columbia Basin as part of the SRFB Reach-Scale Effectiveness Monitoring Program (Table 2). At the workshop, we presented some of the short term trends for certain parameters for the Upper Columbia sites. Given the site specific nuances and short term duration of the efforts to date, it may not be appropriate to evaluate effectiveness of the individual Upper Columbia sites. The results from monitoring efforts at the individual Upper Columbia sites is included in the statewide categorical analysis.

Recommendations

After 6 years of monitoring, the data that have been collected, along with observations and lessons learned along the way, have led to recommendations regarding the monitoring program. The following recommendations have been made for each project category:

- Fish Passage Projects have been found to be very effective; however, this effect is only detectable when fish population densities below the barrier are reasonably high (> 0.04 fish/m2).

- For In-Stream Habitat Projects, monitored projects should be located within Intensively Monitored Watersheds so that the effects of those projects can be captured in terms of changes at the population level. Riparian Planting Projects have shown that after the second year of monitoring, measuring percent cover of native or desired species is more beneficial than measuring plant survival, as survival of the original plantings is less important and less detectable. This sampling should be repeated in Year 5 and Year 10 post-implementation. Additionally, measurement of canopy density and vegetation structure should be delayed for 10 years until vegetation has had a chance to establish. Qualitative assessment of invasive species should also be included as part of each monitoring event and active control of select invasive species should be implemented to limit competition with new plantings. Additionally, control or exclusion of herbivores should be implemented at planting sites to ensure success. These recommendations also apply to those Livestock Exclusion Projects that include a planting component.

- It is recommended that Channel Connectivity Projects be combined with Constrained Channel Projects to develop an approach for monitoring the development and maintenance of floodplain habitat. A more successful monitoring model than the current one would be to implement a floodplain reconnection project over a large area and then enhance or augment natural off-channel habitat development processes in areas where these habitats are likely to be maintained. Design of Floodplain Enhancement Projects should also include detailed topographic surveys for wadeable streams and bathymetric surveys for larger river projects to determine recommendations for design strategies. Monitoring changes in stream morphology should include re-surveying the project area post-project implementation, and again after several years (i.e. Years 0, 1, 5, and 10) to more accurately assess the changes in the stream and floodplain. Additionally, aerial photos and field mapping should be used to measure and identify the new habitat areas created by the projects. Each year of monitoring should include mapping of the habitat to document the extent that the habitat remains connected and/or continues to develop. Measurement of the level of connection (flow levels, number of days of connection) should be included as part of the effectiveness evaluation.

- Long-term success of Diversion Screening Projects depends on continued maintenance, so funding for maintenance and cleaning of diversion screens should be included in the funding for the project.

- It is recommended that the second round of field monitoring for Habitat Protection Projects be delayed for 5 to 10 years after the initial assessment. Additionally, remote sensing (aerial photos or satellite images) should be used to assess the value of the parcel to the habitat in the watershed through time. It is recommended that these sites be revisited every 5 to 10 years to make sure that they are still intact and functioning as natural habitat.

Summary

The Salmon Recovery Funding Board Effectiveness Monitoring Program involves the monitoring of projects throughout the state in nine different monitoring categories. The use of standard protocols allows data and project information to be shared across the region and the state. The data collected and lessons learned through project implementation can be used to prioritize funding and project selection, allowing a more cost effective approach to salmon recovery.

Effectiveness of Habitat Restoration Actions in the Entiat River Subbasin, WA

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Background

The Integrated Status and Effectiveness Monitoring Program (ISEMP) is attempting to detect effects on populations of Chinook salmon and steelhead resulting from habitat restoration actions at multiple scales as part of the Entiat Intensively Monitored Watershed (IMW) experiment. The Entiat IMW design tests hypotheses which examine the effects of approximately 80 mainstem instream treatments and 6 side channel modifications on a suite of habitat metrics and population measures at the reach and subbasin scale (Ward 2006). Two of these hypotheses, focused at the reach level, were tested and reported at the UCRTT 2010 Analysis Workshop:

H1: The implementation of a suite of approximately 80 instream channel modifications will significantly improve the magnitude and variability at the reach level of physical habitat and macroinvertebrate indicators favorable to spring Chinook salmon and steelhead.

H2: The implementation of a suite of approximately 6 side-channel restoration projects will improve the magnitude and variability at the reach level of physical habitat and macroinvertebrate indicators favorable to spring Chinook salmon and steelhead.

Methods

Entiat River habitat effectiveness monitoring has been ongoing since 2005 concurrent with the annual implementation of additional habitat restoration treatments. The pre-IMW experimental design followed a traditional Before-After-Control-Impact (BACI) design, collecting as much pre-treatment data as possible and balancing the number of controls vs. treatments. Several restoration sites and their control reaches have 4 to 5 years of monitoring data and were the focus of this preliminary analysis. The adaptive management question addressed by this analysis is whether the project types affect the environmental parameters (physical/chemical variables) that were the target of the action. A subset of the indicators sampled were analyzed based on their assumed importance to fish, including: coefficient of variation about the thalweg depth; width-to-depth ratio, and percent pools.

Data was analyzed for 6 mainstem sites, representing 3 paired control/treatments. All sites were plane-bed channel types (Rosgen B or F). Sites have 4 to 5 years of monitoring data each with at least 2 years of post treatment data.

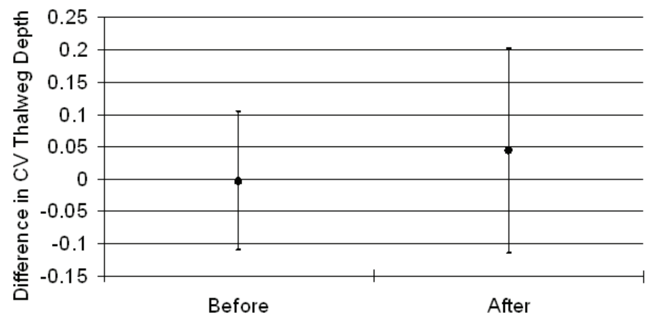

Figure 1. Mean differences in the coefficient of variation about thalweg depth for before and after periods. Error bars represent 95% confidence intervals.

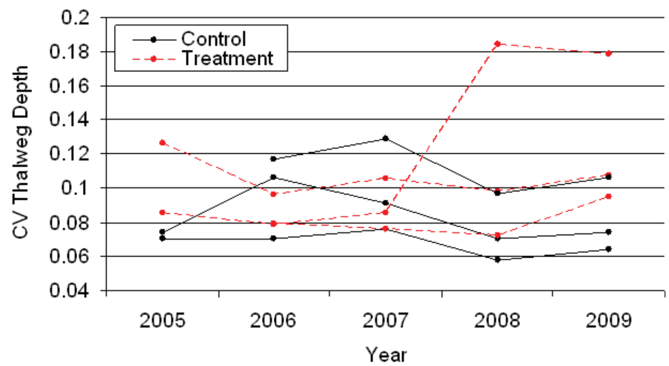

Figure 2. Coefficient of variation about thalweg depth for control and treatment sites for years 2005 – 2009.

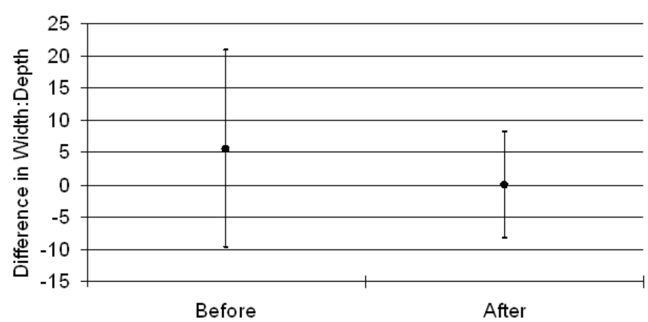

Figure 3. Mean differences in the width:depth ratio for before and after periods. Error bars represent 95% confidence intervals.

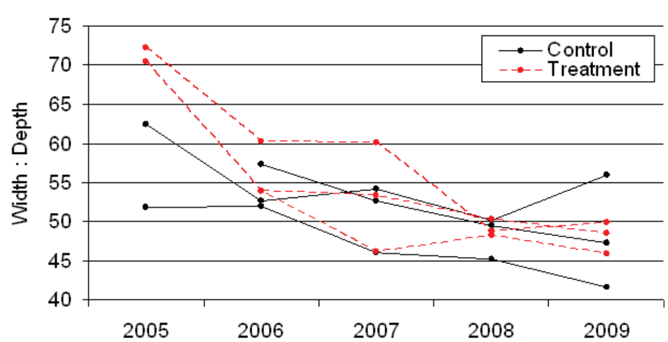

Figure 4. Width:depth ratio for control and treatment sites for years 2005 – 2009.

Results and Conclusions

For all habitat attributes analyzed (CV thalweg depth; width-to-depth ratio, % pools), wide confidence intervals for Before and After means preclude the detection of treatment effects with the BACI analysis approach used for the 3 paired sites (Figures 1, 3, 5). Coefficient of variation around the thalweg depth for nearly all sites showed small annual fluctuations with only one treatment site showing a pronounced increase in complexity after treatment (Figure 2). In general, width-to-depth ratios for both treatment and control sites largely trended downward over time (Figure 4). Smaller width-to-depth values indicate an increase in depth or reduction in channel width. Percent pools, of which control sites had none, increased at 2 sites post-treatment. For one of these sites the increase in pools was short lived and returned to zero two years after treatment. The increase in percent pools persisted at the other treatment site into 2009, two years after treatment (Figure 6).

The large confidence intervals surrounding the means in before and after differences for control and treatment sites preclude the detection of treatment effects for the 3 paired sites analyzed. As multiple years of post-treatment data is necessary to determine a persistent treatment effect, analyses in future years will have more sites to draw on for analysis. Determining the fish response to habitat treatments will also be important for future analyses. Additionally, if a goal is to refine restoration treatments based upon the performance of sites already treated, the analysis of individual paired sites might be warranted to determine what treatment types had the desired effect within specific channel types and the persistence of this effect over time.

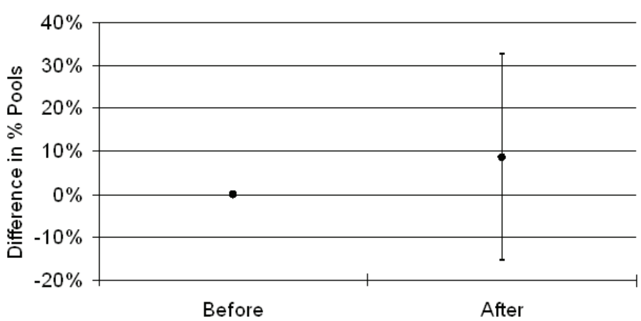

Figure 5. Mean differences in percent pools for before and after periods. Error bars represent 95% confidence intervals.

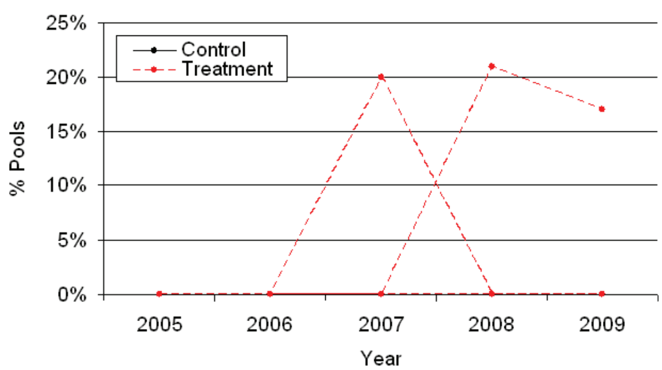

Figure 6. Percent Pools for control and treatment sites for years 2005 – 2009. All control sites had 0 pools in all years.

UCRTT Deliberations

The data presented here supports previous conclusions that the BACI design was insufficient to detect changes due to high variance and small sample size. The current mixed model approach of the IMW in the Entiat is more likely to detect real changes in fish and habitat metrics in response to habitat restoration actions. It is important that action implementation stick to the spatial and temporal prescription of the monitoring program in order to give the program the best chance of detecting real changes.

The IMW monitoring approach being implemented in 2011 will enable the use of a mixed model approach with greater power to detect treatment effects. Nested implementation of treatments over time will provide additional replication. The mixed model approach will enable the partitioning of variance into fixed and random effects. Traditional BACI is limited to analyzing fixed effects (before / after differences) and associated error. Based on simulated data within the context of a BACI experimental design, power curves for traditional BACI and Mixed Model analysis approaches are nearly identical. Mixed modeling approaches performed slightly better at detecting a treatment effect, and have the advantage of being able to deal with more complex experimental designs.

Population ecology and effectiveness monitoring of small-scale Instream habitat restoration structures in the Entiat River

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Background

The Integrated Status and Effectiveness Monitoring Program (ISEMP) is attempting to detect effects on populations of Chinook salmon and steelhead resulting from habitat restoration actions at multiple scales. In this study, in order to complement the larger-scale effectiveness monitoring done by ISEMP as part of the Entiat Intensively Monitored Watershed (IMW), population size and individual growth and movement for O. tshawytscha and O. mykiss were examined at the reach scale, in one reach treated with small-scale habitat features and one control reach. Two hypotheses were tested, including: 1) fish growth and movement would show density dependence and 2) density dependence would differ between the treated and control reaches. Within the treated reach (approximately 125 m long, near river mile 3.5, about 0.5 km downstream of an untreated control reach of similar morphology) a series of four engineered log jams and five

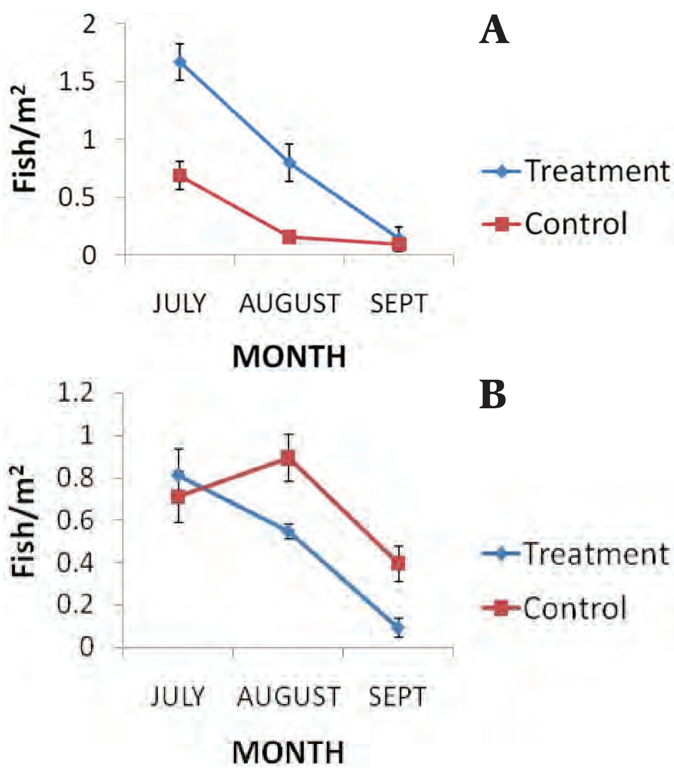

Figure 1. Mean density of (a) Chinook and (b) steelhead in reaches treated with restoration structures and in control (untreated) reaches for three sampling months, July-September 2009. Differences between treatment and control reaches and temporal effects were analyzed with repeated measures ANOVA. Chinook: Reach $F_{18,36} = 25.63$, $p < 0.001$, Time $F_{18,36} = 66.45$, $p < 0.001$, Reach X Time $F_{18,36} = 12.74$, $p < 0.001$; Steelhead: Reach $F_{18,36} = 3.64$, $p = 0.07$, Time $F_{18,36} = 22.42$, $p < 0.001$, Reach X Time $F_{18,36} = 4.16$, $p = 0.02$.

rock barbs were installed by the U.S. Bureau of Reclamation to create salmonid rearing habitat. These structures formed pools that averaged about 12 m2 in area (range: 4-20 m2) and created pools averaging 40 cm in depth (range: 26-60 cm). Thus, the structures added microhabitat scale variation in rearing habitat within the treated reach.

Methods

Snorkeling and a combination of snorkeling and seining were used to census and capture fish multiple times from July 13 to September 20, 2009, at pools in both treated and control reaches. At each capture event, size data (length and mass) were observed for all captured Chinook and steelhead, each captured fish was marked with a subcutaneous injection of visual implant elastomer, and population data was collected including the density (relative to the size dimensions of the habitat) of steelhead, Chinook and other fish species. Recapture frequency between repeated censuses (separated by 24 hours) were used to estimate emigration and short-term habitat affinity. Growth of individual fish was calculated over the longest period in which they were recaptured. Growth and movement were compared with the average density by pool/structure encountered by the fish during the period between initial capture (marking) and final recapture in the investigation of the effects of density dependence.

Results and Discussion

Fish density declined substantially with time at the treatment reach compared with the control reach,; however, Chinook and steelhead showed different patterns in density through the season (Fig. 1). Chinook density responded to the treatments early in the season, being significantly higher averaged over the treated reach compared with the control reach (Fig. 1a; statistics presented in figure legends). Steelhead density is more variable and even slightly higher in the control reach during the second part of the summer (Fig. 1b). The fact that the treated reach in August was indistinguishable in Chinook density from the control reach in July suggests that temporal variability in fish density might lead to misleading results under certain before-after treatment sampling designs. Time factors in repeated measures ANOVA were always significant. While the decline in Chinook density later in the summer could be due to the emigration of summer Chinook and prior to the immigration of spring Chinook, the similar decline in steelhead density suggests that there is an overall reduction in activity or emigration from treat-

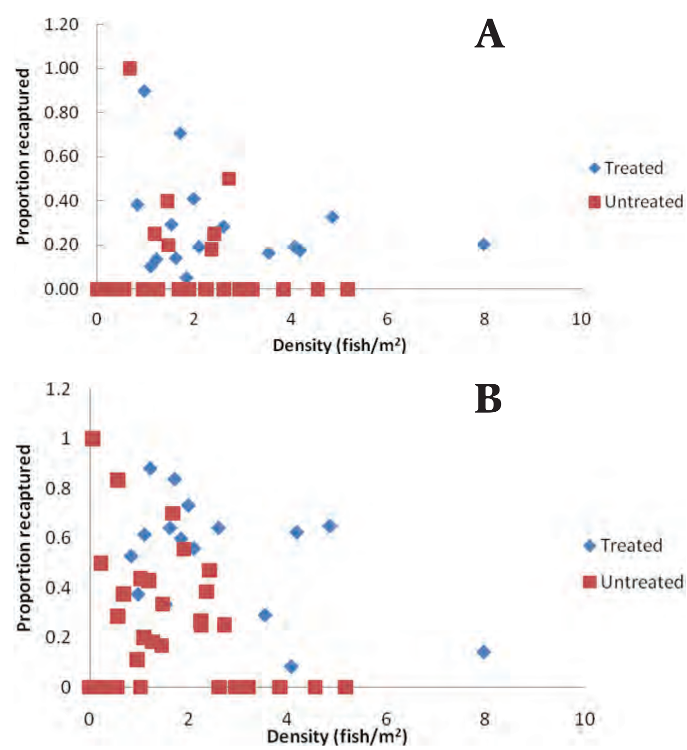

Figure 2. Proportion of (A) Chinook salmon and (B) steelhead recaptured 24 hours after mark-and-release in a treated reach with pools created by restoration structures (blue diamonds) and in pools from a reach without structural treatments (red squares). Recapture proportions were analyzed by ANCOVA for density dependence. Chinook: Reach $F_{1,46} = 17.40$, $p < 0.001$, Density, $F_{1,46} = 0.363$, $p = 0.549$; Steelhead: Reach $F_{1,46} = 19.51$, $p < 0.001$, Density $F_{1,46} = 5.924$, $p = 0.019$.

ed and untreated reaches during this time. Movement patterns were both density- and habitat-dependent. Both Chinook and steelhead tended to move less frequently in the treated reach relative to the untreated reach, although movement for Chinook was not density-dependent (Fig. 2a) as in steelhead (Fig. 2b). These movement patterns reflect higher affinity of both species for the microhabitat treatments, which is suggestive of higher habitat quality despite increased opportunity for competitive interactions. Movement patterns also changed during the season although this could only be demonstrated for Chinook salmon in the treated reach because there were insufficient recaptures in the untreated reach. Chinook had lower habitat affinity in the later months which corresponded to the time where their density declined to equal that of the untreated reach (Fig. 3a). Steelhead showed the opposite pattern with higher habitat affinity later in the season regardless of restoration treatment (Fig. 3b). Similar to the analysis of density dependent movement (Fig. 4a), the number of Chinook salmon recaptures was only sufficient in the treated reach for analysis of density-dependent growth. Restoration treatment appeared to make a difference; log structures had consistently high growth that declined with density whereas rock structures were more variable (Fig. 4a). Growth rates for both Chinook and steelhead are presented as functions of average total fish density (all species combined) in each microhabitat sampled. Although functions fitted through the data point are either not significant due to insufficient replication or not fully defined in the case of the non-linear estimates of curves through each habitat type for steelhead (Fig. 4b) the total fish density

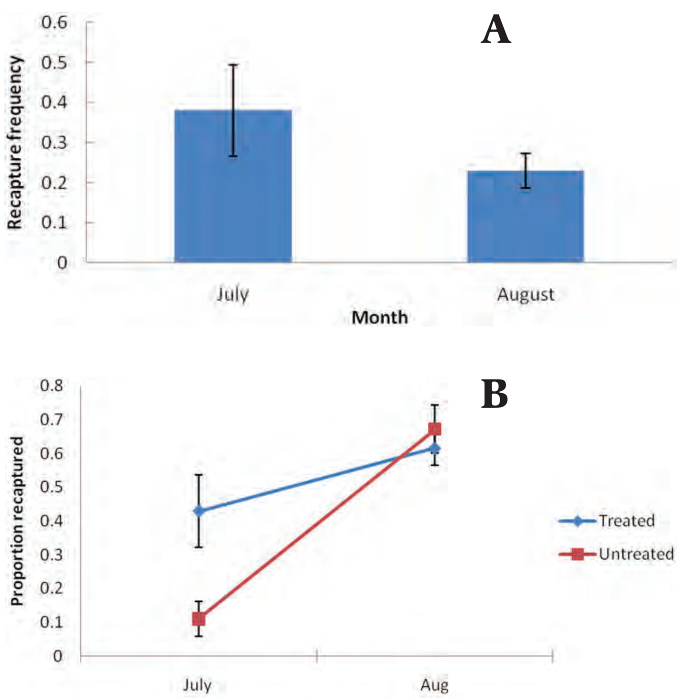

Figure 3. Temporal variation in recapture frequency in both reaches. For Chinook, recapture frequency changed with time and marginally with fish density (ANCOVA Month $F_{1, 13}$ = 4.72; p= 0.049, Density $F_{1, 13}$ = 3.36, p = 0.090). Steelhead recapture rates differed between reach and month and covaried with density (Reach $F_{1, 33}$ = 23.64, p < 0.001, Month $F_{1, 33}$ = 4.76, p = 0.036, Density $F_{1, 33}$ = 9.02, p = 0.005). Interaction term was marginally significant (Reach X Month $F_{1, 33}$ = 3.20, p = 0.083).

Adaptive Management Recommendations

- It is encouraging that these smaller-scale wood structures appear to benefit juvenile fish but the studies have some sample size and duration limitations. We recommend continuing with the studies to increase sample size and evaluate the effectiveness over multiple seasons, years, and locations.
- Small-scale structures are recommended as a component of larger overall efforts to achieve habitat diversity objectives for the lower Entiat if properly sited and, in particular, if they are used in combination with larger channel-spanning structures and are not put in at the expense of existing functional riparian habitat.

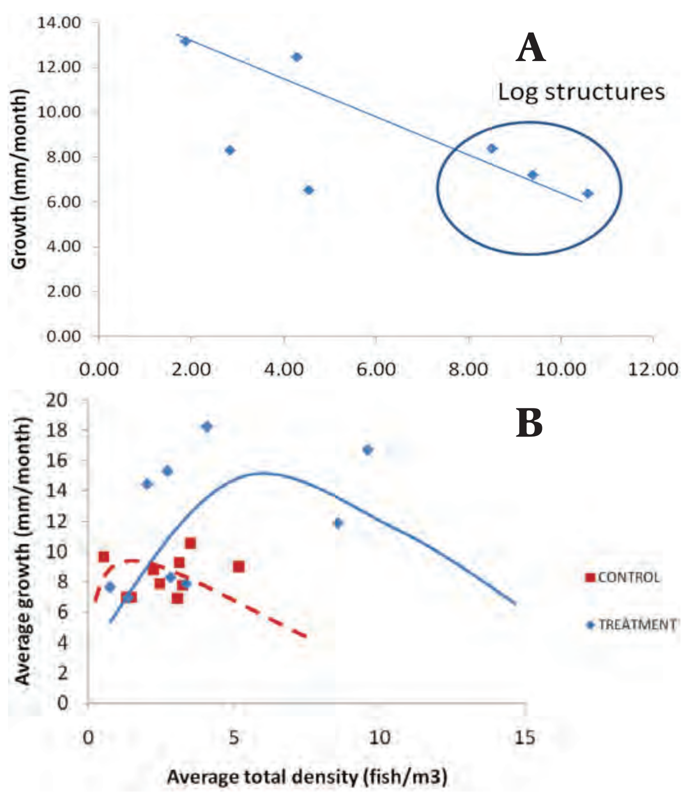

Figure 4. Density dependent growth rates for (A) Chinook and (B) steelhead in the reach treated with restoration structures. Log structures at which fish were recaptured for long-term growth analysis are circled, data points without circles are rock structures with labels to indicate that negative residual deviation from the growth function involved different rock structures for each species.

found to occur in the treated reach (not shown) is below the carrying capacity predicted from the growth results (up to 15 fish per m3). Possible Allee effects are indicated in the case of steelhead; low density in a few microhabitats in the treated reach and most in the control reach resulted in the lowest growth rates measured in the study system. Establishing the significance of functions that describe the density-growth relationship will require better replication of structure types (logs vs. rocks) within treated reaches.

These results suggest that focused studies of small-scale restora-

UCRTT Deliberations

"Do the apparently positive results of this study suggest that the UCRTT will be recommending installation of more small wood structures?," was the immediate feedback the UCRTT received from WATs and project sponsors. While the study was short term, only one year, and only looked at a small sample size of structures in a particular habitat type (the Lower Entiat), the study was intensive and well designed. Similarly, the Biological Strategy objective of "increasing stream habitat complexity" suggests that treatments ought to be developed over a wide range of shapes and sizes. Smaller pools, for example, may have biological benefits unrealized by large pools, and a range of habitat sizes can increase "instream habitat diversity." However, concerns about siting, scaling, and structure longevity will likely be amplified for small-scale projects. For instance, it may be counter productive to recovery objectives if the installation process damages riparian habitat, particularly if a small-scale project may not survive the next flood or have other long-term benefits. Furthermore, smaller-scale treatments may be less likely to effect the geomorphic changes on the river (like "thalweg development" and "channel forming processes") that is the second half of the two-pronged approach in the lower Entiat. Therefore, small-scale structures may be a part of meetinghabitat restoration objectives and will continue to be considered for future implementation, particularly if these types of structures are used where existing habitat values won't be diminished or used to augment channel forming processes and floodplain function.

tion treatments might be necessary to detect impacts to fish populations. Short-term data such as these help identify temporal variation in the use of treated vs. untreated habitat and whether there is a measurable change in density dependent life history traits such as growth and movement. Restoration treatments show some measurable positive impact on the species of concern but further analysis and more data are required to establish these conclusions more firmly.

Effectiveness of Actions in Beaver Creek

Patrick J. Connolly[1], Kyle D. Martens[1], Dana E. Weigel[2], and Wesley T. Tibbits[1]

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[2]U.S. Bureau of Reclamation and University of Idaho

Background

Actions were taken to replace four diversion dams in lower Beaver Creek with rock vortex weirs in order to enhance fish passage while maintaining the ability to divert water to gravity-fed irrigation ditches. Some of these diversion dams had been in place for over 100 years, and have impaired or completely blocked upstream migration of fish. Three diversion dams were replaced in 2003 (Lower Stokes, Thurlow Transfer, and Upper Stokes), and the forth and most-downstream (Rkm 2) diversion dam was replaced in 2004 (Fort-Thurlow). Four vortex weirs were designed and installed under the supervision of U.S. Bureau of Reclamation engineers and completed in accordance to National Marine Fisheries Service and Washington Department of Fisheries and Wildlife fish passage criteria. An effectiveness monitoring effort was warranted since installing rock vortex weirs represents a relatively new methodology and little information was available for their effectiveness of passing fish species of the Pacific Northwest.

Objectives

The primary objectives of the study were to: 1) assess effectiveness of the modified irrigation diversion structures for passage of fish, and 2) to document subsequent changes in fish populations in Beaver Creek.

Methods

An extensive PIT-tagging program with four PIT-tag detection antennas and a fish sampling weir was used to monitor the success of upstream passage of fish and to assess growth and survival within Beaver Creek (Figure 1). Electrofishing was used to survey and collect fish to measure change in fish assemblage, smolt production, and diversity of life history expression above the modified structures. Three sites in Beaver Creek were chosen for isotope analysis to represent the range of change in use by anadromous fish as the diversions were replaced with vortex weirs (Figures 2 and 3). For example, the lowest site (Rkm 3) was above two water diversions and we expected a large increase in

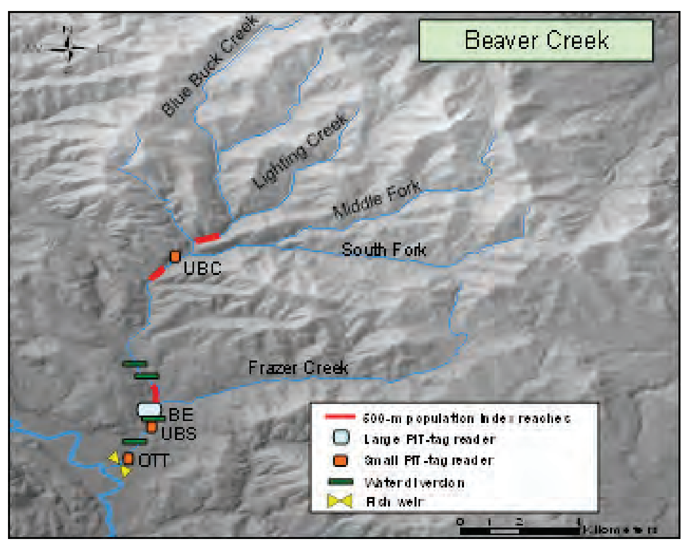


Figure 1. Sites for locations of PIT-tag interrogators, fish trap, and 500-m population electrofishing surveys in Beaver Creek. A2 = Upper Beaver Creek small interrogator, B0 = R1 large interrogator, A4 = R1 small interrogator, and A6 = Lower Beaver Creek small interrogator.

UCRTT Deliberations

- The monitoring program in Beaver Creek provides a unique and in-depth evaluation of the effectiveness of fish passage efforts in a small sub-watershed.
- This study also provides life history, phenotypic, and ecological information that could provide valuable insight for future evaluations following the re-colonization of Beaver Creek.
- The barrier passage efforts in Beaver Creek appear to have alleviated the primary limiting factor for this major spawning area of the Methow population.

anadromous fish in this reach after the diversions were replaced with vortex weirs. The middle site (Rkm 13) was selected because we expected to see some limited anadromous fish use after the water diversions were replaced with vortex weirs. Samples for isotope analysis were collected from fish, algae, leaves (cottonwood, red alder), and insects in fall 2004, and spring and fall 2005 and 2006, and the spring 2007.

Three 500m index sites (location of these sites was based largely on geomorphology and access) were sampled using electrofishing to obtain population and growth estimates (which were also obtained from the recapture of tagged fish at the fish sampling weir). Surveys were conducted during the spring, summer, and fall to collect previously PIT-tagged fish. Recapture data were analyzed by season of year. Recapture events were used when a fish was captured within the next season from its tagging or last recapture event. Since no sampling occurred during winter, we assessed growth for fish tagged (or recaptured) in the fall and recaptured in the spring. Recaptured fish were used only if they were recaptured after 10 days of their tagging or last recapture date. We defined seasons as: spring (March-May), summer (June-August), fall (September-November), and winter (December-February).

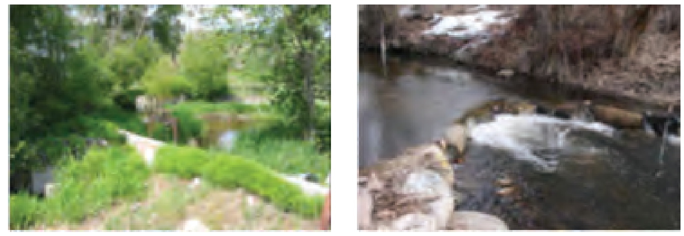
Results

After the lowermost remaining water diversion in Beaver Creek was replaced with a vortex weir, we collected or detected mountain whitefish, coho, and juvenile and adult Chinook at the R1 index site or large interrogator (Figure 4). Based on changes in fish assemblage, connectivity has been reestablished for a number of members of the fish community. Our PIT tag interrogator data indicate a four-fold increase from 2005-06 to 2007-08 in the number of potentially spawning adult steelhead getting past Rkm 4, with some getting past Rkm 12 by 2007 (Figure 5). Success of natural recolonization appears to be progressing, but it will likely take more time to realize full potential. In 2005, 2006 and 2008 the majority of recolonizing adults were wild.

The vortex weirs were demonstrated to be very effective in passing fish, including successful upstream passage of juvenile salmonids at all flow levels, even at flow levels as low as 2.3 cfs (0.07 m3/s; Figure 6). However, the rate at which rainbow trout/juvenile steelhead (Oncorhynchus mykiss) swam past the vortex weirs was significantly slower than the passage rate at the control reach ($X2 = 8.32$, $P = 0.004$).

In Beaver Creek, O. mykiss juveniles off all ages were most prevalent at the lowermost (R1) index site. The biomass of age-1 and older juvenile O. mykiss at the R1 index site was almost double the biomass of at other index sites sampled in the Methow watershed.

We found similar results of age-1 or older fish densities from 2004 to 2005 (Figure 7). The population of age-0 O. mykiss decreased in the R1 and R2 index sites in 2005, while the R4 index site's population increased. The biomass of O. mykiss in R1 and R2 decreased from 2004 to 2005, while the biomass increased



Figures 2 and 3. Before and after photographs of Beaver Creek. Left: Diversion dam in Beaver Creek that impaired or completely blocked fish passage upstream. Right: Diversion dam replaced with instream vortex weir allowing fish passage and maintaining ability to divert water for irrigation.

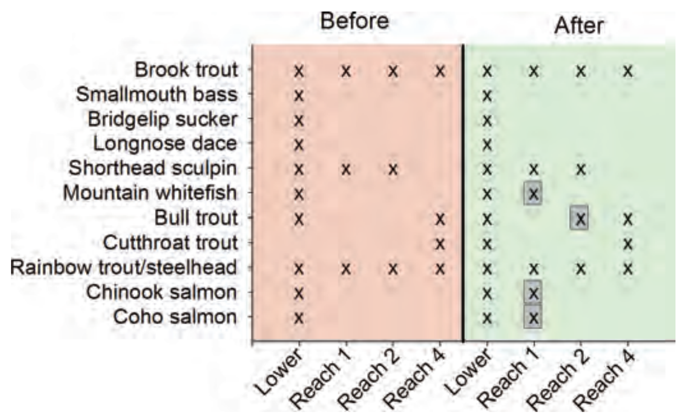


Figure 4. The presence of fish species in selected sections of Beaver Creek before and after the reconstruction of the lowest remaining water diversion.

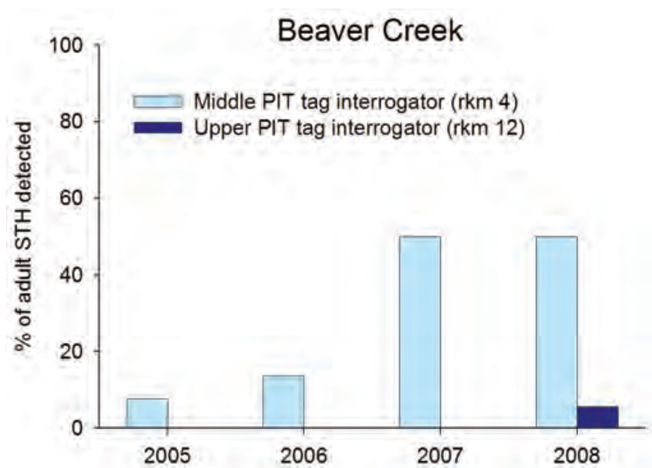


Figure 5. Percentage of adult steelhead caught at the weir and then detected upstream at the PIT tag detectors in Beaver Creek.

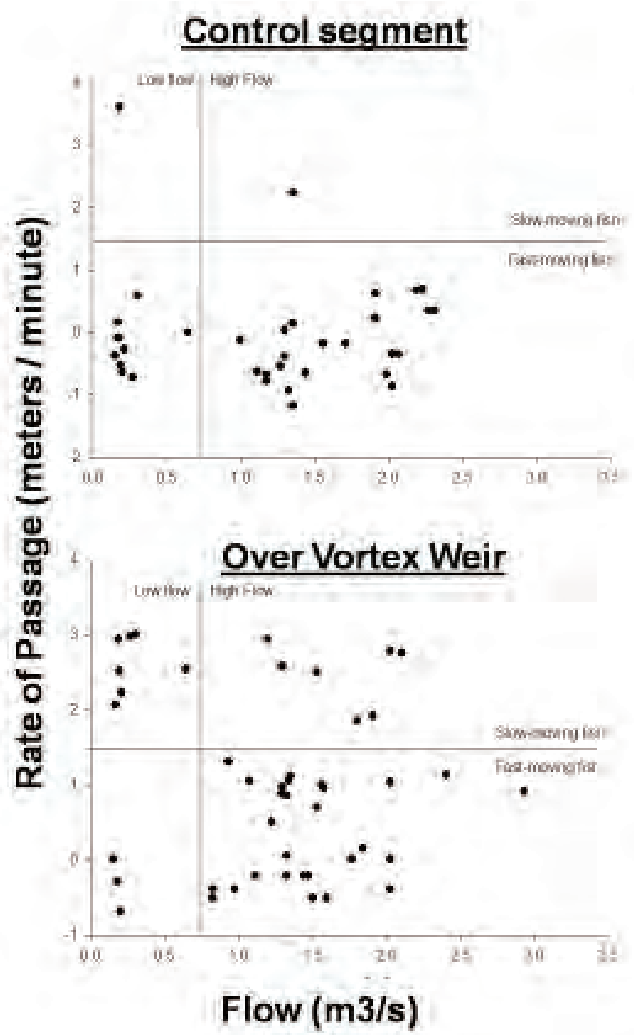


Figure 6. Rate of passage of juvenile steelhead across vortex weirs at various flows.

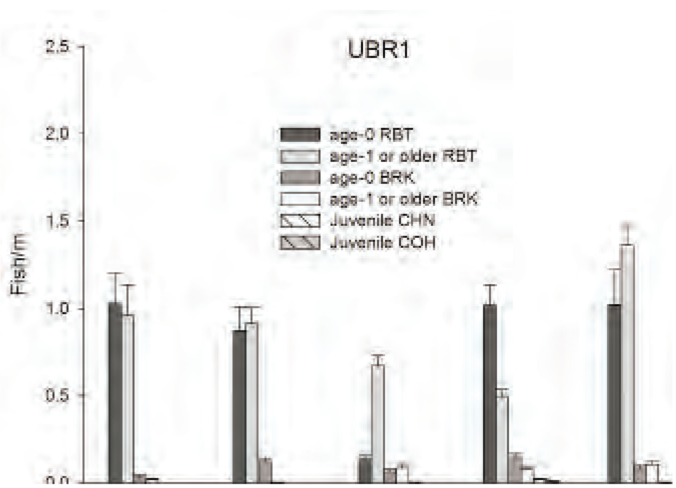


Figure 7. Salmonid abundance in upper Beaver Creek (Reach R1, Rkm 5) from 2004 to 2008.

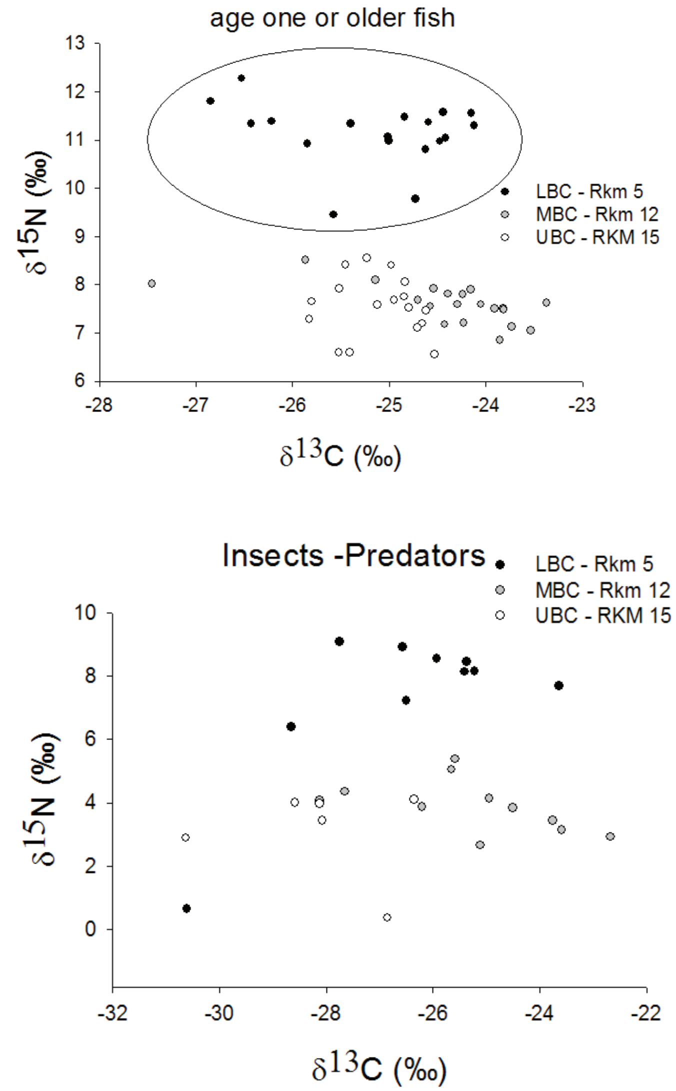


Figure 8. Isotope ratios (N, C) from 2004-2007.

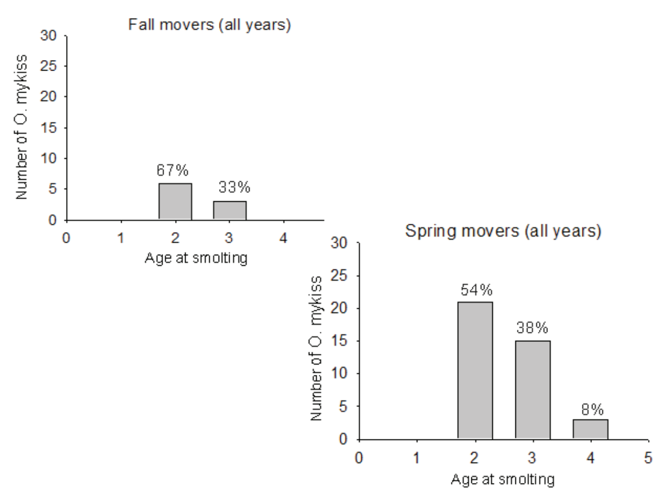


Figure 9. Lower Beaver Creek (R1) 2004-2007 age of smolts from two life history trajectorie, as detected in the Columbia River PIT tag interrogation network.

Year	Number PIT tagged	Number detected					
		2004	2005	2006	2007	2008	2009
2004	291	0	0	2	4	2	1
2005	169	--	0	0	1	3	1
2006	136	--	--	0	0	5	0
2007	113	--	--	--	0	1	1
2008	37	--	--	--	–	0	0

Table 1. Number of age 1 O. mykiss PIT tagged above Rkm 12, and then detected moving downstream past Rkm 4 (Stokes reader).

Year	Number PIT tagged	Number detected					
		2004	2005	2006	2007	2008	2009
2004	150	27	53	16	0	0	0
2005	140	–	31	30	1	0	0
2006	104	–	--	1	15	5	0
2007	50	--	--	--	13	8	1
2008	279	–	--	--	--	60	32

Table 2. Number of age 1 O. mykiss PIT tagged near Rkm 5, and then detected moving downstream past Rkm 4 (Stokes reader).

in R4. The population of age-0 and age-1 or older O. mykiss in Beaver Creek decreased at each upstream sampling site.

Because of the infancy of our analysis, we did not attempt a statistical analysis of the isotope data but present a brief qualitative analysis (Figure 8). The marine-derived isotopic signature indicates that anadromous fish currently use lower Beaver Creek (Rkm 5; solid circles in Figure 8) but also were present in lower Beaver Creek prior to the conversion of the Fort Thurlow and Lower Stokes water diversions to vortex weirs. Isotopic signatures suggest that the middle (rkm12) and upper (Rkm 15) reaches of Beaver Creek were not used by anadromous salmonids.

Juvenile O. mykiss that were tagged above Rkm 12 and that were subsequently detected moving downstream past the lower vortex weir at Rkm 4 were typically detected from 3 to 6 years after tagging and were detected at low levels (Table 1). Juvenile O. mykiss that were tagged above Rkm 5 and that were subsequently detected moving downstream past the lower vortex weir at Rkm 4 were typically detected from 1 to 3 years after tagging and were detected at higher levels (Table 2). A pattern of downstream movement was observed, with O. mykiss emigration prominent in April through June and in September through November.

We found differential smolting success of steelhead from the expressed life history strategies, where those juveniles that remain in the creek until smolting are contributing more to the smolt population than are fish which leave Beaver Creek in the fall at age-1 (Figure 9). Steelhead and other members of the fish community are actively recolonizing Beaver Creek but lower Beaver Creek is producing the majority of steelhead smolts.

Data Gaps and Research Needs

Summary of Key Management Questions

The goal of the recovery process is to restore viable and sustainable populations of naturally producing salmon and steelhead in the Upper Columbia Basin. Progress toward meeting this goal is measured with several indicators that are reported from scientific monitoring of fish populations and fish habitat. Therefore, it follows that certain amounts of the right types of monitoring are required to demonstrate progress toward reaching the recovery goal.

The "right type" of monitoring 1) collects data and reports the necessary indicators from the collected data, 2) focuses on the populations of interest, and 3) focuses on the locations within the Upper Columbia that are important to the fish of interest. For many metrics, existing monitoring programs are already collecting the necessary data and reporting the necessary indicators. However, in some other cases, the necessary data are not being collected or the necessary indicators are not being reported. These cases are called "data gaps."

The Upper Columbia Regional Technical Team's Monitoring and Data Management Committee created rating criteria to prioritize known data gaps, and used this rating criteria to compile and prioritize a list of data gaps. The Monitoring and Data Management Committee also generated a framework and process for rating newly identified data gaps within established priority tiers. Many critical gaps remain – both in the collection of new data and in the generation of results from existing data. Data gaps are dynamic: new monitoring may close some gaps while other gaps are opened as existing studies or monitoring efforts end. Some data gaps exist because funding has not yet been allocated to the proper monitoring while other gaps exist because monitoring programs that are funded or that will be receiving funding have either not operated long enough to generate the necessary metrics or have other priorities besides the Upper Columbia recovery effort. A prominent theme of the UCRTT 2010 Analysis Workshop was the question of how to best generate the necessary results from existing monitoring data: the answer to which will likely require improved cooperation, better reporting mechanisms, and additional funding in key data gap areas.

What is still needed to answer key management questions?

- Existing monitoring programs, including data collection and the generation of metrics, need to be prioritized in relation to the identified data gaps. Data gaps might be closed by simple changes within existing monitoring efforts. The framework and criteria developed by the Monitoring and Data Management Committee can be used for this purpose.
- Status and trend data from the Canadian portions of the Okanogan steelhead population is a data gap. These data should be compiled into the overall status and trends assessment for the Upper Columbia that has, until now, focused only on the portion of the Okanogan subbasin within the U.S.
- Patterns of genetic diversity are a high risk factor for all Upper Columbia spring Chinook and steelhead populations. Consistent and efficient genetic analyses are prominent data gaps. Therefore, a spatially balanced genetic sampling program for Chinook salmon and steelhead should be established throughout the Upper Columbia. This sampling program would need to be repeated at intervals to understand the status and trends in genetic diversity. This program would be particularly useful if it was designed 1) to monitor the influences of hatchery impacts to population genetic structure, 2) to help understand what are the desired conditions for spatial structure and diversity, and 3) to elucidate the contribution of rainbow trout production and diversity to steelhead, something that recent studies suggest may be significant.
- Monitoring the effectiveness of restoration actions is essential for learning and adapting the management of the recovery process. More information about the effectiveness of restoration actions is needed. This means we need more effectiveness monitoring studies and/or larger sample sizes.
- To better direct restoration actions, we need to better understand which factors drive fish survival and growth and whether growth and survival can be attributed to spatial location and life history type. Additional juvenile life history information is needed which will require additional life history studies.
- Predicted changes in climate patterns may influence the recovery process but much uncertainty surrounds these patterns and their effects. These data gaps may be alleviated with several studies that are proposed or underway in the Upper Columbia.

The remainder of the chapter consists of articles reporting the contents of presentations given either during the UCRTT Analysis Workshop held on January 12 and 13, 2010 or during the deliberations of the UCRTT that followed:

Upper Columbia Data Gaps Assessment

Keely Murdoch

Keely is a Fisheries Biologist with the Yakama Nation and is the Chairperson of the UCRTT's Monitoring and Data Management Committee.

The UCRTT's Monitoring and Data Management Committee (MaDMC) completed an assessment to prioritize information needs within the Upper Columbia relative to specific questions identified in the Recovery Plan. The assessment is part of the adaptive management process identified within the Plan and will be used to determine monitoring and evaluation priorities to answer key management questions. The assessment is a working document (Peven and Murdoch 2010) which will be updated as new information becomes available. Much of the information to determine the status of steelhead and spring Chinook through the ESU is being collected through the ongoing M&E programs such as those developed for the Chelan and Douglas County PUD hatchery compensation programs, the Integrated Status and Effectiveness Monitoring Program (ISEMP) and the Okanogan Basin Monitoring and Evaluation Program (OBMEP).

To understand where additional effort is needed for monitoring recovery, the MaDMC initially compiled and listed data and information gaps relating to recovery within the Upper Columbia. Reference sources the MaDMC used to compile known monitoring data gaps include: the Upper Columbia Salmon Recovery Plan (UCSRB 2007), the Upper Columbia Biological Strategy (Andonaegui et al. 2008), and additional UCRTT input. The MaDMC then reviewed the compiled list to remove duplication and redundancy so that each data gap could be rated only once.

The MaDMC defines a gap in information as a critical uncertainty that has not been addressed. Work is currently underway for some of the gaps (listed in "current progress" box); however, until the studies or monitoring is complete, and have been peer reviewed (within the appropriate process), they are still considered 'gaps'.

To prioritize the data gaps with as little subjectivity as possible, the MaDMC developed rating criteria. The rating criteria was based upon an assessment of whether the data gap decreases our ability to assess VSP parameters (abundance, productivity, spatial structure, or diversity) or could directly relate in an action which could improve the current status of VSP parameters. The rating criteria also considered the geographical scale of the gap (local, subbasin, or ESU-wide) as well as potential future use of the information. More detail on the rating criteria can be found in Peven and Murdoch (2010).

Using the rating criteria, each known data gap was scored and ranked from highest to lowest. Because the importance of some data gaps was not clear, the difference of a few points between scores may not translate to a difference in priority. Therefore, all scores were divided into quartiles. The quartiles became prioritized Tiers. Tier 1 data gaps are considered the data gaps with the most immediate need to be filled. The information box on this page describes current progress to address priority data gaps (i.e., data gaps which are now receiving funding) and the next steps (priority data needs that are currently unfunded).

In addition to the tiered rankings, The data gaps identified by MaDMC were combined with the analysis by Peven and Hillman (2008), and information concerning whether the data is 1) currently being collected, 2) the funding and implementing agencies, 3) what the data gaps are, and 4) comments/recommendations were developed.

Current Progress

(Priority Tier-1 data gaps now receiving funding)

- Steelhead monitoring has been insufficient for the evaluation of viable salmonid population (VSP) parameters throughout the Upper Columbia.
- This gap is ccurrently receiving funding through BPA, NOAA fisheries, and Chelan PUD but more time is required to generate the necessary metrics for viable salmonid population parameters.
- The relative performance between hatchery and naturally produced spring Chinook and steelhead throughout the Upper Columbia should be determined.
- This gap is currently receiving funding through BPA, Chelan County PUD, and Douglas County PUD but more time is required to generate the necessary metrics.
- Estimate the precision and accuracy of redd counts wherever these counts are used to determine spawning escapement.
- This gap is currently receiving funding from BPA, Chelan County PUD, and Douglas County PUD but more time is required to generate the necessary metrics.
- Assess the genetic and/or demographic contribution of resident redband rainbow trout to Upper Columbia anadromous steelhead.
- Work conducted by Weigel et al. (this volume) begins to address this question in the Methow basin. Similarly genetic data from resident red-band rainbow trout are being collected by the Wild Fish Conservancy in Icicle Creek. We believe that continued research should focus on areas with large red-band rainbow populations such as the Methow and Okanogan subbasins.

Next Steps

(Priority Tier-1 data gaps in need of funding)

- An analysis of spring Chinook genetic samples collected in the Entiat Subbasin is needed to assess VSP diversity criteria for de-listing.
- A reference condition for genetic variation for steelhead and spring Chinook in the Upper Columbia needs to be developed so that we can better define the VSP diversity goal and how to track progress toward that goal.
- Patterns of genetic diversity are a high risk factor for all Upper Columbia spring Chinook and steelhead populations. Consistent and efficient genetic analyses are prominent data gaps.
- Determine the effects of exotic species and predatory native species on recovery of salmon and steelhead and the feasibility to eradicate or control their numbers.

Columbia Basin-Wide RM&E Assessment

Chuck Peven

Chuck is a Fisheries Biologist with Peven Consulting, Inc. and member of the UCRTT's Monitoring and Data Management Committee.

During 2009, a series of sub-regional and regional workshops were convened by NOAA, CBFWA, BPA, and NPCC. These workshops were well attended with representations from federal, state, and tribal agencies as well as observers from the ISRP, ISAB, and PNAMP. The purpose of these workshops was to develop an efficient and effective framework and implementation strategy for anadromous salmon and steelhead monitoring for viable salmonid population criteria (VSP) and related FCRPS BiOp habitat and hatchery action effectiveness monitoring. In addition, these workshops also produced a prioritized list of monitoring gaps, recommendations to address these gaps, and a prioritized list of projects for implementing the Anadromous Salmonid Monitoring Strategy (Figure 1).

In addition to the workshops, workgroups led by the Action Agencies, NPCC, and NOAA Fisheries have developed a report entitled, Recommendations for Implementing Research, Monitoring and Evaluation for the 2008 NOAA Fisheries FCRPS BiOp that evaluated whether current work funded by the Action Agencies was covering all of the RPAs in the FCRPS BiOp that relate to RM&E. This report can be found listed under "2008 FCRPS BiOp Research, Monitoring and Evaluation" at: http://www.salmonrecovery.gov/ResearchReportsPublications.aspx.

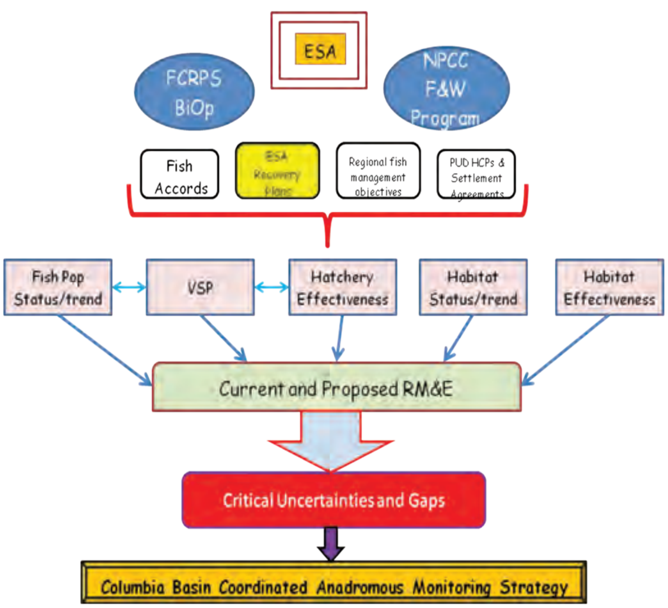


Figure 1. The Columbia Basin Coordinated Anadromous Monitoring Strategy is informed by fisheries management mandates, monitoring approaches and programs , as well as uncertainties and data gaps.

Appendices

Appendix A: The Process Used to Develop the Key Management Questions

The 2010 Upper Columbia UCRTT Analysis Workshop was built around a list of key management questions, with sessions and discussion designed to address, as far as possible, each of the questions on the list. While not comprehensive, this list of management questions was derived from two main sources: Appendix P to the Upper Columbia Spring Chinook and Steelhead Recovery Plan and the NOAA Guidance for Monitoring Recovery of Salmon and Steelhead.

Appendix P of the *Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan*:

The *Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan* (Recovery Plan), as adopted by NOAA in October 2007, contained a placeholder for a Monitoring and Evaluation Plan and although a draft of Appendix P existed before the formal adoption of the Recovery Plan, it was not completed in time to be included in the original adoption. The draft Appendix P was reviewed by the UCRTT, which sent comments to NOAA in a memo dated 20 August 2007. NOAA received the UCRTT comments, and revisions to Appendix P, including the addition of management questions that would be answered by monitoring in the Upper Columbia, beginning in June 2008.

NOAA Guidance for Monitoring Recovery of Salmon and Steelhead:

In early October 2008, while Appendix P was still being revised, NOAA released a draft "Guidance for Monitoring Recovery of Salmon and Steelhead" document. The NOAA guidance gave long-awaited direction on priorities for salmon recovery monitoring programs and included key management questions.

Revised Appendix P:

Appendix P, still under revision when the draft NOAA guidance was released, was modified to be consistent with that guidance. A revised Appendix P was delivered to the UCSRB by NOAA in early November 2008 and is currently in use. The list of questions in the current version of Appendix P was heavily influenced by the NOAA Guidance.

UCRTT Review of the Key Management Questions List:

As part of the preparations for the 2010 UCRTT Analysis Workshop, the committee of the UCRTT responsible for planning the workshop reviewed the list of management questions from Appendix P in January 2009. Discussion was held in the committee about the potential to answer each of the questions in the workshop, given current data and existing monitoring and research programs. A subset of the Appendix P questions was selected as being at least partially answerable using existing data. This subset of the Appendix P questions created by the UCRTT committee became the list of Key Management Questions around which the UCRTT Analysis Workshop was formed.

Appendix B: The Process of Developing the Analysis Workshop and this Synthesis Report

The process for developing the 2010 UCRTT Adaptive Management Workshop and this Synthesis Report began with the completion of the list of Key Management Questions (KMQs; Appendix A).

The 2010 UCRTT Adaptive Management Workshop Agenda

The agenda of the 2010 UCRTT Adaptive Management Workshop was structured around the list of KMQs. The KMQs fit within five topic areas, so, five workshop sessions were structured to accommodate speakers who would present information relevant to all the KMQs. Each presenter was asked for an abstract and presentation material and was assigned a time slot on the agenda. A sixth session was also included to specifically wrap up the Workshop and discuss how information from the Workshop would be documented.

The Moderators and Session Panels

Members of the UCRTT were invited to serve as Moderators for each technical session and UCSRB staff moderated the wrap-up session. In addition to sheparding the presenters and audience through session agendas, moderators were also asked to keep track of discussions that were held after each presentation. At the end of each session, a discussion was held between the UCRTT, the audience, and a panel of each session presenter. The moderators were responsible for making sure that discussions from earlier in the session were continued and brought to bear on KMQs, in particular, the moderators focused on the following adaptive management questions:

- Were we able to answer the key management questions?
- If yes, then what are the answers?

- If no, then what do we need in order to answer the key management questions?

The panel discussion was also time for presenters to interact with each other, to consider how all the information from the session could be integrated, and for the UCRTT and audience to pose additional questions or comments. UCRTT deliberations on the Workshop results began in earnest during these panel discussions.

Drafting the Synthesis Report

The first step in drafting the synthesis report was to circulate and approve an outline. It was recognized from the beginning that this document would have to clearly convey complicated information to scientists and lay people alike. Therefore, a focus was on presenting summarized/synthesized information up front and boldly displayed. This would allow a busy reader to “scan the headlines.” Additional information, heavy with graphics, was presented to support the major findings. Finally, the report was organized, like the Workshop, with six chapters corresponding with the six sessions and the five topics of KMQs.

UCRTT Deliberations

The synthesis document not only captured the contents of the Workshop presentations but also focused on capturing the UCRTT’s deliberations about the Workshop results. The UCRTT spent significant time deliberating the workshop findings at their meetings in February, March, May, and June of 2010. Initially, deliberations were aimed at capturing overall impressions and at drafting responses to the KMQs. Subsequently, individual presentations were discussed in-depth and deliberations regarding these were integrated back into answers for the KMQs. Over time, the document took the present shape.

Adaptive Management Science Conference

The next step in the adaptive management process will be to present the Synthesis Report to the Board and the public. This is anticipated to occur in the fall of 2010 and will represent the culmination of the technical portion of the adaptive management process.

Appendix C: List of Acronyms

AMOVA Analysis of Molecular Variance

ANOVA Analysis of Variance

AP Abundance and Productivity

AREMP Aquatic and Riparian Effectiveness Monitoring Program

BACI Before After Control Impact

BiOP Biological Opinion

BOR Bureau of Reclamation

BPA Bonneville Power Administration

CBFWA Columbia Basin Fish and Wildlife Authority

CCNRD Chelan County Natural Resources Department

CSF Community Salmon Fund

CV Coefficient of Variation

DNA Deoxyribonucleic Acid

DPS Distinct Population Segment

EDT Ecosystem Diagnostic & Treatment

EMDS Ecosystem Management Decision Support System

ESA Endangered Species Act

ESU Evolutionary Significant Unit

FCRPS Federal Columbia River Power System

GIS Geographic Information System

HCP Habitat Conservation Plan

HUC Hydrologic Unit Code

HWS Habitat Work Schedule

IBI Index of Biotic Integrity

ICTRT Interior Columbia Technical Recovery Team

IMW Intensively Monitored Watershed

ISAB Independent Scientific Advisory Board

ISEMP Integrated Status and Effectiveness Monitoring Program

ISRP Independent Scientific Review Panel

KMQ Key Management Question

LWD Large Woody Debris

MaDMC Monitoring and Data Management Committee

NMFS National Marine Fisheries Service

NOAA National Oceanic and Atmospheric Administration

NPCC Northwest Power and Conservation Council

OBMEP Okanogan Basin Monitoring and Evaluation Program

pHOS Proportion of Effective Hatchery-Origin Spawners

PIBO PACFISH/INFISH Biological Opinion

PNAMP Pacific Northwest Aquatic Monitoring Program

PUD Public Utility District

RCO Recreation and Conservation Office

RME Research, Monitoring, and Evaluation

RMSE Root Mean Square Error

RPA Reasonable and Prudent Alternative

SAR Smolt to Adult Ratio

SRFB Salmon Recovery Funding Board

SS/D Spatial Structure and Diversity

UCSRB Upper Columbia Salmon Recovery Board

UCRTT Regional Technical Team

VSP Viable Salmonid Population

WAT Watershed Action Team

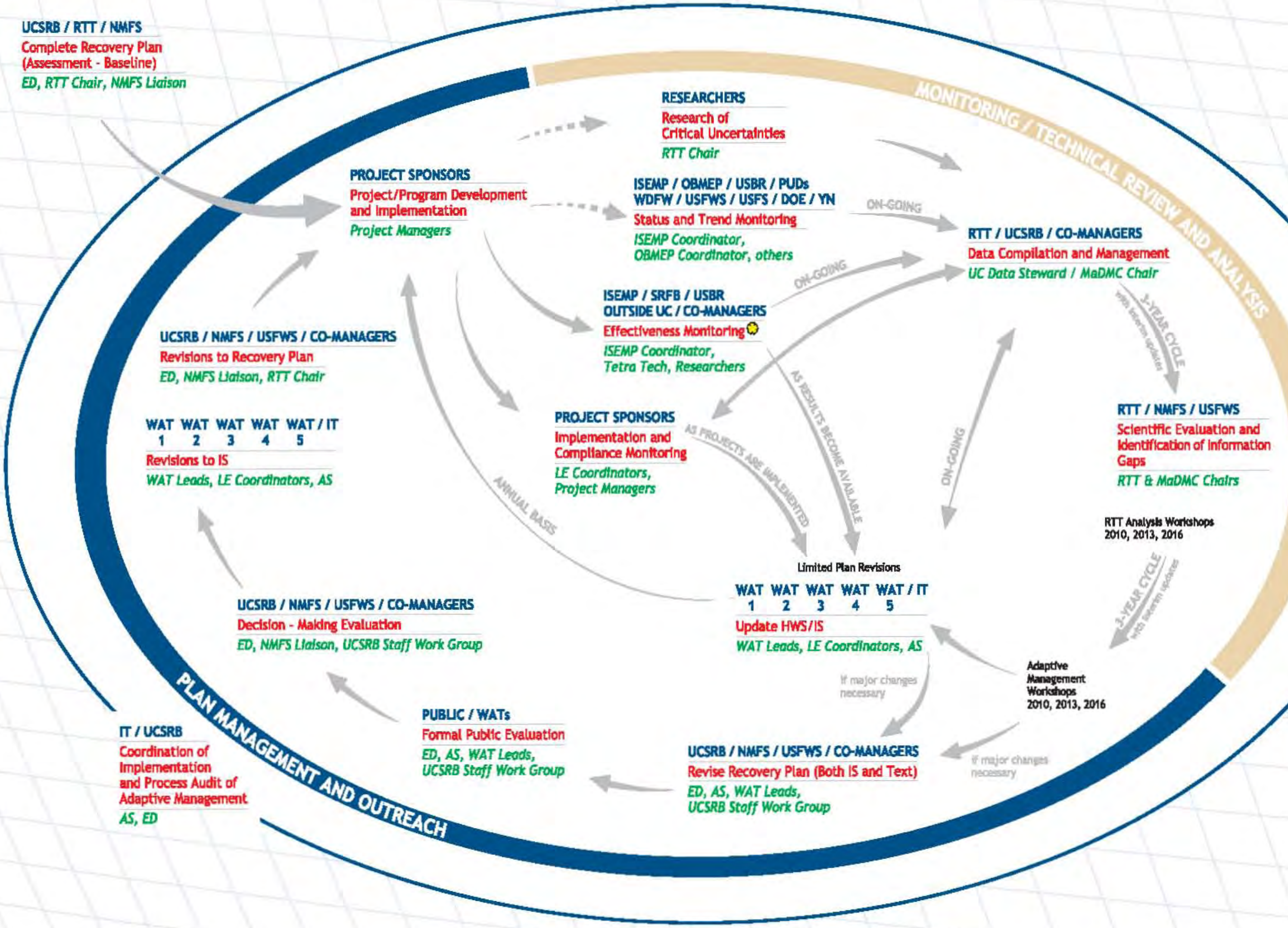
WDFW Washington Department of Fish and Wildlife

Appendix D: Bibliography

To access documents referenced in this UCRTT 2010 Analysis Workshop Synthesis Report, visit www.ucsrb.com.

HABITAT ADAPTIVE MANAGEMENT FRAMEWORK

- FOR UPPER COLUMBIA SALMON RECOVERY -



LEGEND

- Responsible Entities
- Activity
- Facilitator/Coordinator
- From outside UC as well

The WATs of the Upper Columbia:

Wenatchee Subbasin
Wenatchee Habitat Subcommittee of the Wenatchee Watershed Planning Unit (WWPU)

Entiat Subbasin
Entiat Habitat Subcommittee of the Entiat Watershed Planning Unit (EWPU)

Methow Subbasin
Methow Restoration Council (MRC)

Okanogan Subbasin
Similkameen Okanogan Watershed Action Team (SOWAT)

Douglas County Watersheds
Douglas County Watershed Planning Unit (DCWPU)

Acronyms

AS	Associate Director
DOE	Department of Ecology
ED	Executive Director
HWS	Habitat Work Schedule
IS	Implementation Schedule
ISEMP	Integrated Status and Effectiveness Monitoring Program
IT	Implementation Team
LE	Lead Entity
MaDMC	Monitoring and Data Management Committee
NMFS	National Marine Fisheries Service
OBMEP	Okanogan Basin Monitoring and Evaluation Program
PUD	Public Utility District
RTT	Regional Technical Team
SRFB	Salmon Recovery Funding Board
TRT	Technical Review Team
UCSRB	Upper Columbia Salmon Recovery Board
USBR	United States Bureau of Reclamation
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
WAT	Watershed Action Team
WDFW	Washington Department of Fish and Wildlife
YN	Yakama Nation

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