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Managing Water in the West

Methow River Subbasin Effectiveness Monitoring Program – *Final Report*

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The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

Methow River Subbasin Effectiveness Monitoring Program
– *Final Report*

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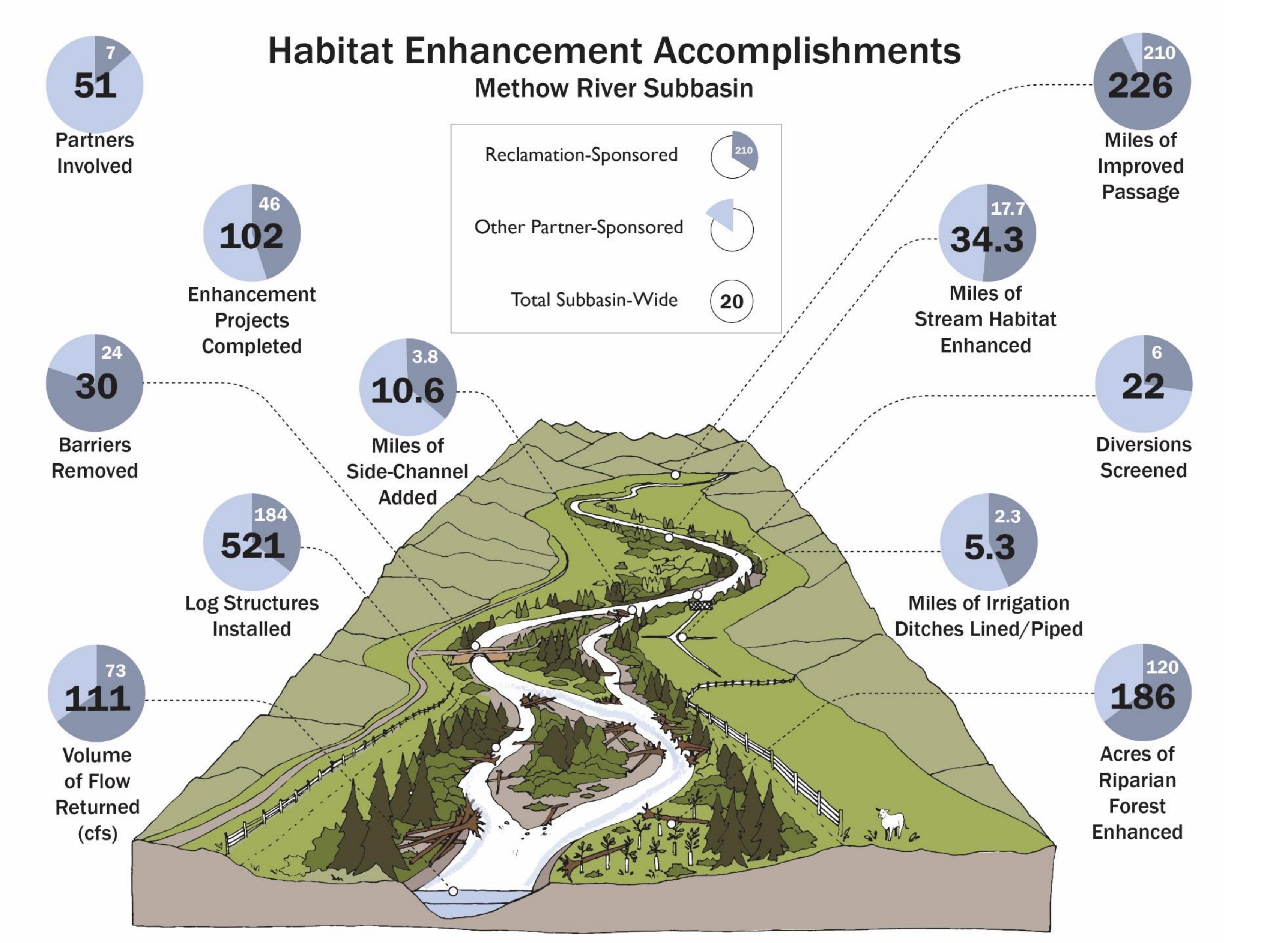
1 Executive Summary

In this report, the Pacific Northwest Region of the Bureau of Reclamation (Reclamation) summarizes research, monitoring, and evaluation (RM&E) activities associated with tributary habitat improvements that support salmon and steelhead in the Methow Basin that are listed under the Endangered Species Act (ESA). The Methow River is a tributary of the Columbia River. Since the listings, Reclamation invested significant resources in both RME and tributary habitat improvement activities in the Methow Basin as one aspect of implementing the Federal Columbia River Power System (FCRPS) Biological Opinion (BiOp). In this BiOp, Reclamation, with the Corps of Engineers (COE) and Bonneville Power Administration (BPA) consulted with NOAA Fisheries, on the continued operation and maintenance of the FCRPS. Reclamation operates Grand Coulee and Hungry Horse dams, 2 of the 14 dams covered in the FCRPS consultation. There are no FCRPS facilities in the Methow River or tributaries to the Methow River. Reclamation contributions to tributary habitat improvements for salmon, and the effectiveness of this work is conducted within a Framework of local and regional partners.

This report summarizes the RM&E efforts in the Methow Subbasin, with a focus on Reclamation's programs, but it also includes efforts by collaborating entities that help understand the effects of habitat actions on fish populations. The information presented in this report comes from a variety of sources, including salmon and steelhead status and trends monitoring, habitat action effectiveness monitoring, and ecological modeling.

1.1 Habitat Enhancement Actions

Numerous partners, including Reclamation, BPA, Yakama Nation and Colville Confederated tribes, natural resource agencies, utilities, private landowners, and non-profit groups have implemented a host of aquatic habitat enhancement actions in the Methow Subbasin over the past two decades. The type and quantity of enhancement actions have changed over time. Early projects from the late 1990s were primarily related to fish screening and passage and were largely carried out in response to initial salmon and steelhead ESA listings. Inadequate fish screens were upgraded and new ones were installed on unscreened diversions. Passage improvements included barrier removals associated with irrigation diversions in Beaver Creek in the mid-2000s that removed barriers to adult and juvenile fish. More recently, instream flow and habitat enhancement have been the focus in the subbasin, and these have occurred throughout the middle and upper mainstem Methow, the Twisp River, the Chewuch River, and in numerous smaller tributaries. Implementation of these habitat actions increased substantially beginning in 2008, with the largest number of actions implemented in 2013. These actions span a wide range of types, intensities, and sizes, and have resulted in a range of ecological responses. For a complete summary of all Action Agency habitat actions within the Columbia River Basin, please see the 2016 FCRPS Comprehensive Evaluation – Section 1 (AA 2016).


Habitat Enhancement Accomplishments
Methow River Subbasin
Reclamation-Sponsored
210
Other Partner-Sponsored
Total Subbasin-Wide
20
7
51
Partners Involved
46
102
Enhancement Projects Completed
24
30
Barriers Removed
3.8
10.6
Miles of Side-Channel Added
184
521
Log Structures Installed
73
111
Volume of Flow Returned (cfs)
210
226
Miles of Improved Passage
17.7
34.3
Miles of Stream Habitat Enhanced
6
22
Diversions Screened
2.3
5.3
Miles of Irrigation Ditches Lined/Piped
120
186
Acres of Riparian Forest Enhanced

1.2 Status and Trends Monitoring

Status and trends monitoring in the Methow includes on-going data collection efforts by numerous entities to document fish population status and trends over time. These include smolt trapping, redd surveys, carcass surveys, PIT-tagging programs, and various other efforts primarily aimed at identifying trends in fish population abundance and productivity. Most of this work has been done through hatchery effectiveness evaluation with WDFW and PUDs. Status and trends monitoring provides data that are useful for understanding life-stage survival bottlenecks and can also be used to evaluate the effectiveness of habitat enhancement actions in improving fish population performance.

Spawner abundance measures in the Methow have included redd surveys, carcass counts, and PIT tagging. Consistent redd surveys have occurred since 2002, carcass counts for spring Chinook have occurred since 2006, and PIT tagging has occurred in more recent years. The redd data show that spawning areas for spring Chinook are located throughout the middle and upper mainstem Methow (i.e., above the Twisp River confluence), the Twisp, the Chewuch, and in the lower reaches of large tributaries to these systems, with the greatest density of spawning in the Big Valley Reach of the Methow, which is located upstream of Winthrop. Steelhead spawning is more widespread, extending down to the mouth of the mainstem Methow and including numerous smaller tributary streams, with the greatest densities in the middle Twisp River and on the mainstem Methow around Winthrop and Mazama. In general, although there has been fluctuation in adult returns over the years, the adult data do not show any significant positive or negative trends over time.

Monitoring juvenile survival and growth is often a more effective way to isolate the effects of enhancement actions and to assess project effectiveness because juvenile performance is more closely associated with tributary habitat (i.e., Methow Subbasin). Smolt trap data were used in combination with spawner data to evaluate egg-to-emigrant survival for spring Chinook and steelhead in the Twisp River and for the Methow Subbasin as a whole. Although the Methow populations have not increased or decreased significantly over time, Twisp spring Chinook show the strongest positive trend, and have consistently shown the highest egg-to-emigrant survival. Increases in spring Chinook egg-to-emigrant survival in the Twisp may indicate a response to enhancement actions. However, there are many potential confounding variables, including natural fluctuations in habitat conditions, high standard error in some of the trap estimates, and the lag time between habitat improvements and population response.

1.3 Action Effectiveness Monitoring

Methow Subbasin action effectiveness monitoring is designed to evaluate the effects of specific salmon and steelhead enhancement actions at the site and reach scales. The two primary studies are the evaluation of fish passage projects in the Beaver Creek sub-watershed and evaluation of floodplain and channel habitat enhancement in the Methow

M2 Reach (Twisp to Winthrop) using a Before-After-Control-Impact (BACI) study design.

Effectiveness monitoring has demonstrated important benefits of habitat enhancement in the M2 Reach and has broadened our understanding of ecological processes. In the first year of monitoring following implementation of habitat enhancement actions, both the Whitefish Island and 3R sites experienced increased seasonal connectivity to the mainstem, increased overall habitat capacity, increased pool depths, and increased large wood cover; and each showed an increase in juvenile salmon and steelhead rearing densities compared to control sites (Martens et al. 2014). Subsequent years of post-treatment monitoring by Hutcherson et al. (2019) observed less drastic increases in juvenile abundance, with *Oncorhynchus mykiss* (steelhead or Rainbow Trout) abundances showing significant increases and higher volumetric densities (number of fish per cubic meter of habitat) of all species of juvenile salmonids in the fall. Although not conclusive, these results are generally consistent with findings from other studies in the Methow including at Hancock Springs (tributary to upper Mainstem Methow) and Elbow Coulee (Twisp River), as well as in other nearby basins such as the Entiat River, where it was found that constructed pools with wood and rock structures supported higher densities of steelhead and Chinook compared to untreated areas (Jorgensen 2014; BPA 2013; Polivka et al. 2015).

Studies of the effectiveness of fish passage enhancement in Beaver Creek demonstrate that passage was successfully restored to portions of Beaver Creek (Weigel et al. 2013; Grabowski 2013). Juvenile and adult steelhead migration were improved, and juvenile spring Chinook, Coho, and mountain whitefish were found upstream where they had not been detected before. This project did not include evaluating juvenile growth or survival before and after enhancement. Adult recolonization has occurred slowly following barrier removal and was possibly affected by the 2011 flood and 2014 forest fire and subsequent flooding.

1.4 Ecological Models

Evaluating project effectiveness in the Methow Subbasin has included the use of both qualitative and quantitative computer models that simulate ecological processes. These are based on ecological theory and use data collected in the field to create and test hypotheses about how habitat actions affect fish survival and production at a range of spatial scales. The results from these models, in addition to other research and monitoring work in the subbasin, facilitate our understanding of how enhancement actions function within complex ecological systems, and can help inform appropriate adaptive management and monitoring. The primary models include an Aquatic Trophic Productivity (ATP) model and a food web model, which were developed in collaboration with Reclamation, USGS, University of Idaho, and Idaho State University. The need for models in the Columbia River basin that incorporate food-web dynamics was identified by the Independent Scientific Advisory Board (ISAB) to better understand how salmon and steelhead populations might improve as a result of enhancement activities or management strategies (ISAB 2011a, 2011b). Various studies within and outside of the subbasin have been used to populate, calibrate, and verify the models.

The ATP model uses an energetics approach in which fish production and biomass are explicitly tied to transfers of energy within the food web. To simulate the ecological effects of habitat enhancement actions, the relative environmental inputs of the model can be adjusted to simulate habitat actions, allowing model output to predict the effects of the action on fish population performance. The model has been used to evaluate the expected response to specific habitat enhancement actions at three sites in the Methow Subbasin (Benjamin and Bellmore 2016). These include the Whitefish Island side channel, the Middle Methow (M2) reach, and the Twisp River Floodplain project. Results showed that all modeled enhancement actions resulted in increased fish biomass, but the magnitude of uplift varied depending on unique stream and project characteristics. A comparison of the model to data collected in the field support the fundamental model concepts and reinforces the continuation of enhancement work in the subbasin. Furthermore, the ATP model was used to evaluate enhancement action alternatives at the Barkley Bear segment of the M2 reach (Benjamin et al. 2018).

Modeling results for the Twisp River were relatively consistent with empirical fish data collected in the basin. The salmon carcass addition scenario improved modeled fish production the most by increasing the availability of high-quality food for fish and aquatic invertebrates. Both the side channel reconnection and increased habitat suitability scenarios increased modeled fish biomass, whereas riparian enhancement increased the seasonal availability of in-stream terrestrial detritus (for more details see Benjamin and Bellmore 2016).

Modeling results for the Whitefish Island side channel case study were also relatively consistent with empirical data. The model showed that improved habitat areas in both post-enhancement scenarios increased modeled fish biomass as a result of improved access to habitat and prey resources that were available year-round rather than seasonally. This finding is generally consistent with the BACI studies performed at this site (Hutcherson et al. 2019), which observed higher juvenile abundances for some life stages of *O. mykiss* and higher overall salmonid density in the fall following enhancement. These simulations suggest that the habitat improvements at Whitefish Island have improved the capacity of the side channel to sustain juvenile salmonids.

For the Middle Methow model case study, each of the scenarios resulted in increased salmonid biomass via different mechanisms. The side channel addition scenario and the improved habitat suitability scenario increased biomass of all stocks, increased nutrient retention and assimilation due to longer residence time in the side channel, increased terrestrial leaf litter and invertebrate inputs from expanded riparian areas, and increased total available habitat within the river segment (Benjamin and Bellmore 2016).

1.5 Integrating Lessons Learned

All of these efforts, along with other relevant studies within the Methow and in other nearby basins, provide useful information on the effectiveness of habitat enhancement. There are many lessons learned from these endeavors, ranging from the effectiveness of specific treatments at the habitat unit scale to the effectiveness of multiple large enhancement actions at the reach scale. Summaries of key findings and lessons learned, as well as the recommendations for future actions based on these findings, are provided in Section 7 of the report.

2 Introduction

2.1 Overview

This report summarizes the US Bureau of Reclamation (Reclamation) and collaborating agencies' research, monitoring, and evaluation (RM&E) efforts related to the effectiveness of habitat enhancement actions for ESA-listed salmon and steelhead in the Methow River Subbasin. This report is an update to Reclamation's 2012 Methow IMW Annual Report (Reclamation 2013) and describes the current status and findings of the effort. This report focusses primarily on Reclamation-funded RM&E, but also synthesizes information from collaborating entities that adds to our understanding of habitat action effectiveness in the Methow. A summary of habitat enhancement actions that have been performed over the years throughout the subbasin is also included to provide context for the overall effort. With a few exceptions that are noted in the report, the information presented here is a summary and synthesis of existing data and studies, and readers are encouraged to consult the primary sources of specific studies for additional information.

Reclamation's monitoring effort in the Methow Subbasin aimed to evaluate the effectiveness of Upper Columbia River (UCR) Spring Chinook Salmon (hereafter 'spring Chinook') and UCR Steelhead Trout (hereafter 'steelhead') habitat enhancement measures in order, in part, to identify future adaptive management actions. The program evolved into a modified version of an Intensively Monitored Watershed (IMW) study. The classic definition of an IMW is a large-scale experiment with a well-developed, long-term monitoring program to determine population/watershed-scale fish and habitat responses to enhancement actions (Bennett et al. 2016). However, the Methow Subbasin's effectiveness monitoring study design differs from the other more traditional IMWs in the region in that it relies primarily on a modeling framework supported by data collected in the Subbasin, and therefore does not meet the classic definition of an IMW. For this and other reasons discussed in Section 2.4, this report refers to the monitoring effort in the subbasin as an effectiveness monitoring study rather than as an IMW.

This report synthesizes information from a variety of RM&E efforts in the subbasin, including fish status and trends monitoring, habitat monitoring, a site-specific habitat action effectiveness monitoring study, a fish food-web study, hatchery effectiveness monitoring and other projects. These various efforts provide useful information on their own, and also contribute data to the development of ecosystem and life cycle analyses, which are used as a tool to test hypotheses about the effects of habitat actions on fish. The combination of all these research and monitoring efforts allows for the evaluation and prediction of fish population responses to enhancement actions at multiple scales. Much of the RM&E work in the Subbasin, primarily at the broader watershed levels, is ongoing. This report is intended to be a synthesis and integration of these various studies as a means to update our understanding of the effectiveness of habitat actions. In most cases, the report is not intended to be the primary technical source for the studies that are presented. In the few instances where new data analysis was performed as part of this effort, it is described in those sections.

The goals of this report are the following:

1. Summarize Reclamation's tributary RM&E efforts in the Methow River Subbasin.
2. Identify key findings and lessons learned from the Methow RM&E efforts to inform and improve future habitat enhancement actions and monitoring in the subbasin for restoration planners and practitioners. To the extent possible given the available information, summarize what has been learned to date to help inform the following questions (in no particular order):
    a. What are the effects of individual habitat improvement actions? Are benefits resulting from habitat improvement actions sustained over time?
    b. Were some actions more effective than others in producing desired fish responses?
    c. What are the juvenile spring Chinook and steelhead abundances (e.g. smolts out) over time for the period 1996-2017 (or as data are available)?
    d. What are the relationships between habitat actions and fish survival or productivity in this subbasin?

This report includes the following sections:

Introduction – This introduces the overall effort and sets the work within the context of the watershed and Reclamation's tributary RM&E efforts.

Habitat Enhancement in the Methow – This is a summary of habitat enhancement actions undertaken by Reclamation and other partners in the subbasin since the late 1990s. A complete enhancement action list is included as an appendix.

Status and Trends Monitoring – This includes summaries and analyses of fish monitoring data in the basin from approximately 2002 to 2017, or where data are available.

Habitat Action Effectiveness Monitoring – This includes results of site-specific habitat enhancement effectiveness monitoring, including the two primary studies funded by Reclamation – Beaver Creek and the middle Methow (M2 Reach).

Aquatic Trophic Productivity Model – This includes a summary of the ATP model and describes results from model simulations that predict the effectiveness of enhancement actions.

Key Findings and Lessons Learned – Key findings from the numerous RM&E efforts are integrated and presented by topic to help inform future enhancement and monitoring.

Annotated Bibliography – This includes brief summaries of published and unpublished information that pertains to habitat enhancement effectiveness in the Methow Subbasin. It is included as an appendix.

2.2 Action Agency Tributary Habitat Improvement Efforts

Much of the work for salmonid habitat enhancement[1] and monitoring in the Methow River Subbasin is implemented either directly or indirectly as a result of commitments required under the Endangered Species Act (ESA). Following decades of precipitous declines in abundance, spring Chinook and steelhead in the Methow Subbasin were added to the Endangered Species list in the late 1990s – the UCR Summer Steelhead Evolutionarily Significant Unit (ESU) was listed in 1997 as “Threatened” and the UCR Spring Chinook ESU was listed in 1999 as “Endangered”.

Human development (utilization and provision of living spaces, water, electricity, food, and multiple other resources) has altered much of the salmon and steelhead habitat in the Columbia River Basin. These fish are affected by numerous human impacts throughout their life cycles. These impacts are sometimes referred to as the 4 “H” s – Harvest, Habitat, Hatcheries, and Hydropower. Fish destined for the Methow Subbasin pass 9 dams on the Columbia River during both their juvenile and adult migrations. Four of these dams are part of the Federal Columbia River Hydropower System (FCRPS). The FCRPS consists of 14 hydropower facilities in total located within the Columbia River Basin, which are operated by either the US Army Corps of Engineers or the US Bureau of Reclamation. The Bonneville Power Administration (BPA) markets the power generated from these facilities. Collectively, these three federal agencies are known as the Action Agencies. Beginning in 2000 (and updated most recently in 2019), NOAA Fisheries issued a Biological Opinion (BiOp) on the FCRPS, which directed the Action Agencies to take measures to improve conditions for ESA-listed salmon and steelhead. In addition to measures that relate specifically to the operation of the hydropower system, the BiOp also includes measures in the other “H” s – Harvest, Habitat, and Hatcheries, plus predator management and RM&E.

Accordingly, several of the measures in the BiOp, termed Reasonable and Prudent Alternative actions (RPA actions), call for habitat improvement activities to be implemented in tributary basins such as the Methow. RPA actions 34 and 35 outline the types of tributary habitat actions to be implemented. Specific habitat enhancement actions are developed by local experts and are guided by current salmon research and monitoring.

[1] A number of terms are used in the literature to describe this type of work, including restoration, rehabilitation, mitigation, creation, improvement, and enhancement (NRC 1996; Roni and Beechie 2013). As the definition of restoration is to return an ecosystem to its original, pre-disturbance state, this document avoids the use of the term restoration in favor of enhancement when referring to actions that rehabilitate, mitigate, create, or improve habitat conditions.

In addition, these implementation-focused RPA actions are complemented by an RM&E program to evaluate action effectiveness. The objective of habitat RM&E is to help answer specific management questions regarding habitat improvement actions, provide a scientific basis for future actions, and evaluate the extent to which tributary habitat BiOp performance standards are being accomplished. RPAs pertinent to RM&E in the Methow primarily include RPAs #50 and #51, which require monitoring of fish population status and trends, and RPAs #56 and #57, which require the monitoring of tributary habitat actions to evaluate the relationships between fish productivity and action effectiveness. In combination, the tributary habitat enhancement and effectiveness monitoring RPA actions form the underlying framework for the Methow effectiveness monitoring effort.

The FCRPS BiOp is an important element of a larger regional effort to conserve and restore Columbia River Basin salmon and steelhead and the ecosystems that support them under the Endangered Species Act and the Northwest Power Act. This includes a suite of additional NOAA BiOps addressing the effects of other federal actions on salmon and steelhead in the Basin, including federal land management, in-river harvest, ocean harvest, hatcheries, water quality standards, floodplain management, and toxics. It also includes additional BiOps with the United States Fish and Wildlife Service addressing Bull Trout and Kootenai River White Sturgeon. In addition, it includes broad actions being implemented by federal agencies and non-federal dam owners under the Northwest Power Act, including actions that protect and enhance non-listed salmon and steelhead, resident fish, and wildlife. From an ecosystem perspective, the Action Agencies alone are funding a multitude of actions to benefit both fish and wildlife each year. Funding is provided by the electric ratepayers of the FCRPS, with additional funding provided to meet non-power project purposes, such as flood risk management and navigation, through Congressional appropriations.

In order to understand the full suite of recovery actions being performed for ESA-listed Upper Columbia populations, and their effectiveness, it is important to consider the other efforts beyond tributary habitat enhancement, and readers are encouraged to consult additional sources of information, such as NOAA Status Reviews, for this information.

2.3 Summary of Methow Effectiveness Monitoring Program

Although the Methow RM&E efforts do not fully meet the standards of an IMW, the study is based generally on the IMW concept, which includes detailed monitoring of adult and juvenile fishes, habitat actions, and environmental variables for the purpose of determining population status and informing recovery actions. As noted above, Bennett et al. (2016) defines an IMW as a large-scale experiment with a thorough long-term monitoring program from which fish and habitat responses to enhancement actions may be evaluated. Based on a framework developed by the Action Agencies, the Pacific Northwest Aquatic Monitoring Program (PNAMP), and NOAA Fisheries, monitoring within an IMW is typically conducted over multiple years and at various spatial scales in an effort to detect a response at multiple fish life-stages within populations. Specific hypotheses are often tested through before-after–control-impact (BACI) experiments, which monitor control and experimental sites before and after an enhancement action to isolate the effect of the action from other environmental variables. In many subbasins, including the Methow, supplemental data are provided for use in effectiveness monitoring studies by the Columbia Habitat Monitoring Program (CHaMP), which collects information at hundreds of sites across the Columbia Basin over a period of years, and is intentionally paired with population status monitoring.

The Methow program is different from traditional IMWs in that it does not employ a long-term watershed-scale experimental design that measures the effects of enhancement actions at the fish population scale. Instead, it incorporates a variety of RM&E study types, including a reach-scale BACI study, a watershed-scale fish passage study, numerous action-specific monitoring efforts, ecological modeling, and status and trends monitoring.

One of the more unique aspects of the Methow program is the use of a modeling framework to collect data and evaluate effectiveness of enhancement actions. The modeling framework incorporates both qualitative and quantitative computer models to simulate ecological systems. These models are based on ecological theory and are calibrated through extensive data collection. The models create and test hypotheses about how habitat actions affect fish survival and production at a range of spatial scales. They are used to help understand how enhancement actions function within complex ecological systems and can help guide appropriate adaptive management and monitoring. The primary model developed for the Methow is the Aquatic Trophic Productivity (ATP) model. Section 6 discusses the modeling efforts in greater detail.

Input data for the models has come from a variety of sources, including the following:

1. Fish habitat monitoring programs, such as the BPA- and NWFSC-supported CHaMP, the Aquatic-Riparian Effectiveness Monitoring Program (AREMP) and Pacfish/Infish Biological Opinion (PIBO) by the USFS, and the water quality monitoring program by Washington Department of Ecology (WDOE);
2. Fish production monitoring programs by WDFW, USFS, USFWS, and Yakama Nation (YN) monitoring the status and trends of salmon, steelhead and bull trout populations in the basin;
3. Effectiveness monitoring programs, such as the UCSRB's salmon recovery program, the Habitat Conservation Program by WDFW and Douglas County PUD, YN's Natural Production Program, BPA and NPPC's Fish and Wildlife Program, and Reclamation and FCRPS fish and habitat monitoring program;
4. Numerous Reclamation-funded academic research efforts through the University of Idaho and Idaho State University; and
5. Other basin or habitat action investigations funded by Reclamation and the other Action Agencies, such as BACI studies.

The modeling framework allows for simulations that predict potential fish benefits from a range of potential habitat enhancement actions. The benefits can be evaluated at specific life stages for target species and at a range of spatial scales. These predictions are useful for understanding the benefits of action types and for planning future habitat enhancement and management.

In addition to the modeling framework, there are numerous studies that provide important information on fish-habitat relationships and the effectiveness of enhancement actions. These efforts range from small site-specific monitoring to reach-scale analyses. The two primary studies include an evaluation of the effectiveness of fish passage enhancement in Beaver Creek and work in the middle mainstem Methow River to evaluate the effectiveness of floodplain and channel enhancement using a BACI study design.

Status and trends monitoring programs by resource agencies and the Yakama Nation can also help to understand the fish response to enhancement actions. These primarily include on-going juvenile and adult fish monitoring programs. Data from these efforts allow for the evaluation of trends in fish production and survival over time as enhancement actions in the basin have increased. These data can also help to better understand factors affecting juvenile fish survival in the Subbasin, such as density dependence dynamics, which along with the information described previously, can help to plan future enhancement efforts.

2.4 Methow Effectiveness Monitoring Effort Coordination and History

This Methow effectiveness monitoring study is a collaborative effort among numerous partners, including the Upper Columbia River Salmon Recovery Board (UCSRB), the Methow Conservancy, the Washington Department of Fish and Wildlife (WDFW), the Washington Department of Ecology (WDOE), the Douglas County Public Utility District (DCPUD), the Yakama Nation (YN), the U.S. Fish and Wildlife Service (USFWS), the Northwest Fisheries Science Center (NWFSC), Methow Salmon Recovery Foundation and the U.S. Forest Service (USFS). Furthermore, research and monitoring work was funded through agreements between Reclamation’s Columbia-Snake Salmon Recovery Office (CSRO) and the U.S. Geological Survey – Columbia River Research Laboratory (USGS-CRRL), the Cooperative Ecosystem Study Unit at University of Idaho College of Natural Resources (U of I), and the Methow Salmon Recovery Foundation (MSRF).

Monitoring to collect information on pre-treatment conditions began in 2007-2008 and helped facilitate the development of the ATP and food web models and life cycle analysis. These efforts included a fish habitat monitoring program, a fish production monitoring program, a barrier removal and steelhead passage survival and genetics study, a channel complexity pre-treatment food web and fish production study, a nutrient enrichment pre-treatment primary and secondary production study, a hatchery steelhead rearing study, and a steelhead relative (hatchery versus wild) reproductive success study. Efforts associated with these studies are summarized in the 2012 IMW Report (Reclamation 2013) and in the Methow Subbasin Monitoring Inventory (Crandall 2009).

An action effectiveness BACI study on the middle Methow River (M2 Reach) has been a particular focus of the effectiveness monitoring program and has assisted with data calibration and validation of the ATP model. Reclamation initiated the BACI study to evaluate the effects of habitat enhancement actions in the M2 Reach (Twisp to Winthrop) of the Methow. After three years of baseline data collection, side-channel enhancement actions including Whitefish and the M2-3R project were implemented between 2013 and 2014, with post-implementation monitoring documenting conditions and fish use from 2015 to 2018. Results from this effort are included in Hutcherson et al. (2019) and are summarized in this report.

In addition to the M2 Reach actions that are part of the BACI study, there have been numerous other habitat enhancement actions in the Methow, including: the replacement of fish migration barriers at irrigation diversions with rock vortex weirs; culvert replacements for increased habitat access; increasing access to existing side channels for refuge and rearing for juvenile fish; creation of new off-channel habitat; riparian improvements to stabilize eroding streambanks and provide shade to decrease water temperatures; placement of large woody material for instream habitat complexity; and the reconnection of floodplains to the mainstem Methow and tributaries. A map and discussion of the various enhancement actions in the subbasin are provided in Section 3. Reclamation plans to continue to work with Project Sponsors and partners to provide funding support and technical assistance depending on yearly budgets and FCRPS ESA consultation guidance in the Methow Subbasin.

Localized and basin-wide monitoring is currently ongoing and will allow for future additional comparisons of pre- and post-enhancement conditions. These efforts primarily include status and trends monitoring by numerous different entities, which will continue to provide information useful to the Methow Subbasin effectiveness monitoring effort.

3 Habitat Enhancement in the Methow

3.1 Habitat Enhancement Programs and Cooperating Entities

Habitat enhancement has been ongoing in the Methow Subbasin since the 1990s and has been performed by numerous entities as part of various different programs. Reclamation and other Action Agencies have supported enhancement work as part of BiOp commitments. Other major programs that have supported enhancement actions in the basin include the Northwest Power and Conservation Council's (NPCC) Fish and Wildlife Program, Washington State Salmon Recovery Planning, the Columbia Basin Fish Accords, and Douglas, Chelan, and Grant County PUDs habitat programs (i.e., Habitat Conservation Plans Tributary Committees and the Priest Rapids Coordinating Committee Habitat Subcommittee). The Council's Fish and Wildlife Program is funded through BPA and is part of their management of the federal hydropower system. Recovery Planning related efforts in the Methow basin are primarily administered through the UCSRB and include annual grants for habitat enhancement work. Accord projects in the Methow Subbasin are primarily performed by the Yakama Nation and the Colville Tribes. There are various other programs that have funded enhancement work in the basin and there are many different private and public entities that have performed individual habitat enhancement actions.

A variety of plans and assessments identify limiting factors, ecological concerns, and action opportunities and prioritizations. These include the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan (UCSRB 2007) and associated Biological Strategy (UCRTT 2014), the NPCC Subbasin Plan (NPCC 2004), the WA Conservation Commission's Limiting Factors Analysis (Andonaegui 2000), and Reclamation's Methow Geomorphic Assessment (Reclamation 2008). Numerous more detailed Reach Assessments have been performed at smaller spatial scales to identify sources of stream impairment, limiting factors for target species, and specific action opportunities. Reclamation, the Yakama Nation, the Methow Salmon Recovery Foundation (MSRF), and the Cascade Columbia Fisheries Enhancement Group have assessed over 155 river miles (approximately one-fifth of the entire stream length in the watershed) throughout the Methow Subbasin using Reach Assessments since 2008 (Table 1).

Table 1. Reach assessments carried out in the Methow Subbasin.

Reach assessment	River miles	Entity	Completed
Twisp to Carlton reach assessment	29 – 40	Cascade Columbia Fisheries Enhancement Group	2017
Middle Methow (LRT) project opportunity assessment	41.1 – 45.5	Yakama Nation	2011
Middle Methow (M2) reach assessment	41.5 – 50	Reclamation	2010
Winthrop (W2) geomorphic/ecological assessment	50 – 55	Yakama Nation	2011
Methow River – Wolf Creek to Winthrop	51.5 – 54.2	Reclamation	2012
Big Valley reach assessment	55 – 62	Reclamation	2008
Upper Methow reach assessment	61 – 80	Yakama Nation	2016
Lower Twisp reach assessment	0 – 7.8	Yakama Nation	2010
Middle Twisp reach assessment	7.8 – 18.1	Yakama Nation	2015
Chewuch River reach assessment	0 – 20	Yakama Nation	2010
Lower Libby Creek reach assessment	0 – 1.4	Yakama Nation	2012
Beaver Creek reach assessment	0 – 11.1	Yakama Nation	2017
Upper Twisp River and tributary habitat assessment	18.1 – 30.3	Yakama Nation	2018
Lower Methow River Reach Assessment	0 – 30	Methow Salmon Recovery Foundation	In progress

3.2 Action Types and Locations

A wide variety of actions have been implemented to improve salmonid habitat. These range from irrigation efficiency improvements to in-stream habitat enhancement actions (Figure 1). The subsections below provide brief descriptions of each action type and pie charts show the number of actions implemented in each subbasin of the Methow. Some enhancement actions are discussed in greater detail later in this report, and a complete list is available in Appendix A. The enhancement actions that are included here are those implemented to directly improve or protect aquatic or riparian habitat for salmonids. Including other action types, such as road decommissioning or other hillslope process-oriented projects, was outside the scope of this effort. However, it is recognized that these other actions can have important benefits to watershed functions that influence aquatic habitat. The categorization of enhancement actions below is consistent with those identified in the FCRPS Comprehensive Evaluations (2013, 2016).

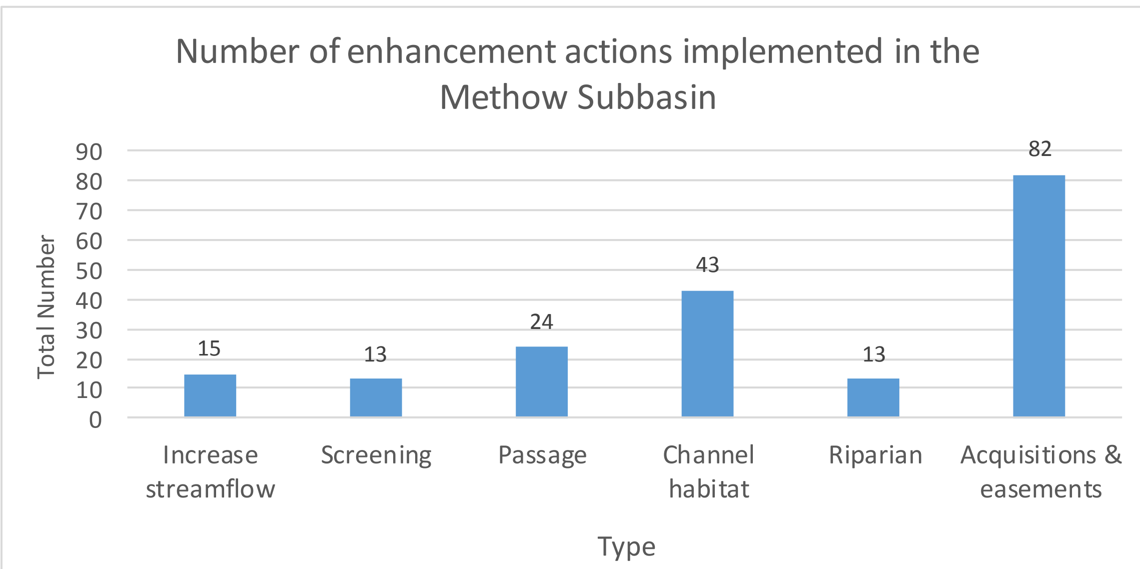
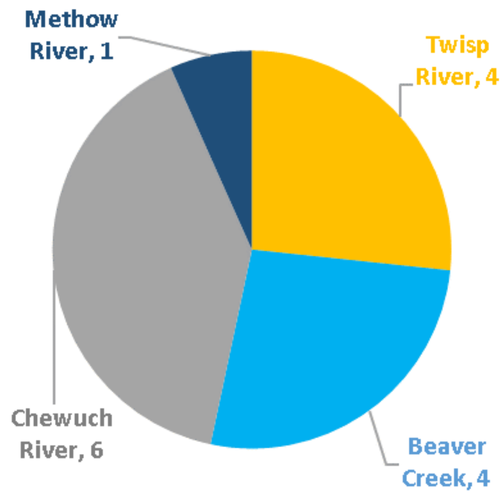


Figure 1. Total number of actions by type implemented in the Methow Subbasin since 1998.

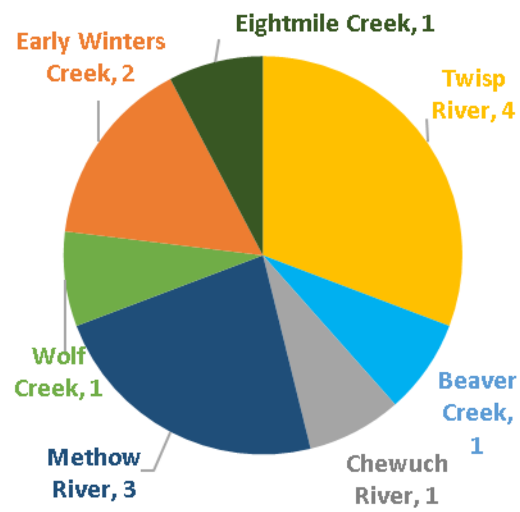
3.2.1 Instream Flow Improvement



Instream flow actions increase instream flow through water right acquisitions, diversion conversions, and irrigation efficiency improvements (the figure to the right shows number of projects by subbasin). Acquisitions involve directly leasing or purchasing water rights and transferring them to instream rights for at least a portion of the year (typically summer baseflow). Conversions include converting direct stream withdrawals to wells. Efficiency improvements include upgrading open irrigation canals to pipe systems or lining irrigation canals to prevent seepage. All of these improvements can leave more water in streams for fish use, which is particularly important during late summer low flows. Instream flow improvements can make very impactful improvements to salmonid habitat, but quantifying the effect of these highly variable projects is challenging due to differences in timing, agreement type, and location, among others. The Chewuch River received the highest proportion of instream flow improvement actions, and it it estimated that at least 50 cfs have been returned to instream flows during low-flow periods.

Figure 2. A barrier road culvert on Poorman Creek, as well as an irrigation diversion immediately downstream of the culvert, were replaced in 2009 with a natural-bottom culvert and rock vortex weir that allow passage at all flows. Photo from Reclamation.

3.2.2 Fish Screening



Fish screening activities have been ongoing since the 1990s and typically entail installing or upgrading fish screens so they comply with NMFS standards. Fish screens are located at irrigation diversions and prevent juvenile fish from becoming entrained in the canal system. Upgrading damaged or non-compliant fish screens is important for limiting juvenile mortality due to entrainment in irrigation canals. Fish screening actions have been implemented throughout the Methow Subbasin. Some projects that have occurred on private property without funding support or that have occurred on the National Forest may not be included in this tally. As of the time of this report, all of the major known diversions in the subbasin have been upgraded with fish screens or have been otherwise configured to reduce or eliminate entrainment.

Figure 3. Upgraded diversion with fish screen on the Chewuch River.

3.2.3 Fish Passage and Access

Improving fish passage through barrier removal increases habitat connectivity for anadromous and resident fishes. The highest density of actions involving barrier removal in the Methow Subbasin has occurred in the Beaver Creek watershed. Approximately 6.5 miles of spawning and rearing habitat was cut off by a series of diversion dams. Removal of these dams and replacing culverts that limited fish passage with bridges successfully restored fish passage through the system and allowed steelhead to reestablish a breeding population upstream. All barriers in the mainstem of the Methow, Twisp, and Chewuch have been addressed; evaluations of additional barriers or partial barriers in the smaller tributaries is ongoing.

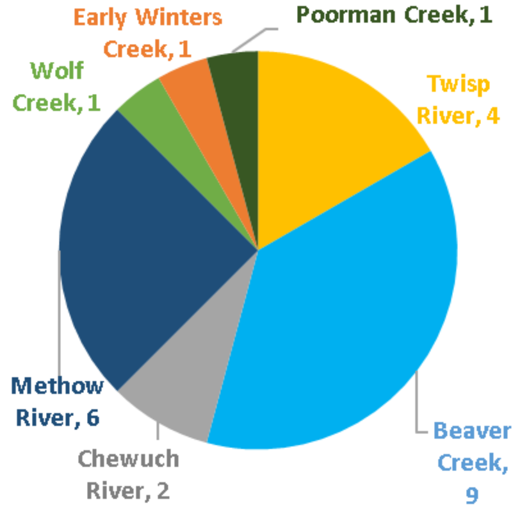
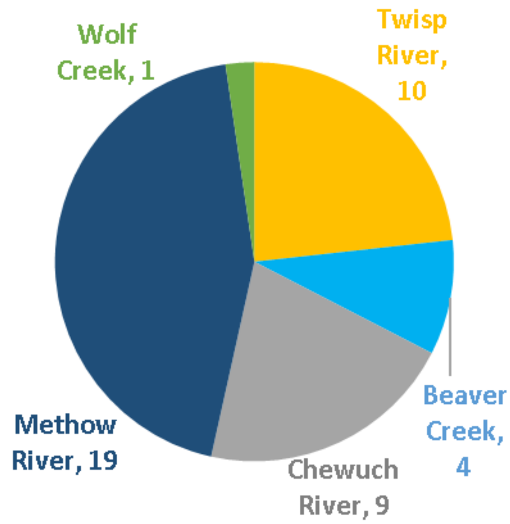


Figure 4. Failing double culverts were replaced with a channel spanning bridge on Beaver Creek to improve fish passage and geomorphic process.

3.2.4 Stream and Floodplain Enhancement



Stream and floodplain habitat enhancement includes improving habitat quality and quantity using a variety of treatment strategies targeting in channel or off-channel habitats. Treatments may include levee removal, channel modification, placement of large wood structures, off-channel habitat creation, pool creation, and placement of spawning gravels. These activities provide high quality rearing and spawning habitat immediately following implementation, and promote natural habitat forming processes in the intermediate and long term. Most habitat enhancement actions have occurred in the Methow, Twisp, and Chewuch Rivers.

In order to provide context for the magnitude of completed enhancement actions, we calculated the total length of stream treated with enhancement actions (from the project database – Appendix A) and compared it to: 1) the total length that has been identified as needing enhancement, and 2) the total length of stream occupied by anadromous fishes in the subbasin. Reach Assessments, or other related evaluations, were queried to estimate the lengths of streams in need of treatment. The results were tabulated by sub-watershed and for the subbasin as a whole and are included in Table 2. The Twisp River has had the highest proportion of anadromous stream length treated, followed closely by the Chewuch River and Beaver Creek. The Methow River and its tributaries have had the lowest proportion of anadromous length treated.

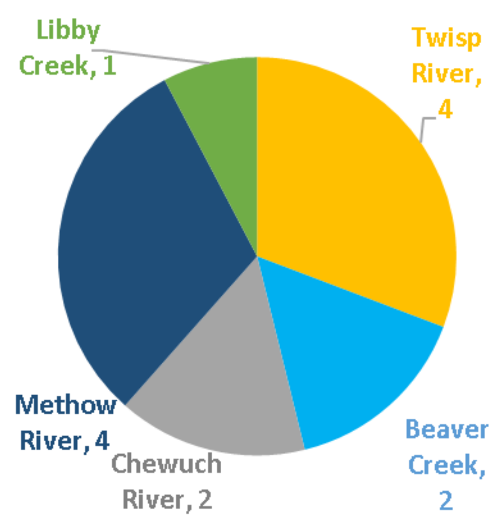
Table 2. Percentage of anadromous stream length and assessed stream length treated with enhancement projects.

Stream System	Percentage of "treatable" miles treated	Percent of anadromous miles treated
Methow*	21%	9%
Twisp*	51%	30%
Chewuch*	53%	25%
Beaver	20%	23%
Methow Subbasin Total	35%	17%

*Includes tributaries

Figure 5. Constructed large wood jam at Whitefish Island, mainstem Methow River (photo by Inter-Fluve 2016).

3.2.5 Riparian Rehabilitation

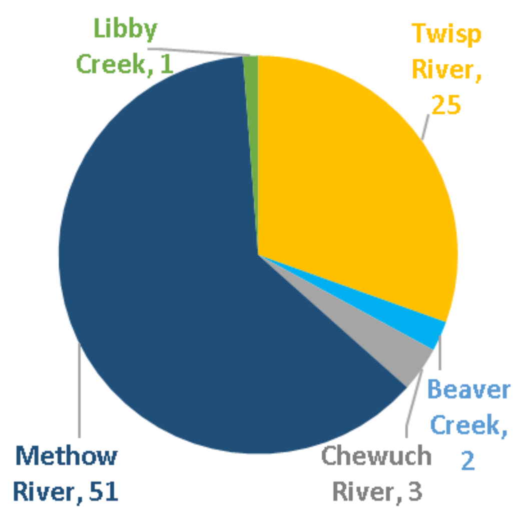


Riparian habitat enhancement actions typically involve planting native species and removing invasive species in riparian zones that have been negatively affected by logging, agriculture, or development. Riparian rehabilitation provides intermediate-term benefits of bank stabilization and long-term benefit of large wood recruitment, reduction of fine sediment inputs, and stream shade. Project numbers reported here include projects where riparian restoration was the primary emphasis, and do not necessarily include other restoration efforts where riparian restoration was a secondary project component. These numbers also do not include many riparian restoration efforts that have occurred on National Forest lands.

Figure 6. Riparian revegetation at the M2-3R site (photo by Inter-Fluve 2016).

3.2.6 Acquisitions and Easements

Acquisitions and easements are used to protect the ecological integrity of privately-owned stream habitat and riparian areas. Property may be acquired to protect existing high-quality habitat, or to allow for rehabilitation of degraded habitat. Conservation easements are written legal agreements between a qualified conservation organization and a private landowner that protect specific conservation values such as forests, riverfronts, and fish and wildlife habitat in perpetuity. The chart at right represents total number of acquisitions carried out in each subbasin.



The majority of the Methow Subbasin is publicly owned as part of the Okanogan National Forest (Figure 7). Other entities in the subbasin, such as the Yakama Nation and the Methow Conservancy, own lands and manage them largely for conservation purposes. The Methow Conservancy also owns numerous conservation easements on private properties within riparian zones and in other sensitive areas in the lower and middle Methow valley and the lower portions of tributaries. Of the reaches that have been assessed in the basin for enhancement action opportunities (i.e. areas covered by reach assessments), over one-third of the lineal feet of river frontage is either in public ownership or has been placed in a conservation easement (Figure 7).

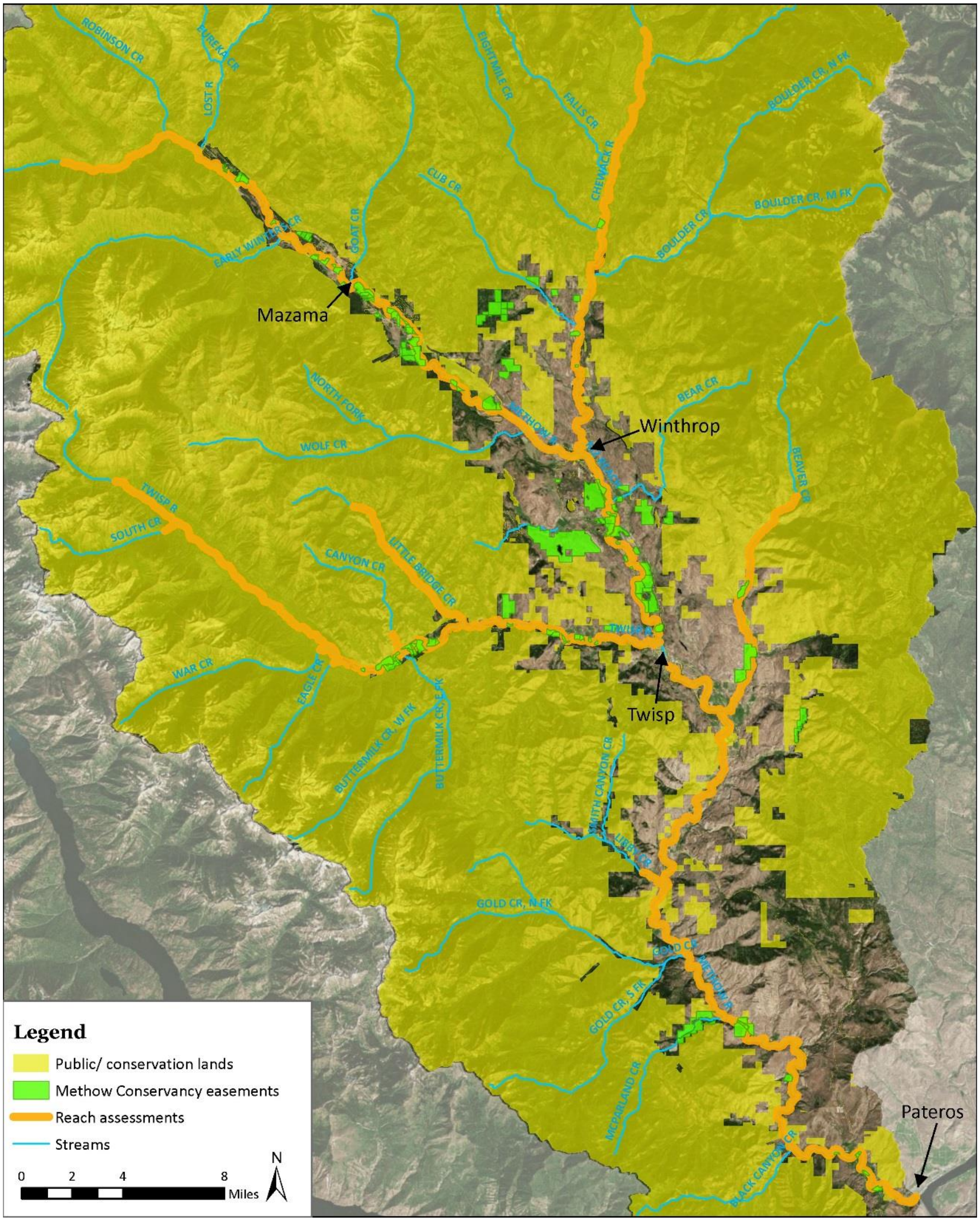


Figure 7. Conservation easements and lands owned by agency partners within the subbasin.

3.3 Subbasin Implementation Context

The type and quantity of habitat enhancement actions in the subbasin has changed over time since the 1990s (Figure 8). Actions from 1998-2003 were primarily related to fish screening and were carried out in response to ESA listings. Inadequate fish screens were upgraded and new ones were installed on unscreened diversions. Fish passage and access improvement actions represented a large portion of total actions from 2003-2010. Many of these were rock vortex weir installations in Beaver Creek. The majority of instream flow activities occurred from 2007 to 2013 with most occurring in the Chewuch River. Instream habitat improvement actions were primarily implemented starting in 2009 with a peak in 2013 to improve rearing habitat for juveniles. Since 2013, the number of enhancement actions implemented per year has decreased. However, the complexity and size of recent enhancement actions in the Subbasin has increased to compensate for the relative decrease in number of actions. Figure 9 shows action types by subbasin. Figure 10 and Figure 11 show the spatial distribution of assessments and enhancement actions in the Methow Subbasin.

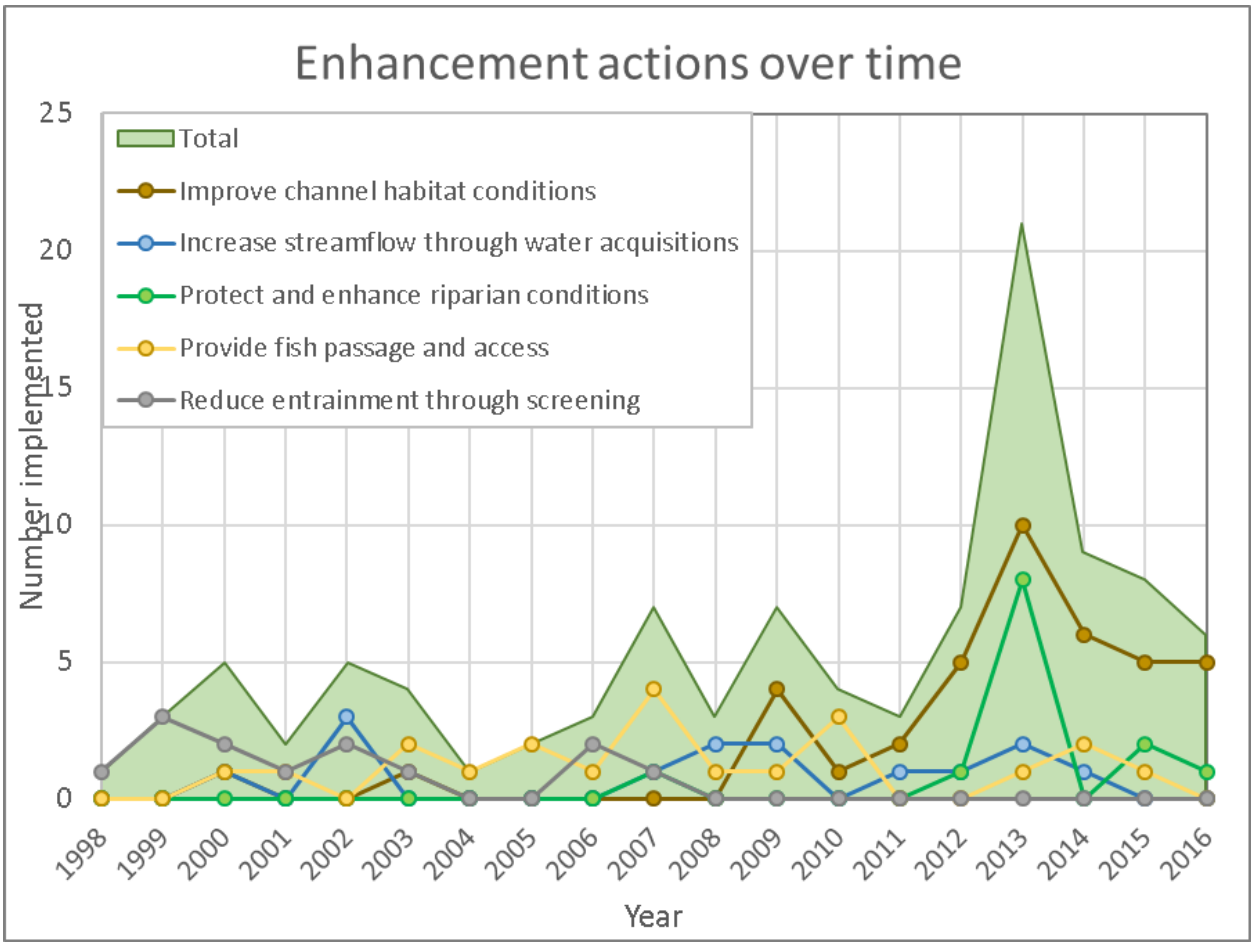


Figure 8. Actions implemented 1998 to 2016 by category. Acquisitions and easements are excluded from this figure.

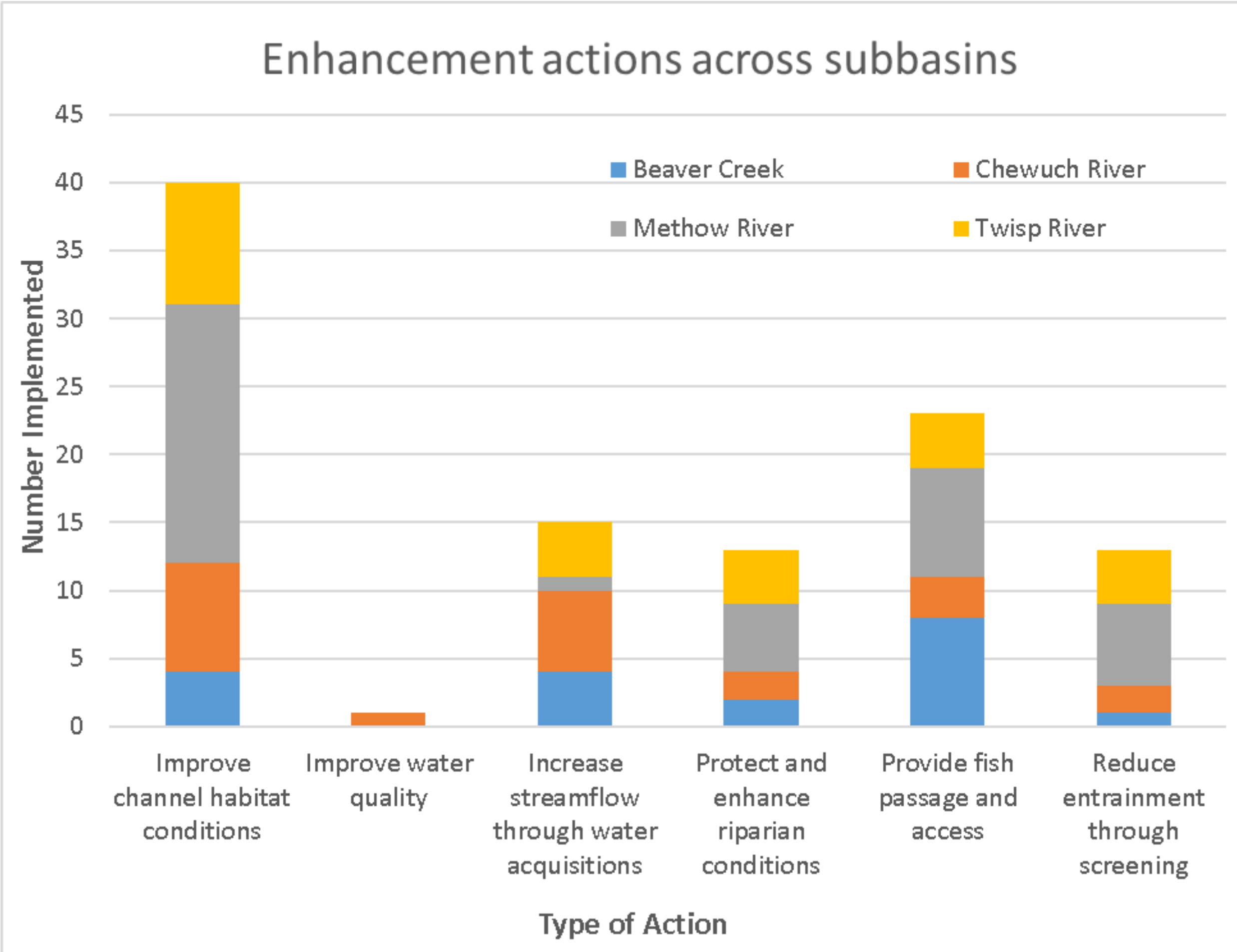


Figure 9. Total number of actions implemented in the Methow watershed since 1998.

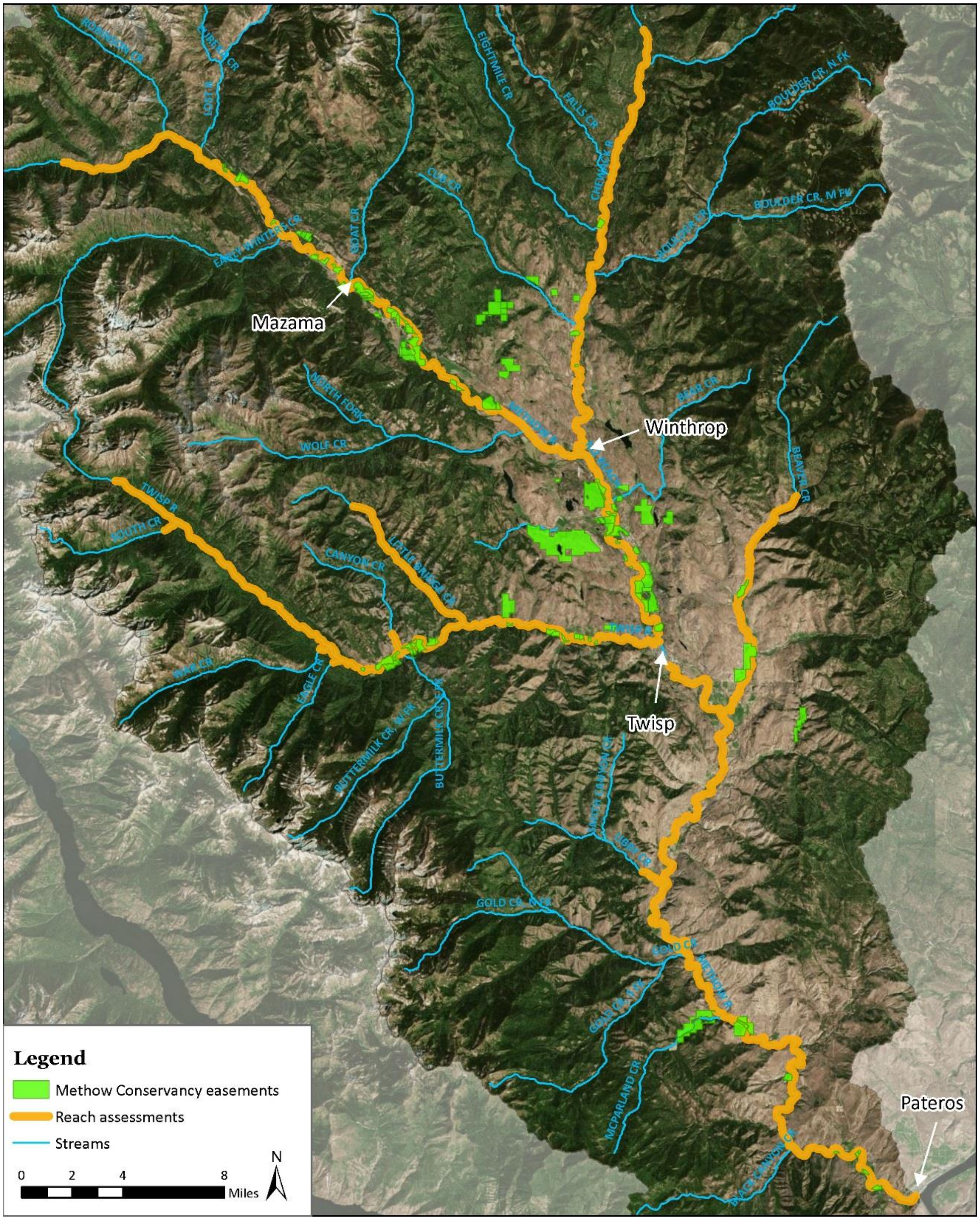


Figure 10. Reach assessments, easements, and implemented actions in the Methow Subbasin.

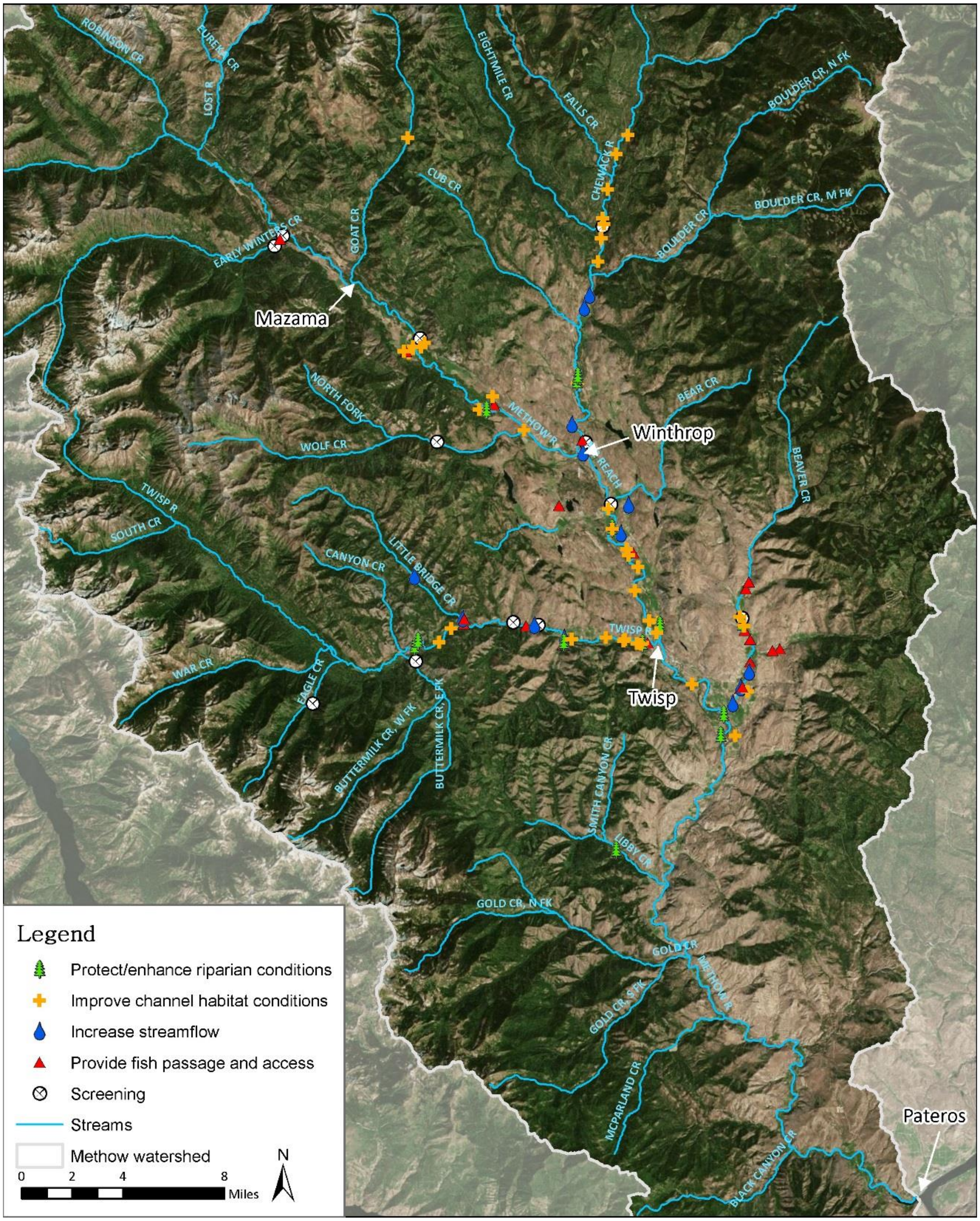


Figure 11. Habitat enhancement actions in the Methow Subbasin from 1998 to 2018.

4 Status and Trends Monitoring

For the purposes of this report, we consider status and trends monitoring to be the on-going data collection efforts by numerous entities to document fish population status and trends over time. These include smolt trapping, redd surveys, carcass surveys, PIT-tagging programs, and various other efforts primarily aimed at identifying trends in fish population abundance and productivity. There have also been efforts to document habitat conditions and trends throughout the subbasin (e.g. through stream habitat surveys) but incorporating these data was outside the scope of this effort. For this report, we have collected the most recently available status and trends data and have performed various new analyses in order to evaluate trends in fish population performance, especially as it relates to the on-going habitat enhancement work being performed in the subbasin.

Methow Subbasin monitoring data are available from a variety of sources at a range of spatial and temporal scales. Federal and state resource agencies, tribes, universities, consultants, and public utilities all conduct habitat and fish monitoring as a part of various programs. For the purposes of this report, specific datasets were obtained and summarized, and in some cases new analyses were performed to investigate trends in fish population performance and the potential relationship to habitat enhancement actions. It is important to point out, however, that these data were not collected for the purpose of evaluating habitat enhancement projects. Nevertheless, they are used here to help evaluate if populations are responding to habitat enhancement actions at the watershed and population scales.

At the time of this report, data from salmonid carcass surveys in the Methow Subbasin were available from 2006 to 2017 and redd count data were available from 2002 to 2016. Egg-to-emigrant estimates based on these data and the lag time between brood year outmigration and return to freshwater means no analyses were possible after year 2015. Future updates to this report will include additional years of data in these analyses. Unless otherwise noted, most of the data in this section were collected by WDFW under funding from Douglas PUD to support the Wells Dam Anadromous Fish Agreement and Habitat Conservation Plan. Details on collection methodology and additional data can be found in Snow et al. (2018).

4.1 Spawner Abundance

Spawner abundance monitoring sets the foundation for other types of life stage/ population-level monitoring and is an important viable salmonid population (VSP) parameter. Spawner abundance is used to scale expectations of smolt production and recruitment. Carcass surveys of spawned-out spring Chinook, redd counts of both steelhead and spring Chinook, and PIT-tagging data have all been used to measure spawner abundance. Surveys have included the entire distribution of spring Chinook and steelhead within the Methow Subbasin.

Carcass surveys have been carried out since 2006 on an annual basis in the Methow River and tributaries known to support spring Chinook spawning. Most spring Chinook spawners in the Methow Subbasin are hatchery fish. Numbers of both wild and hatchery spawners track together over time, with both hatchery and wild carcass counts exhibiting a recent decline from 2014 to 2017 (Figure 12). Spawner abundance is affected by both in- and out-of-basin variables, including tributary habitat conditions, ocean conditions, and harvest. Steelhead are iteroparous and carcass surveys are therefore not as informative of spawning activity.

Redd counts have been performed annually since 2002 in the Methow River and tributaries known to support steelhead and spring Chinook spawning (Figure 13). Redd counts for spring Chinook and steelhead do not show extreme positive or negative trends over time, though redd counts for steelhead have declined compared to those for spring Chinook in the same period. The highest redd densities for spring Chinook occur in the Methow River between Winthrop and Mazama, with moderately high spawning density in the Chewuch River near Boulder Creek and Falls Creek (Figure 14). Spawning in the Twisp is more dispersed for spring Chinook. The highest steelhead redd densities occur in the Twisp River near Buttermilk Creek and in the Methow River near Winthrop and Mazama. Spawning in the Chewuch is more dispersed for steelhead (UCSRB 2015).

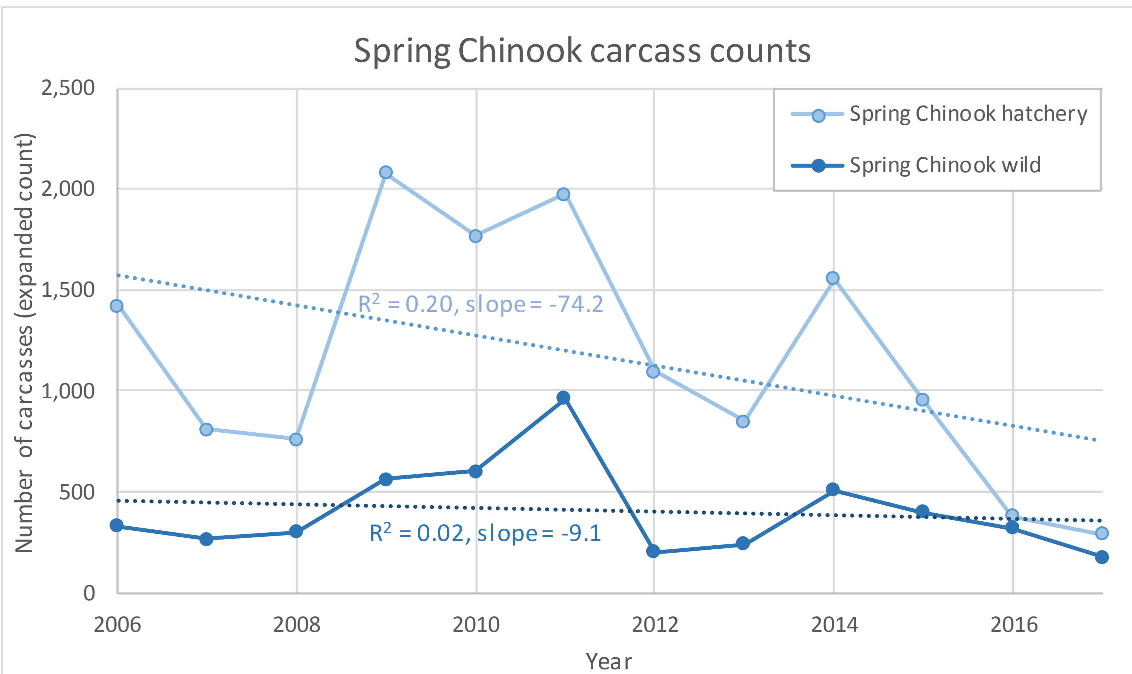


Figure 12. Spring Chinook carcass counts showing hatchery and wild fish (data from Snow et al. 2018).

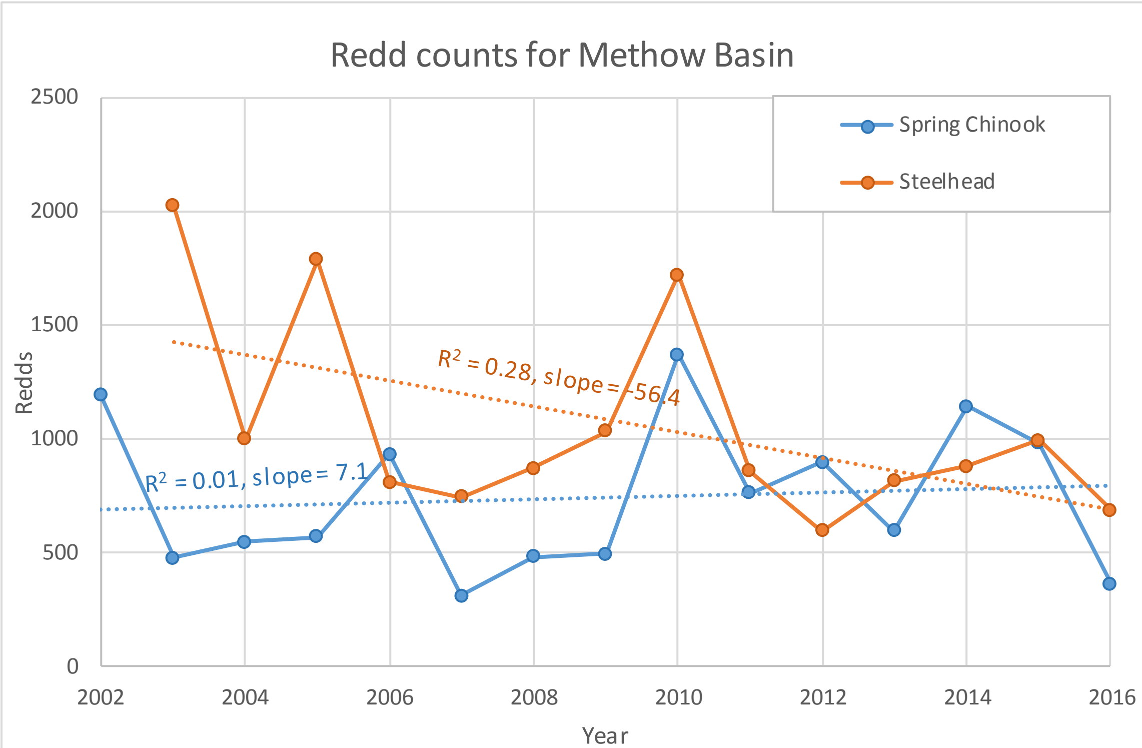


Figure 13. Redd counts for spring Chinook and summer steelhead in the Methow Subbasin (data from Snow et al. 2018).

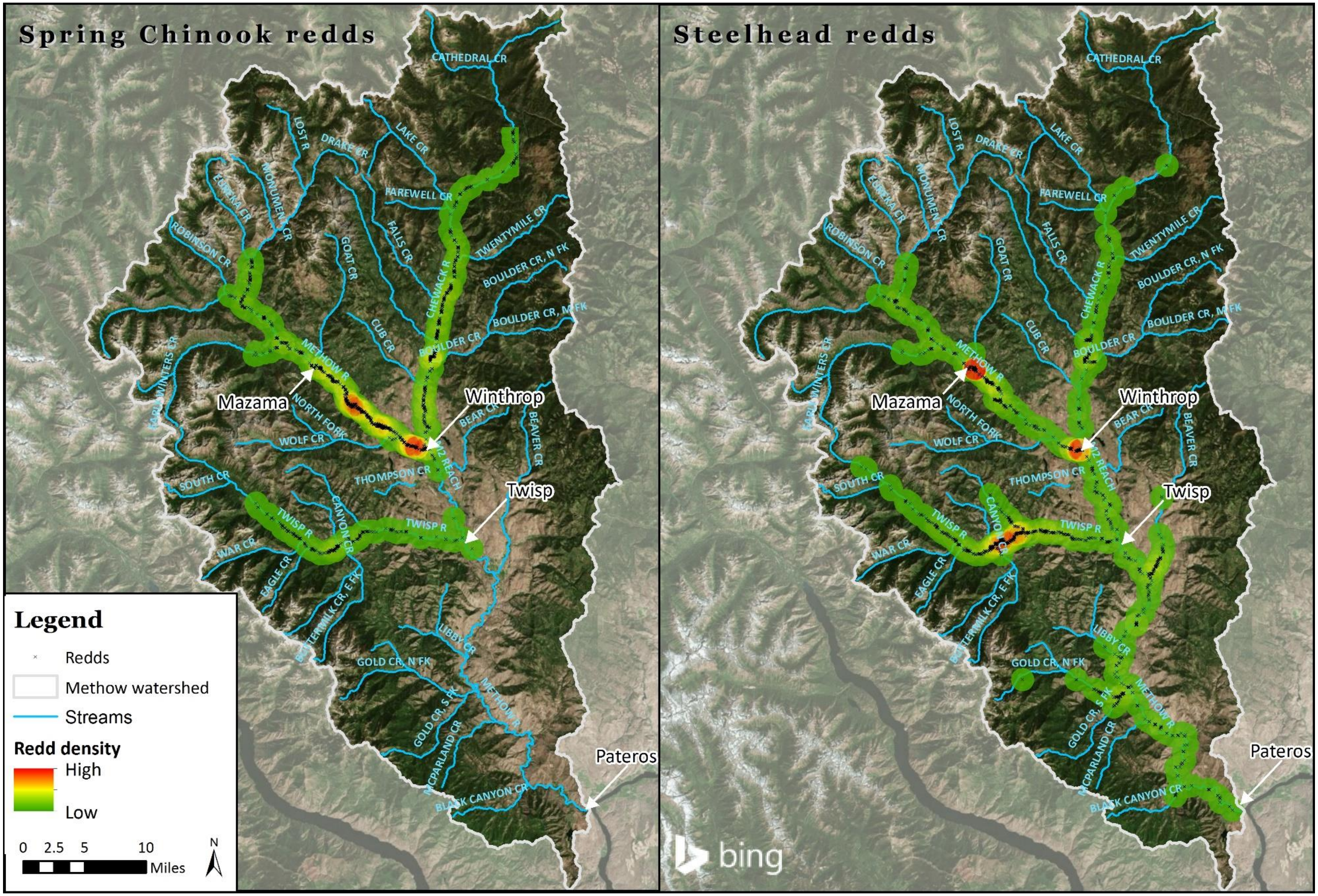


Figure 14. Spring Chinook and steelhead redds in the Methow Subbasin. Spawning hotspots shown in yellow and red were calculated spatially according to density (UCSRB 2015).

4.2 Juvenile Production and Survival

Juvenile production and survival data of spring Chinook salmon and steelhead are useful for determining trends within the Methow Subbasin. Metrics confined to the juvenile life stage are particularly valuable for evaluating fish response to certain enhancement actions, such as fish passage or in-stream habitat improvement projects, because they are not sensitive to large, out-of-basin, confounding variables, and have a relatively short time lag from implementation to response. The time lag between habitat changes and detection of a response at the juvenile life stage ranges from 0-4 years depending on species and freshwater residency time (Figure 15). Increased juvenile abundance, growth, and/or survival as a response to habitat enhancement actions may improve overall population performance over time.

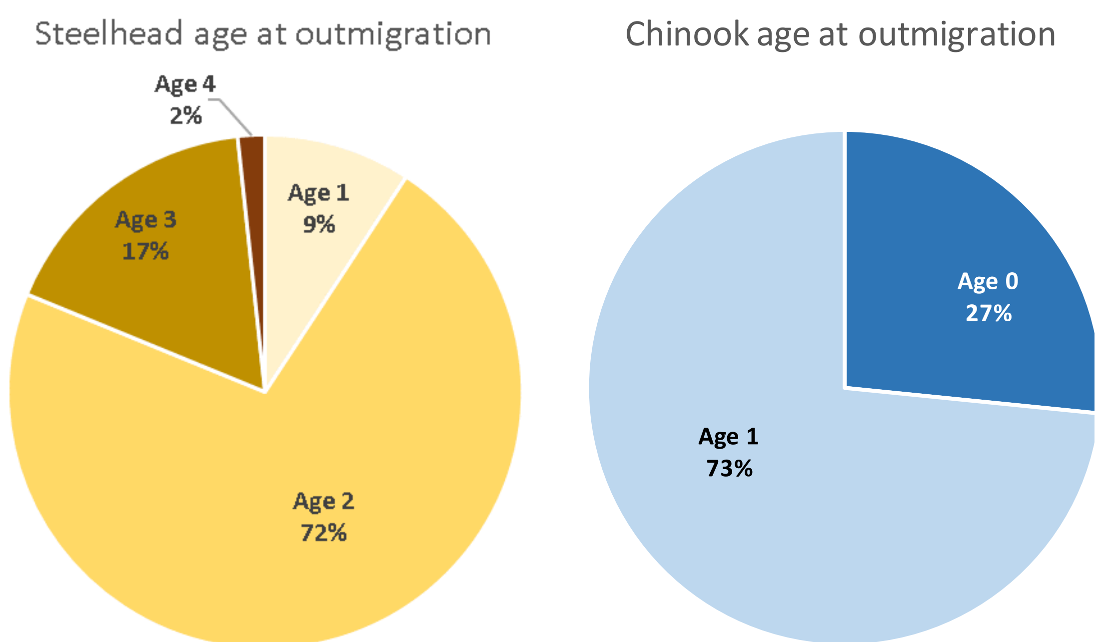


Figure 15. Age at outmigration for Methow Subbasin steelhead (2003-2013 broods) and spring Chinook (2003, 2005-2015 broods) (data from Snow et al. 2018). A very small number of steelhead may have longer juvenile freshwater residence times, in some cases up to 7 years (Mullan et al. 1992).

Juvenile abundance estimates have been conducted on an annual basis in the Methow and Twisp rivers using rotary screw traps since 2002 (Snow et al. 2018). These traps collect downstream migrating juveniles and have standard errors that vary year to year depending on trapping efficiency (Figure 16). Spawner surveys are used to estimate the abundance and distribution of spawning adults, and egg deposition estimates are calculated using fecundities from hatchery broodstock that are adjusted according to hatchery and wild proportions by age class. These data allow for calculations of egg-to-emigrant survival, which is a good indicator of rearing habitat conditions and therefore can be used to understand the effects of enhancement actions. We define total emigrants as the total number of age-0 and age-1+ fish from a given brood year that out-migrate. For spring Chinook, we define total smolts as the number of age-1+ smolts from a given brood year that out-migrate from the Methow River. Steelhead and spring Chinook smolts were identified based on smolting characteristics (e.g., silver coloration, loss of parr marks, elongation of the caudal peduncle, etc.).

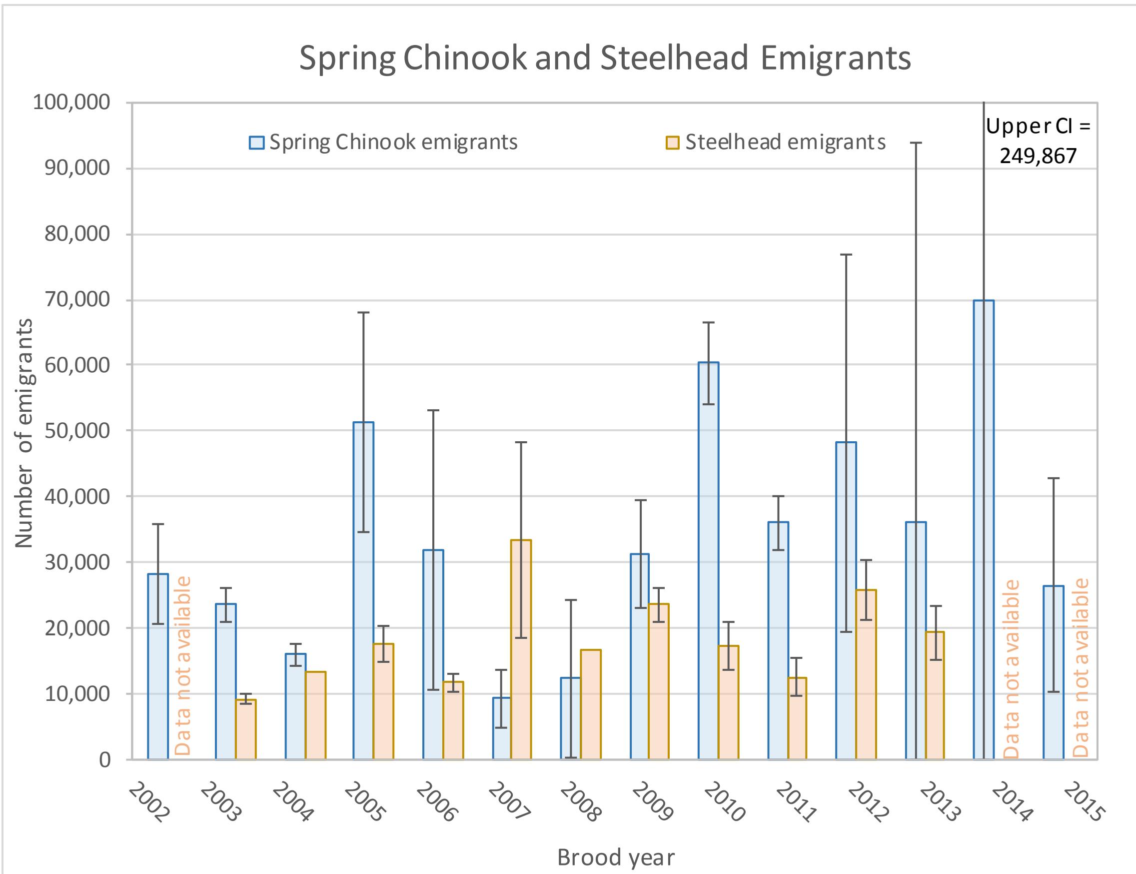


Figure 16. Emigrants over time for complete spring Chinook and steelhead broods in the Methow Subbasin (data from Snow et al. 2018). Error bars represent 95% confidence interval, and error bars are not available for 2004 and 2008 steelhead. Steelhead emigrant data are not available for 2002, 2014, and 2015.

Egg-to-emigrant survival data are available for steelhead brood years from 2002 to 2013, and spring Chinook brood years from 2002 to 2015 for both the Twisp River and Methow Subbasin as a whole. Egg-to-emigrant survival is a valuable metric because it indicates the suitability of a basin as incubating and rearing habitat and is not sensitive to out-of-basin variables. Trends in egg-to-emigrant survival over time are shown below in Figure 17 and Figure 18. Although the Methow population has not increased or decreased significantly over time, Twisp River spring Chinook show a positive trend, and has consistently shown the highest egg-to-emigrant survival.

Mortality at the egg and fry stage can be large and variable depending on many different environmental factors, such as water temperature, discharge, and substrate conditions. Juvenile survival also varies in response to food availability, habitat quality and quantity, and the presence of predators and competitors. Overwinter movement, distribution, habitat use, and survival of juvenile salmonids has often been overlooked by fisheries 42 researchers due to difficulties in monitoring during winter conditions, despite the considerable duration of occupancy of winter habitats and the susceptibility of fish to mortality during winter conditions. A study is currently underway to characterize the winter movement, distribution, habitat utilization, and survival of juvenile Chinook Salmon emigrating from production areas within the Methow River (M. Mumma, Reclamation, personal communication, June 20, 2019).

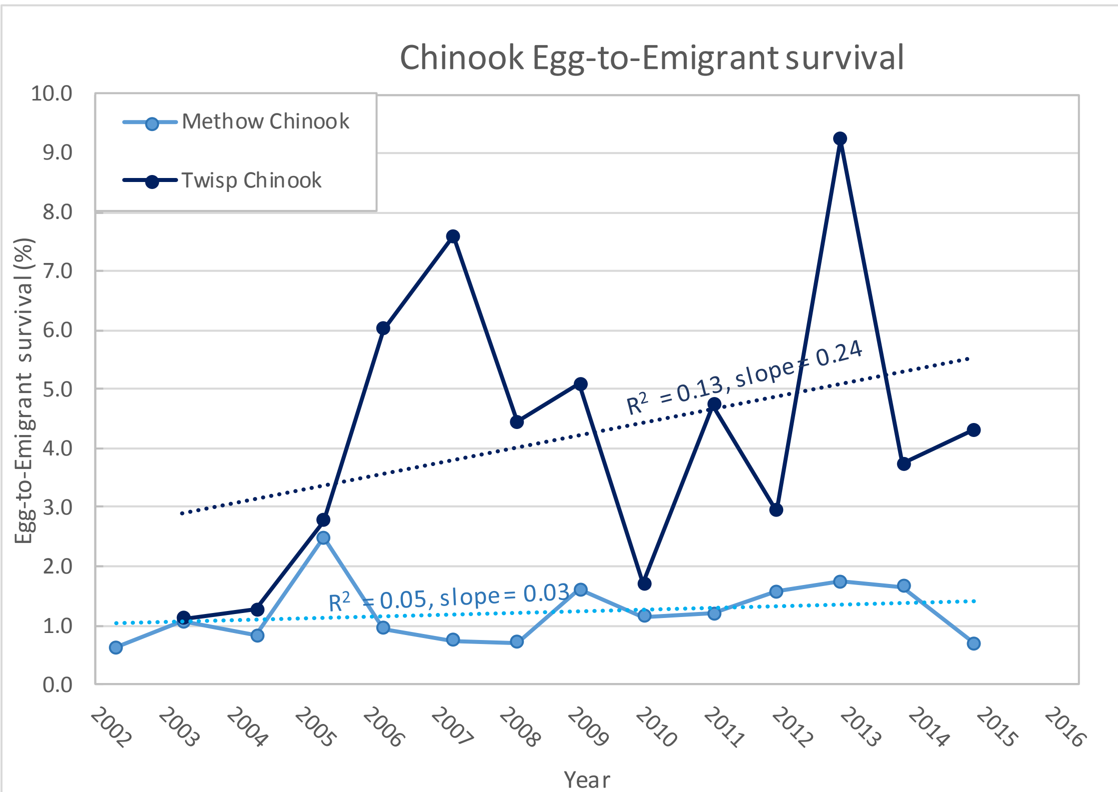


Figure 17. Egg-to-emigrant survival (%) for UCR Spring Chinook in the Twisp River and Methow Subbasin as a whole (data from Snow et al. 2018).

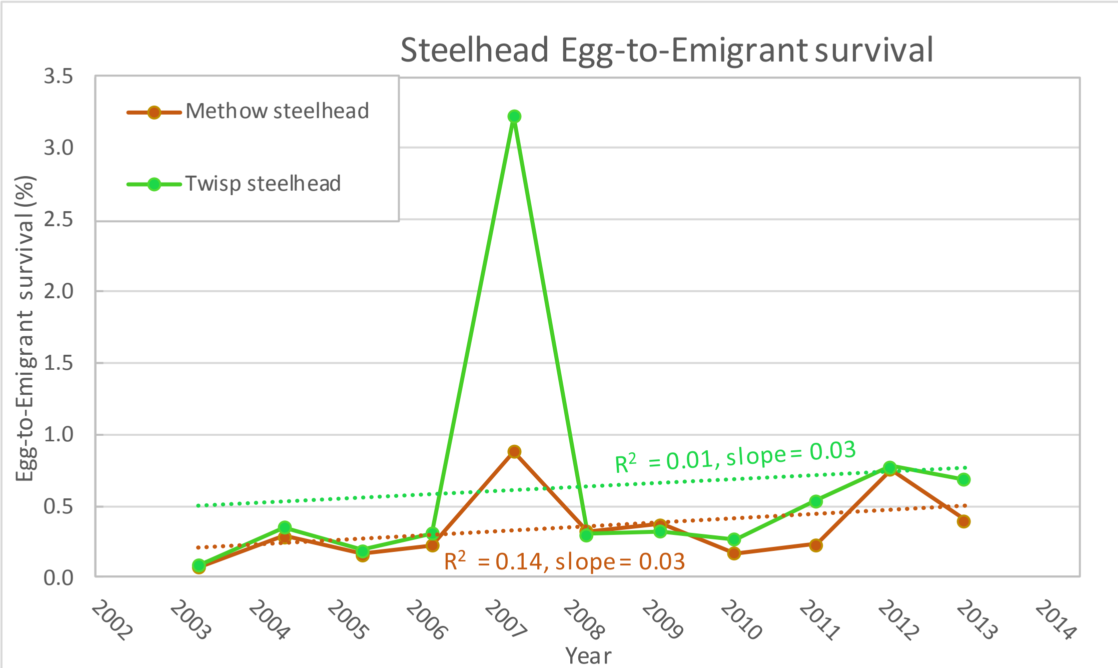


Figure 18. Egg-to-emigrant survival (%) for UCR steelhead in the Twisp River and Methow Subbasin as a whole (data from Snow et al. 2018).

Juvenile emigrant and redd data can be evaluated together to determine density-dependent survival, juvenile equilibrium carrying capacity (K)[2], and number of spawners needed to reach equilibrium carrying capacity for juveniles (K_{sp}) within a subbasin or watershed. Density-dependent survival of fish occurs when increasing fish density decreases survival and/or growth of individuals. One mechanism of density dependence is when food resources become depleted at high fish density, reducing survival and/or growth. Another is when rearing habitat becomes filled at high density, and remaining fish are forced to use less suitable habitat that leads to higher mortality rates and lower growth rates. Here, we evaluate the presence of density dependence for wild juvenile spring Chinook in the Twisp River watershed and the Methow Subbasin as a whole by fitting stock-recruitment functions to juvenile and spawner data. The available data for steelhead were insufficient for this analysis.

Only spring Chinook emigrants (age-0 and 1+ fish) and smolts (age-1+ fish) in the Twisp River showed evidence of density dependence (Figure 19). Although the range in spawning escapement (redds) is low, the Ricker model indicates that about 160-260 redds in the Twisp River will produce equilibrium capacities of about 19,000 emigrants or 6,500 smolts. This suggests that spawning habitat, rearing habitat, or food availability may be limiting production of juvenile spring Chinook within the Twisp River. This

[2] Population carrying capacity (K) should not be confused with habitat carrying capacity (C), which is defined as the maximum population of a given species that a particular environment can sustain. To the best of our knowledge, no one has estimated habitat carrying capacity (C) for the Methow Subbasin.

simple analysis suggests that improvements in habitat quantity and quality may increase juvenile production in the Twisp River.

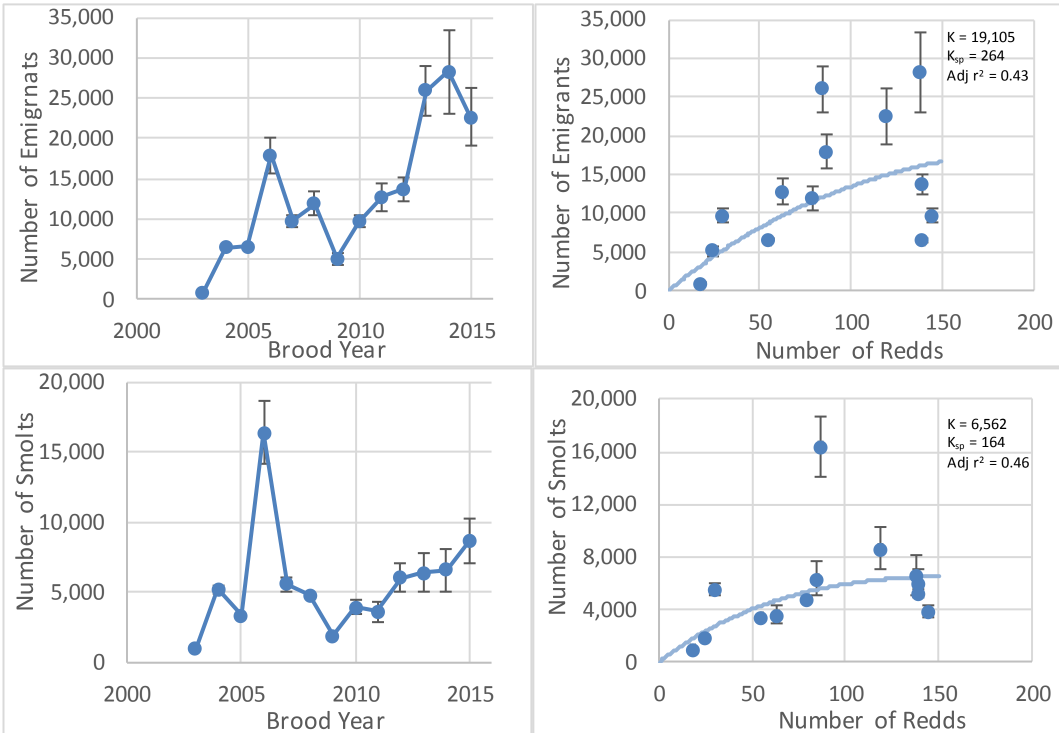


Figure 19. Time series of numbers of emigrants and smolts (with 95% CI), and emigrants and smolts vs number of redds for wild Twisp River spring Chinook (data from Snow et al. 2018). Modeled curves are Ricker models.

In contrast, in the Methow Subbasin, the number of spring Chinook emigrants and smolts has increased linearly over time (Figure 20). This indicates that density dependence is not a factor in regulating juvenile spring Chinook numbers within the Methow Subbasin. Indeed, the significant linear relationships indicate that under the recent past spawning escapements, density independent factors currently affect juvenile population size. As such, spawning escapements during the recent past have not been large enough to reach juvenile equilibrium capacity within the entire subbasin.

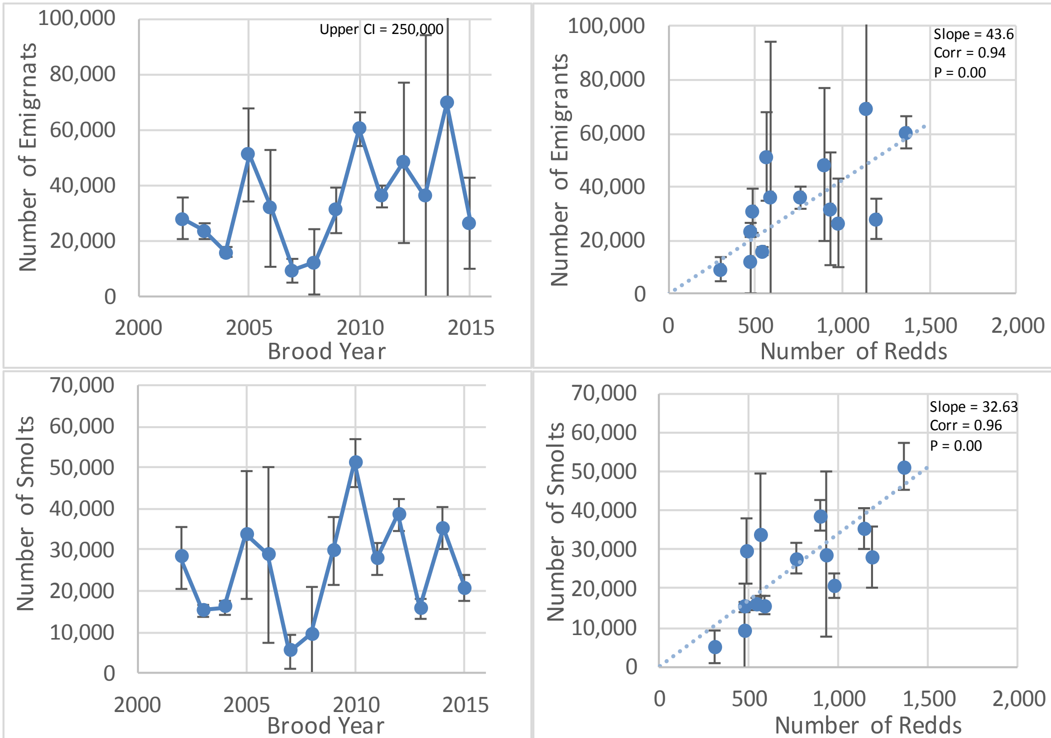


Figure 20. Time series of numbers of emigrants and smolts (with 95% CI), and emigrants and smolts vs number of redds for wild spring Chinook within the entire Methow Subbasin (data from Snow et al. 2018).

The lack of density dependence in the Methow may be a result of several factors. For example, the entire Methow Subbasin could be "under-seeded", where recent spring Chinook spawning escapements are not large enough to fill available habitat. Recall that juvenile data are only available for brood years 2002 to present. Larger spawning escapements have occurred in the past, but there are no juvenile data associated with those larger escapements. Alternatively, recent habitat enhancement actions may have increased carrying capacity within the basin. There is currently no easy way to demonstrate the latter because there are no pretreatment data at the subbasin scale and there is no control or reference population to compare with the Methow spring Chinook population.

The lack of density dependence in Methow spring Chinook as shown in Figure 20 appears to be at odds with the findings of the ISAB (2015). The ISAB (2015) concluded that Methow spring Chinook showed evidence of density dependence (see their Figure V.1. on page 76). Importantly, their analysis was based on adult returns per spawner, not juvenile production per spawner. Thus, their analysis includes the entire life cycle of the fish, not just the spawning and rearing phases. They did not evaluate density dependence for juvenile Methow spring Chinook. Notably, their analysis included brood years 1980 to 2005, which included one very large spawning escapement of 10,971 adults. As shown in their Figure V.1., that one brood year had a large influence on the analysis, as the other spawning escapements included in the analysis ranged from only 31 to 1,695 adults. In short, density dependence in Methow spring Chinook likely occurs at spawning escapements larger than those we evaluated, or it occurs outside the Methow River Subbasin.

Our ability to draw conclusions about population regulation in the Methow and Twisp is limited by several factors. These include the potential effects of hatchery fish as well as multi-species interactions, which are not accounted for in the above analyses. There is also uncertainty and measurement error associated with juvenile outmigrant estimates, particularly for the Methow smolt trap where several years of large confidence intervals in the emigrant and smolt estimates affect precision (see Figure 20). Collecting emigrant and smolt estimates in future years as well as reducing the error of those estimates are important for increasing our ability to evaluate juvenile productivity in the basin. Improving spatial resolution of these data by operating smolt traps in other sub-watersheds within the Methow would also be valuable and allow managers to focus enhancement efforts in appropriate places.

4.3 Life Cycle Monitoring

Life cycle monitoring metrics such as smolt-to-adult return (SAR) and natural replacement rate (NRR) track fish through an entire life cycle and show how individual brood years perform. SAR tracks fish from smolt to returning adult and is highly sensitive to out-of-basin variables, especially ocean conditions. NRR shows how many returning adults are produced from each spawning adult and is sensitive to both in-basin and out-of-basin variables. NRR indicates if a natural population is replacing itself (NRR = 1), decreasing in size (NRR < 1), or increasing in size (NRR > 1). NRR and SAR have a large time lag between change in habitat and response that is at least as long as the life cycle of a single brood year (typically 1-4 years for Chinook and 2-6 years for steelhead) (Figure 15).

SAR for spring Chinook and steelhead in the Twisp and Methow subbasins do not show a substantial trend over time but do show a spike from 2005 to 2007 for Methow and Twisp River wild spring Chinook (Figure 21).

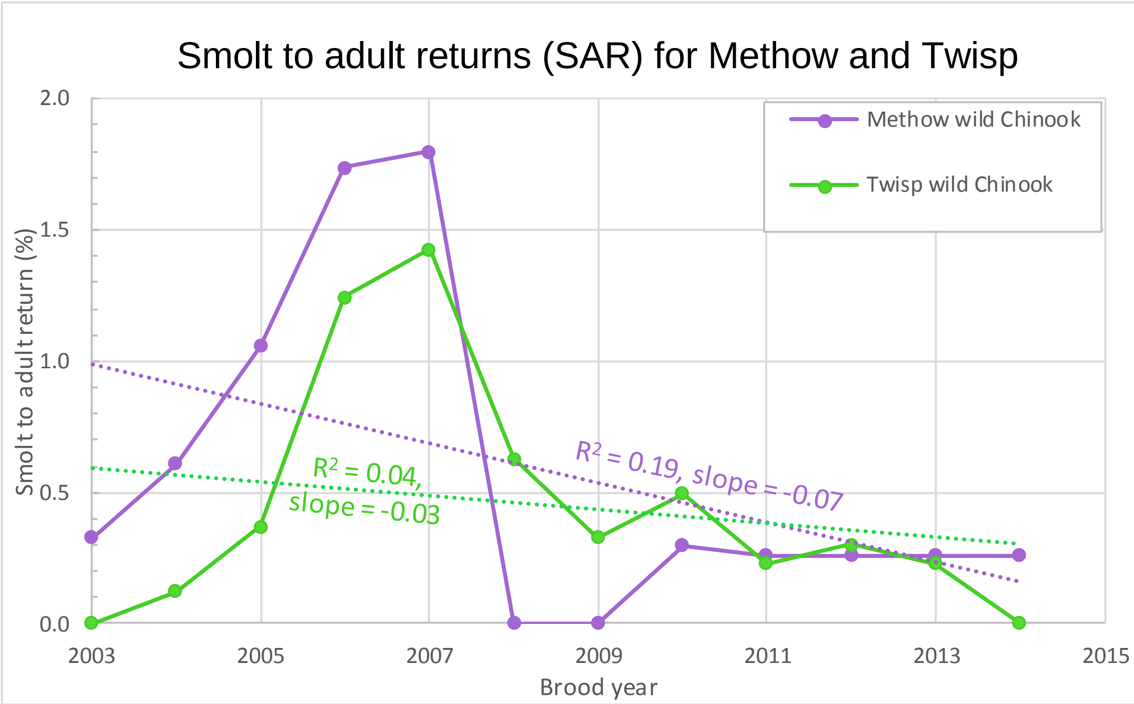


Figure 21. Smolt to adult returns for Methow and Twisp River wild spring Chinook (data from Snow et al. 2018).

NRR data are available for the Methow Subbasin from 1992 to 2011 (Figure 22). Spring Chinook NRR was very high from 1995 to 1998 when spawner abundance was very low. NRR for spring Chinook was under 1 for 15 of 19 years of data, whereas steelhead NRR ranged from 0.04 to 0.74 for all years. NRR depends on in- and out-of-basin factors, and density dependent survival at multiple life stages. These data suggest that naturally reproducing populations of steelhead and spring Chinook are not self-replacing under current conditions.

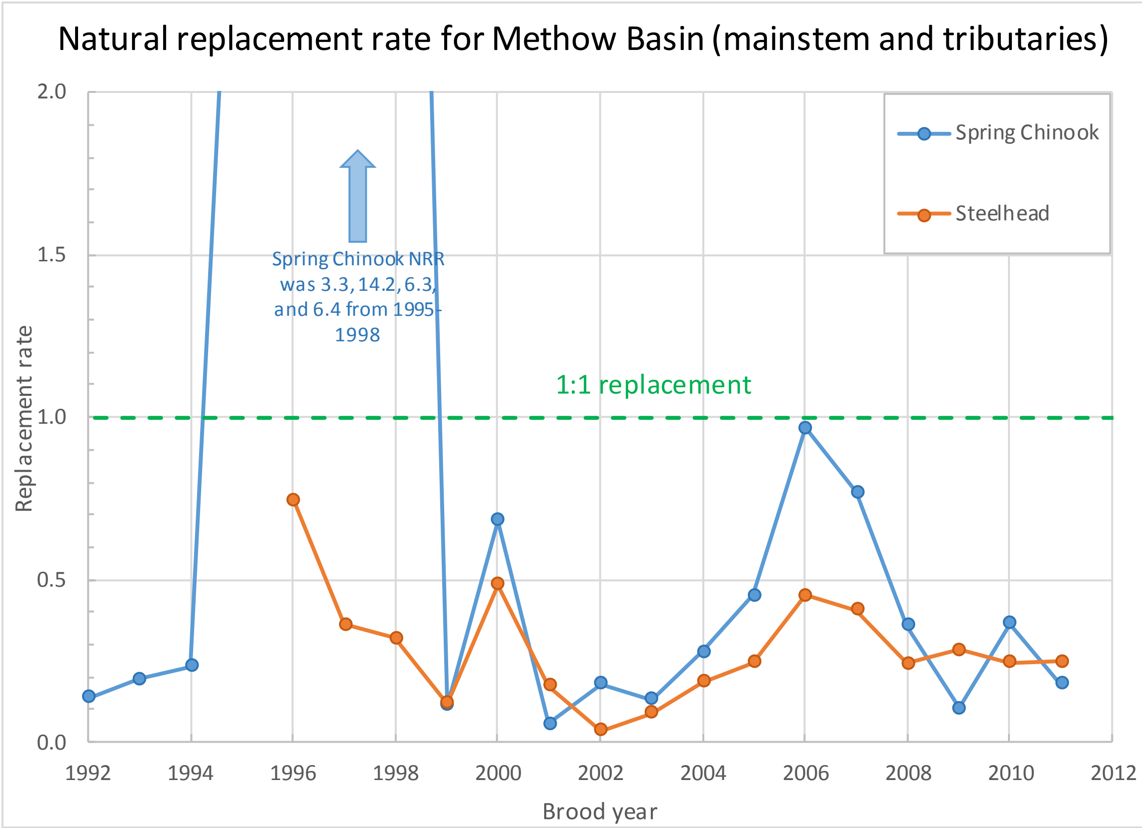


Figure 22. Natural replacement rate (NRR) for Methow Subbasin spring Chinook and steelhead. The green line indicates 1:1 replacement in which the average adult produces one offspring that survives to spawn in the future.

5 Habitat Action Effectiveness Monitoring

Site-specific monitoring and evaluation are being used to evaluate action effectiveness and to guide future enhancement actions in the Methow Subbasin. Effectiveness monitoring has occurred at numerous enhancement sites in the basin at a range of intensities. These range from short-term post-treatment monitoring of fish use of enhancement sites to large-scale multi-year BACI studies. The two most comprehensive efforts are the Beaver Creek fish passage enhancement study and the Methow M2 Reach action effectiveness study[3]. Both the Beaver Creek study and the M2 study are complete. Each of these efforts has a BACI study type design configured to answer specific questions about action effectiveness. These core studies have been funded primarily by Reclamation, with support and collaboration from other entities including tribes, government resource agencies, universities, and non-profit organizations.

In addition to these two large-scale studies, there have been other effectiveness monitoring efforts in the Methow Subbasin and in other nearby basins that add to our overall understanding of action effectiveness. A few of these are described in this document, including the Hancock Springs Project in the upper Methow Valley and the Elbow Coulee Project on the Twisp River. There is also relevant information from studies in other nearby basins, including research on fish use of enhancement sites on the Entiat River.

These various studies provide a host of useful information on the effects of enhancement actions on the physical environment, fish communities, and ecological processes. Overall, they show that enhancement actions are working, particularly at the local scale; and these results are useful for the planning and design of future actions. However, there are still questions about effects on fish populations at the watershed-scale, and the available data are currently insufficient to detect a change at that scale. There are, however, efforts underway to use information from these habitat action studies, in combination with other available information in the basin, to inform watershed-scale modeling and analysis that will help understand larger-scale effects.

5.1 M2 Reach BACI Study

5.1.1 Overview and Methods

The Methow M2 Reach study evaluates the effectiveness of habitat improvement actions including side channel, large wood addition, and floodplain and riparian enhancement. This study was designed to help understand the effects of enhancement actions on ESA-

[3] Literature for the M2 study cited in this section includes Bellmore et al. (2013) and Bellmore et al. 2015, which uses data collected during 2009-2010; Martens et al. (2014), with data collected by USGS between 2008-2012; and Martens and Connolly (2014), which uses data from 2009-2012 collected by USGS. Post-treatment efforts referenced here include Martens et al. (2014), which discusses immediate post-treatment data from 2013 at Whitefish Island; Hutcherson et al. (2019), which details the M2 BACI post-treatment data collection and results; and a groundwater-surface water study by Mejia et al. (2016).

listed fish, to characterize food web dynamics in complex floodplain systems, and to help inform the development of predictive ecological models. This is a cooperative, multi-entity effort that is led by Reclamation but includes many partners.

The key objectives of the study are provided below. These are excerpted and summarized from Tibbits et al. (2012):

1. Assess productivity and connectivity of the enhancement reach and control reaches
2. Assess changes in fish population metrics as a result of stream enhancement actions
3. Develop a reach-based fish production model to assess the potential effectiveness of enhancement actions
4. Assess the current food web dynamics based on aquatic productivity and fish diet information

Methods and findings related to the first 2 objectives are provided in the subsections below. Findings related to Objective 3 are related to the ATP model and are summarized in Section 6. Findings related to Objective 4 are summarized in Section 5.2.

The study employs a multi-year BACI sampling design. Six side channel sites were used to investigate various fish performance and ecological relationships. Two of these side channels were treatment sites and four were reference sites. The two treatment sites were located within the M2 Reach of the Methow River, which is between Twisp and Winthrop, WA. There were four reference sites, two located upstream of the M2 Reach, one within the M2 Reach, and one downstream of the M2 Reach (Figure 23 and Table 3). Over the course of this effort, as part of this and other related studies, additional sites have been sampled and were sometimes used in the analyses, including mainstem channel sites and tributary sites.

Side channels that were included in this study were selected based primarily on availability; existing enhancement treatments throughout the basin eliminated a number of potential reference sites, as did anthropological disturbance. As a result, the number of possible reference sites to include in the study were few, and from these, the level of hydrologic connection to the mainstem and adherence to certain similar physical attributes as the other sites were considered when choosing the reference and control sites to include in the study. For more information on the BACI study design and methodology, see Martens et al. (2014) and Martens and Connolly (2014).

In addition to the two treatment sites that were part of this study, there have been several other actions constructed in the M2 Reach by various entities. These include the WDFW Floodplain Project (RKm 73.6), the 1890s Side Channel (YN, RKm 66.8), the Sugar Dike log jam (YN, RKm 68.4), 2-Channels large wood (YN, RKm 72.8), Eagle Rocks log jams (YN, RKm 70.4), and RM 42 large wood (YN, RKm 67.6). These actions were all constructed between 2012 and 2014, and although they are not included as individual sampling sites in the BACI study, they are expected to collectively influence fish performance in the M2 Reach.

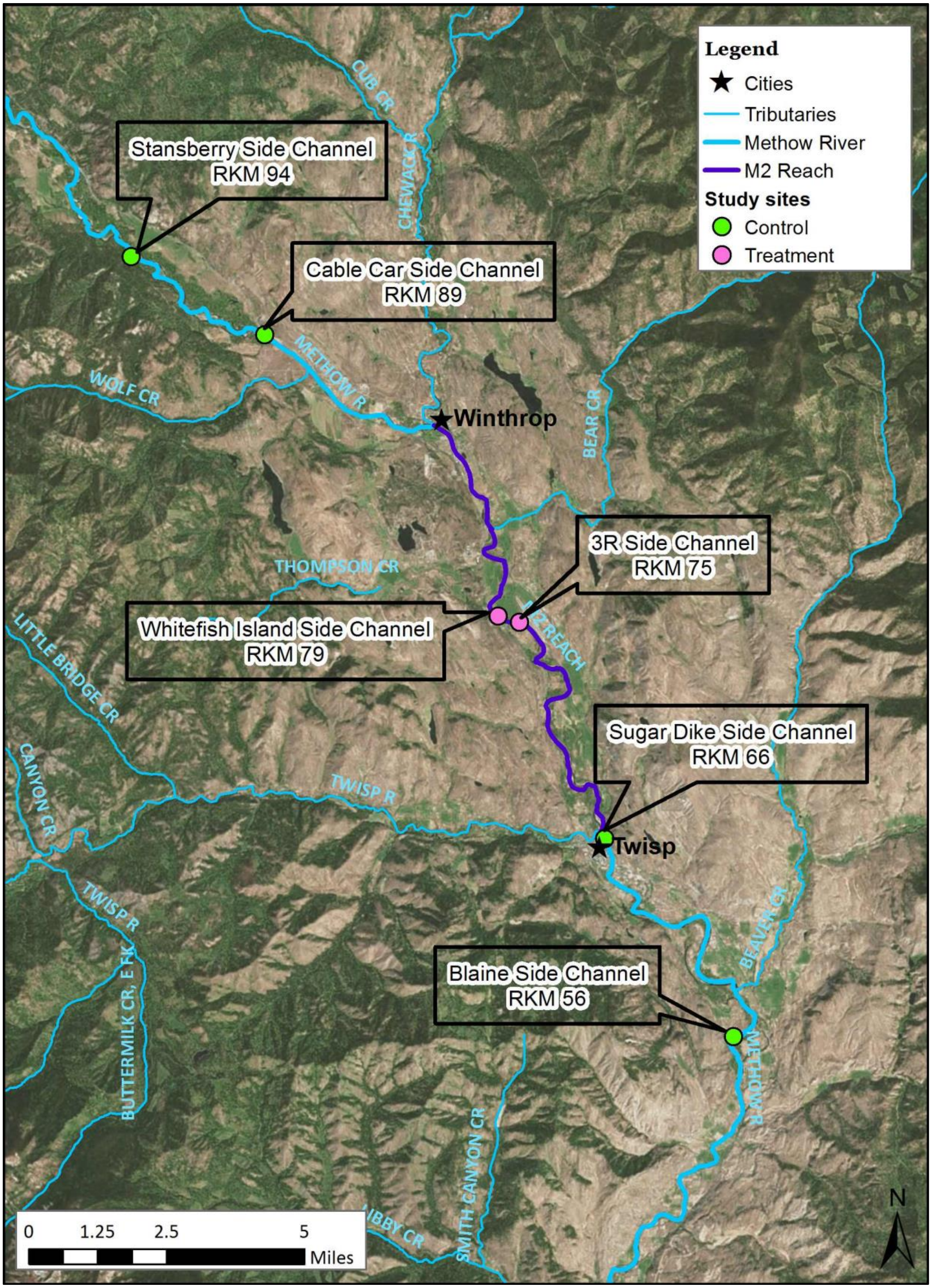


Figure 23. BACI study sites in the M2 reach of the Methow Subbasin.

Table 3. Descriptions of M2 Reach monitoring sites. Location map of sites provided in Figure 21.

Site	Type	River KM	Description
Stansberry	Reference	94	Seasonally connected at the outlet; habitat unit alterations occurred directly adjacent to side channel though no significant habitat unit alterations in side channel itself
Cable Car	Reference	89	At least partially connected to the mainstem year-round; no significant habitat unit alterations over course of study
3R (aka "River Rock)	Treatment	75	Pre-treatment seasonally disconnected; post-treatment is perennially connected at the bottom; pools were enlarged and wood added for cover
Whitefish Island	Treatment	79	Pre-treatment seasonally disconnected with isolated pools; post-treatment is perennially connected; pools were enlarged and wood added for cover
Sugar Dike	Reference	66	Seasonally disconnected with isolated pools; natural reduction in pool habitat over course of study
Blaine	Reference	56	Seasonally disconnected; no significant habitat unit alterations over course of study

**additional reference sites were included in the original pre-treatment efforts but were not included in the post-treatment sampling.*

Measured Attributes

Physical Habitat Measurements
- **Habitat unit survey**
- **Channel dimensions**
- **Water temperature**

Fish Measurements
- **Day and night electrofishing**
- **Day and night snorkeling**
- **PIT tagging**

Food Web Measurements
- **Benthic invertebrates**
- **Terrestrial invertebrates**
- **Gut content analysis**

Baseline monitoring started in 2008 in the M2 Reach prior to habitat enhancement actions. In general, the monitoring activities consisted of habitat surveys, fish sampling, isotope analyses, invertebrate sampling, hydrological connection analyses, and PIT tag analyses. Sampling at all six side channel sites was done three times a year: in the summer after flows have subsided enough to allow for safe and effective sampling (July-September), in the fall (October-November), and in the spring before flows rise and side channels fully reconnect to the mainstem river (March-April).

Pre-treatment sampling occurred between 2009 and 2012. Action implementation (treatment) occurred at Whitefish Island in 2012 and at 3R in 2014. Post-treatment sampling began in the summer of 2015 and continued through spring 2018. Sampling at Stansberry (a reference site) ended in 2016 due to the inability to use the side channel as a reference site following the implementation of an enhancement action in 2015. Blaine and Cable

Car (both reference sites), which were sampled during the pre-treatment effort, were added as unaltered reference sites in summer of 2016 to help offset the loss of Stansberry side channel as a reference site.

5.1.2 Fish and Habitat Relationships (pre-treatment)

The three years of pre-treatment data provided useful information on fish and habitat relationships in the study area and provided an important baseline for evaluating fish response to enhancement actions.

Pre-treatment data showed that juvenile spring Chinook salmon and steelhead utilized all types of side channels (i.e. seasonally connected only, year-round partially connected, and year-round fully connected), but Coho salmon were more frequently found in side channels that were only seasonally connected, with few to no Coho in partially or fully connected side channels (Martens and Connolly 2014).

Generally, side channels contained higher densities of all juvenile salmonids – including steelhead and spring Chinook – compared to mainstem lateral margin habitat. For steelhead and spring Chinook, fish densities in side channels were similar to those found in tributary habitats (Martens and Connolly 2014).

Juvenile Coho and steelhead rearing densities were positively correlated with total cover and multiple types of cover (i.e. various types of large wood, substrate, undercut banks), whereas spring Chinook were correlated only with the instream large woody debris cover type (Martens and Connolly 2014). In side channels that were disconnected from the mainstem for most of the year, fish survival in isolated pools was correlated with pool depth, with pools greater than 1 meter showing increased survival for steelhead, Coho, and spring Chinook for nearly all seasons sampled (Martens and Connolly 2014).

Increased rates of survival were most apparent for all species between the summer and fall sampling periods, when true survival (i.e. no emigration was possible due to disconnection) in deep pools was 74%, 72%, and 88% for steelhead, Chinook, and Coho salmon, respectively. The values were 44%, 46%, and 74% (respectively) in shallow pools less than 1 meter deep. Warm air temperatures in the summer and fall may be part of the reason for these survival discrepancies between deep and shallow pools, in that deeper pools offer increased thermal refuge in comparison to shallow pools.

All of the side channel sites in the study had little to no use by large predatory species such as bull trout, brook trout, resident rainbow trout, or cutthroat trout, even though these fish are known to occur in the mainstem. The particular lack of these fish in disconnected side channels suggests that these habitat types may provide important refuge for target species (Martens and Connolly 2014). There is also evidence that competition for prey between target (i.e. spring Chinook and steelhead) and non-target (e.g. sculpin and whitefish) fish may be less in disconnected side-channels (Bellmore et al. 2013), further emphasizing the importance of these habitat types for fish.

CASE STUDY: WHITEFISH ISLAND

CONSTRUCTED: 2012

SPONSOR: Methow Salmon Recovery Foundation using design and technical assistance from Reclamation and construction funding from BPA and others

TARGET SPECIES: Steelhead and Chinook salmon

Prior to habitat improvement, aquatic habitat in the Whitefish Island side channel in the Middle Methow River consisted of a series of isolated pools that were disconnected from the main channel approximately 9 months of the year. Activation of the inlet occurred only when the Methow River was above 800 cfs during winter and spring. Habitat complexity was low as a result of limited side channel and floodplain connection and low bedform complexity in the main channel. These conditions were likely a result of channel bank hardening and the loss of riparian forested areas in the upper watershed, as well as historic removal of large wood and logjams in the channel. Together, these practices resulted in simplified channel conditions and loss of complex structures that provided juvenile fish with important cover and refuge habitat.

PROJECT ELEMENTS

- Two bar apex engineered logjams, one at the head of the island and one in the side channel.
- Five engineered logjams along the side channel left bank.
- Two large wood assemblies along the side channel left bank.
- One live crib-wall along the side channel right bank.
- Various large wood placements on gravel bars adjacent to the main channel and side channel.
- Improving riparian plant diversity and abundance within the side channel and river island environments.

The goal of the Whitefish Island Project was to increase off channel habitat connectivity and complexity to increase both immediate and long-term fish survival and production. The Whitefish Island project aimed to increase the availability of off-channel habitat by increasing the hydrological connection to the mainstem, improving feeding, hiding, and resting habitat for juvenile fish, winter rearing conditions, and providing refuge habitat during migration. The Whitefish Island Project also intended to improve the quality of the off-channel habitat by deepening pools and increasing the number of pools and riffles in the channel.

Whitefish Island side channel in August 2016.

Following implementation, the Whitefish Island side channel now maintains surface water connection with the Methow River for most of the year. Some pools still become isolated at extreme low flows while maintaining perennial water with cover, which allows fish to survive these low flow conditions. When flows in the mainstem exceed 300 cfs, a minimum of 20 cfs diverts into the Whitefish Island side channel. The reconnected side channel has greater wetted area and water depth than the pre-treatment channel. Several log structures were installed and pools were deepened, which provide additional structural and hydraulic complexity for rearing juvenile fish.

CASE STUDY: 3R SIDE CHANNEL

The 3R River Rock side channel is located in the M2 Reach of the Methow River at river km 75. Prior to treatment, the 3R side channel was seasonally disconnected, connecting to the mainstem only during high flows in the spring and early summer months. During these low flow months, the side channel would consist of one to three isolated pools at the top end and one isolated pool near the bottom. Some of the pools were deep and had groundwater inputs that provided warmer winter and cooler summer temperatures favorable to fish.

Treatment in the 3R side channel in 2014 included improving the connectivity and habitat complexity within 2.7 acres of wetland and backwater habitat. Excavation was used to create two backwater alcoves connecting the deepest pools, as well as large wood placement for cover. In higher flows, water from the mainstem river backs up into the alcove, providing slow water refuge and cover for fish. Alcove creation increases habitat availability for juvenile salmonids in the low flow months and allows for movement of fish in and out of the previously isolated pool near the bottom of the side channel. Additional components of the 3R project included three engineered log structures constructed downstream of the side channel in the mainstem Methow River. Planting of native riparian vegetation occurred throughout the backwater and wetland complex and along the treated portion of the mainstem.

Mainstem log jam placed at the 3R project. Before photo: Brian Fisher (MSRF). After photo: Inter-Fluve (2016).

5.1.3 Fish Population Response (post-treatment)

Prior to enhancement in 2012, the Whitefish Island side channel was seasonally disconnected from the Methow River. The side channel was classified in relation to groundwater-surface water connection by Mejia et al. (2015) as a “transient”, or neutral, site at which there was no gaining or losing of groundwater. Pre-enhancement fish sampling revealed low, but highly variable, summer population estimates (<500) for both juvenile steelhead and spring Chinook in Whitefish Island (Figure 24; Martens et al. 2014). In the year immediately following construction (constructed summer 2012, data collected 2012-13), fish species assemblages were generally the same as during pre-treatment, but juvenile spring Chinook and steelhead abundances in the channel were an order of magnitude higher (Figure 24; Martens et al. 2014). Additional years of data from 2016 – 2018 show continued elevated abundance of juvenile salmonids at Whitefish Island following enhancement (Figure 26).

Habitat unit type, area, and average depth appeared to be important in determining population abundance for juvenile spring Chinook, Coho, and steelhead. The increase in juvenile salmon populations observed in Whitefish Island in the initial years post-enhancement (Figures 26 and 27) is assumed to be a result of the treatments (Hutcherson et al. 2019), which not only increased connectivity but also pool volumes and cover, attributes that were found to provide important fish benefits in the pre-treatment data (Martens et al. 2014).

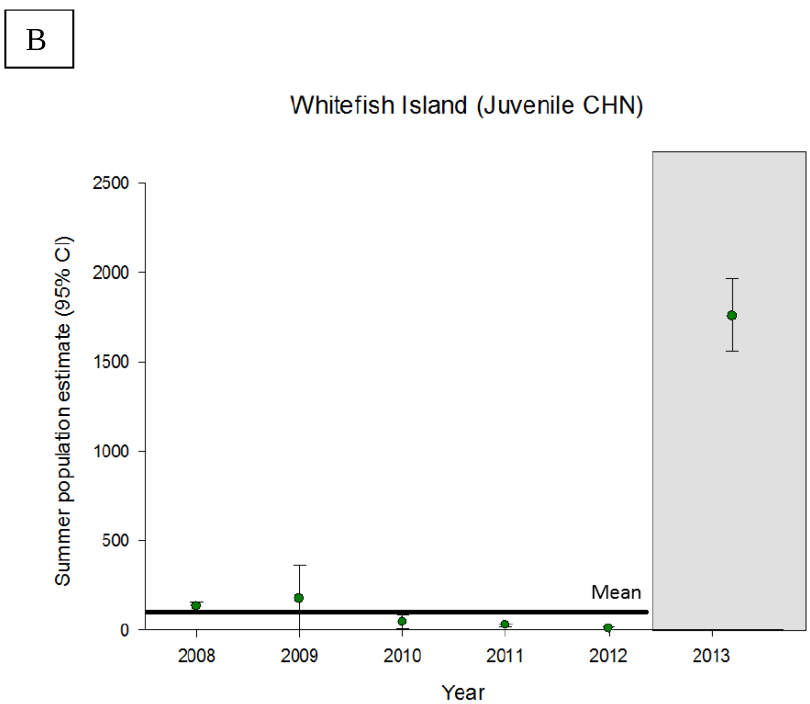


Figure 24. A. Age-0 rainbow trout/steelhead (STH) population abundance estimates in the Whitefish Island side channel, 2008-2013, as reported by Martens et al. (2014); and B. juvenile spring Chinook (CHN) population abundance estimates in the Whitefish Island side channel, 2008-2013, as reported by Martens et al., 2014.Grey boxes (around 2013 results in both figures) indicate the first year of data collected after habitat enhancement actions occurred at Whitefish Island. Both figures from Martens et al. (2014).

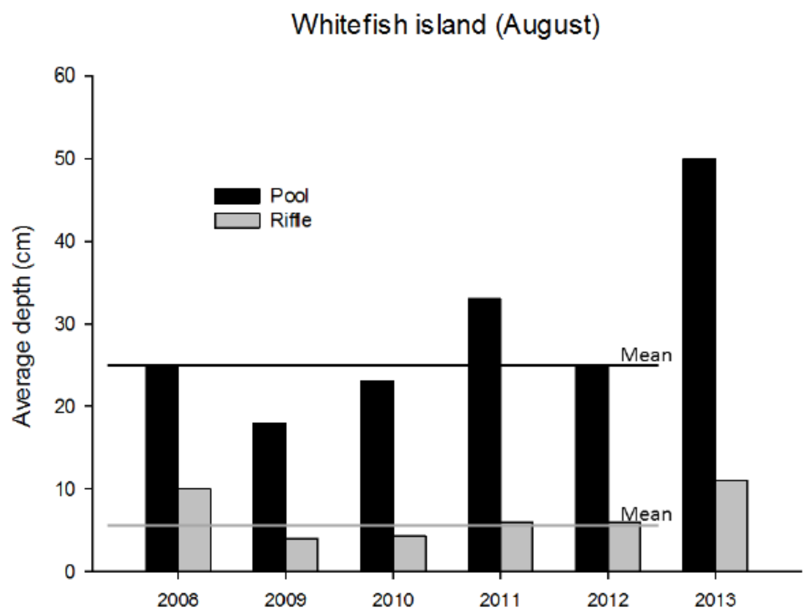


Figure 25. Average depth of pool and riffle habitat units in the Whitefish Island side channel pre-enhancement (2008-2012) and post-enhancement (2013). Data collected post spring high flows after side channel enhancement. Figure from Martens et al. (2014).

The multi-site data through the full period of post-treatment monitoring are presented in Figure 26 and Figure 27 (Hutcherson et al. 2019). Results from post-treatment monitoring indicate that treatment sites (3R and Whitefish Island) showed higher whole-site (all sampling units combined) abundance estimates for salmon and steelhead during summer and fall 2015 and spring 2016 sampling efforts compared to their pre-treatment abundances. This trend continued through 2018 at Whitefish Island, with the additional years of post-treatment abundance estimates significantly higher than pre-treatment abundance estimates when compared to reference sites. However, no significant differences between all years of pre- and post-treatment periods were observed at 3R when compared to reference sites. Juvenile salmonid abundance estimates that had increased immediately post-treatment at 3R returned within a year back to pre-treatment levels.

When evaluating the individual species and age-class abundances, the response to treatment is variable depending on season, species, and treatment site. No significant differences were found for Chinook for either site and the data were insufficient to investigate Coho due to uneven distributions among the sites. No significant changes were found for steelhead at 3R. However, there were significant differences with respect to changes in steelhead abundance at Whitefish. Age-0 juveniles were significantly more abundant in summer and spring sampling periods and age-1+ steelhead were significantly more abundant in fall and spring sampling periods following treatment. It is possible that the increase of steelhead is due to greater habitat area or connectivity created by the project (Hutcherson et al. 2019).

Although these abundance estimates are useful for evaluating population change within a particular side channel over time, they do not account for differences in size of the various side channels. Using fish density allows for comparisons of the intensity of fish use among side channel sites. Densities of *Oncorhynchus* spp. sampled in pools at all side channel sites are shown in Figure 27. At 3R, no significant differences in densities were detected pre- and post-treatment compared to reference sites (Hutcherson et al. 2019). At Whitefish Island, no significant density differences were detected based on habitat surface area (fish per square meter). However, volumetric densities (number of fish per cubic meter) of all salmonids combined were significantly higher during the post-treatment fall sampling period, though not during the other seasonal sampling periods, and no steelhead or Chinook volumetric density differences were detected when analyzed independently (Hutcherson et al. 2019). The statistically significant increases in the all-salmonid volumetric densities during the fall could mean that the habitat improvements, such as deeper pools, increased juvenile survival through the summer when stream flows are low and temperatures are high.

Although Hutcherson et al. (2019) were unable to evaluate Coho salmon individually, Coho were included in the “all salmonids” analyses. The effect of the Coho reintroduction program in the Methow Subbasin on the all-salmonid abundances and densities pre- and post-treatment is not clear.

Growth and condition factor of juvenile salmonids at Whitefish Island and 3R were evaluated, although data were limited by the irregular distribution of species and recapture of individuals already marked. Statistical evaluations for growth were only evaluated for Chinook Salmon during the fall sampling period at Whitefish Island and 3R and for subyearling steelhead during the fall and spring sampling periods at Whitefish Island. No statistically significant differences in juvenile salmonid condition or growth were detected between treatment and reference sites pre- to post-treatment (Hutcherson et al. 2019). In addition, no statistical differences were noted for survival to Rocky Reach Dam between reference and treatment sites, and from pre- to post-treatment.

Other studies of the food web at Whitefish Island suggest that available food is sufficient to support increased numbers or densities of juvenile fish at Whitefish Island (Paris et al. 2019; Bellmore et al. 2013). This is consistent with analyses of juvenile salmonid production and survival in the Methow Subbasin provided in Section 4.2 of this report, and supports the idea that density dependence might not be a factor in regulating juvenile spring Chinook numbers (i.e., the subbasin may be “under-seeded”).

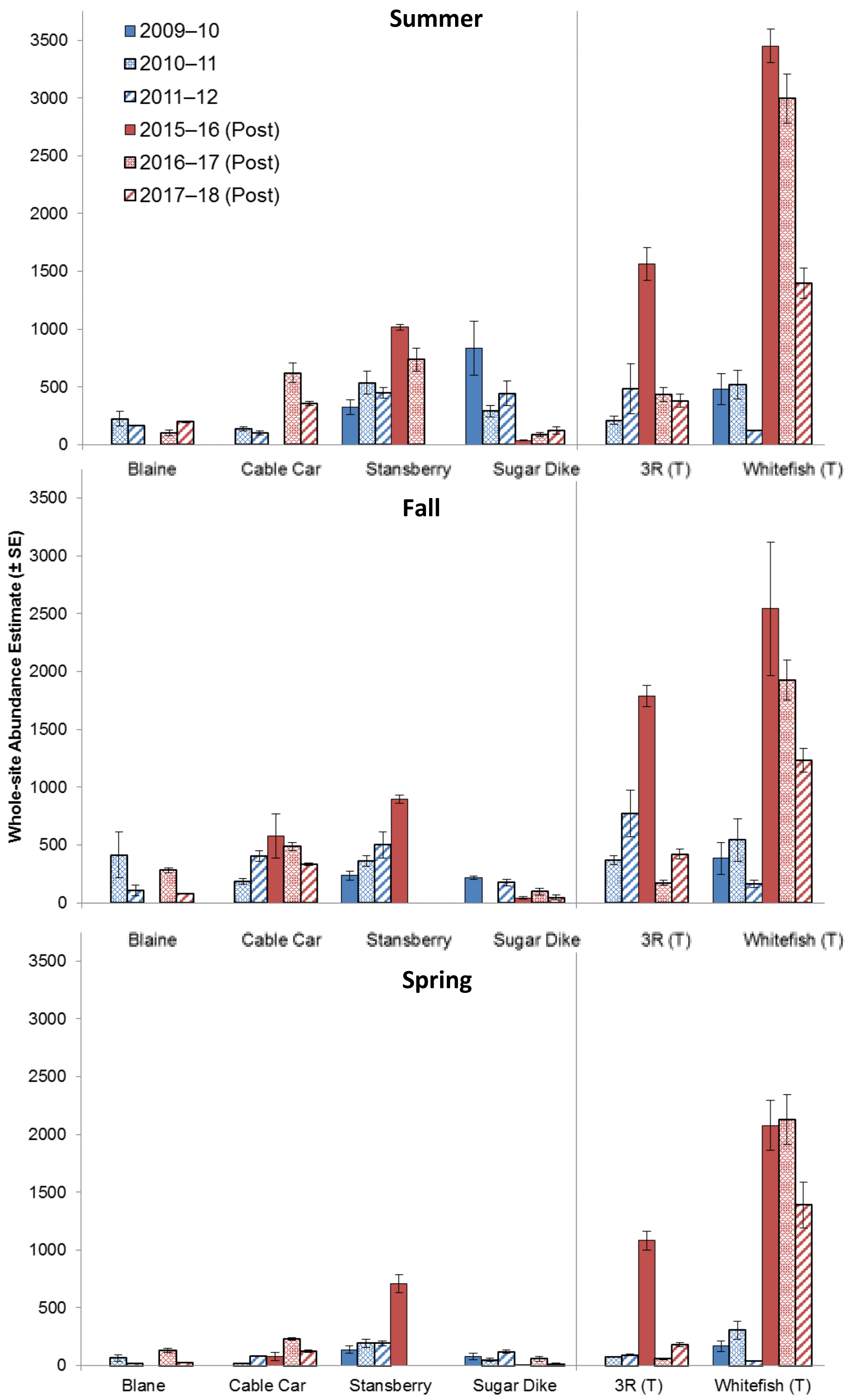


Figure 26. Whole-site abundance estimates (± standard error; SE) for Oncorhynchus species (spring Chinook, Coho, and both age-0 and age-1+ steelhead) in Methow River side channels during pre-treatment (2009–12) and post-treatment (2015–18) collection periods. Blaine, Cable Car, Stansberry, and Sugar Dike (to the left of the grey vertical line) are all control side channels, while 3R and Whitefish (to the right of the grey vertical line) are treatment sites. Figure from Hutcherson et al. (2019).

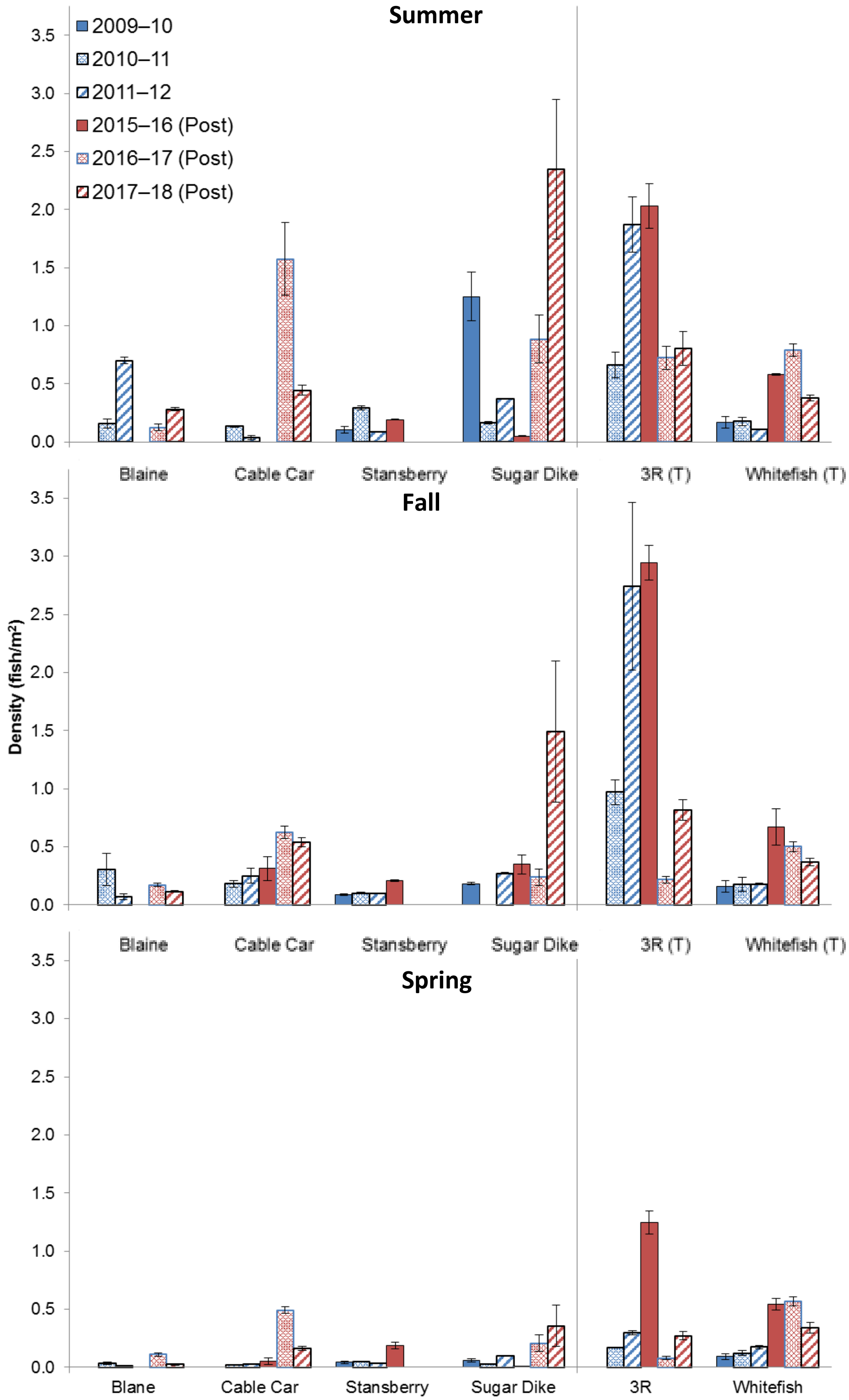


Figure 27. Density (fish/m²; ± standard error [SE]) of all salmonids (spring Chinook, Coho, and both age-0 and age-1+ steelhead) for sampled pool habitats in Methow River side channels during pre- and post-treatment sampling periods. Blaine, Cable Car, Stansberry, and Sugar Dike (to the left of the grey vertical line) are all control side channels, while 3R and Whitefish (to the right of the grey vertical line) are treatment sites. Figure from Hutcherson et al. (2019).

5.2 Food Web Study

5.2.1 Overview and Methods

Food web investigations have been performed in the middle Methow in an effort to evaluate food web dynamics and the response to enhancement actions (Bellmore et al. 2013). This is a collaboration between Reclamation and the Idaho State University, with multiple graduate students contributing to the effort. The study has been performed in conjunction with the M2 Reach BACI study described previously and includes sampling at 3 of the same sites (Stansberry, Sugar Dike, and Whitefish Island). In addition to understanding the food web response to enhancement actions, the study is also being used to parameterize and validate the ATP model (see Section 6).

Data collection for the pre-treatment effort occurred at five different side channel sites and one mainstem site within the M2 Reach, and has included measurements of aquatic habitat, fish populations, fish consumption, water quality, aquatic macroinvertebrate populations, periphyton, adult carcass counts, and terrestrial macroinvertebrate and organic matter inputs. The five side channels have varying levels of hydrologic connectivity and habitat conditions. From these data, the authors were able to explain major pathways of material flow in different floodplain habitats, assess the potential for food limitation of rearing juvenile spring Chinook salmon and steelhead, evaluate the potential for exploitative competition for food between target and non-target fishes, and quantify the relative importance of different habitats to sustaining juvenile salmon and steelhead production.

In a related analysis, the investigators aggregated the habitat patch sites used in the food web analysis to create a meta-food web in order to investigate how the strength of trophic interactions changes at the larger floodplain mosaic scale (Bellmore et al. 2015).

5.2.2 Study Findings

Food web study results highlight the importance of side channels to juvenile spring Chinook salmon and steelhead in the Methow Subbasin. Fish assemblages, prey selection, and carrying capacity were all influenced by the type of habitat (side channel vs. main channel) and the level of hydrologic connectivity between side channels and the mainstem. Fish assemblages among side channel habitats differed. Spring Chinook and steelhead utilized all of the habitats studied. Larger, more piscivorous species like bull trout and cutthroat trout were generally absent from side channels, although increased connectivity to the main channel increased the likelihood of these species being present.

The relative abundance and consumption of prey species varied across the different side channels and main channel (Bellmore et al. 2013). In the main channel, nearly 80% of total fish production was fueled by only four prey taxa, whereas side channel fish production was supported by a wider range (between 6 and 13) of taxa. Food web structures were also linked to the level of hydrologic connectivity. In particular, less connected side channels had higher proportions of lentic invertebrates (e.g., Daphnia, Amphipoda, Isopoda, Leptophlebiidae) driving fish production. Total invertebrate biomass was not significantly different among habitats, although biomass was generally higher in the main channel compared to side channels with the exception of terrestrial invertebrates (Bellmore et al. 2013). In addition, the composition of invertebrates consumed by the fish assemblage was more different between habitats than between species. A greater percentage of the invertebrate food source was consumed by salmonids in side channels when compared to the main channel where sculpin and whitefish dominated the consumption (Bellmore et al. 2013), indicating the importance of these habitat patches within the landscape that provide a wide variety of local food webs. With respect to the effect of habitat restoration, it was speculated that treatments that increase habitat complexity and bed movement would increase benthic invertebrate food available to drift-feeding ESA-listed juvenile salmonids (Bellmore et al. 2014 and Reclamation 2013).

This study found that carrying capacity for both main channel and side channel habitats exceeded measured fish density based on the available prey base. In other words, available rearing habitat for juvenile spring Chinook salmon and steelhead was under-seeded relative to food availability. This may indicate that there are insufficient numbers of spawning adults to fully seed the habitat. In the main channel, non-target species such as mountain whitefish and sculpin dominated prey consumption and competed with juvenile salmonids, reducing juvenile carrying capacity. Disconnected side channels had low non-target fish production, resulting in higher spring Chinook and steelhead carrying capacity. This study did not show a correlation between hydrologic connectivity and fish production (Bellmore et al. 2013).

The total available food for juvenile salmonids, or the ability of the site to sustain fish, was not substantially different at Whitefish Island after enhancement compared to before. Although increased trophic transfer efficiency (the proportion of annual prey production that is consumed by the fish assemblage) and more diverse taxa assemblages were found in Whitefish Island during the post-treatment sampling period, similar increases were observed in reference side channels and therefore the treatment effects were not significantly different than the controls. The authors concluded that the variation observed during the study may have been within the range of natural variability, and as a result, any potential effect of habitat enhancement was unable to be detected. It is worth noting that the available aquatic invertebrate prey at Whitefish Island was significantly greater than annual demand by fish in the side channel (i.e., the amount of food consumed by fish) (Paris et al. 2019).

In the related analysis of the meta-food web (Bellmore et al. 2015), when all of the sampled habitat patches were considered together, the increased spatial complexity revealed weak trophic interactions, such as instances where target species would find refuge from predators. These weaker overall interactions promote biodiversity and stability of food webs. These types of systems are more resilient, robust, and buffered from potentially harmful disturbance. This has important implications for enhancement actions and supports the creation of diverse habitat patch types throughout a site, which may be important for sustaining fish populations over the long-term.

5.3 Beaver Creek

5.3.1 Overview

Enhancement activities over the past 15 years in the Beaver Creek watershed have included removing fish passage barriers, screening irrigation diversions, increasing instream flow, and instream habitat enhancement. Prior to enhancement actions, Beaver Creek had several diversion dams that acted as complete barriers for upstream migrating adult and juvenile fishes (Grabowski 2013). Anadromous fish were present in lower Beaver Creek before barrier removal but were not present in middle and upper reaches of Beaver Creek (Martens and Connolly 2010). The goal of enhancement actions in the Beaver Creek watershed was to reestablish a steelhead population upstream of the barriers and increase steelhead production.

Rock vortex weirs have been constructed at former barrier locations to provide passage through the Lower Stokes (2003), Thurlow Transfer (2003), Upper Stokes, and Fort-Thurlow (2004) barriers. Other fish passage actions addressed the Thurlow Transfer Ditch (2007), Redshirt (2007), Batie (2007), Marrachi (2010), and Tice (2010) barriers. Replacing several irrigation canals with pressurized pipe systems and water leases through actions sponsored by Trout Unlimited from 2007-2012 increased instream flow 3.5-4.25 cfs at the mouth (natural baseflow is less than 10 cfs). Instream habitat has been improved at three sites from 2009-2013 using large wood placement and channel re-meandering. Riparian plantings have been installed at multiple sites to provide long term wood to the system and improve channel conditions. A map of several of the fish passage and screening actions is included in Figure 29.

Figure 28. Fort Thurlow diversion in 2002, prior to enhancement actions. Photo from Reclamation.

CASE STUDY: BEAVER CREEK

Beaver Creek is a third order stream that enters the Methow River at RM 35.4. It drains a watershed area of 69.1 square miles (USFS 2004 in Martens and Connolly 2010) and has a snowmelt driven hydrograph with high flows in May and June and baseflows in August through October. Beaver Creek historically supported steelhead and may have supported coho salmon and Chinook salmon (Grabowski 2013). Bull trout, rainbow trout, cutthroat trout, and brook trout are also present.

Many pushup dams constructed of concrete, wood, rock, and plastic sheeting were installed in Beaver Creek over the last 100 years to feed agricultural diversions. The Fort-Thurlow and Lower Stokes diversions were both considered to be complete passage barriers for steelhead, as spawning had only been recorded in lower Beaver Creek downstream of the barriers (Reclamation 2004 and Reclamation 2005 in Martens and Connolly 2010). Rock vortex weirs or roughened channels were constructed at former barrier locations to provide passage through the Lower Stokes, Thurlow Transfer, Upper Stokes, and Fort-Thurlow barriers.

PROJECT RESULTS

- Increased connectivity, instream flow, and instream habitat.
- Replacing several irrigation canals with pressurized pipe systems increased efficiency and has increased instream flow 3.5-4.25 cfs at the mouth.
- Instream habitat has been improved at three project areas using large wood placement and channel re-meandering.
- Riparian plantings have been installed at multiple sites to provide long term wood to the system and improve channel conditions.
- Steelhead spawning was observed upstream of the former barrier locations following removal, and a reproducing population has established.

Completed roughened channel at one of the Fort Thurlow sites in August 2016, following adaptive management actions.

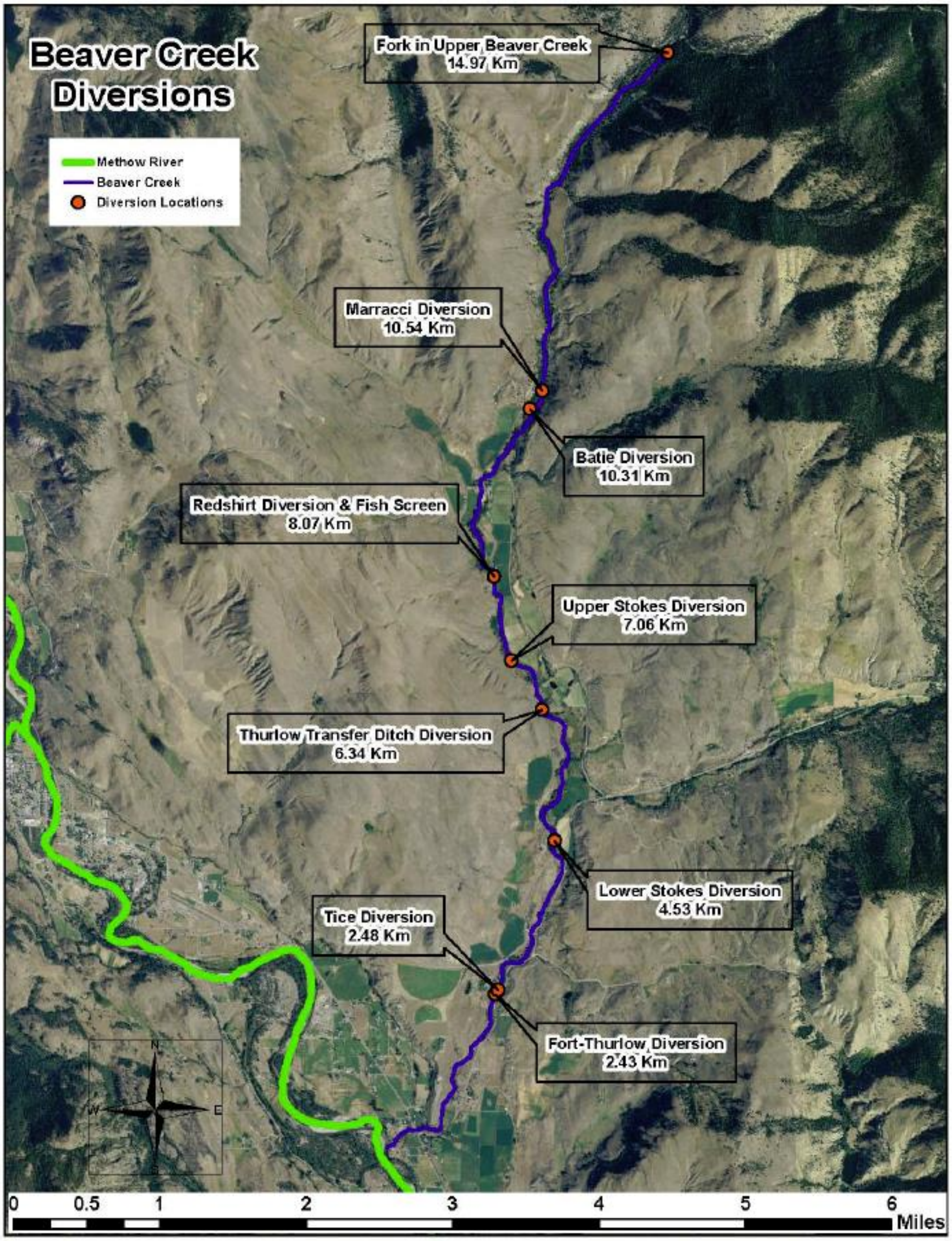


Figure 29. Map of fish passage and screening sites in Beaver Creek. From Reclamation and BPA (2013).

5.3.2 Study Findings

Barrier removal successfully restored fish passage to Beaver Creek. Fish surveys after enhancement found juvenile spring Chinook, juvenile Coho, and mountain whitefish, which were all absent above the barriers before removal (Martens and Connolly 2010). Brook trout were present above and below the barrier before removal and were observed passing upstream after barrier removal (Martens and Connolly 2010). Steelhead entered Beaver Creek during the first spawning season after barrier removal (Weigel et al. 2013).

Anadromous parr tagged in Beaver Creek returned as adults indicating an anadromous population was established in this newly opened habitat (Weigel et al. 2013). Fluvial rainbow trout crossed with steelhead and directly contributed to population establishment by producing offspring that returned as adults (Grabowski 2013). Hatchery fish were a small proportion of colonizing adults and did not appear to contribute to recolonization of the study area (Weigel et al. 2013). Few adults made it to upper reaches of Beaver Creek in the first 4 years after removal (Weigel et al. 2013).

Adult steelhead numbers did not increase during the first 4 years after barrier removal, and colonization and expansion of steelhead was a slower process than expected (Weigel et al. 2013). The number of colonizing adults fluctuated from 2005-2008 and followed adult counts at Wells Dam conducted by WDFW (Grabowski 2013). Tag movement data show that returning adults have migrated further upstream each year (Grabowski 2013). Access to new rearing habitat will hopefully lead to a sustained process of colonization and population growth (Martens and Connolly 2010).

There are steelhead redd survey data available for Beaver Creek from 2002 to 2013 (Snow et al. 2016). Redd counts are provided within three Beaver Creek reaches (see Figure 30). For reference, Reach BV1 is below all of the diversions in Beaver Creek. The data show that there has been spawning in some years in the upper Beaver Creek reaches, possibly related to barrier removal projects. However, the sampling has been inconsistent within these upper reaches, and the data are only really useful for looking at long-term trends in reach BV1, in which redd counts have fluctuated over time with a marked decline from 2008 to 2013. In recent years, redds have not been sampled in BV2 and BV3 because of reliance on adult counts from a PIT-tag antenna near the upstream end of BV1. Intermittent sampling has also occurred in all of Beaver Creek from 2014 to 2017 because wildfire impacts have prevented redd surveys due to poor water quality (C. Snow, personal communication, 09/25/2017). In general, the currently available adult redd data and analyses are limited and prevent a full understanding of long-term trends, except to say that adult fish have spawned upstream of former barriers for at least some years. Future analysis that combines redd data with the newer PIT-tag data could help to better understand long term trends and the effectiveness of barrier removal projects.

Although a steelhead sub-population did reestablish upstream of the barriers in Beaver Creek, juveniles that reared in Beaver Creek prior to smolting returned at very low rates compared to those that reared in the Methow River (Connolly and Weigel, unpublished data in Grabowski 2013). It is unclear if this low return rate is due to out-of-basin or in-basin factors.

Several disturbance events have affected steelhead recolonization and productivity in Beaver Creek. A large flood occurred in Beaver Creek in 2011. This flood likely caused acute mortality of juvenile salmonids that were unable to find suitable high-flow refugia. The flood also destroyed the Fort-Thurlow and Marracci rock vortex weirs, which were repaired in 2014 as part of adaptive management. The Fort-Thurlow weir re-established itself as a barrier prior to repairs. These weir failures highlight the ongoing maintenance that is required with using this type of approach for diversions. Failures of rock weirs are relatively common (Reclamation 2009), and project sponsors should consider alternative methods, such as roughened channels, as well as consult the available literature for guidance on design methods and lessons learned from past failures.

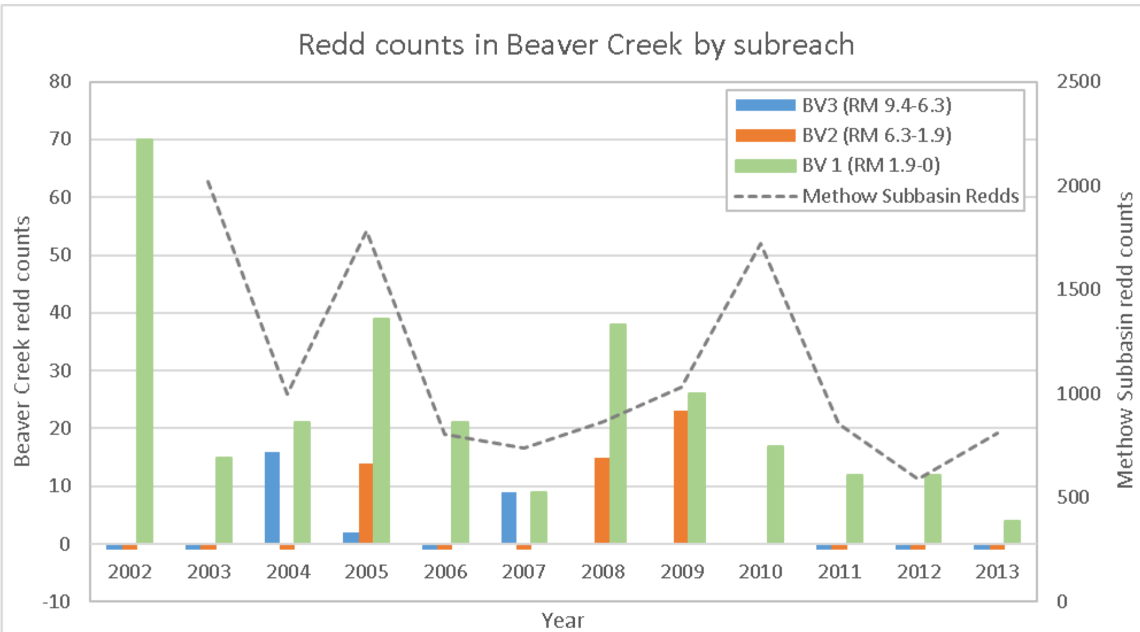


Figure 30. Redd counts in Beaver Creek from 2002 to 2013 overlaid with redd counts from the entire Methow Subbasin for reference (Snow et al. 2015). Negative values indicate no survey was performed for that reach.

The 2014 Carlton Complex fire (Figure 31) occurred in 2014 and burned 40% of the Beaver Creek watershed and 16% of the riparian corridor at moderate to high severity (Johnson and Molesworth 2014). Dead *Onchorynchus mykiss* (steelhead or Rainbow Trout) were observed immediately following the fire and again after ash and debris flows in mid-August. Flash flood events occurring shortly after the wildfire and the number of roads in the subbasin may have exacerbated fine sediment loading into the lower 8 miles of Beaver Creek in the short-term. This lower reach experienced more intense habitat degradation compared to burned areas upstream that have lower road densities, and fish in these systems may face more extreme acute effects as well as increased long-term consequences of the fire.

Studies of the fish population response to these large environmental events is on-going. Post-fire sampling in 2014 found four relatively large steelhead present in Beaver Creek, indicating a decline in species richness and a drastic decrease (>99%) in steelhead abundance in Beaver Creek. Pre-fire sampling efforts found rainbow trout/steelhead, brook trout, shorthead sculpin, mountain whitefish, and low numbers of Chinook and Coho salmon (Watson and Crandall 2014).

Numerous mechanisms may have been responsible during or after the fire for the observed decline in fish species and abundances. It is possible that some fish were able to move out of Beaver Creek to find refuge elsewhere in the Subbasin, whereas spikes in stream temperature during the fire along with heavy ash and sediment loading post-fire are likely contributing factors to direct mortality of fish in Beaver Creek (Watson and Crandall 2014).

Figure 31. Burned riparian area and natural log jam in lower Beaver Creek from the Carlton Complex fire, four years after the fire. Photo provided by Reclamation.

Lasting impacts of the fire are anticipated in the basin; for instance, reduced shading is expected to increase summer water temperatures and diurnal temperature fluctuation (Johnson and Molesworth 2014) in the short term until vegetation can mature. Likewise, fine sediment loading from the fire is expected to negatively affect migration, spawning, and juvenile rearing habitat quality in the short-term (Johnson and Molesworth 2014).

Over the longer-term, however, these events may result in increased quantities of favorable habitat for salmonids. Post-fire mass wasting and debris flows are a natural process and over the long-term may provide positive benefits to the system via increased sediment and wood recruitment from the immediately adjacent burned areas, supporting healthy geomorphic processes, such as improved floodplain connection and instream complexity (Miller et al. 2003; Benda et al. 2003; Dunham et al 2003). Although spring high flows may cause acute spikes in turbidity, they are likely to be of short duration and have a diminishing return through successive years of spring runoff and recovery and provide cobble and gravel to the system. Increases in large woody material into the channel as a result of the fire and flood may create complex habitat features. Increased nutrient loading from burned areas into Beaver Creek post-fire also may provide short-term positive benefits, increasing aquatic invertebrate densities and therefore providing a more robust food base for juvenile salmonids. In addition, several habitat enhancement actions in the basin survived the fire and continue to successfully provide instream habitat, increased floodplain inundation, and efficient attenuation of streamflow energy. Therefore, although some negative effects may have resulted from both the Carlton Complex wildfire and flooding in 2014, it is anticipated that the habitat and the salmonid populations will recover over time (Johnson and Molesworth 2014).

5.4 Other Studies

5.4.1 Elbow Coulee

The Elbow Coulee site is located on the Twisp River at RM 6.6. Enhancement actions were implemented by MSRF in 2008 to improve connectivity to a side channel that was disconnected from the Twisp River by a levee. A sill was constructed in the levee to allow flows to enter the side channel when Twisp River discharge reached 200 to 400 cfs. In addition, large wood was rearranged in the channel to improve habitat. Perennial ground water connectivity kept the downstream end of the channel wetted year-round. Monitoring showed that the side channel was inundated during nine activation events spanning 284 days over a three-year period. The enhanced connectivity to the mainstem increased fish abundance three-fold in the side channel and allowed fish to access the habitat from the upstream end. Species richness increased with the appearance of Coho salmon and Bridgelip Sucker, and abundances of ESA-listed species increased substantially (BPA 2013).

5.4.2 Hancock Springs

The Hancock Springs habitat enhancement project was implemented by the Yakama Nation in 2011 and included channel reconstruction, placement of large wood for habitat, and riparian vegetation enhancement. These enhancement actions were evaluated using a treatment-control reach design, with the untreated control reach located just downstream of the treatment reach. For details on study design and methods, please see Jorgenson (2014). The study revealed substantial changes in physical habitat, macroinvertebrate production, and fish response as a result of the enhancement work. Physical habitat changes included an increase in percent pool, increased cobbles and gravels, decreased fine sediment, and increased wood density and habitat cover. Various metrics of fish performance were greater in the treatment reach compared to the untreated reach; these included steelhead and spring Chinook redds, total fish abundance, total fish biomass, and total fish production, which was nearly 5-fold higher in the treatment reach compared to the untreated control. Indices of macroinvertebrate production and their consumption by fish were also improved by the enhancement work. Consumption of total invertebrate prey was over 6 times higher in the treatment reach and nearly 100% of insect biomass produced in the treatment reach was consumed by fish, compared to 16% in the untreated control. Although there were substantial improvements to habitat and food conditions for native salmonids, non-native brook trout dominated the fish communities in both reaches. However, enhancement appeared to reduce the relative consumption of food resources by brook trout (Jorgensen 2014).

5.4.3 Groundwater-Surface Water Exchange

Groundwater-surface water exchange can be a critical component of rearing salmon habitat. Mejia et al. (2016) conducted a comparison of fish growth in side channels with groundwater inputs (gaining sites) to those without (losing) or those with intermittent groundwater inputs (transient). The study was performed in 2014 using sites in the mainstem Methow and Twisp rivers. Fish grew almost twice as fast in gaining than in losing sites, while fish from transient sites grew as much as gaining sites but had a lower overall condition. The level of hyporheic input to a side channel affects the water temperature and nutrient availability, which in turn affects primary production and production of invertebrates (as well as invertebrate community assemblage), which in turn affects growth of juvenile salmonids. Water temperatures, which are affected by these hyporheic inputs, also have direct effects on juvenile fishes, in which the warmer winter water temperatures and cooler summer water temperatures provide more optimum conditions for growth (Mejia, et al. 2016).

5.4.4 Stream Metabolism Variability

Stream habitat conditions are influenced by a number of factors, from anthropogenic influences to seasonal shifts in air temperature, solar radiation, and precipitation. To better understand the spatial and temporal variability in stream food web ecology of the Methow River, Mejia et al. (2019) recorded environmental characteristics and modeled intra-annual patterns of gross primary production (GPP) and ecosystem respiration (ER). Environmental characteristics measured at 10 sites across the Methow Subbasin included dissolved oxygen, periphyton (chlorophyll-a and ash free dry biomass [AFDM]), nutrient concentrations (dissolved inorganic nitrogen [DIN] and soluble reactive phosphorus [SRP]), temperature, photosynthetically active radiation (PAR), drainage area, discharge, and relative bed stability.

The authors found that GPP and ER increased with drainage area, as expected. However, the expectation of peaks in ecosystem metabolism during the summer and fall (e.g., due to light, leaf litter, and stable flows) were less consistently observed. Only four of the sites followed summer GPP peaks and autumn ER peaks, while the rest either peaked in winter, spring, or remained relatively constant. The primary driver of the peak GPP or ER timing was related to site disturbances, with winter-peak sites lacking seasonal disturbances (i.e., high discharge events, ice formation), allowing periphyton biomass to accumulate throughout the year until high flow events in the spring. The authors also found that GPP was positively associated with water temperature at most sites and negatively associated with discharge. The best predictors of GPP were AFDM, discharge, and SRP. For the ER model, GPP was the best explanatory variable, with discharge, temperature, and PAR explaining a portion of the variability (Mejia et al. 2019).

5.4.5 Entiat River

Although outside of the Methow Subbasin, research by Polivka et al. (2015) similarly investigated the effectiveness of large wood and rock habitat enhancement structures on juvenile spring Chinook and steelhead rearing in the lower Entiat River. As the Entiat is also a tributary to the Upper Columbia River and has similar basin characteristics to the Methow, we believe the results of these studies are relevant and applicable to work in the Methow Subbasin.

Data collection occurred from 2009 to 2013 at the Milne Project in the lower Entiat River and at several nearby untreated reference segments. Results showed that both species (Chinook and steelhead) had greater abundance (approximately double) at restored pools than at natural pools in early summer; however, the effect was typically absent by September. Extensive sampling in untreated habitat, both within the restored segment and in reference segments, suggested that the increased fish numbers at the structures were a result of increased habitat capacity as opposed to simply redistribution of fish in the reach. Pool size, depth, velocity, temperature, and several interaction terms appeared to influence fish abundance.

6 Aquatic Trophic Productivity Model

The monitoring data discussed in Section 4 are used in ecological models to create and test hypotheses about the relationships between habitat actions and fish survival and production. The primary model used in the Methow Subbasin is the Aquatic Trophic Productivity (ATP) model, which was developed in collaboration with the USGS, Forest Service Pacific Northwest Research Station, and University of Idaho. This model and associated modeling products have largely been completed since the 2012 Annual Report (Bellmore et al. 2014, Benjamin and Bellmore 2016, Bellmore et al. 2017); and the model findings are discussed in more detail below. Additional studies that support the ATP model have looked at life cycle survival, habitat recolonization after barrier removal, off-channel habitat productivity and use, the relationship between hyporheic flows and juvenile growth, and a variety of other topics. Key findings of these additional studies are presented throughout this section as they provide insight into ecological responses to habitat enhancement.

6.1 Model Background

The ATP model is a dynamic river food web simulation model (Benjamin and Bellmore 2016) and is the principal model developed for the Methow program. This model uses an ecosystem energetics approach, whereby the capacity of the river ecosystem to sustain fish is directly tied to the movement of organic matter between different components of the river food webs (Figure 31). In turn, transfers of organic matter are directly linked to (1) the physical and hydraulic conditions of the stream, (2) the structure and composition of the adjacent riparian zone, and (3) marine nutrient subsidies delivered by adult salmon. To simulate the ecological effects of habitat enhancement actions on the river ecosystem, these relative environmental inputs can be adjusted within the model. The ATP model has been used to evaluate the expected response to specific habitat enhancement actions at three sites including the Whitefish Island side channel, the Middle Methow reach, and the Twisp River Floodplain project. A description of the three case studies and their modeled results are provided later in this section.

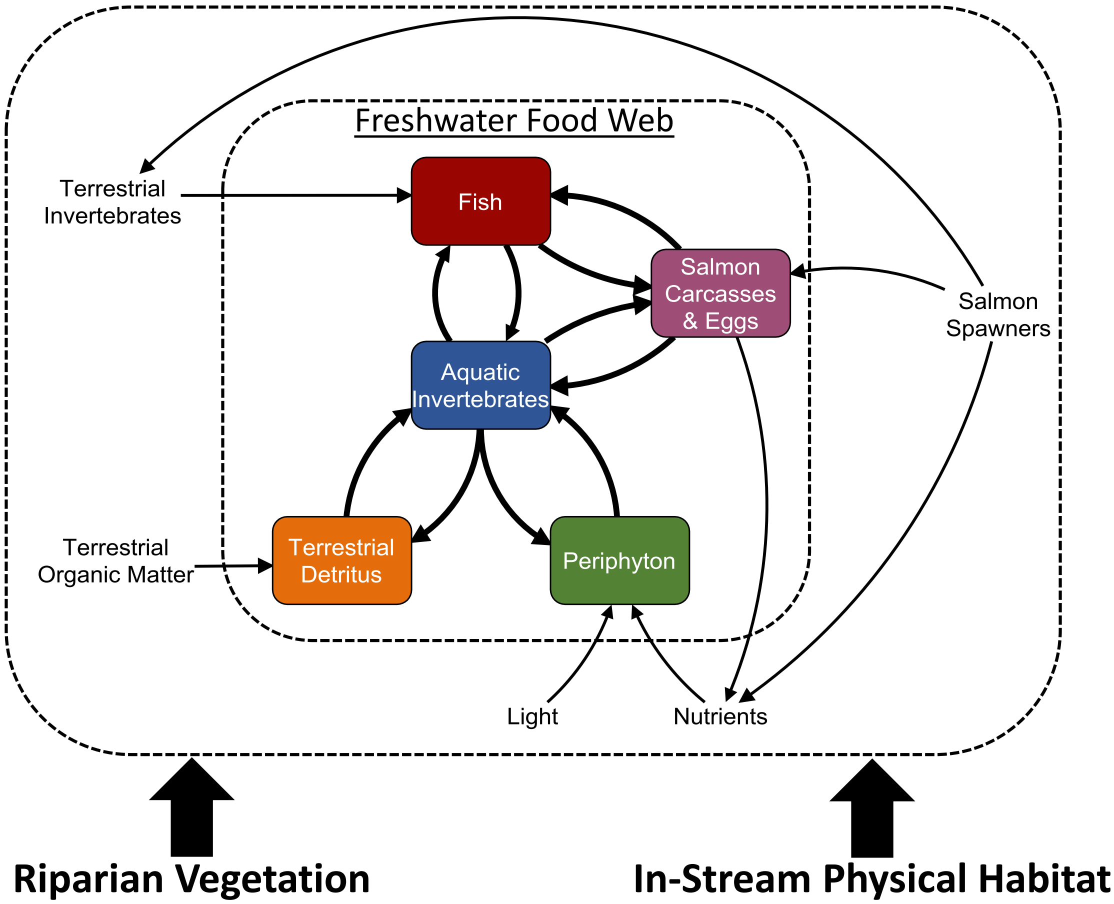


Figure 32. ATP modeling framework showing primary stocks (colored boxes), within-system energy flows (thick arrows), and inputs from outside the system (thin arrows). Figure from Bellmore et al. 2017.

6.2 Model Parameters

The ATP model is organized into groups of biomass stocks that represent the general trophic structure of river ecosystems. Using this ecosystem-based approach, the four primary biomass stocks include: (1) in-stream primary producers (periphyton), (2) terrestrially derived organic matter (e.g., leaf litter), (3) aquatic invertebrates, and (4) fish. The change in biomass over time for each of these stocks is determined by a series of mass balance equations that represent the processes of consumption (+), respiration or decay (-), and mortality or export (-).

External energy inputs are also included in the model to represent the energy and materials that enter the river system from external locations. External inputs include (1) light and nutrients, which provide the energy and materials necessary for periphyton production; (2) lateral inputs from the riparian zone, which provide detrital organic matter (leaf litter) and direct food resources for fish (terrestrial invertebrates); and (3), returning adult salmon. Returned adult salmon carcasses provide a source of marine-derived nutrients that are integrated into the food web by periphyton and direct consumption of carcass material by other fish and invertebrates. See Bellmore and

Benjamin (2016) for more details on ATP model framework, parameters, and calculations.

6.3 Model Parameterization and Validation

In the Methow, the environmental data necessary to parameterize the ATP model were obtained from various sources (see Benjamin and Bellmore 2016). For parameters in which it was not practicable to measure in the field, or that have known values, estimates were developed for the model based on available literature. In cases where no literature values existed, parameter values were adjusted to produce model runs that were stable and that sufficiently matched empirically measured biomass values from the basin (Bellmore et al. 2013, Zuckerman 2015). Bellmore and others (2017) found that the model was able to closely match the seasonal dynamics of fish, invertebrate and periphyton biomass in the middle Methow (M2 reach).

6.4 Model Results

Several case studies were run through the ATP model to evaluate the effects of potential enhancement actions or the effectiveness of completed habitat actions (in the case of Whitefish Island) throughout the Subbasin. Several model scenarios were run for each case study, such as adding salmon carcasses (nutrient addition), reconnecting a side channel, increasing the proportion of suitable habitat for juvenile fish based on water depth and velocity (typically accomplished by adding large wood and increasing pool area) within existing channels, and increasing riparian vegetation. In general, all scenarios increased fish biomass. However, the relative increase depended substantially on the specific site conditions. For example, the Twisp River is an oligotrophic system, and as a result, had a proportionately greater response to salmon carcass (nutrient) addition than did other sites. For more information, see the modeling case studies below.

In addition to evaluating different types of actions at the subbasin or reach scale, the ATP model can be used to compare and prioritize enhancement design alternatives for a single project site. Benjamin et al. (2018) used the ATP model to evaluate the relative benefits of four different proposed fish habitat enhancement alternatives at the Barkley Bear site in the M2 reach of the Methow River. The four alternatives included varying levels of side channel reconnection, floodplain reconnection, and large wood addition; and the relative uplift was based on habitat preferences for juvenile Chinook salmon. The ATP model ultimately provided estimates of carrying capacity for each of the four alternatives. The two alternatives that provided the most uplift in carrying capacity were those that focused on floodplain reconnection and complex floodplain habitats (Benjamin et al. 2018). Furthermore, these two alternatives were robust to changes in discharge and thermal regimes, which are likely to occur under climate change.

CASE STUDY: LOWER TWISP FLOODPLAIN

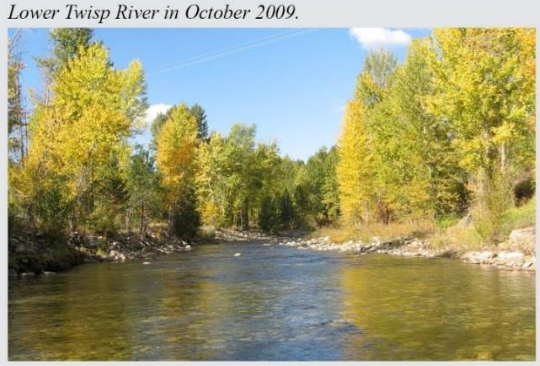
Project Goal: Increase the floodplain and off channel habitat connectivity and channel complexity in a 1.6 km section of the Twisp River. The ATP model was used to evaluate potential enhancement treatments.

Model Scenarios: Four model simulations were run: adding salmon carcasses, reconnecting a side channel, increasing habitat suitability, and increasing riparian vegetation.

Model Findings: Salmon carcass additions improved fish production the most in the model by increasing the availability of high-quality food for fish (direct consumption) and aquatic invertebrates, which also provide food for fish (indirect consumption). Side channel reconnection also increased fish biomass. Increasing habitat suitability increased fish biomass and decreased aquatic invertebrate biomass as a result of more fish predation.

The riparian enhancement scenario increased the seasonal availability of in-stream terrestrial detritus, but these increases did not travel up the food web to aquatic invertebrates and fish. The Twisp River is a nutrient poor (oligotrophic) system, and it is logical that salmon carcass addition would have the largest positive impact on fish production.

Lower Twisp River in October 2009.



CASE STUDY: WHITEFISH ISLAND SIDE CHANNEL

Project Goal: Deepen and add wood to an existing high flow channel to increase frequency of inundation. The ATP model was used at this site to help understand how an existing habitat enhancement project may have changed the food web dynamics and fish production in the side channel.

Model Scenarios: Three model simulations were run: one pre-enhancement scenario and two post-enhancement scenarios with different parameter values.

Model Findings: For post-enhancement scenario 1, the simulated 300%-increase in fish biomass was primarily due to the 5-fold increase in wetted area following enhancement. The previously seasonal influx of water and food now occurs year-round thereby increasing food availability for fish. For scenario 2, the 726%-increase in habitat quality allowed fish more opportunities to access and use these additional food resources. Note that fish biomass incorporates all fish (sculpin, rainbow trout, Chinook, etc.) and is not exclusive to steelhead or Chinook salmon. These simulations suggest that the habitat improvements that have occurred at Whitefish Island may significantly increase the capacity for the side channel to sustain juvenile salmonids.

An engineered log jam at Whitefish Island side channel three years after construction (2016).

CASE STUDY: MIDDLE METHOW

Project Goal: Evaluate the effects of potential enhancement treatments within the middle Methow River.

Model Scenarios: Four model simulations were run: adding salmon carcasses, reconnecting a side channel, increasing habitat suitability, and increasing riparian vegetation.

Model Findings: Salmon carcass addition resulted in increased fish biomass by providing rapid biomass increases in autumn that persisted throughout the rest of the year. Riparian vegetation enhancement resulted in increased seasonal availability of in-stream terrestrial detritus, but did not affect higher levels of the food web (invertebrates or fish). Side channel addition increased all biomass stocks via several mechanisms, such as increased nutrient retention and assimilation due to longer residence time in the side channel, increased terrestrial leaf litter and invertebrate inputs from expanded riparian areas, and increased total available habitat within the river segment. Improving habitat suitability increased fish biomass in a similar way to the side channel addition scenario.

Middle Methow River in August 2016.

6.5 Model Interpretation

The ATP model was developed as a decision support tool to inform restoration and management actions prior to implementation, linking the success of target fishes to the broader food web and associated energy flows that support them. The effort by Benjamin et al. (2018) to understand the effects to juvenile salmonid carrying capacity under four potential restoration alternatives did inform design of enhancement actions that target salmon and trout species in the Methow Subbasin. However, there are limitations in the ability to accurately interpret model outputs. Although the ATP model incorporates many ecological relationships, like all models, it is still a simplified version of reality. As such, it is important to interpret the model simulation results not as certain outcomes but rather as hypotheses predicting what might occur from ecosystem alterations in the Methow. Furthermore, there is generally inadequate data available to test results for accuracy. Benjamin et al. (2019) note that although the model is useful for examining specific restoration alternatives, it may be better suited to assessing broader actions at a larger scale than specific projects.

7 Key Findings and Lessons Learned

The key findings, lessons learned and recommendations provided in the remainder of this report were developed based on the results of the numerous studies conducted throughout the Methow Subbasin to evaluate specific enhancement actions, document fish population status and trends over time, and answer specific research questions. Each key finding or lesson learned is based on the results of one or more of these studies, and will reference the section of this report in which the studies are cited and summarized in more detail.

7.1 Fish Use Patterns, Trends, and Responses to Enhancement Actions

The available data on fish use in the basin provide information on use patterns, trends, and potential responses to habitat enhancement efforts. RM&E actions have been performed by a variety of entities including federal and state resource agencies, tribes, universities, consultants, and public utilities. Data have been collected at numerous spatial and temporal scales and include on-going status and trends monitoring (e.g. redd and carcass surveys, PIT tagging, and smolt trapping) as well as a host of other various RM&E efforts that help provide information on fish use patterns, fish-habitat relationships, and fish survival and production trends.

The monitoring to date has yielded some results suggesting that enhancement efforts in the basin are improving salmonid survival and productivity. To monitor enhancement efforts, it is appropriate to rely on in-basin metrics of fish performance, including trends in juvenile abundance, productivity, egg-to-emigrant survival, and others that are confined to the juvenile life stage.

Even in these juvenile analyses, however, detecting an ecological response to enhancement actions is challenging for a number of reasons. For one, enhancement actions encompass a wide range of locations, intensities, and sizes, and are being implemented over a period of time rather than all during one year, so the variation in treatment scenarios is high and makes it challenging to develop robust study designs or to make suitable comparisons. Fish may move in and out of the subbasin throughout the study period, while the number of juveniles and their timing of entry into the subbasin is also dependent on variable environmental conditions (e.g. streamflow, water temperature, sediment load), which will affect how many juveniles encounter and use locations of habitat enhancement in any given year. In addition, large areas of the watershed need to be improved to detect fish responses. For example, Roni et al. (2010) reported that more than 20% of a watershed would need to be improved to measure a population/watershed-scale response to enhancement. Although a large percentage of degraded habitat within the Methow Subbasin has been enhanced (see Table 2), the lack of pre-treatment data, no subbasin controls or references, and low seeding levels limit our ability to detect treatment effects at the subbasin scale. Finally, some actions such as riparian revegetation and conservation easements may take decades until they start providing ecological benefits. Other actions such as large wood placements and floodplain reconnection provide a more immediate habitat benefit, but are also expected to evolve and accrue benefits over time as the system responds. Thus, time lags between implementation and habitat improvement, and habitat improvement and fish response are variable, which makes drawing conclusions from time series data difficult. The effects of enhancement actions on salmonids in the Methow are expected to become more apparent as additional years of post-implementation data are collected.

Figure 33. Juvenile salmonids in a deep Whitefish Island pool where a large wood crib wall was installed (2015 Photo courtesy of John Crandall).

Lessons Learned

Fish Status and Trends

- Spring Chinook spawning occurs at highest densities in the Methow River between Winthrop and Mazama, with moderately high spawning density in the Chewuch River near Boulder Creek and Falls Creek. Spawning in the Twisp is more dispersed for spring Chinook (Section 4.1).
- Steelhead spawning occurs at highest densities in the Methow River near Winthrop and Mazama, and in the Twisp River between Bridge Creek and Canyon Creek. Spawning in the Chewuch is more dispersed for steelhead (Section 4.1).
- The majority of spring Chinook juveniles outmigrate at age 1 (78%), and the majority of steelhead outmigrate at age 2 (69%), underscoring the need for suitable rearing habitat year-round (Section 4.2).
- Chinook and steelhead emigrant abundances show high variability between years. Spring Chinook appear to be trending upward over time although steelhead do not show a strong trend (Section 4.2).
- Egg-to-emigrant survival has increased for spring Chinook in the Twisp over time (Section 4.2).
- There is evidence of density dependent survival for Twisp River spring Chinook juveniles (Section 4.2).
- The available data are not sufficient to determine if density dependent survival is limiting production for spring Chinook in the Methow Subbasin as a whole or for steelhead in the Twisp or Methow. Additional data are needed to better understand these relationships (Section 4.2).
- Wild spring Chinook and steelhead have NRR less than one (except Chinook from 1995-1998), indicating that they are not replacing themselves during most years. This could be because of a lack of sufficient habitat capacity, or because of low survival throughout their life history (Section 4.3).

7.2 Fish Passage Improvements

More fish passage improvement actions funded by Reclamation have been carried out in Beaver Creek than any of the other subbasins in the Methow. Monitoring has demonstrated several ecological benefits of these actions; however, the population response depends on many factors not specifically addressed by improving passage alone. Upstream habitat suitability, downstream habitat limitations, and adult and juvenile life stages available to colonize the habitat all influence the fish response to passage improvement.

Figure 34. Roughened channel constructed to replace a barrier at one of the Fort Thurlow diversions. Photo provided by Reclamation.

Lessons Learned

Fish Passage Restoration

- Rock vortex weirs successfully improved fish passage through former barriers in Beaver Creek, but rock weirs are susceptible to failure during floods and require ongoing monitoring and maintenance to ensure they continue to meet objectives (Section 5.3).
- Recolonization following barrier removal may occur slowly and be strongly influenced by out-of-basin factors (Section 5.3).
- Resident rainbow trout inter-breed with wild steelhead and contribute to recolonization following barrier removal (Section 5.3).
- The population uplift generated by barrier removal depends on factors limiting fish production before barrier removal, and how well improving passage to new habitat addresses those limiting factors (Section 5.3).

7.3 Floodplain and Side Channel Habitat Enhancement

Floodplain and side channel habitat enhancement has been a focus in the basin over the last several years. These actions are often large-scale, and involve reconnecting previously disconnected habitat or creating entirely new habitat, or some combination of the two. Site-specific habitat action BACI studies and ATP modeling efforts have been used to predict and evaluate action effectiveness, and have demonstrated positive ecological responses to these activities.

Modeling and research shows a range of results with respect to the relative benefits of perennial versus seasonally connected side channels. The most beneficial condition likely varies by location depending on multiple factors including target species, life-stage, reach conditions, available food, flow conditions, and others. Given these uncertainties, providing a variety of side channels with differing hydrologic connectivity, such as is typically found in undisturbed systems, has the highest probability of benefiting target species. Restoring this complexity is also expected to support species life history diversity, thereby increasing population productivity and resilience over time.

Figure 35. Yakama Nation Chewuch River Right side channel creation and enhancement (Inter-Fluve 2017).

Lessons Learned

Floodplain and Side Channel Habitat Enhancement

- Side channels contain higher densities of rearing steelhead and Chinook compared to mainstem habitat and provide refuge from larger piscivorous fish (Section 5.1).
- Juvenile Chinook, Coho, and steelhead utilized all types of channels with different hydrologic (surface water) connectivity. Pre-treatment data suggested that Coho may prefer side channels with only seasonal connectivity, but post-treatment data showed heavy use in connected side-channels by all species, including Coho (Section 5.1).
- Increasing hydrologic connectivity between off channel habitat and the mainstem has been shown to increase use by target species, particularly for seasonally disconnected side channels where fish previously had only a limited time to access the habitat (Section 5.1). Modeling of the Whitefish Island Project revealed similar results, which were related to increased capacity and food availability (Section 6.4).
- In the middle and upper Methow River, fish production was supported by a wider range of prey taxa in side channels compared to the mainstem, and the type of side channel appeared to have a strong influence on food web dynamics. In addition, a greater percentage of the invertebrate food sources are consumed by ESA-listed salmonids in side channels compared to the main channel. Increasing connectivity may increase fish production because the abundant food resources frequently found in side channels become more available to fish (Section 5.2).
- Hyporheic upwelling moderates surface water temperatures and can increase fish production. Placing side channels in areas likely to receive upwelling, such as the inside of a meander bend, or constructing groundwater collection galleries, have both been used to increase groundwater connectivity (Section 5.4).
- Side channel enhancement projects that have sufficiently deep pools with large wood have been shown to improve habitat suitability and carrying capacity of the habitat, especially for side channels that are seasonally disconnected. Methow Subbasin studies of seasonally disconnected side channels showed that pools deeper than one meter increased rates of survival for juvenile Coho, Chinook, and steelhead compared to shallower pools (Section 5.1).
- In the mainstem Methow and Twisp, modeled side channel addition increased fish biomass through increased habitat capacity, increased retention of organic matter, and increased invertebrate production (Section 6.4).

Floodplain and Side Channel Habitat Enhancement, continued

- Food web modeling showed that restoration strategies that focused on increasing hydrologic connection to the floodplain and restoration of complex floodplain habitats provided the most uplift in carrying capacity (Section 6.4)
- Diverse habitat patches within the floodplain landscape are valuable because they host very different local food webs that are used extensively by juvenile Chinook and steelhead (Section 5.2).
- Metabolism modeling showed asynchronous peaks in stream ecological productivity that occur throughout the year and are influenced by variations in disturbance/climate (Section 5.4.4).

7.4 Enhancement of Channel Complexity

Enhancement of habitat complexity can take many forms, and may include channel reconfiguration, large wood placement, boulder placement, pool excavation, and addition of spawning gravels. Research in the Methow Subbasin and in other nearby similar systems has shown that enhancement of channel complexity has positive benefits to native fish communities. These benefits have been documented in settings ranging from large mainstem rivers like the Methow to small spring-fed systems like Hancock Springs. The benefits appear to accrue through multiple pathways, including directly through improved condition of physical habitat and indirectly through improvements to food resources and food web dynamics.

Figure 36. Excavating pools and installing log jams increases habitat suitability for spring Chinook and steelhead. Photo is of log jam on the Chewuch River installed as part of enhancement actions at the Chewuch RM 10 site.

Lessons Learned

Channel Complexity

- Studies in the mainstem and side-channels of the Methow River showed that target species densities are positively associated with deep pools with large wood and overhead cover (Section 5.1).
- Work on the nearby Entiat River revealed that early-summer rearing density of juvenile Chinook and steelhead was approximately doubled at placed large wood structures compared to untreated areas (Section 5.4).
- Channel reconstruction and large wood enhancement in a small stream can increase spawning densities, total fish production, and the degree of consumption of invertebrate food resources. Enhancement may also decrease the relative consumption of food resources by non-target species such as brook trout (Section 5.4).
- Large wood configured to promote local scour and bed movement has been shown to increase benthic invertebrate food available to drift-feeding ESA-listed juvenile salmonids (Section 5.2).
- In the Methow and Twisp, ATP model results indicate that an increase in habitat suitability (i.e. optimizing velocities and depths to better match juvenile salmonid preferences) would be expected to increase fish biomass and decrease aquatic invertebrate biomass due to more consumption by fish (Section 6.4).

7.5 Food Web Dynamics

Food web studies provide important insights into factors that drive fish production in complex floodplain systems. These studies provide information on species community composition, predator-prey interactions, and food availability and consumption. The primary sources of information on food web dynamics in the Methow Subbasin are a food web study conducted in the middle Methow (see Section 5.1.2) and the ATP model (see Section 6). Although food web dynamics are critically important to fish, they are frequently poorly understood, and we are fortunate in the Methow to have some understanding of these processes. Furthermore, the incorporation of food web interactions into the ATP model provides a useful tool that can help guide enhancement action planning and inform design.

Lessons Learned

Food Web Dynamics

- Food web analysis in the middle Methow showed that the structure of food webs, including species compositions and the types and strengths of predator-prey interactions, varied among habitat patches, presumably influenced by the type of habitat (e.g. mainstem versus side channel) and the degree of hydrologic connectivity. The analysis also showed that when you scale up to the larger channel-floodplain system, high spatial complexity produces weak trophic interactions, which promotes biodiversity and stability of food webs that are important for sustaining fish populations (Section 5.1.2).
- In the Twisp River, and to a much lesser extent in the Methow River, modeled carcass additions increased fish production through the influence on food availability, both from direct feeding on carcasses and from an increase in invertebrate production (Section 6.4)
- In the Methow and Twisp, modeled riparian enhancement (increased aerial coverage and stream shade) increased terrestrial detritus but did not increase invertebrate or fish biomass (Section 6.4).
- In the middle Methow, for both mainstem and side channel sample sites, the available prey base appeared to be able to support a greater density of rearing juvenile salmonids than was present at those sites, suggesting that the carrying capacity for juvenile rearing had not been reached (Section 5.1.2).

7.6 Recommendations

Recommendations for future research, monitoring and enhancement actions in the Methow Subbasin are listed below. These build off of the key findings and lessons learned presented in the previous sections.

1. Prioritize projects that increase the hydrologic connectivity to or availability of off-channel and floodplain habitats, which may improve food resource availability, increase fish use/production, provide uplift in carrying capacity, and be robust to climate change-driven alterations in discharge and thermal regimes (Section 5.1; Section 5.2, Section 6.4).
2. Create diverse habitat patch types within the larger channel-floodplain system because they promote biodiversity and stable food webs. Utilize enhancement strategies that provide high off channel habitat diversity, such as a combination of perennially connected, seasonally connected, high flow activated, flow-through, alcove, spring-fed, and wetland types (Section 5.1.2).
3. The creation or enhancement of diverse side channels with groundwater input also has high biological benefit. Where possible, maximize hyporheic and groundwater connectivity in side channel enhancement projects (Section 5.4).
4. Restore habitats with asynchronous peaks in stream ecological productivity throughout the year as are found in highly complex systems to allow fish to seek out and take advantage of productive habitats year-round (Section 5.4.4).
5. Create habitat enhancement projects with deep pools (e.g., greater than one meter deep), large wood, and overhead cover to increase salmonid rearing densities and improve survival for juvenile salmonids, particularly in side channels that are seasonally disconnected (Section 5.1).
6. Determine limiting factors of the target population before performing barrier removal to scale expectations of recolonization rates, and pair the barrier removal with habitat enhancement or other actions as deemed appropriate during the limiting factors analysis (Section 5.3).
7. Given the appearance of density dependent survival for spring Chinook, prioritize habitat enhancement actions in the Twisp River basin; focus particularly on actions that increase rearing habitat and food availability (Section 4.2).
8. Implement management actions that increase the spawning escapement of spring Chinook and steelhead within the Methow Subbasin as a whole, given the potential for under-seeding of juveniles relative to food availability (Section 4.2).
9. Continue collecting data in areas that may inform future work or priority areas:
    a. Continue to monitor fish migrating in and out of the Methow Subbasin. Improve or develop monitoring methods that increase the accuracy and precision of estimates (Section 4.2).

b. Consider developing a life-cycle model for Methow spring Chinook and steelhead. The model would help identify life-stage bottlenecks and testable hypotheses (Section 4.2).
c. Consider operating emigrant traps or develop mark-recapture or mark-resight studies to evaluate juvenile production within other sub-watersheds within the Methow Subbasin, such as the Chewuch (Section 4.2).
d. Identify useful reference or control watersheds to help assess the effects of treatments at the Methow Subbasin scale (Section 5).
e. Continue monitoring passage enhancement actions in Beaver Creek to understand population productivity over time, especially given the significant short-term effects of fire and flood disturbance (Section 5.3)
f. Monitor and evaluate the potential effects of hatchery fish and multi-species interactions, which may be influencing density dependent survival estimates (Section 4.2).
g. Obtain empirical data on the potential effects of nutrient enhancement on target species, and compare with the results of the ATP model (Section 6.4) to provide multiple lines of evidence for evaluating the potential benefits of nutrient enhancement.
h. Evaluate the effects of increased side channel connectivity on potential predation from species such as bull trout or brook trout, since it is not clear if increasing connectivity increases predation on target species, or if this does occur, if it is offset by other benefits to target species (Section 5.2).

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Appendix A – Enhancement Action List

June 2019

Enhancement Action Details			Biological and Physical Details				Abbreviated Summary
Year	Action Name	Agency/Sponsor	2012 Standardized Limiting Factors	Definition of Metrics	Metrics	Watershed	
1998	Methow River Barkley Screening	Washington Department of Fish and Wildlife (WDFW)	1.1: Habitat Quantity: Anthropogenic Barriers	1480. # of screens addressed	1 screen	Methow River	One of numerous WDFW screening projects completed within Okanokan county to reduce fish mortality and entrainment in irrigation systems.
1999	Eightmile Creek Screen Replacement	Washington Department of Fish and Wildlife (WDFW)	1.1: Habitat Quantity: Anthropogenic Barriers	1480. # of screens addressed	1 screen	Eightmile Creek	One of numerous WDFW screening projects completed within Okanokan county to reduce fish mortality and entrainment in irrigation systems.
1999	Okan Co. Buttermilk Ditch Fish Screen	Okanogan County	1.1: Habitat Quantity: Anthropogenic Barriers	1480. # of screens addressed	1 screen	Twisp River	Installed fish screen to prevent juvenile fish entrainment in the diversion.
1999	WDFW Wolf Creek Reclamation Dist Fish Screen	Washington Department of Fish and Wildlife (WDFW)	1.1: Habitat Quantity: Anthropogenic Barriers:9.2: Water Quantity: Decreased Water Quantity	1480. # of screens addressed; 1452. Amount of water secured in acre-feet/year	1 screen; 1000 acre-feet/year returned to stream	Wolf Creek	Installed fish screen to prevent juvenile fish entrainment in the diversion.
2000	WDFW Fulton Canal Fish Screen	Washington Department of Fish and Wildlife (WDFW)	1.1: Habitat Quantity: Anthropogenic Barriers	1480. # of screens addressed	1 screen	Chewuch River	Out of spec fish screen and bypass system was replaced by WDFW's Yakima Screen Shop so that if complies with federal and state fish protection standards.
2000	Okan Co. Skyline Ditch Pipe Installation Phase 1 & 2	Okanogan County	9.2: Water Quantity: Decreased Water Quantity; 1.1: Habitat Quantity: Anthropogenic Barriers	1453. Flow of water returned to the stream as prescribed in the water acquisition in cubic-feet per second (cfs); 1480. # of screens addressed	10 to 23 cfs; 1 screen	Chewuch River	Installed a fish screen, headgate, piping, and new bypass system to increase instream flow in the Chewuch River. The Skyline Ditch company installed a pressurized pipe conveyance system which will reduce diversion to below the maximum design flow of the fish screen. The ditch below the headgate was a high water loss area and was patched with hand-placed plastic. Piping this section significantly reduces leakages & allows further reduction in the diversion returning 10 cfs to fish habitat in the Chewuch River system.
2000	Okan Co. Little Bridge Creek Culvert	Okanogan County	1.1: Habitat Quantity: Anthropogenic Barriers	1441. # of miles of habitat accessed to the next upstream barrier(s) or likely limit of habitable range	5.5 miles of access restored	Twisp River	Culvert replacement of undersized culvert located 50 feet upstream from the mouth of Little Bridge Creek to improve fish passage.
2000	WDFW Twisp-Power Ditch Fish Screen	Washington Department of Fish and Wildlife (WDFW)	1.1: Habitat Quantity: Anthropogenic Barriers	1480. # of screens addressed	1 screen	Twisp River	Fish screening modernized to reduce fry entrainment and juvenile impingement.
2000	Wolf Creek Channel Restoration	Okanogan County	6.1: Channel Structure and Form: Bed and Channel Form; 6.2: Channel Structure and Form: Instream Structural Complexity	1387. # of miles of stream with improved complexity	0.15 miles enhanced	Wolf Creek	Log cross vanes and large wood were installed in the main channel to provide fish passage and habitat.
2001	WDFW Early Winter Canal Fish Screen	Washington Department of Fish and Wildlife (WDFW)	1.1: Habitat Quantity: Anthropogenic Barriers	1480. # of screens addressed	1 screen	Early Winters Creek	Replaced a fish screen on an out-of-spec irrigation diversion to keep salmonids out.
2001	Okan Co. Airey/Risley Ditch Removal	Okanogan County	1.1: Habitat Quantity: Anthropogenic Barriers	1480. # of screens/barriers addressed	1 barrier removed (push up dam removed)	Methow River	Irrigation improvements to increase instream flow

Enhancement Action Details			Biological and Physical Details				Abbreviated Summary
Year	Action Name	Agency/Sponsor	2012 Standardized Limiting Factors	Definition of Metrics	Metrics	Watershed	
2002	Okan Co. Fulton Ditch Lining Project	Okanogan County	9.2: Water Quantity: Decreased Water Quantity	1453. Flow of water returned to the stream as prescribed in the water acquisition in cubic-feet per second (cfs)	2000 ft of canal lined; unknown cfs returned to river	Chewuch River	The directors of the Fulton Ditch Company (FDC) identified five shalerock locations where irrigation water percolates into the substratum. FDC lined these areas with Enviroliner (EL) textile a 30-millimeter ultraviolet resistant geomembrane with a 10-year warranty and an expected longevity of 30 years over 2000 lineal feet at 18 inches wide.
2002	Okan Co. Early Winters Ditch Diversion Structure	Okanogan County	1.1: Habitat Quantity: Anthropogenic Barriers	1480. # of screens addressed; 1453. Flow of water returned to the stream as prescribed in the water acquisition in cubic-feet per second (cfs)	1 screen, unknown cfs returned to river	Early Winters Creek	Installation of a diversion structure with fish screen to replace an inneffective diversion. Main channel large wood, and fish ladder pool, and partial rock weir were installed and a portion of the channel reconfigured. 4 wells were constructed for use during low flow.
2002	Okan Co. Aspen Meadows Ditch Piping	Okanogan County	9.2: Water Quantity: Decreased Water Quantity	1453. Flow of water returned to the stream as prescribed in the water acquisition in cubic-feet per second (cfs)	Unknown cfs returned to the river, 5000 ft of ditch piped	Twisp River	Replaced a portion of the Aspen Meadows irrigation ditch with pipe to prevent water loss on Little Bridge Creek, a tributary to the Twisp River.
2002	Okan Co. Tourangeau Ditch to Well Conversion	Okanogan County	9.2: Water Quantity: Decreased Water Quantity	1453. Flow of water returned to the stream as prescribed in the water acquisition in cubic-feet per second (cfs)	0.5 cfs of instream flow improvement; 1 fish barrier diversion converted to well.	Twisp River	Diversion ditch replaced with well system to improve baseflow and low-flow fish passage.
2002	Okan Co. Eagle Creek Ditch Fish Screen	Okanogan County	1.1: Habitat Quantity: Anthropogenic Barriers	1480. # of screens addressed	1.5 cfs instream flow improvement; conversion to well.	Twisp River	This project objective was to install a well on the landowner's property and to decommission the irrigation ditch by dismantling the headgate and allowing the remainder of the ditch to regenerate naturally. This project eliminated the loss of fish associated with water diversion and transportation loss of water in an open ditch.
2003	MSRF Channel Reconstruction/ Twisp side-channel	Methow Salmon Recovery Found	5.1: Peripheral and Transitional Habitats: Side Channel and Wetland Conditions; 1.1: Habitat Quantity: Anthropogenic Barriers	1387. # of miles of stream with improved complexity; 1476. # of stream miles after treatment; 1388. # of structures installed	0.7 miles of habitat complexity; 0.7 miles side channel available; 6 structures	Twisp River	The existing intake was screened to prevent fish entry into the ditch. The revised intake will be designed to allow fish passage up and down canal to provide access to off-channel habitat created on the MSRF property.
2003	WDFW Methow River Basin Screening	Washington Department of Fish and Wildlife (WDFW)	1.1: Habitat Quantity: Anthropogenic Barriers	1480. # of screens addressed	5 screens	Methow River	Installed fish screens on several irrigation diversions in the basin to prevent fish entrainment and impingement.
2003	Upper Stokes	BOR and Okanogan Conservation District	1.1: Habitat Quantity: Anthropogenic Barriers	1480. # of screens/barriers addressed	1 barrier	Beaver Creek	Replaced existing diversion with roock vortex weir to restore fish passage.
2003	Lower Stokes	BOR and Okanogan Conservation District	1.1: Habitat Quantity: Anthropogenic Barriers	1480. # of screens/barriers addressed	1 barrier	Beaver Creek	Replaced existing diversion with rock vortex weir to improve fish passage. Landowner piped diversion.
2004	Fort Thurlow	BOR and Okanogan Conservation District	1.1: Habitat Quantity: Anthropogenic Barriers	1480. # of screens/barriers addressed	1 barrier	Beaver Creek	Replace existing diversion with RVW, piped 2 years after RVW installed.

Enhancement Action Details			Biological and Physical Details				Abbreviated Summary
Year	Action Name	Agency/Sponsor	2012 Standardized Limiting Factors	Definition of Metrics	Metrics	Watershed	
2005	Wolf Creek Diversion/Patterson Mountain	Wolf Creek Reclamation Dist	1.1: Habitat Quantity: Anthropogenic Barriers	1441. # of miles of habitat accessed to the next upstream barrier(s) or likely limit of habitable range	8 miles of summer habitat	Wolf Creek	Efforts for Year 2001 called for repair of the existing surface flow on Wolf Creek. This structure impeded fish passage during most of the summer months thereby restricting use of approximately 8 miles of quality habitat passage thus increasing habitat availability. The second effort will be continuation of the Districts efforts to replace open ditching on Patterson Mountain. When completed water savings is expect to approach 1000 acre feet per year. Total cost for theses projects is $275,373.
2005	YN Hancock Creek Restoration Phase 2	Yakama Nation	1.1: Habitat Quantity: Anthropogenic Barriers; 9.2: Water Quantity: Decreased Water Quantity	1480. # of barriers/screens addressed; 1441. # of miles of habitat accessed to the next upstream barrier(s) or likely limit of habitable range; 1453. Flow of water returned to the stream as prescribed in the water acquisition in cubic-feet per second (cfs)	1 barrier (culvert removed)	Methow River	Acquired two parcels in the project area and removed a levee to restore connectivity and habitat forming processes to three side channels. Banks were re-graded for stability and a step-pool morphology created in the side channel to improve salmonid habitat.
2006	MSRF Early Winters Creek Dike Removal	Methow Salmon Recovery Found	1.1: Habitat Quantity: Anthropogenic Barriers; 5.1: Peripheral and Transitional Habitats: Side Channel and Wetland Conditions	1403. # of riparian acres treated; 1476. # of stream miles after treatment	2 acres floodplain restored; 2 miles side channel access restored	Early Winters Creek	Project improved fish screening by constructing a new headgate and rock-lined wasteway channel to prevent overtopping of the fish screen.
2006	OCD Hottell Intake Gate	Okanogan Conservation Dist	1.1: Habitat Quantity: Anthropogenic Barriers	1480. # of screens addressed	1 screen	Twisp River	Expired surface water diversion with check dam and fish screen was removed and replaced with a groundwater well and pump system. The side channel was restored by grading and large wood placement to improve habiatat for salmonids.
2006	CCFEG Rockview Diversion and Side Channel Restoration	Washington Department of Fish and Wildlife (WDFW), Cascade Columbia Fisheries Enhancement Group	1.1: Habitat Quantity: Anthropogenic Barriers	1480. # of screens addressed	1 screen,	Methow River	This project piped the Fort/Thurlow and Miller Ditches, resulting in potential return to the stream of 1.5 to 2.25-c.f.s. and return could represent approx. 25% of Beaver Creek s average summer low flow volume.
2007	OCD Fort-Thurlow Lower Beaver Piping	Okanogan Conservation Dist	1.1: Habitat Quantity: Anthropogenic Barriers	1453. Flow of water returned to the stream as prescribed in the water acquisition in cubic-feet per second (cfs)	1.5-2.25 cfs, 8,900 feet of canal lined	Beaver Creek	Installed rock vortex weirs to improve fish passage.
2007	OCD Redshirt Barrier Removal	Okanogan Conservation Dist	1.1: Habitat Quantity: Anthropogenic Barriers	1453. Flow of water returned to the stream as prescribed in the water acquisition in cubic-feet per second (cfs); 1480. # of screens addressed	5 miles of new habitat access; 1 screen/barrier addressed	Beaver Creek	This project involved the construction of a new upstream fish passage structure. The existing fish ladder was replaced with a roughened channel made of grouted rock. The existing concrete dam was modified by increasing the elevation of the dam 6 inches to increase operator safety when placing flash boards in addition to reconstructing the downstream splash apron to stabilize the structure. An operable headgate with sediment retention capability and a removable adult fish barrier at the head of the ditch alleviates sediment and redd stranding.

Enhancement Action Details			Biological and Physical Details				Abbreviated Summary
Year	Action Name	Agency/Sponsor	2012 Standardized Limiting Factors	Definition of Metrics	Metrics	Watershed	
2007	MSRF Chewuch Diversion	Methow Salmon Recovery Found	1.1: Habitat Quantity: Anthropogenic Barriers; 6.1: Channel Structure and Form: Bed and Channel Form; 6.2: Channel Structure and Form: Instream Structural Complexity	1480. # of screens addressed; 1441. # of miles of habitat accessed to the next upstream barrier(s) or likely limit of habitable range	1 barrier removed; 35.6 new miles of habitat available	Chewuch River	Batie irrigation diversion was reconstructed in response to a channel re-meandering project to improve fish passage.
2007	Batie Irrigation Diversion	BOR and Okanogan Conservation District	1.1: Habitat Quantity: Anthropogenic Barriers; 6.1: Channel Structure and Form: Bed and Channel Form; 6.2: Channel Structure and Form: Instream Structural Complexity	1480. # of screens/barriers addressed	1 barrier	Beaver Creek	Irrigation improvements including new headgate on USFS land, and livestock exclusion.
2007	OCD Little Bridge Creek (Aspen Meadows)	Okanogan Conservation Dist, USDA - US Forest Service (USFS)	1.1: Habitat Quantity: Anthropogenic Barriers; 6.1: Channel Structure and Form: Bed and Channel Form; 6.2: Channel Structure and Form: Instream Structural Complexity; 4.1: Riparian Condition: Riparian Vegetation	1480. # of screens/barriers addressed; 1401. # of miles of fence installed in a riparian area; 1403. # of riparian acres treated	1 screen/barrier removed; 5.4 miles fenced; 23 acres treated	Twisp River	Provide off-channel watering and restrict livestock access to Beaver Creek.
2007	Lower Beaver Creek Livestock exclusion	Okanogan Conservation District	4.1: Riparian Condition: Riparian Vegetation	1401. # of miles of fence installed in a riparian area	0.5 miles fenced	Beaver Creek	Provide access to spring-fed ponds and streams and improve channel conditions at road crossings.
2007	Heath floodplain restoration	Methow Salmon Recovery Foundation	5.1: Peripheral and Transitional Habitats: Side Channel and Wetland Conditions; 1.1: Habitat Quantity: Anthropogenic Barriers	1387. # of miles of stream with improved complexity; 1441. # of miles of habitat accessed to the next upstream barrier(s) or likely limit of habitable range	1 miles off-channel access restored	Methow River	The Methow Salmon Recovery Foundation assumed responsibility for prior work initiated by the Chewuch Basin Council, which disbanded in 2009. MSRF continued to facilitate funding and implementation of projects to convert portions of several open earthen canals (Chewuch, Skyline, and Fulton) into piped systems, reducing the amount of water lost to conveyance and leaving more for fish in the Chewuch River. In 2005, Reclamation reached an agreement with the Chewuch Canal Company (CCC) on a Diversion Reduction Agreement under which CCC, in exchange for compensation, would voluntarily reduce its authorized diversion when flows above the confluence of the Methow and Chewuch Rivers in Winthrop are below 200 cfs. Following development of an agreement between CCC and Washington Rivers Conservancy (WRC) in 2007, MSRF transitioned the Chewuch and Fulton efficiency projects to WWP-TU.
2008	MSRF Chewuch Basin Irrigator Efficiency	Methow Salmon Recovery Foundation	9.2: Water Quantity: Decreased Water Quantity	1453. Flow of water returned to the stream as prescribed in the water acquisition in cubic-feet per second (cfs)	10-15 cfs; 6.3 miles of increased flow	Chewuch River	Reconnected the Elbow Coulee side channel by removing the manmade dike and installing a rock sill grade control. Large wood was placed in the upper end of the channel and riparian vegetation re-established.

Enhancement Action Details			Biological and Physical Details				Abbreviated Summary
Year	Action Name	Agency/Sponsor	2012 Standardized Limiting Factors	Definition of Metrics	Metrics	Watershed	
2008	MSRF Elbow Coulee River Restoration	Methow Salmon Recovery Found	5.1: Peripheral and Transitional Habitats: Side Channel and Wetland Conditions; 4.1: Riparian Condition: Riparian Vegetation	1476. # of stream miles after treatment; 1403. # of riparian acres treated	0.5 miles off-channel habitat created; 1 acre riparian floodplain created	Twisp River	Create a completely enclosed and pressurized irrigation system, adds 0.5 cfs to Beaver Creek.
2008	Fort Thurlow Pump Project	Methow Salmon Recovery Foundation	1.1: Habitat Quantity: Anthropogenic Barriers	1453. Flow of water returned to the stream as prescribed in the water acquisition in cubic-feet per second (cfs)	0.5 cfs	Beaver Creek	Converted open canal to 8,965 feet of enclosed pipe. This increased flow by 0.5cfs permenantly in the Chewuch River.
2008	TU-WWP Little Barkley Piping	Trout Unlimited - Washington Water Project, MSRF	9.2: Water Quantity: Decreased Water Quantity	1453. Flow of water returned to the stream as prescribed in the water acquisition in cubic-feet per second (cfs)	0.5 cfs	Methow River	Improve irrigation efficiency by 5 cfs in Little Barkley Ditch, permanently remove diversions by 0.5 cfs.
2009	Little Chewuch Piping Project	MSRF, TU-WWP	9.2: Water Quantity: Decreased Water Quantity	1453. Flow of water returned to the stream as prescribed in the water acquisition in cubic-feet per second (cfs)	0.5 cfs	Chewuch River	Improve floodplain function, reduce risk of fish stranding, and improve rearing habitat. Remains of the Fender sawmill and Rockview irrigation ditch were removed from the floodplain.
2009	Fender Mill Floodplain Rehabilitation Project	MSRF	1.1: Habitat Quantity: Anthropogenic Barriers; 5.1: Peripheral and Transitional Habitats: Side Channel and Wetland Conditions; 4.1: Riparian Condition: Riparian Vegetation	1476. # of stream miles after treatment; 1403. # of riparian acres treated; 1388. # of structures installed	0.23 miles off-channel habitat created; 0.5 acres riparian habitat treated; 15 structures installed	Methow River	Converted an open canal to 3,050 feet of enclosed pipe. This increased flow by 0.5 cfs permanently. The project implementation begain in 2009 and ended in 2010.
2009	Operskalski Complexity Rehabilitation Project	MSRF	6.2: Channel Structure and Form: Instream Structural Complexity; 4.1: Riparian Condition: Riparian Vegetation	1387. # of miles of stream with improved complexity; 1403. # of riparian acres treated	0.05 miles of additional complexity, 0.13 miles of riparian habitat	Beaver Creek	Replaced a barrier road culvert with bottomless arch culvert to restore fish passage.
2009	Poorman Creek Culvert Replacement	MSRF	1.1: Habitat Quantity: Anthropogenic Barriers; 4.1: Riparian Condition: Riparian Vegetation	1441. # of miles of habitat accessed to the next upstream barrier(s) or likely limit of habitable range; 1403. # of riparian acres treated	1 mile new habitat access; 0.8 acres riparian	Poorman Creek	Road protection and increase instream complexity using large wood
2009	YN Wolf Creek Road Bank Stabilization and Wood Enhancement Project	Yakama Nation	6.2: Channel Structure and Form: Instream Structural Complexity	1387. # of miles of stream with improved complexity	0.10 miles	Methow River	Increased bank stability and complexity at two private properties by constructing buried rock and wood structures that also provide salmonid habitat.
2009	MSRF Sletten and Green Habitat Complexity Projects	Methow Salmon Recovery Found	6.2: Channel Structure and Form: Instream Structural Complexity	1387. # of miles of stream with improved complexity; 1388. # of structures installed	0.09 miles of complexity added; 8 structures	Methow River	This project renovated a diversion, turning it from an open canal to a closed pipe and reduced the need for annual in-stream diversion maintenance (1 acre protected).
2010	Methow Valley Irrigation District East Diversion Modification Project	MSRF	1.1: Habitat Quantity: Anthropogenic Barriers	1441. # of miles of habitat accessed to the next upstream barrier(s) or likely limit of habitable range; 1480. # of screens/barriers addressed	120 miles of stream with improved access; 1 barrier addressed	Methow River	Adaptive management of 2009 project. Repositioned 3 boulders, placed small woody debris, moved gravel from a bar to the right bank, and planted 145 willow cuttings.

Enhancement Action Details			Biological and Physical Details				Abbreviated Summary
Year	Action Name	Agency/Sponsor	2012 Standardized Limiting Factors	Definition of Metrics	Metrics	Watershed	
2010	Operskalski Adaptive Management Program	MSRF	6.1: Channel Structure and Form: Bed and Channel Form; 6.2: Channel Structure and Form: Instream Structural Complexity; 4.1: Riparian Condition: Riparian Vegetation	1387. # of miles of stream with improved complexity; 1388. # of structures installed; 1403. # of riparian acres treated	0.05 miles of habitat complexity; 2 structures; small amount of riparian restoration	Beaver Creek	Replace diversion with rock vortex weir to improve fish passage. Pipe irrigation system to improve instream flows.
2010	OCD Marrachi Diversion	Okanogan Conservation Dist	1.1: Habitat Quantity: Anthropogenic Barriers	1441. # of miles of habitat accessed to the next upstream barrier(s) or likely limit of habitable range; 1480. # of screens/barriers addressed	19 miles improved habitat passage; 1 barrier addressed	Beaver Creek	Fulton Ditch relied on a 7ft high rock dam diversion at RM 0.7 on the Chewuch River that effectively blocked fish passage at low flows. The project replaced the rock dam with a partial span structure with high flow gates at the intake. Improved fish passage was provided by constructing a roughened channel that functions at low flows. This channel now averages 20 feet in width and 100 feet in length with a 4% slope.
2010	MSRF Fulton Dam - Barrier Removal	Methow Salmon Recovery Found	1.1: Habitat Quantity: Anthropogenic Barriers; 9.2: Water Quantity: Decreased Water Quantity	1480. # of screens/barriers addressed; 1441. # of miles of habitat accessed to the next upstream barrier(s) or likely limit of habitable range; 1453. Flow of water returned to the stream as prescribed in the water acquisition in cubic-feet per second (cfs)	1 barrier addressed; 7 miles of stream made accessible; 1 cfs added to instream	Chewuch River	Hand work to restore degraded banks and revegetate Hancock Springs.
2011	YN Hancock Springs Restoration Project Phase I	Yakama Nation	6.1: Channel Structure and Form: Bed and Channel Form; 6.2: Channel Structure and Form: Instream Structural Complexity; 5.1: Peripheral and Transitional Habitats: Side Channel and Wetland Conditions; 4.1: Riparian Condition: Riparian Vegetation; 8.1: Water Quality: Temperature	1387. # of miles of stream with improved complexity; 1403. # of riparian acres treated	0.5 miles of habitat complexity	Methow River	Surface water right of landowner was converted to a groundwater right to provide water while also allowing for channel reconfiguration. Existing undersized culverts (velocity barrier) under Wolf Creek Road were removed.
2011	YN Hancock Creek Restoration Phase 3	Yakama Nation	6.1: Channel Structure and Form: Bed and Channel Form; 6.2: Channel Structure and Form: Instream Structural Complexity; 5.1: Peripheral and Transitional Habitats: Side Channel and Wetland Conditions; 4.1: Riparian Condition: Riparian Vegetation	1387. # of miles of stream with improved complexity; 1388. # of structures installed; 1403. # of riparian acres treated	0.5 miles of habitat complexity; 26 of structures; 4.5 of acres of riparian restoration	Methow River	Add gravel, soil, and bank substrate materials to further improve channel geometry at the upper end of Hancock Creek. Additionally add in-stream habitat complexity elements (wood habitat) and construct riffle-run sequences in the improved channel. Intensive native plant (wetland and riparian) restoration.
2011	Tice Diversion	BOR and Okanogan Conservation District	9.2: Water Quantity: Decreased Water Quantity	1453. Flow of water returned to the stream as prescribed in the water acquisition in cubic-feet per second (cfs)	0.42 cfs	Beaver Creek	Replaced diversion with pump and moved point of diversion downstream to RM 1.54.

Enhancement Action Details			Biological and Physical Details				Abbreviated Summary
Year	**Action Name**	**Agency/Sponsor**	**2012 Standardized Limiting Factors**	**Definition of Metrics**	**Metrics**	**Watershed**	
2012	Whitefish Island	BOR and MSRF	6.1: Channel Structure and Form: Bed and Channel Form; 6.2: Channel Structure and Form: Instream Structural Complexity; 5.1: Peripheral and Transitional Habitats: Side Channel and Wetland Conditions; 4.1: Riparian Condition: Riparian Vegetation; 8.1: Water Quality: Temperature	1387. # of miles of stream with improved complexity; 1387. # of miles of stream with improved complexity; 1473. # of acres of wetland affected by treatment; 1403. # of riparian acres treated; 1387. # of miles of stream with improved complexity	0.2 miles; 0.2 miles; 0.3 miles; 0.71 miles; 0.3 miles	Methow River	Project included reconnecting the historic side channel to year-round flows, placing engineered log jams in the river and planting native trees and shrubs, creating more than 1,700 feet of fully connected off-channel habitat with a mixture of constructed pools and riffles.
2012	Methow Eagle Rocks Large Wood Enhancement	Yakama Nation Fisheries	6.2: Channel Structure and Form: Instream Structural Complexity; 4.1: Riparian Condition: Riparian Vegetation	1387. # of miles of stream with improved complexity; 1403. # of riparian acres treated	0.1 miles; 0.3 miles	Methow River	Three large wood structures installed along bank of mainstem Methow River to improve salmonid habitat.
2012	8 Mile Ranch	Yakama Nation Fisheries and USFS	6.1: Channel Structure and Form: Bed and Channel Form; 6.2: Channel Structure and Form: Instream Structural Complexity; 4.1: Riparian Condition: Riparian Vegetation	1388. # of structures installed; 1401. # of miles of fence installed in a riparian area	3 structures; 0.75 miles treated (fenced)	Chewuch River	Install main channel large wood with three scour pools, and revegetate 7 acres of riparian.
2012	RM 10	Yakama Nation Fisheries	6.2: Channel Structure and Form: Instream Structural Complexity; 5.1: Peripheral and Transitional Habitats: Side Channel and Wetland Conditions; 6.1: Channel Structure and Form: Bed and Channel Form	1388. # of structures installed; 1476. # of stream miles after treatment; 1388. # of structures installed	0.8 miles treated; 0.23 miles side channel created; 0.23 miles (1 structure)	Chewuch River	Installed main channel and off channel large wood to improve salmonid habitat. Constructed a backwater side channel.
2012	TU-WWP Beaver Creek - 2012 Leases	Trout Unlimited Washington Water Project	9.2: Water Quantity: Decreased Water Quantity	1453. Flow of water returned to the stream as prescribed in the water acquisition in cubic-feet per second (cfs)	0.5 cfs	Beaver Creek	Trout Unlimited (TU) secured three 2012 irrigation leases for 84 acres on Beaver Creek in the Methow sub-basin, resulting in over .5 cfs and 30.69 afy saved as instream flow for fish in this flow-limited tributary to the Methow River. Enhanced instream habitat for listed salmonids in 2012, with potential to continue the savings in future years.
2012	YN Twisp Ponds Left Bank Large Wood Enhancement	Yakama Nation	6.2: Channel Structure and Form: Instream Structural Complexity	1387. # of miles of stream with improved complexity; 1388. # of structures installed	0.5 miles; 3 structures	Twisp River	Improve fish habitat and fish production by creating 3 large pools in the Chewuch River with associated large wood margin jams. Project was done in collaboration with MSRF and at the same time as the YN Twisp Ponds Left Bank Floodplain project. This project helped to restore a functional riverine system. redevelop a riparian buffer zone and revegetate approximately 7 acres.
2012	YN Twisp Ponds Left Bank Floodplain Restoration	Yakama Nation	4.1: Riparian Condition: Riparian Vegetation	1515. # of acres of upland non-wetland habitat treated	7 acres	Twisp River	Project was done in collaboration with MSRF and at the same time as the YN Twisp Ponds Left Bank Large Wood Enhancement project. This project helped to restore and redevelop a riparian buffer zone and revegetate approximately 7 acres.

Enhancement Action Details			Biological and Physical Details				Abbreviated Summary
Year	Action Name	Agency/Sponsor	2012 Standardized Limiting Factors	Definition of Metrics	Metrics	Watershed	
2013	M2 WDFW Floodplain Project	Methow Salmon Recovery Foundation	6.2: Channel Structure and Form: Instream Structural Complexity; 5.1: Peripheral and Transitional Habitats: Side Channel and Wetland Conditions; 4.1: Riparian Condition: Riparian Vegetation; 6.1: Channel Structure and Form: Bed and Channel Form	1387. # of miles of stream with improved complexity; 1388. # of structures installed; 1403. # of riparian acres treated; 1387. # of miles of stream with improved complexity	0.3 miles; 0.3 miles; 0.7 miles; 0.3 miles	Methow River	Enhance complexity by constructing engineered log jams in mainstem and side channel, side channel reconnection, levee removal, barrier culvert replacement to allow fish passage, and riparian enhancement of 12 acres.
2013	Twisp River Well Conversion Project - Hottell (Devany) Diversion	Trout Unlimited - Washington Water Project	9.2: Water Quantity: Decreased Water Quantity	1453. Flow of water returned to the stream as prescribed in the water acquisition in cubic-feet per second (cfs)	5 cfs	Twisp River	Eliminate a surface water diversion which potentially caused injury and mortality to ESA-listed fish species by drilling a well and updating irrigation systems. Allows the 5 cfs previously diverted to stay in the Twisp River.
2013	Upper Beaver Creek Project	Methow Salmon Recovery Foundation	9.2: Water Quantity: Decreased Water Quantity; 1.1: Habitat Quantity: Anthropogenic Barriers; 2.3: Injury and Mortality: Mechanical Injury; 6.1: Channel Structure and Form: Bed and Channel Form; 4.1: Riparian Condition: Riparian Vegetation; 6.2: Channel Structure and Form: Instream Structural Complexity	1452. Amount of water secured in acre-feet/year; 1441. # of miles of habitat accessed to the next upstream barrier(s) or likely limit of habitable range; 1480. # of screens addressed; 1387. # of miles of stream with improved complexity; 1476. # of stream miles after treatment; 1387. # of miles of stream with improved complexity	2.08 cfs; 2.8 miles; 1 screen; 0.5 miles; 0.5 miles; 0.5 miles	Beaver Creek	Reconnect Beaver Creek to the floodplain, remeandering the channel and replacing a section that was channelized into a roadside ditch and armored. Remove the last fish barrier in Beaver Creek, a rock dam sending flows into the Batie Irrigation Ditch, with a new irrigation diversion that allows fish passage. Increase instream habitat diversity and ensure fish passage at low flows.
2013	Right and Left Elbow Project	Methow Salmon Recovery Foundation	5.1: Peripheral and Transitional Habitats: Side Channel and Wetland Conditions	1476. # of stream miles after treatment	0.3 miles (right elbow)	Twisp River	Increase inundation frequency in existing groundwater channel at Right Elbow by enlarging the levee breach and extending the channel. Reduce stranding potential at Left Elbow by increasing flows into the existing side channel during higher flow events in the Twisp. Left Elbow was a repair of the original Elbow Coulee project.
2013	Methow Large Wood Habitat sites C and D	Yakama Nation Fisheries	6.2: Channel Structure and Form: Instream Structural Complexity	1387. # of miles of stream with improved complexity; 1388. # of structures installed	2 structures	Methow River	Project consisted of the installation of large wood enhancements along the banks fo the Methow River at Sites called "C" and "D" where riprap or other modifications had been previously made.
2013	RM 11.75-13	Yakama Nation Fisheries	4.1: Riparian Condition: Riparian Vegetation; 6.2: Channel Structure and Form: Instream Structural Complexity; 6.1: Channel Structure and Form: Bed and Channel Form; 5.1: Peripheral and Transitional Habitats: Side Channel and Wetland Conditions	1406. # of riparian miles treated; 1387. # of miles of stream with improved complexity; 1387. # of miles of stream with improved complexity; 1476. # of stream miles after treatment	0.25 miles; 0.6 miles; 0.6 miles; 0.1 miles	Chewuch River	Installed main channel and off channel large wood to improve salmonid habitat.
2013	Old Schoolhouse Habitat Improvement Project	Yakama Nation Fisheries	4.1: Riparian Condition: Riparian Vegetation; 6.1: Channel Structure and Form: Bed and Channel Form; 6.2: Channel Structure and Form: Instream Structural Complexity	1403. # of riparian acres treated; 1476. # of stream miles after treatment; 1387. # of miles of stream with improved complexity	0.5 mile; 0.9 miles; 1.0 miles;	Beaver Creek	Installation of 12 LWD margin jams over 0.9 miles of Beaver Creek.

Enhancement Action Details			Biological and Physical Details				Abbreviated Summary
Year	Action Name	Agency/Sponsor	2012 Standardized Limiting Factors	Definition of Metrics	Metrics	Watershed	
2013	MSRF Fine Riparian	Methow Salmon Recovery Found	4.1: Riparian Condition: Riparian Vegetation	1403. # of riparian acres treated	0.15 riparian miles treated, 1.25 acres of riparian non-wetland habitat treated	Beaver Creek	The goals of the project are to create better channel definition and flow return to the mainstem Methow River, restore a functioning riparian buffer, and slow bank erosion by planting native riparian vegetation.
2013	MSRF Macpherson Side Channel	Methow Salmon Recovery Found	4.1: Riparian Condition: Riparian Vegetation; 5.1: Peripheral and Transitional Habitats: Side Channel and Wetland Conditions; 6.1: Channel Structure and Form: Bed and Channel Form; 6.2: Channel Structure and Form: Instream Structural Complexity	1403. # of riparian acres treated; 1476. # of stream miles after treatment; 1387. # of miles of stream with improved complexity; 1480. # of screens/barriers addressed	1 acre riparian habitat treated; 1 mile off-channel habitat & complexity added; 2 barriers addressed	Chewuch River	Side channel was re-meandered, placed fill was removed, and an undersized culvert was replaced with a bridge to improve off channel habitat for salmonids.
2013	MSRF Pete Creek	Methow Salmon Recovery Found	6.2: Channel Structure and Form: Instream Structural Complexity; 4.1: Riparian Condition: Riparian Vegetation	1387. # of miles of stream with improved complexity	0.3 miles	Chewuch River	Four groundwater wells installed to investigate groundwater continuity in floodplain and determine feasibility of restoration projects through 2011. Riparian plantings were installed for riparian buffer.
2013	MSRF Bulldog	Methow Salmon Recovery Found	4.1: Riparian Condition: Riparian Vegetation	1403. # of riparian acres treated	6 acres	Chewuch River	Re-established 6 acres of riparian buffer that was previously cleared. 15 pieces of large wood placed in the active floodplain. Fill that was placed in historical flood channels was removed.
2013	MSRF 3R Riparian	Methow Salmon Recovery Found	4.1: Riparian Condition: Riparian Vegetation	1403. # of riparian acres treated	1.34 riparian acres	Methow River	The long term goals of this project are to improve anadromous fish habitat and water quality by providing riparian shade, increasing large woody debris potential and improving bank stabilization. Prior to 2009 the landowner set out to re-vegetate the 14 acre riparian property with native trees and shrubs. Since 2009, 1000 plants have been added to what was previously planted. Current stocking levels exceed 1300 plants.
2013	MSRF Witte Riparian	Methow Salmon Recovery Found	4.1: Riparian Condition: Riparian Vegetation	1406. # of riparian miles treated	0.11 miles of riparain restoration	Methow River	Riparian enhancement
2013	MSRF M2 WDFW Floodplain Restoration	Methow Salmon Recovery Found	6.1: Channel Structure and Form: Bed and Channel Form; 8.1: Water Quality: Temperature; 4.1: Riparian Condition: Riparian Vegetation; 5.1: Peripheral and Transitional Habitats: Side Channel and Wetland Conditions; 6.2: Channel Structure and Form: Instream Structural Complexity	1387. # of miles of stream with improved complexity; 1406. # of riparian miles treated; 1388. # of structures installed	1 miles improved complexity; 0.7 riparian miles treated; 12 acres riparian plantings; 27 structures	Methow River	The primary goal of the project is to reconnect the river to its floodplain and increase in-stream habitat for listed fish. 2013 work included removal of 1,200 feet of levee necessary to reconnect flood flows with the state-owned property across from the irrigation diversion. Fish passage through culverts was improved under the Old Twisp Highway. Large wood was installed in the main channel and off channel habitat to reduce bank erosion while increasing available fish habitat.
2013	MSRF Poorman Creek Barrier Removal	Methow Salmon Recovery Found	1.1: Habitat Quantity: Anthropogenic Barriers	1441. # of miles of habitat accessed to the next upstream barrier(s) or likely limit of habitable range; 1480. # of barriers/screens addressed	1 miles of new access: 1 barrier (culvert removed)	Twisp River	Improve fish passage and provide access to over 1 mile of Poorman Creek by replacing an undersized road culvert, replace existing irrigation pump with a diversion and access weirs installed instream

Enhancement Action Details			Biological and Physical Details				Abbreviated Summary
Year	Action Name	Agency/Sponsor	2012 Standardized Limiting Factors	Definition of Metrics	Metrics	Watershed	
2013	MSRF Daudon Riparian	Methow Salmon Recovery Found	4.1: Riparian Condition: Riparian Vegetation	1406. # of riparian miles treated; 1403. # of riparian acres treated	0.2 miles of riparain restoration; 1.75 acres of riparian restoration	Twisp River	The long term goals of this project are to improve anadromous fish habitat and water quality by providing riparian shade, increasing large woody debris potential and improving bank stabilization. The project re-vegetated approximately 1,000 linear feet of riverbank with 150 native trees and shrubs.
2013	MSRF TRLLC Riparian	Methow Salmon Recovery Found	4.1: Riparian Condition: Riparian Vegetation	1403. # of riparian acres treated	4 acres of riparian restoration	Twisp River	Riparian enhancement along the Twisp River.
2013	MSRF Twisp Left Bank Complexity & Riparian	Methow Salmon Recovery Found	6.1: Channel Structure and Form: Bed and Channel Form; 6.2: Channel Structure and Form: Instream Structural Complexity; 4.1: Riparian Condition: Riparian Vegetation	1387. # of miles of stream with improved complexity; 1406. # of riparian miles treated	0.25 miles with improved complexity	Twisp River	Stabilize expected bank erosion through bank construction and riparian planting.
2013	MSRF Heath Middle Pond Habitat Improvement	Methow Salmon Recovery Found	1.1: Habitat Quantity: Anthropogenic Barriers	1476. # of stream miles after treatment; 1480. # of barriers/screens addressed; 1403. # of riparian acres treated	0.5 of miles of habitat and 20 acres of floodplain available; 1 partial barrier addressed; 0.2 acres riparian treated	Methow River	
2013	MSRF Wolfridge Riparian	Methow Salmon Recovery Found	4.1: Riparian Condition: Riparian Vegetation; 6.2: Channel Structure and Form: Instream Structural Complexity	1403. # of riparian acres treated; 1388. # of structures installed	0.25 acres of riparian restoration; 3 structures; 0.15 miles of improved complexity	Methow River	Large wood was installed to prevent bank erosion and provide salmonid habitat. Riparian vegetation was also planted to limit bank erosion.
2013	MVID instream flow improvement project	Trout Unlimited	9.2: Water Quantity: Decreased Water Quantity	1453. Flow of water returned to the stream as prescribed in the water acquisition in cubic-feet per second (cfs)	2 cfs; 11 cfs; 4.5 miles improved water quantity	Twisp River	Improve instream flows in lower 4.5 miles of the Twisp River by eliminating MVID irrigation diversion and returning up to 15cfs of flow permenantly. Prevent fish injury and mortality associated wtih MVID's Twisp River pushup dam, fish screen operations, and the stranding of redds and juveniles in the MVID West Canal's intake canal and fish return channel.
2013	TU-WWP Chewuch Leases	Trout Unlimited - Washington Water Project	9.2: Water Quantity: Decreased Water Quantity	1453. Flow of water returned to the stream as prescribed in the water acquisition in cubic-feet per second (cfs)	24 cfs	Chewuch River	Trout Unlimited-Washington Water Project (TU) secured a diversion reduction agreement with CCC managers that reduced diversions from 56 to 33.4 cfs when the Chewuch River falls below 200 cfs.
2014	Methow - Beaver Creek Weirs Access Enhancement Project; Fort Thurlow and Marracci Sites	Methow Salmon Recovery Foundation	1.1: Habitat Quantity: Anthropogenic Barriers	1387. # of miles of stream with improved complexity; 1480. # of barriers/screens addressed	0.25 miles of improved complexity; 2 barriers addressed	Beaver Creek	Re-establish fish passage at two irrigation diversions. Both diversions had been constructed as rock vortex weirs that allowed fish passage, but were destroyed in 2011 during a 500-year event. This project, creating a chute-pool roughened channel, would

Enhancement Action Details			Biological and Physical Details				Abbreviated Summary
Year	Action Name	Agency/Sponsor	2012 Standardized Limiting Factors	Definition of Metrics	Metrics	Watershed	
							provide fish passage in perpetuity and eliminating the annual need for maintenance.
2014	Chewuch River Permanent Instream Flow Enhancement Project	Trout Unlimited - Washington Water Project	9.2: Water Quantity: Decreased Water Quantity	1453. Flow of water returned to the stream as prescribed in the water acquisition in cubic-feet per second (cfs)	10-15 cfs	Chewuch River	Converted 6 miles of earthen canal to a pressurized pipe system and upgraded irrigation infrastructure to increase water efficiency and instream flows.
2014	Middle Methow River Rock Reach (M23R) Floodplain and Side Channel Enhancement Project	Methow Salmon Recovery Foundation	6.1: Channel Structure and Form: Bed and Channel Form; 8.1: Water Quality: Temperature; 4.1: Riparian Condition: Riparian Vegetation; 5.1: Peripheral and Transitional Habitats: Side Channel and Wetland Conditions; 6.2: Channel Structure and Form: Instream Structural Complexity	1387. # of miles of stream with improved complexity; 1406. # of riparian miles treated; 1476. # of stream miles after treatment	0.3 miles; 0.2 miles; 0.2 miles	Methow River	Enhance complexity in the Middle Methow reach by construction three engineered log jams along 1,000 feet of bank and creating a 250-foot-long backwater alcove habitat.
2014	1890's Side Channel	Yakama Nation Fisheries	5.1: Peripheral and Transitional Habitats: Side Channel and Wetland Conditions; 4.1: Riparian Condition: Riparian Vegetation; 8.1: Water Quality: Temperature; 6.2: Channel Structure and Form: Instream Structural Complexity	1476. # of stream miles after treatment; 1403. # of riparian acres treated	0.8 miles; 1.0 miles	Methow River	Reconnection of a historic river channel to the Methow River during low and high flows. Low flows utilize groundwater piping. Project added 4,000' of off-channel habitat.
2014	Twisp RM 3 Large Wood	Yakama Nation Fisheries	6.2: Channel Structure and Form: Instream Structural Complexity	1387. # of miles of stream with improved complexity 1388. # of structures installed	0.1 miles; 3 structures	Twisp River	Three main channel large wood structures installed on Twisp River to improve salmonid habitat.
2014	Poorman Road Large Wood	Yakama Nation Fisheries	6.2: Channel Structure and Form: Instream Structural Complexity	1388. # of structures installed	2 structures	Twisp River	Two large wood structures installed along the bank of Twisp River.
2014	YN M2 Two Channels Large Wood Enhancement	Yakama Nation	6.2: Channel Structure and Form: Instream Structural Complexity; 4.1: Riparian Condition: Riparian Vegetation	1476. # of stream miles after treatment;1406. # of riparian miles treated; 1388. # of structures installed	0.2 miles; 0.1 miles; 1 structure	Methow River	This project creates 1 bank margin complexity large wood structure stabilized by log pilings on river right, and creates an associated scour pool in an otherwise plain bed channel segment of the Methow River. The project also adds large wood elements with rootwads on to an existing riprap bank along roughly 200 feet of river bank.
2014	YN M2 Sugar Dike Large Wood Enhancement	Yakama Nation	6.2: Channel Structure and Form: Instream Structural Complexity	1387. # of miles of stream with improved complexity	0.5 miles	Methow River	Backwater and main channel log jam installed along riprap of the Sugar Dike.
2014	Post fire landowner assist/habitat protection	Methow Salmon Recovery Foundation	1.1: Habitat Quantity: Anthropogenic Barriers	1441. # of miles of habitat accessed to the next upstream barrier(s) or likely limit of habitable range; 1480. # of screens/barriers addressed	4 miles; 7 barriers addressed to date	Beaver Creek	Post fire restoration activities.
2015	MSRF-MC Poorman Creek Wetland Habitat	Methow Salmon Recovery Found	4.1: Riparian Condition: Riparian Vegetation	1406. # of riparian miles treated or 1403. # of riparian acres treated	13.8 acres	Twisp River	Riparian protection fencing was installed in 2015 to isolate work areas from on-going agricultural activities.

Enhancement Action Details			Biological and Physical Details				Abbreviated Summary
Year	Action Name	Agency/Sponsor	2012 Standardized Limiting Factors	Definition of Metrics	Metrics	Watershed	
2015	River Right	Yakama Nation Fisheries	8.1: Water Quality: Temperature; 6.2: Channel Structure and Form: Instream Structural Complexity; 6.1: Channel Structure and Form: Bed and Channel Form; 5.1: Peripheral and Transitional Habitats: Side Channel and Wetland Conditions; 4.1: Riparian Condition: Riparian Vegetation	1476. # of stream miles after treatment; 1387. # of miles of stream with improved complexity; 1387. # of miles of stream with improved complexity; 1473. # of acres of wetland affected by treatment; 1406. # of riparian miles treated	0.5 miles; 0.2 miles; 0.5 miles; 0.47 miles; 0.5 miles	Chewuch River	Excavated a side channel and installed main channel and off channel large wood to improve salmonid habitat.
2015	RM 13-15	Yakama Nation Fisheries	6.1: Channel Structure and Form: Bed and Channel Form; 6.2: Channel Structure and Form: Instream Structural Complexity; 5.1: Peripheral and Transitional Habitats: Side Channel and Wetland Conditions	1387. # of miles of stream with improved complexity; 1387. # of miles of stream with improved complexity; 1476. # of stream miles after treatment	0.25 miles; 2.5 miles; 0.2 miles	Chewuch River	Installed main channel and off channel large wood to improve salmonid habitat.
2015	Fender Mill Side Channel	Yakama Nation Fisheries	6.2: Channel Structure and Form: Instream Structural Complexity; 5.1: Peripheral and Transitional Habitats: Side Channel and Wetland Conditions	1387. # of miles of stream with improved complexity; 1477. # of stream miles before treatment	0.5 miles (3 acres); 0.5 miles (3 acres)	Methow River	Constructed a groundwater-fed side channel along Methow River with off channel large wood structures to improve habitat for salmonids.
2015	MSRF Beaver Ck - Culvert to Bridge (Stokes ranch)	Methow Salmon Recovery Found	1.1: Habitat Quantity: Anthropogenic Barriers	1441. # of miles of habitat accessed to the next upstream barrier(s) or likely limit of habitable range	3.6 miles	Beaver Creek	One bridge installed on Beaver Creek at Stokes Ranch because the culverts were too small to handle runoff from post-fire flooding. This was not a passage barrier on Beaver creek.
2015	USFS Cub Creek Road Decommissioning	USDA - US Forest Service (USFS)	7.2: Sediment Conditions: Increased Sediment Quantity	1394. # of miles of road improved or decommissioned in a riparian area	2 miles	Chewuch River	Decomissioned 2 miles of road (2.9 acres).
2015	USFS Libby Creek/Little Brudge Creek Livestock Exclusion Fence	USDA - US Forest Service (USFS)	4.1: Riparian Condition: Riparian Vegetation	1403. # of riparian acres treated; 1401. # of miles of fence installed in a riparian area	3 riparian acres protected; 1.0 mile fenced	Libby Creek	Excluded livestock from the stream. 1 miles of fencing; @ 25' buffer = 3 acres
2015	MSRF Methow River Car/Debris Removal	Methow Salmon Recovery Found	6.2: Channel Structure and Form: Instream Structural Complexity	1387. # of miles of stream with improved complexity	0.17 miles	Methow River	Removed debris after fire and flood damage.
2015	Methow Watershed Beaver Reintroduction	Methow Salmon Recovery Foundation, USFS, WDFW	4.1: Riparian Condition: Riparian Vegetation; 8.1: Water Quality: Temperature; 6.2: Channel Structure and Form: Instream Structural Complexity; 7.2: Sediment Conditions: Increase Sediment Quanity	# of beavers introduced	348 beavers	Methow River	Annual on going project to reintroduce beaver into the Methow.
2015	Goat Creek Complexity for Confluentus	MSRF and National Forest Foundation	6.1: Channel Structure and Form: Bed and Channel Form; 6.2: Channel Structure and Form: Instream Structural Complexity	1388. # of structures installed; 1387. # of miles of stream with improved complexity	0.9 miles increased habitat complexity; 7 log jam structures and 27 single logs felled into the creek	Methow River	Installed three main channel log jams to improve salmonid habitat.

Enhancement Action Details			Biological and Physical Details				Abbreviated Summary
Year	Action Name	Agency/Sponsor	2012 Standardized Limiting Factors	Definition of Metrics	Metrics	Watershed	
2016	YN Chewuch Camp Ground	Yakama Nation	4.1: Riparian Condition: Riparian Vegetation; 6.1: Channel Structure and Form: Bed and Channel Form; 8.1: Water Quality: Temperature; 5.1: Peripheral and Transitional Habitats: Side Channel and Wetland Conditions; 6.2: Channel Structure and Form: Instream Structural Complexity	1406. # of riparian miles treated; 1388. # of structures installed; 1476. # of stream miles after treatment; 1387. # of miles of stream with improved complexity	0.1 miles treated; 3 structures; 0.1 miles; 0.3 miles	Chewuch River	The primary objective of the Methow Riparian Restoration project is to systematically restore riparian habitat on large publicly owned parcels within the Methow Valley which will lead to improved habitat conditions for all salmonids and other terrestrial wildlife.
2016	CCFEG Methow Riparian Planting	Cascade Columbia Fisheries Enhancement Group	4.1: Riparian Condition: Riparian Vegetation	1403. # of riparian acres treated		Methow River	The primary goal of Silver Side Channel Revival project is to improve and increase salmonid habitat within the one-mile side channel and floodplain corridor to increase the abundance and productivity of ESA-listed UCR spring Chinook salmon and UCR steelhead. Through this effort, we will achieve both short term and long-term habitat recovery goals for the site.
2016	CCFEG Silver Side Channel Revival	Cascade Columbia Fisheries Enhancement Group	6.1: Channel Structure and Form: Bed and Channel Form; 5.1: Peripheral and Transitional Habitats: Side Channel and Wetland Conditions; 6.2: Channel Structure and Form: Instream Structural Complexity	1387. # of miles of stream with improved complexity	1.0 mile increased habitat complexity	Methow River	Added large wood to 0.9 miles of Goat Creek to improve salmonid habitat and reduce fine sediment transport downstream.
2016	Newby Narrows	Yakama Nation	6.1: Channel Structure and Form: Bed and Channel Form; 5.1: Peripheral and Transitional Habitats: Side Channel and Wetland Conditions; 6.2: Channel Structure and Form: Instream Structural Complexity	1476. # of stream miles after treatment; 1387. # of miles of stream with improved complexity; 1388. # of structures installed	1200 foot long side channel with wood placements, 6 main channel log jams	Twisp River	Increase main channel habitat complexity, improve floodplain connectivity, create new side channel habitat. Work to be completed in 2017.
2016	Twisp Ponds	Yakama Nation	6.1: Channel Structure and Form: Bed and Channel Form; 5.1: Peripheral and Transitional Habitats: Side Channel and Wetland Conditions; 6.2: Channel Structure and Form: Instream Structural Complexity	1476. # of stream miles after treatment; 1387. # of miles of stream with improved complexity; 1388. # of structures installed	680 foot long side channel with wood placements, 800 foot long backwater alcove	Twisp River	Improve floodplain connectivity, create new side channel and alcove habitat. Provide connectivity to previously constructed floodplain ponds.
2016	Twisp Floodplain	USBR	6.1: Channel Structure and Form: Bed and Channel Form; 5.1: Peripheral and Transitional Habitats: Side Channel and Wetland Conditions; 6.2: Channel Structure and Form: Instream Structural Complexity	1476. # of stream miles after treatment; 1387. # of miles of stream with improved complexity; 1388. # of structures installed	440 foot long side channel with wood placements, 8 main channel log jams	Twisp River	Improve floodplain connectivity, create new side channel and alcove habitat. Fill existing diversion ditch. Improve main channel habitat complexity.

Enhancement Action Details			Biological and Physical Details				Abbreviated Summary
Year	Action Name	Agency/Sponsor	2012 Standardized Limiting Factors	Definition of Metrics	Metrics	Watershed	
2018	M2 WDFW Flow Connection	Methow Salmon Recovery Found	5.1: Peripheral and Transitional Habitats: Side Channel and Wetland Conditions; 4.1: Riparian Condition: Riparian Vegetation	1476. # of stream miles after treatment; 1403. # of riparian acres treated; 1401. # of miles of fence installed in a riparian area	0.69 miles floodplain side channel; 1750 feet of cattle exclusion fence; 300 native riparian trees planted	Methow River	This project removed the remaining part of the levee at the M2 WDFW Floodplain site. By removing this levee that blocked flow down an intermittent floodplain channel, we reconnected approximately 3 acres (0.69 miles) of floodplain side channel. The project also installed about 1,750 feet of cattle exclusion fence, and planted 300 native riparian trees.
2018	Frazer Creek Bridge - Lazy K	Methow Salmon Recovery Found	1.1: Habitat Quantity: Anthropogenic Barriers; 6.2: Channel Structure and Form: Instream Structural Complexity	1480. # of screens/barriers addressed; 1387. # of miles of stream with improved complexity; 1388. # of structures installed	1 barrier; 0.1 mile; 2 main channel log structures	Beaver Creek	This project replaced a failed culvert with a 60' long clear span bridge and installed 2-large wood habitat features in Frazer Creek at approximate river mile 1.1.
2018	Twisp Horseshoe Bend - Phase 1 Culvert Construction	Yakama Nation	5.1: Peripheral and Transitional Habitats: Side Channel and Wetland Conditions; 6.2: Channel Structure and Form: Instream Structural Complexity	1476. # of stream miles after treatment; 1387. # of miles of stream with improved complexity; 1388. # of structures installed	525 feet of side channel constructed; 7 log structures in side channel; 2 log structures in main channel	Twisp River	Enhanced a 525-foot-long side channel with culvert at inlet to accomodate a landowner walking trail and access road, and construct a partially buried riverbank log structure. Approximately 60 logs placed. Several whole trees and slash were salvaged from site clearing and were incorporated into the project.
2018	Chewuch River Mile 17-20	Yakama Nation	6.2: Channel Structure and Form: Instream Structural Complexity	1387. # of miles of stream with improved complexity; 1388. # of structures installed	1.5 miles; 11 main channel log structures; 4 side channel log structures	Chewuch River	Increase habitat complexity by adding large wood structures throughout the Chewuch River and natural side channels. Place 15 log structures with a total of 190 logs with rootwads in the channel over a total of approximately 1.5 river miles.
2003	TPL Arrowleaf/Methow River Conservation	Trust for Public Land (TPL)	4.1: Riparian Condition: Riparian Vegetation	Number of acres acquired	1020 ac	Methow River	Acquisition of 1020 acres along the Methow River that was going to be subdivided into residential lots. Aimed at protecting aquatic and terrestrial species.
2005	WDFW Methow Watershed Phase II	Washington Department of Fish and Wildlife (WDFW)	4.1: Riparian Condition: Riparian Vegetation	Number of acres acquired	250 aacres (100 floodplain acres protected)	Methow River	Acquire or protect (easements) forested riparian habitats to improve connectivity with public lands and protect aquatic and terrestrial species.
2006	MSRF Twisp River Conservation Acquisition	Methow Salmon Recovery Found	4.1: Riparian Condition: Riparian Vegetation	Number of acres acquired	10.36 acres	Twisp River	Acquired 10.36 acres along the Twisp River to complete the purchase and protection of 24.24 acres of contiguous riverfront side channel and riparian habitat.
2008	Lower Twisp River Acquisitions and Easements	Methow Conservancy	4.1: Riparian Condition: Riparian Vegetation	# of acres acquired/protected	270 riparian acres; 613 total acres; 6.9 riverfront miles	Twisp River	Easements protecting 270 riparian acres in the Lower Twisp River.
N/A	Beaver Creek Acquisitions and Easements	Methow Conservancy	4.1: Riparian Condition: Riparian Vegetation	# of acres acquired/protected	56 riparian acres; 441 total acres; 2.4 riverfront miles	Beaver Creek	Easements protecting 56 riparian acres in Beaver Creek.

Enhancement Action Details			Biological and Physical Details				Abbreviated Summary
Year	Action Name	Agency/Sponsor	2012 Standardized Limiting Factors	Definition of Metrics	Metrics	Watershed	
N/A	Lower Chewuch River Acquisitions and Easements	Methow Conservancy	4.1: Riparian Condition: Riparian Vegetation	# of acres acquired/protected	35 riparian acres; 91 total acres; 0.8 riverfront miles	Chewuch River	Easements protecting 35 riparian acres in the Chewuch River.
N/A	Middle Methow River Acquisitions and Easements	Methow Conservancy	4.1: Riparian Condition: Riparian Vegetation	# of acres acquired/protected	147 riparian acres; 741 total acres; 5.4 riverfront miles	Methow River	Easements protecting 147 riparian acres in the Middle Methow River.
N/A	Upper Methow River Acquisitions and Easements	Methow Conservancy	4.1: Riparian Condition: Riparian Vegetation	# of acres acquired/protected	825 riparian acres; 1,239 total acres; 12.6 riverfront miles	Methow River	Easements protecting 825 riparian acres in the Upper Methow River.
2009	MSRF Twisp River Conservation Acquisition 2	Methow Salmon Recovery Found	4.1: Riparian Condition: Riparian Vegetation	# of acres acquired/protected		Twisp River	The primary objective of this project is to actively protect and restore properties by purchasing and retiring the development rights that conflict with riparian and floodplain functions. 1,000 lineal feet of waterfront along the lower reach of the Twisp River were protected.
2011	MSRF Methow River Risley Acquisition	Methow Salmon Recovery Found	4.1: Riparian Condition: Riparian Vegetation	# of acres acquired	17.8 acres	Methow River	MSRF acquired approximately 17.8 acres of riparian, wetland, & side channel habitat, with some adjacent road and road embankments. The acquisition will protect over 1,500 linear ft of shoreline, off-channel wetlands, a side channel, floodplain, & riparian habitat from residential & recreational development. These habitats are currently functioning well and provide natural water storage & habitat diversity, including critical rearing, refuge, and migratory habitat for Endangered Species Act listed spring Chinook, summer steelhead, and bull trout, and a variety of wildlife.
2012	MSRF Middle Methow River Hoffman Acquisition	Methow Salmon Recovery Found	4.1: Riparian Condition: Riparian Vegetation	# of acres acquired	12+ acres	Methow River	The project includes acquisitions of portions of 3 contiguous parcels with river frontage of about 2100 linear feet. Portions of 2 properties were actually acquired. The third property owner declined the fair market value offer. The properties encompass 12 +/- acres of adequately functioning riparian and floodplain habitat adjacent to the river, but which are impacted by existing roads, push-up levees, and abandoned vehicles. Acquisition of the properties will assure future disturbance associated with access road maintenance, recreational site development, and view shed maintenance such as tree removal will not occur.
2012	MSRF Methow River Bird Island Acquisition	Methow Salmon Recovery Found	4.1: Riparian Condition: Riparian Vegetation	# of acres acquired	17 acres	Methow River	The project is to acquire approximately 17 acres of riparian and side channel habitat adjacent to the Methow River at RM 48.7. Acquisition will protect seasonal side channel, floodplain, & riparian habitat from residential development & will provide

Enhancement Action Details			Biological and Physical Details				Abbreviated Summary
Year	Action Name	Agency/Sponsor	2012 Standardized Limiting Factors	Definition of Metrics	Metrics	Watershed	
							opportunities for active restoration in the side channel.
2012	WDFW Silver Side Channel Restoration and Conservation Easement	Washington Department of Fish and Wildlife (WDFW)	4.1: Riparian Condition: Riparian Vegetation	# of acres placed under conservation easement	120 acres	Methow River	The project used a Conservation Easement on approximately 120 acres. This project is within the "Silver Reach", three miles downstream of Twisp, and protects a key off channel habitat that was once the main channel.
2012	MSRF Twisp River - Hadfield	Methow Salmon Recovery Found	4.1: Riparian Condition: Riparian Vegetation	# of acres acquired		Twisp River	Acquisition and conservation easements to protect riparian habitat.
2012	MSRF Twisp River - Gann	Methow Salmon Recovery Foundation	4.1: Riparian Condition: Riparian Vegetation	# of acres acquired		Twisp River	Acquisition and conservation easements to protect riparian habitat.
2012	Twisp River Acquisition (Hovee)	Methow Salmon Recovery Foundation	4.1: Riparian Condition: Riparian Vegetation	# of acres acquired		Twisp River	Riparian property acquisition
2013	MSRF WDFW Floodplain wetland easement (McIvor)	Methow Salmon Recovery Found	4.1: Riparian Condition: Riparian Vegetation	# of acres acquired	13 acres	Methow River	Acquisition 13 acres of wetland that has seasonal connectivity to the Methow River.
2014	MSRF M2 Amundsen Floodplain	Methow Salmon Recovery Found	4.1: Riparian Condition: Riparian Vegetation	# of acres acquired	16.01 acres	Methow River	Acquisition of 16.01 acres of floodplain on the Methow River to support development of Yakama Nation 1890's side channel project.
2015	M2 sugar acquisition	Methow Salmon Recovery Foundation	4.1: Riparian Condition: Riparian Vegetation	# of acres acquired		Methow River	
2016	MSRF Twisp River Floodplain Lower Acquisition	Methow Salmon Recovery Found	4.1: Riparian Condition: Riparian Vegetation	# of acres acquired	5 acres	Twisp River	The Twisp Floodplain Lower Acquisition Project acquired about 5 acres of floodplain, wetland and river front property. This acquisition expands on the existing 35 acres of adjacent protected property. This project will permanently protect 5 additional acres of active floodplain and 1,000 feet of stream bank along the river in the Lower Twisp River.

Appendix B – Annotated Bibliography

June 2019

Summary Bibliography

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Twisp River Stream Habitat Assessment River Mile 0 to 7.8	2010	Inter-Fluve, Inc	Inter-Fluve Inc	Yakama Nation

Title	Date	Authors	Prepared By	Prepared For
Probability of Streamflow Permanence Model (PROSPER): A spatially continuous model of annual streamflow permanence throughout the Pacific Northwest	2019	Jaeger, K.L, Sando, R., McShane, R.R., Dunham, J.B., Hockman-Wert, D.P., Kaiser, K.E., Hafen, K., Risley, J.C., Blasch, K.W.		
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Effectiveness of a Redesigned Water Diversion Using Rock Vortex Weirs to Enhance Longitudinal Connectivity for Small Salmonids	2010	Martens KD, Connolly PJ	USGS	North American Journal of Fisheries Management 30 pp. 1544-1552

Title	Date	Authors	Prepared By	Prepared For
Methow River Studies, Washington - Abundance Estimates from Beaver Creek and the Chewuch River Screw Trap, Methodology Testing in the Whitefish Island Side Channel, and Survival and Detection Estimates from Hatchery Fish Releases, 2013	2014	Martens KD, Fish TM, Watson GA, Connolly PJ	USGS	Reclamation
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Title	Date	Authors	Prepared By	Prepared For
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Title	Date	Authors	Prepared By	Prepared For
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Methow Intensively Monitored Watershed 2012 Annual Report	2013	Reclamation	Reclamation	
Draft Chewuch River Habitat Assessment	2008	Reclamation	Reclamation	
2014 List of Tributary Habitat Projects Completed for the 2010 Federal Columbia River Power System Biological Opinion	2015	Reclamation	Reclamation	NOAA Fisheries
2013 List of Tributary Habitat Projects Completed for the 2010 Federal Columbia River Power System Biological Opinion	2014	Reclamation	Reclamation	NOAA Fisheries
Bureau of Reclamation's 2012 List of Tributary Habitat Projects Completed for the 2010 Federal Columbia River Power System Biological Opinion	2013	Reclamation	Reclamation	NOAA Fisheries
Reclamation's 2009 Annual Report of Tributary Habitat Projects Completed for the 2008 Federal Columbia River Power System Biological Opinion	2010	Reclamation	Reclamation	NOAA Fisheries

Title	Date	Authors	Prepared By	Prepared For
Bureau of Reclamation's 2010 List of Tributary Habitat Projects Completed for the 2010 Federal Columbia River Power System Biological Opinion	2011	Reclamation	Reclamation	NOAA Fisheries
Endangered Species Act Federal Columbia River Power System 2014-2018 Implementation Plan	2014	Reclamation, USACE, BPA	Reclamation, USACE, BPA	NOAA Fisheries
Endangered Species Act Federal Columbia River Power System 2011 Annual Progress Report - Section 1	2012	Reclamation, USACE, BPA	Reclamation, USACE, BPA	NOAA Fisheries
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Title	Date	Authors	Prepared By	Prepared For
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2002 Index Watershed Salmon Recovery Monitoring Report	2002	Seiler G, Volkhardt G, Murdoch A, Hawkins S, Fuss H, Ehinger B	WDFW, WDOE	Washington Salmon Recovery Funding Board
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Monitoring and Evaluation of the Wells Hatchery and Methow Hatchery Programs 2013 Annual Report	2014	Snow C, Frady C, Repp A, Goodman B, Murdoch A	WDFW	Douglas PUD, Grant PUD, Wells HCP Hatchery Committee
Monitoring and Evaluation of Wells and Methow Hatchery Programs in 2008	2009	Snow C, Frady C, Repp A, Murdoch A, Blankenship SM, Bowman C, Small MP, Von Bargen J, Warheit KI	WDFW	Douglas County PUD, Wells Habitat Conservation Plan Hatchery Committee
Monitoring and evaluation of Wells and Methow hatchery programs in 2010	2011	Snow C, Frady C, Repp A, Murdoch A, Small M, Bell S, Dean C	WDFW	Douglas County PUD, Wells Habitat Conservation Plan Hatchery Committee
Monitoring and evaluation of Wells and Methow hatchery programs: 2012 annual report	2013	Snow C, Frady C, Repp A, Murdoch A, Small M, Dean C	WDFW	Douglas County Public Utilities District, Wells Habitat Conservation Plan Hatchery Committee
Endangered Species Act Section7(a)(2) Supplemental Biological Opinion	2014	Stelle W	NOAA Fisheries	USACE, BPA, Reclamation

Title	Date	Authors	Prepared By	Prepared For
Monitoring of Stream Restoration Habitat on the Main Stem of the Methow River, Washington, During the Pre-Treatment Phase (October 2008-May 2012) with a Progress Report for Activities from March 2011 to November 2011	2012	Tibbits WT, Martens KD, Connolly P	USGS	Reclamation
Endangered Species Act Federal Columbia River Power System 2014 Annual Progress Report - Section 1	2015	USACE, Reclamation, BPA	USACE, Reclamation, BPA	NOAA Fisheries
Entiat effectiveness monitoring study: monitoring the effectiveness of habitat restoration actions in the lower Entiat River	2005	Ward M	Terraqua Inc, Upper Columbia Salmon Recovery Board Regional Technical Team	
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Post Fire and Flood Fish Assessment in Beaver Creek	2014	Watson G, Crandall J	MSRF	
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Colonization of Steelhead in a Natal Stream after Barrier Removal	2013	Weigel DE, Connolly PJ, Martens KD, Powell MS	Reclamation, USGS, University of Idaho	Transactions of the American Fisheries Society 142(4) pp. 920-930
Fluvial rainbow trout contribute to the colonization of steelhead (Oncorhynchus mykiss) in a small stream	2014	Weigel DE, Connolly PJ, Powell MS	USGS, USBOR, University of Idaho	Environmental Biology of Fishes
Flow regime, temperature, and biotic interactions drive differential declines of trout species under climate change	2011	Wenger SJ, Isaak DJ, Luce CH, Neville HM, Fausch KD, Dunham JB, Dauwalter DC, Young MK, Elsner MM, Rieman BE, Hamlet AF, Williams JE		PNAS Vol. 108, No. 34, pp. 14175-14180
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Title	Date	Authors	Prepared By	Prepared For
Estimation of Juvenile Salmon Habitat in Pacific Rim Rivers Using Multiscalar Remote Sensing and Geospatial Analysis	2011	Whited DC, Kimball JS, Lorang MS, Standford JA		River Research and Applications, 2011

Executive summary of the FCRPS 2008 Biological Opinion

By:	
	2008
Prepared by:	NOAA Fisheries
Prepared for:	
Funding Source:	
KeyWords:	Hatchery Harvest Predator Habitat Hydropower RPA Implementation BiOp

ESUs/ species referenced:

All 13 ESA-listed species in the Columbia River.

Watershed(s):

Columbia

Abstract/ document summary:

This document presents a brief overview of the the 2008 Biological Opinion.

The ESA requires the agencies that operate the FCRPS (FCRPS Action Agencies) to ensure that their actions are not likely to jeopardize the continued existence of a listed species, nor result in the destruction or adverse modification of habitat designated as critical to its conservation. The three FCRPS Action Agencies are the Army Corps of Engineers, Bonneville Power Administration, and the Bureau of Reclamation. The FCRPS Action Agencies must consult with the National Marine Fisheries Service (NOAA Fisheries) on actions they intend to undertake that may affect a listed anadromous fish species or its critical habitat. The product of this consultation is a Biological Opinion regarding the FCRPS and the mainstem effects of other projects, as well as authorization for harm to these listed that may be incidentally caused by FCRPS operations.

In this instance, the FCRPS Action Agencies reached the conclusion that operation of these projects, without further mitigation, would jeopardize listed species. As a result, they have presented NOAA Fisheries not only with proposed operations, but also with a package of additional measures designed to benefit listed species. NOAA Fisheries has included the additional mitigation proposed by the FCRPS Action Agencies in its analysis, as well as other mitigation measures NOAA Fisheries believed to be needed to avoid jeopardizing the listed species. Collectively, these additional actions are called, in the language of the ESA, a Reasonable and Prudent Alternative. The Reasonable and Prudent Alternative for the FCRPS operations contains 73 detailed sets of additional mitigation actions that are required to avoid jeopardy and adverse modification of critical habitat.

The actions evaluated in this 2008 FCRPS Biological Opinion are, in general, a 10-year operations and configuration plan for the FCRPS facilities, as well as the mainstem effects for various other hydro projects on Columbia River tributaries operated for irrigation purposes. The FCRPS action includes additional habitat, hatchery, predation management, and harvest actions to mitigate for the adverse effects of the hydrosystem.

In August 2007, the FCRPS Action Agencies completed an assessment of the biological effects of the FCRPS and the mainstem effects of other hydro projects on listed salmon and steelhead. The FCRPS Action Agencies submitted this biological assessment to NOAA Fisheries on August 21, 2007 for evaluation and consultation. The FCRPS Biological Opinion is the result of NOAA Fisheries' consultation with the FCRPS Action Agencies, an evaluation of the documents they prepared, and a determination on whether the actions pose jeopardy for listed species or their habitat.

FCRPS 2010-2013 Implementation Plan

By:

2010

Prepared by: BPA, USACE, USBOR

Prepared for:

Funding Source:

KeyWords: Hatchery Harvest Predator Habitat Hydropower RPA Implementation BiOp Project Limiting Factor

ESUs/ species referenced:

All 13 ESA-listed species in the Columbia River

Watershed(s):

Columbia

Abstract/ document summary:

The 2010-2013 Implementation Plan summarizes the significant actions that will be implemented by the Action Agencies from 2010 through 2013 to protect ESA-listed salmon and steelhead affected by the operation of the FCRPS. Work to be performed is summarized in this Implementation Plan and supported by a detailed list of projects. The purposes of the Implementation Plan are to:

1. Assign agency responsibility and accountability for implementing specific actions.
2. Determine and document strategies, priorities, actions, and timetables.
3. Facilitate and measure agency progress toward performance standard and targets.
4. Provide a basis for agency management and progress reporting.
5. Provide a dynamic framework for adapting actions and achieving results over the period of the Implementation Plan.
6. Provide an opportunity for the Regional Implementation Oversight Group (RIOG) and other regional parties to review the Action Agencies' plans and actions.

Consistent with the BiOp, the actions described in this plan are focused on (1) achieving biological performance standards, (2) achieving programmatic performance targets, and (3) addressing factors that limit certain life stages for specific evolutionarily significant units (ESUs) or distinct population segments (DPSs) of salmon and steelhead. The plan is structured around the Reasonable and Prudent Alternative (RPA) table used in the BiOp and for annual BiOp progress reporting. Although the plan covers a four-year time frame (2010- 2013), the Action Agencies will hold regional discussions as results and progress are evaluated through the annual progress reports. If needed, mid-course modifications may be made to implementation actions; these modifications will be detailed in the annual progress reports. Adaptive management will continue to be used to make adjustments to actions based on new scientific information and in response to changing circumstances, to meet
biological performance objectives effectively and efficiently. Near the end of this implementation period, the Action Agencies will complete a comprehensive report evaluating their progress, currently scheduled for June 2013. The results of this evaluation will inform the next implementation period, which will be from 2014 through 2016. (The next Implementation Plan is due December 2013.) The comprehensive report will include an update of the status for each of the interior basin species (including consideration of available information on recruit-per-spawner, lambda, and abundance trends for populations rolled up to the ESU level) to determine whether we are on track or if additional actions and types of actions may be needed to get the ESUs on track by the end of the BiOp period.

Endangered Species Act Federal Columbia River Power System 2013 Comprehensive Evaluation Section 1

By:

2013

Prepared by:	Reclamation, USACE, BPA
Prepared for:	NOAA Fisheries
Funding Source:	Reclamation, USACE, BPA
KeyWords:	Hatchery Harvest Predator Kelt Habitat Hydropower Returns RPA Implementation

ESUs/ species referenced:

All 13 Columbia River ESA-listed species

Watershed(s):

Columbia

Abstract/ document summary:

This Comprehensive Evaluation provides a thorough report of progress by the federal Action Agencies in carrying out the elements of the Biological Opinion (BiOp) for the operation of the Federal Columbia River Power System (FCRPS). It reflects an extensive regional effort to improve the survival of Columbia and Snake River salmon and steelhead throughout their life cycles. This report is required under the BiOp, issued in 2008 by the National Oceanic and Atmospheric Administration's National Marine Fisheries Service (NOAA Fisheries).

This Comprehensive Evaluation is organized in three sections, each with increasing levels of detail. First, a series of tables provide an overview of progress "at a glance." Section 1 includes RPA action implementation highlights and identifies findings that will inform future RPA action implementation. This section also presents information in formats requested by the federal-state-tribal Regional Implementation Oversight Group (RIOG). Generally, statements in Section 1 are supported by details and information in Section 2. Section 2 reports multi-year accomplishments on RPA implementation by action. Section 3 lists projects implemented through 2012 and includes completed habitat metrics.

Winthrop Area (W2) Assessment of Geomorphic and Ecologic Indicators

By:

2011

Prepared by: Reclamation

Prepared for:

Funding Source: Reclamation

KeyWords: Habitat RPA Implementation BiOp Limiting Factor Juvenile Salmonids Restoration Assessment RME IMW M

ESUs/ species referenced:

Upper Columbia River Spring Chinook, Upper Columbia River steelhead, Upper Columbia River bull trout, Pacific Lamprey

Watershed(s):

Methow

Abstract/ document summary:

This assessment provides scientific information on the geomorphology and habitat condition in the “W2 Reach” (Wolf Creek to Winthrop section) of the Middle Methow River between river mile (RM) 55 and 50. This information can be used to identify potential habitat improvement projects, to inform future monitoring of fish habitat improvement projects, and evaluate how these projects are addressing key limiting factors to protect and improve survival of salmon and steelhead listed under the Endangered Species Act (ESA).

This report documents physical features and analyzes riverine processes that may affect the overall health of the system at the reach scale. Two valley segments were identified in the assessment area based on hydrologic considerations. These valley segments are referred to as the Upper W2 and Lower W2, and are divided at the confluence of the Chewuch River. This division was necessary because flow inputs from the Chewuch River account for about 30 percent of the Methow River’s flow in the Lower Middle Methow. The Upper W2 was further divided into two channel segments based on geologic valley confinement. The upstream section was moderately confined and is referred to as Channel Segment M8; and the downstream section was unconfined and is referred to as Channel Segment M7. No divisions were needed for the Lower W2 as the valley segment was geologically confined and the channel segment is referred to as Channel Segment M6. The overall cumulative effects of anthropogenic disturbances have negative impacts on the physical and ecological processes that create and maintain aquatic habitat complexity, quality, and variability. These disturbances have modified the physical and ecological processes by (a) artificially disconnecting the floodplain, (b) restricting lateral channel migration, and (c) clearing and altering riparian vegetation structure and composition.

Middle Twisp River Reach Assessment & Restoration Strategy

By:

2015

Prepared by:	Inter-Fluve, Inc.
Prepared for:	Yakama Nation
Funding Source:	Yakama Nation
KeyWords:	Habitat Restoration RPA Implementation BiOp Limiting Factor RME Salmon LWD Off-channel Side Channel

ESUs/ species referenced:

Upper Columbia River spring Chinook, Upper Columbia River steelhead, Upper Columbia River bull trout, Upper Columbia River Coho, Pacific Lamprey

Watershed(s):

Twisp

Abstract/ document summary:

This assessment evaluates aquatic habitat and watershed process conditions in the Middle Twisp Reach of the Twisp River and identifies habitat restoration strategies. The assessment area is the mainstem Twisp River from river mile (RM) 7.8 to RM 18.1. This reach assessment provides the technical foundation for understanding existing conditions and for identifying restoration strategies and specific restoration opportunities within the Middle Twisp Reach. Conditions are assessed from both the valley- and reach-scales. The aim is to identify restoration actions that address significant factors limiting the productivity of native salmonids, and to ensure that these actions fit within the appropriate geomorphic context of the system. While the proposed restoration measures are expected to benefit a large suite of native aquatic and terrestrial species, there is a particular emphasis on recovery of Endangered Species Act (ESA) listed salmonids, including spring Chinook salmon (Oncorhynchus tshawytscha), steelhead (Oncorhynchus mykiss), and bull trout (Salvelinus confluentus).

More Fish Use Reconnected Side Channel near Elbow Coulee

By:

2013

Prepared by:	Reclamation
Prepared for:	Reclamation
Funding Source:	Reclamation
KeyWords:	side channel twisp juvenile habitat salmon monitoring tributary RME restoration RPA

ESUs/ species referenced:

Upper Columbia River spring Chinook, Upper Columbia River steelhead

Watershed(s):

Twisp

Abstract/ document summary:

More than 50 years ago, a portion of the floodplain and side channel near Elbow Coulee was cut-off from the mainstem Twisp River by a levee. In September 2008, a project was initiated to re-establish connection to the river by breaching the levee. The Elbow Coulee Side Channel Restoration Project was implemented to meet the following objectives: 1) re-establish a side channel to the Twisp River at RM 6.6; 2) increase habitat complexity and large woody debris recruitment potential; 3) reduce stream energy to increase the potential for the accumulation of sediment and wood in the Twisp River; and 4) increase rearing habitat for native juvenile salmonids. A breach was excavated in the existing levee at the upstream entrance to the disconnected side channel. A sill constructed at the breach functions as a grade control structure and limits flow entering the side channel. The sill was designed to activate the side channel when flows in the Twisp River reached 200 to 400 cubic feet per second (cfs), representing a 1.5 to 2 year recurrence interval discharge. Monitoring results obtained since post-construction in 2008 and through 2011 indicate that all four objectives have been met and that the project provides habitat for spring Chinook salmon, steelhead, and potentially bull trout:

1. High flows activated the side channel each year
2. Young-of-the-year spring Chinook and steelhead observed each year using the side channel
3. More fish are using the side channel than before
4. Water temperatures conducive for fish rearing

This report summarizes the monitoring and evaluation of the project as presented by Crandall (2009, 2010, and 2011).

Endangered Species Act Section 7(a)(2) Consultation Biological Opinion and Magnuson-Stevens Fishery Conservation and Management Act Essential Fish Habitat Consultation

By:	
2008	
Prepared by:	NOAA Fisheries
Prepared for:	
Funding Source:	NOAA Fisheries
KeyWords:	Hatchery Harvest Hydropower Habitat RPA Implementation BiOp Action Agencies RME

ESUs/ species referenced:

Watershed(s):

Columbia

Abstract/ document summary:

To achieve the objectives of the Biological Opinion, NOAA Fisheries generally uses the five-step approach for applying the ESA Section 7(a)(2) standards to Pacific salmon (originally developed for the 1995 and 2000 FCRPS Biological Opinions.) The steps are adapted to conform to current legal authorities as follows:

1. Define the biological requirements and current status of each affected listed species and the conservation role and current function for affected designated critical habitat.
2. Evaluate the relevance of the environmental baseline and activities with cumulative effects, occurring in the action area, to the current status of affected listed species and designated critical habitat.
3. Determine the likely effects of the prospective action on listed species and designated critical habitat.
4. Determine (a) whether the species can be expected to survive with an adequate potential for recovery (e.g. trending toward recovery) under the effects of the action, the effects of the environmental baseline, and any cumulative effects, and (b) whether affected designated critical habitat is likely to remain functional (or retain the ability to become functional) to serve the intended conservation role for the species in the near and long term under the effects of the action, environmental baseline and any cumulative effects.
5. If necessary, identify reasonable and prudent alternatives (RPAs) to a proposed or continuing action when the action is likely to jeopardize the continued existence of a listed species or destroy or adversely modify its critical habitat.

Elbow Coulee Floodplain Reconnection and Side Channel Restoration Project 2010 Post-Project Assessment Report

By:

2010

Prepared by:

Prepared for:

Funding Source:

KeyWords: Habitat RPA Restoration Side Channel Tributary BACI RME IMW Model Monitoring Assessment

ESUs/ species referenced:

Upper Columbia River spring Chinook, Upper Columbia River steelhead

Watershed(s):

Twisp

Abstract/ document summary:

In September 2008, the Elbow Coulee Floodplain Reconnection and Side Channel Restoration Project was implemented in order to: 1) re-establish a primary side channel to the Twisp River at RM 6.6; 2) increase habitat complexity and large woody debris recruitment potential; 3) reduce stream energy to increase the potential for accumulation of sediment and wood in the Twisp River; and 4) increase habitat for native fish, especially rearing-age salmonids. Specifically, a rock breach was constructed in an existing dike at the upper entrance to the primary side channel.

Post project assessment will consist of both quantitative and visual examinations of side channel form and function. Specifically, monitoring was conducted to assess the: 1) response of the primary side channel geomorphic configuration to restoration activities designed to create long-term habitat benefits; 2) response of physical characteristics (primarily discharge and water temperature) and the biological community to habitat restoration and the newly re-established aquatic habitats within the primary side channel; and 3) identify steps needed to adaptively manage the project in order to maximize project success.

Two years of monitoring was detailed in a 2008-2009 post-project assessment report (Crandall 2009). Overall, the project had functioned to allow rearing of juvenile spring Chinook salmon and steelhead both of which were target species. Both of these species were observed in the primary side channel in 2009. Additionally, the side channel was activated when discharge in the Twisp River was approximately 300 c.f.s., yet significant flow did not enter the channel until the sill rock was overtopped at a Twisp River flow of approximately 575 c.f.s

Middle Methow Reach Assessment

By:	
2010	
Prepared by:	Reclamation
Prepared for:	
Funding Source:	
KeyWords:	habitat limiting factor restoration assessment geomorphic monitoring REI ecosystem floodplain connectivi

ESUs/ species referenced:

Upper Columbia River spring Chinook, Upper Columbia River steelhead, Upper Columbia River bull trout

Watershed(s):

Methow

Abstract/ document summary:

The Middle Methow reach is located between RM 50.0 and 41.0 on the Methow River. The reach is characterized as moderately confined (RM 50.0-47.0), unconfined (RM 47.0-41.3), and confined (RM 41.3-41.0) based on valley constraints. Limiting factors, the “condition that limit the ability of habitat to fully sustain populations of salmon” (State of Washington 1998 Engrossed Substitute House Bill 77RCW), affecting the Middle Methow River subwatershed habitat conditions include the following (UCSRB 2007, UCRTT 2007):

• Residential development is affecting riparian and floodplain condition.
• Low flows in late summer and winter may affect juvenile survival.
• Structures in tributaries are passage barriers for adult and juvenile salmonids.
• The mainstem Methow is on the state 303(d) list for temperatures.
• Decreased habitat diversity and quantity due to roads, riprap, residential development and agriculture.
• Excessive artificial channel stability due by roads, riprap, residential development, and agriculture.

This report summarizes the above habitat action classes at relevant spatial scales to provide the necessary information to identify appropriate actions within a reach concept. Once actions have been identified for implementation, further analysis will need to be completed (i.e., alternatives evaluation) to address the appropriateness of the action, biological benefit, socio-economic considerations, construction and cost considerations, and an analysis of risks and liabilities to life and property.

Columbia River Hatchery Reform System-Wide Report

By:

2009

Prepared by:	Hatchery Scientific Review Group
Prepared for:	
Funding Source:	BPA, NOAA, NPCC, PSMFC, US Congress
KeyWords:	Hatchery, habitat, assessment, harvest, returns,

ESUs/ species referenced:

All 13 Columbia River, Willamette River, and Snake River ESA-listed salmon and trout species

Watershed(s):

Columbia River

Abstract/ document summary:

The objective of the HSRG's Columbia River Basin review was to change the focus of the Columbia River hatchery system. In the past, these hatchery programs have been aimed at supplying adequate numbers of fish for harvest as mitigation primarily for hydropower development in the Basin. A new, ecosystem-based approach is founded on the idea that harvest goals are sustainable only if they are compatible with conservation goals.

The HSRG approach represents an important change of direction in managing hatcheries in the region. It provides a clear demonstration that current hatchery programs can indeed be redirected to better meet both conservation and harvest goals. For each Columbia River Basin Environmentally Significant Unit (ESU), Distinct Population Segment (MPG) or Major Population Group (MPG) reviewed, the HSRG presents its findings and recommendations in the form of an HSRG solution. This package of recommended changes to current hatchery and harvest program design and operation is intended to demonstrate how the programs could be managed to significantly increase the likelihood of meeting the managers' goals for both harvest and conservation of the ESU/DPS/MPG. The "HSRG solution" also highlights the biological principles that the HSRG believes must form the foundation for successful use of hatcheries and fisheries as management tools. The HSRG review focused on hatchery programs, but took into account natural populations, survival conditions in the mainstems of the Columbia and Snake rivers and the Columbia River estuary, and harvest regimes. The HSRG concluded that the value of habitat improvements (in terms of the abundance and productivity of natural populations) would increase if those improvements were preceded by hatchery reforms. Similarly, hatchery and habitat improvements would be enhanced with harvest reforms. The solutions proposed by the HSRG for Columbia Basin hatchery programs demonstrate that these programs can be redesigned to better meet conservation and harvest goals.

Completion Report Upper Stokes Fish Passage Improvement Project Beaver Creek, Methow Subbasin, Washington

By:

2004

Prepared by:

Prepared for:

Funding Source:

KeyWords: restoration, implementation, tributary

ESUs/ species referenced:

Watershed(s):

Beaver Creek

Abstract/ document summary:

In the fall of 2003, the Upper Stokes Diversion Dam (photo A-1), identified by the Washington Department of Fish and Wildlife (WDFW) as a barrier to fish movement, was replaced by two rock weirs. These allow fish passage for all species and life stages, meet diversion flow requirements for the landowner, and are less noticeable. The project, the second of three in the area, is located on Beaver Creek, a tributary of the Methow River in Okanogan County, Washington. This report explains the design process and regulatory requirements leading to the new diversion and documents the construction that took place. To better illustrate what was accomplished, we have included two appendices. Appendix A shows a series of photographs documenting the work that was done. Appendix B contains "as-built" drawings of the project.

Monitoring the benefits of instream habitat diversity Entiat River, Chelan County, Washington

By:	
2013	
Prepared by:	Reclamation, BPA
Prepared for:	
Funding Source:	Washington State Salmon Recovery Funding Board
KeyWords:	RME, restoration, habitat, juvenile, snorkel, monitoring

ESUs/ species referenced:

Upper Columbia river spring/summer Chinook, Upper Columbia River summer steelhead, Upper Columbia river bull trout

Watershed(s):

Entiat

Abstract/ document summary:

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

2013-Third Year Lessons Learned Project Synthesis Report

By:	
2014	
Prepared by:	CHAMP
Prepared for:	BPA
Funding Source:	BPA
KeyWords:	CHAMP, monitoring, tributary, habitat, juvenile, treatment, control, restoration, BACI, IMW, snorkel, retur
ESUs/ species referenced:	

Watershed(s):

Wenatchee, Entiat, Methow, John Day, Grande Ronde, Tucannon, Lemhi, Secesh, Asotin

Abstract/ document summary:

This report addresses the following questions:
1. Are the metrics generated by the CHaMP protocol reliable?
The CHaMP team has scrutinized every aspect of the sampling program to improve efficiency and data quality since implementation in 2011. This scrutiny has resulted in a suite of metrics that are reproducible and are accompanied by very low measurement error.

2. What have we learned about habitat status and trends?
In many cases, habitat status findings align well with a priori assumptions. At the end of the 2017 survey year, we will have sufficient data to separate long-term linear trends from year-to-year variation in a statistically sound manner. Nonetheless, the preliminary results are encouraging and, within the context of IMWs, illustrate one of the uses of trend data in habitat restoration effectiveness monitoring.

3. Is CHaMP useful?
The Integrated Status and Effectiveness Monitoring Project (ISEMP; BPA Project Number 2003-017-00) relies on CHaMP to support habitat restoration effectiveness monitor-ing. Additionally, standardized CHaMP metrics are being actively used by the Columbia River Inter-Tribal Fish Commission (CRITFC) and the Oregon Department of Fish and Wildlife (ODFW). The utility of CHaMP data can be mean-ingfully summarized through their application towards addressing the three KMQs.

4. Will CHaMP products be available in time to support regional decision making processes?
CHaMP products are being devel-oped to support two major decision-making processes: the Expert Panel pro-cess (2016) and the BiOp process (2018).

5. Has CHaMP made progress towards standardization and unified metric reporting across other habitat survey programs?
CHaMP is not the only program collecting habitat survey data in the Colum-bia River Basin. Collaboration between CHaMP and the Action Effectiveness Monitoring (AEM) initiative has enabled CHaMPMonitoring.org to support and serve data from that effort. However data from other preexisting habitat sur-vey efforts such as PACFISH/INFISH Biological Opinion (PIBO) have not been reduced to identify common metrics, nor has any attempt been made to report those common metrics in a single location. Recognizing the value in identifying common metrics among the multitude of habitat survey initiatives, and reporting those metrics in a single accessible location, BPA has tasked CHaMP with expanding its database to store and serve information collected by PIBO.
By the end of 2014, the CHaMP database will be modified to provide access to common metrics between PIBO and CHaMP.

Methow Beaver Project Accomplishments and Outcomes

By:

2013

Prepared by: Methow Beaver Project

Prepared for:

Funding Source: Washington DOE, Yakama Nation, Nation Fish and Wildlife Foundation - Community Salmon Fund, Ecotrust

KeyWords: beaver relocation, restoration, Before After Control Impact, stream flows, Methow River

ESUs/ species referenced:

Watershed(s):

Methow River

Abstract/ document summary:

After a very successful pilot year, an ambitious first phase effort was proposed to deliver beavers to at least 15 sites in the first four years with the goal of at least 5 sites becoming established in three watersheds. To date we have captured 181 beavers from 54 locations. In a few cases we did not keep the beaver, a few beavers died, and in 6 cases, beavers managed to escape from the holding facility. We have released 163 beavers to 35 sites. Beginning in 2011, all beavers captured were permanently marked with PIT tags for future identification. To date, because of these tags in the tail, two beavers were documented as recaptures of beavers we had previously caught and released. Both had travelled some distance. The furthest was about 37 miles from the release location.

The comprehensive study plan for this effort was completed in March 2011 and a Quality Assurance Plan was approved by the Department of Ecology, and it invovles a comprehensive stream temperature and flow study using a Before-After, Control-Impact design to document the magnitude and scale of temperature improvement and the amount of flow attenuation in streams where beavers are re-introduced. In June 2011, data gathering began at these sites for stream temperature and stream discharge. 82 temperature loggers are currently capturing baseline stream temperature in 18 subwatersheds. Six flow stations with water pressure loggers in 6 subwatersheds are currently documenting rising and lowering stream elevations. Hydrologic ratings curves for these six streams will be constructed in 2013 and flow calculations will then be derived. After the baseline period, beavers will be released at half the sites and all will be monitored for a period to determine what the effects to stream temperature and stream discharge are. We expect this to require another 3-5 years.

Several Conservation Easements were added during the last five years. Two of the more recent additions include the Tawks II and Keith properties on the Upper Methow River that protect more than 0.6 mile of riverfront from development in perpetuity. The Methow Conservancy, through its Cage-a-Tree project has caged 738 trees on 14 properties, most of which had either Methow Conservancy or WDFW conservation easements on them. This project is on-going to maximize its impact on the protection of riparian vegetation and the recruitment of shade producing trees.

National Large Wood Manual - Assessment, Planning, Design, and Maintenance of Large Wood in Fluvial Ecosystems: Restoring Process, Function, and Structure

By:	
2016	
Prepared by:	Reclamation, USACE
Prepared for:	
Funding Source:	
KeyWords:	large wood, restoration, design, engineering

ESUs/ species referenced:

Watershed(s):

Abstract/ document summary:

This manual is intended to help establish more consistent and robust methods to assess, design, and manage wood projects to restore streams and rivers throughout the United States. Various federal and state agencies are increasingly advocating that more wood be used as a “soft”, cost-effective, and ecologically beneficial engineering technique for restoration and mitigation projects to meet environmental mandates and endangered species requirements, while maintaining traditional agency missions. The term soft only implies that wood is a natural part of most streams and, therefore, directly addresses the goal of restoring natural conditions. There should not be anything soft, however, about the analysis and design of wood projects. They should be conducted with the same scientific and engineering rigor as any river project or manipulation. The failure of wood placements in restoration is entirely the fault of the design, not the material. By understanding the geomorphology, hydraulics, and geotechnical aspects of a project and with good engineering, stable wood structures can be designed for various situations and longevities. In many situations it may be desirable to place wood that can move, but designers should understand the function and fate of such placements. In the end, it is stable wood that most directly benefits restoration, and the underlying goal of wood projects should be to restore the function of wood until riparian forests are able to supply the large trees that can sustain those functions. In highly constrained systems where that may not be possible, engineering solutions can still be pursued to restore the function of wood well into the future.

Lower Libby Creek Reach Assessment

By:

2012

Prepared by:	Inter-Fluve, Inc.
Prepared for:	Yakama Nation Fisheries
Funding Source:	
KeyWords:	Reach Assessment, Habitat, Methow River, Libby Creek, Salmon

ESUs/ species referenced:

UCR summer steelhead, UCR spring Chinook

Watershed(s):

Methow

Abstract/ document summary:

This assessment evaluates geomorphic processes and aquatic habitat conditions in the lower 1.4 miles of Libby Creek and identifies strategies to restore and preserve salmonid habitat and natural river processes. Libby Creek supports populations of salmonids that are currently listed under the Endangered Species Act (ESA), including Upper Columbia River summer steelhead and a small population of spring Chinook salmon. Habitat for these species has been impacted by anthropogenic activities throughout the basin.

Lower Twisp River Reach Assessment

By:	
2010	
Prepared by:	Inter-Fluve, Inc.
Prepared for:	Yakama Nation Fisheries Program
Funding Source:	
KeyWords:	Reach Assessment, Habitat, Salmon, Lower Twisp River

ESUs/ species referenced:

UCR summer steelhead, UCR spring Chinook, bull trout

Watershed(s):

Twisp River

Abstract/ document summary:

This assessment evaluates aquatic habitat conditions in the lower Twisp River and identifies strategies to restore and preserve salmonid habitat and natural river processes. This assessment builds off the work conducted as part of the Methow Sub-basin Geomorphic Assessment (USBR 2008a), also known as the Tributary Assessment. Reach Assessments are conducted at a finer scale than Tributary Assessments. Whereas the Tributary Assessment provides a watershed and valley-scale context for primary controls on bio-physical processes, this Reach Assessment describes conditions operating at the scale of individual stream reaches and sub-reaches. This Reach Assessment characterizes geomorphic conditions on the lower Twisp River from the mouth to river mile (RM) 7.8 and uses this information to identify restoration and preservation strategies.

Chewuch River Reach Assessment

By:

2010

Prepared by: Inter-Fluve, Inc.

Prepared for: Yakama Nation Fisheries Program

Funding Source:

KeyWords: Reach Assessment, Habitat, Salmon, Chewuch River

ESUs/ species referenced:

UCR spring Chinook, UCR summer steelhead, bull trout

Watershed(s):

Chewuch River

Abstract/ document summary:

This assessment evaluates aquatic habitat conditions in the lower 20 miles of the Chewuch River and identifies strategies to restore and preserve salmonid habitat and natural river processes. This assessment builds off the work conducted as part of the Methow Sub-basin Geomorphic Assessment (USBR 2008b), also known as the Tributary Assessment. Reach Assessments are conducted at a finer scale than Tributary Assessments. Whereas the Tributary Assessment provides a watershed and valley-scale context for primary controls on bio-physical processes, this Reach Assessment describes conditions operating at the scale of individual stream reaches and sub-reaches. This Reach Assessment characterizes geomorphic conditions on the Chewuch River from river mile (RM) 2.2 to RM 20.0 and uses this information to identify restoration and preservation strategies.

This report includes two primary components:
1. Reach Assessment – Reach and Sub-Unit scale evaluation and project opportunity identification
2. REI Metrics – An analysis of Reach-Based Ecosystem Indicators (REI) at the tributary and reach scales.

Columbia River Food Webs: Developing a Broader Scientific Foundation for Fish and Wildlife Restoration

By:	Alldredge JR, Beauchamp D, Congleton J, Henny C, Huntly N, Lamberson R, Levings C, Naiman RJ, Pearcy W, Rieman B, R
2011	
Prepared by:	Independent Scientific Advisory Board
Prepared for:	Northwest Power and Conservation Council (NPCC), Columbia River Basin Indian Tribes, NOAA Fisheries
Funding Source:	
KeyWords:	food webs, restoration, modeling, habitat, nutrients

ESUs/ species referenced:

Watershed(s):

Columbia

Abstract/ document summary:

The objectives of this report are to provide a fundamental understanding of aquatic food webs in the Columbia River Basin and to illustrate and summarize their influences on native fish restoration efforts. The spatial scope addresses tributaries, impoundments, the free-flowing Columbia and Snake rivers, as well as the estuary and plume. Achieving the Council's vision for the Columbia River Fish and Wildlife Program (NPCC 2009-09) of sustaining a "productive and diverse community" that provides "abundant" harvest, is best accomplished through a time-prioritized action plan, one that complements other approaches while addressing important challenges and uncertainties related to the Basin's food webs. Note that the oceanic food webs, although of immense importance in sustaining fish populations, are not considered beyond the plume since they involve an additional set of complex and rapidly evolving issues. An analysis of oceanic food webs of relevance to the Columbia River requires a separately focused effort (e.g., Hoegh-Guldberg and Bruno 2010).

Density Dependence and its Implications for Fish Management and Restoration Programs in the Columbia River Basin

By:	Alldredge JR, Fausch KD, Maule AG, Myers KW, Naiman RJ, Ruggerone GT, Saito L, Scarnecchia DL, Schroder SL, Schwarz
2015	
Prepared by:	Independent Scientific Advisory Board
Prepared for:	Northwest Power and Conservation Council, NOAA Fisheries, Columbia River Indian Tribes
Funding Source:	
KeyWords:	density dependence, habitat, capacity, salmonids, lamprey, sturgeon

ESUs/ species referenced:

Columbia River salmon and steelhead, lamprey, sturgeon

Watershed(s):

Columbia

Abstract/ document summary:

In response to an assignment from the Northwest Power and Conservation Council, NOAA Fisheries, and Columbia River Indian tribes, the Independent Scientific Advisory Board (ISAB) reviewed the implications of density dependence in fish populations in the Columbia River Basin. The ISAB's key findings include:

• Many salmon populations throughout the interior of the Columbia River Basin are experiencing reduced productivity associated with recent increases in natural spawning abundance, even though current abundance remains far below historical levels. Density dependence is now evident in most of the ESA-listed populations examined and appears strong enough to constrain their recovery. This fact raises the question: Why is density dependence more evident than expected at low abundances?

• The ISAB reanalyzed the admittedly limited historical data to better evaluate the potential capacity for salmon and steelhead in the Columbia Basin before hydrosystem development. The ISAB concludes that historical all-species capacity was likely in the range of 5 to 9 million adult fish per year, which is less than previously published estimates (e.g., 7.5 to 16 million adults per year) but still much higher than current abundance levels (~2.3 million fish per year during 2000-2012).

• Evidence for strong density dependence at current abundance suggests that habitat capacity has been greatly diminished. Roughly one-third of the Basin is no longer accessible to anadromous salmon, and continuing changes to environmental conditions stemming from climate change, chemicals, and intensified land use appear to have further diminished the capacity of habitat that remains accessible. Density dependence was also observed in some less altered watersheds.

• Hatchery releases account for a large proportion of current salmon abundance. Total smolt densities may be higher now than historically. By creating unintended density effects on natural populations, supplementation may fail to boost natural origin returns despite its effectiveness at increasing total spawning abundance.

• Identifying mechanisms that contribute to density dependence in particular habitats and life stages—such as limitations in spawning habitat, rearing habitat or food supply, or predator-prey interactions—can help to guide habitat restoration and population recovery actions.

• Understanding density dependence (e.g., stock-recruitment relationships) in salmon populations is central to evaluating responses to recovery actions and for setting spawning escapement goals that will sustain fisheries and a resilient ecosystem.

A biological strategy to protect and restore salmonid habitat in the upper columbia region

By: Arterburn J, Baldwin C, Bambrick D, Hays S, Hillman T, Kahler T, Lange J, Langshaw R, Murdoch K, Peven C, Polivka K, Rog

2013

Prepared by:	RTT
Prepared for:	Upper Columbia Regional Technical Team
Funding Source:	BPA
KeyWords:	Hatchery, harvest, habitat, hydropower, RPA, BiOp, limiting factor, juvenile, restoration,

ESUs/ species referenced:

All 13 Columbia River, Willamette River, and Snake River ESA-listed salmon and trout species

Watershed(s):

Abstract/ document summary:

This biological strategy identifies the key biological considerations in protecting and restoring habitat. We encourage project sponsors to use this strategy for identifying the locations and types of projects with a high likelihood of providing biological benefit for the recovery of ESA-listed salmonids (focal species) by improving abundance, productivity (freshwater), spatial structure, and diversity for these species and other species of concern (e.g., Westslope cutthroat trout and Pacific lamprey). The RTT recommends that use of this document begin with understanding the background information provided in Sections 1-3 and Appendices A and B; followed by examination of Appendix E (detailed summary of habitat status and ecological concerns for each assessment units); and finally, a familiarization with the new scoring criteria (Appendix C). In addition, in Table 3 the RTT lists the assessment units for each watershed (also in Appendix E) in the hope that the assessment units as described in Table 3 will serve as the definitive assessment-unit list for the Upper Columbia Region. The RTT has also provided additional information pertaining to completed assessments, with recommendations for future assessments (Table 4). Appendix D defines the necessary components of an assessment with recommendations on how project sponsors can use assessments to develop projects. Finally, the RTT encourages further dialogue with stakeholders to ensure that the concepts, criteria, and other information in this document are understood and useable.

Methow Subbasin Geomorphic Assessment

By:	Baesecke H, Bountry JA, Hadfield JS, Hopkins D, Lyon EW, Maguire T, McAffee R, Molesworth J, Mooney D, Piety LA, Sutl
	2008
Prepared by:	Reclamation
Prepared for:	
Funding Source:	Reclamation
KeyWords:	Habitat Salmon RPA Implementation BiOp Limiting Factor Restoration Geomorphic Assessment Ecosystem

ESUs/ species referenced:

Upper Columbia River spring Chinook, Upper Columbia River steelhead, Upper Columbia River Coho, Upper Columbia River bull trout, Pacific Lamprey

Watershed(s):

Methow

Abstract/ document summary:

Reclamation completed a geomorphic assessment of physical river processes and associated habitat for ESA-listed Upper Columbia River spring Chinook salmon and steelhead for nearly 80 river miles of the Methow Subbasin, located in Okanogan County, Washington. U.S. Forest Service fishery scientists assisted Reclamation with habitat evaluations. The assessment area includes a 46.9-mile-long section of the Methow River (river miles 28.1 to 75), the downstream-most 18.1 river miles of the Twisp River (tributary to Methow) and the downstream-most 14.3 river miles of the Chewuch River (tributary to Methow).

The purpose of this report is to describe technical results from a geomorphic assessment of part of the Methow River subbasin and describe a strategy that resource managers can use to sequence and prioritize opportunities for protecting or restoring channel and floodplain connectivity and complexity in the Methow subbasin.

Projected impacts of climate change on salmon habitat restoration

By:	Battin J, Wiley MW, Ruckelshaus MH, Palmer RN, Korb E, Bartz KK, Imaki H
	2007
Prepared by:	NOAA-NFSC
Prepared for:	PNAS 104(16) pp. 6720-6725
Funding Source:	NOAA, University of Washington, Joint Institute for the Study of the Atmosphere and Ocean
KeyWords:	Chinook salmon hydrologic population model stream flow habitat

ESUs/ species referenced:

Watershed(s):

Snohomish

Abstract/ document summary:

Throughout the world, efforts are under way to restore watersheds, but restoration planning rarely accounts for future climate change. Using a series of linked models of climate, land cover, hydrology, and salmon population dynamics, we investigated the impacts of climate change on the effectiveness of proposed habitat restoration efforts designed to recover depleted Chinook salmon populations in a Pacific Northwest river basin. Model results indicate a large negative impact of climate change on freshwater salmon habitat. Habitat restoration and protection can help to mitigate these effects and may allow populations to increase in the face of climate change. The habitat deterioration associated with climate change will, however, make salmon recovery targets much more difficult to attain. Because the negative impacts of climate change in this basin are projected to be most pronounced in relatively pristine, high-elevation streams where little restoration is possible, climate change and habitat restoration together are likely to cause a spatial shift in salmon abundance. River basins that span the current snow line appear especially vulnerable to climate change, and salmon recovery plans that enhance lower-elevation habitats are likely to be more successful over the next 50 years than those that target the higher-elevation basins likely to experience the greatest snow–rain transition.

A review of studies on responses of salmon and trout to habitat change, with potential for application in the Pacific Northwest

By:	Bayley PB
2002	
Prepared by:	Oregon State University, Department of Fisheries and Wildlife
Prepared for:	Washington State Independent Science Panel
Funding Source:	
KeyWords:	Meta Analysis Effectiveness Monitoring Restoration Habitat salmon trout

ESUs/ species referenced:

Watershed(s):

Abstract/ document summary:

An inspection of abstracts from 2,350 references produced a first-cut set of 441 studies and reviews that were subsequently classified and reviewed with respect to their potential to document responses of salmonids to habitat changes, and to guide future monitoring of salmonid watersheds. Although the literature on habitat requirements is vast, it was necessary to distinguish between studies that relied on correlations based on observational designs and those which attempted experimental designs to test cause-and-effect mechanisms. Our understanding about environmental effects on fish is largely based on weak inferences from observational studies, which has a direct bearing on monitoring strategies. Such studies are useful in generating hypotheses on cause-and-effect, but such hypotheses need to be tested through appropriate experimental designs in the context of a validation monitoring approach. Findings from seven reviews (1988-2002) were assessed jointly with specific studies. Articles from 30 studies were reviewed, drawing from single or multiple streams, and purely observational or 'natural experiment' designs, in order to assess what mprovements are needed in future programs.

Bioenergetic Responses by Pacific Salmon to Climate and Ecosystem Variation

By: Beauchamp D, Cross A, Armstrong J, Myers K, Moss J, Boldt J, Haldorson L

2007

Prepared by:

Prepared for: North Pacific Anadromous Fish Commission Bulletin

Funding Source: National Science Foundation

KeyWords: Climate change, ecosystem,

ESUs/ species referenced:

Pink salmon

Watershed(s):

Abstract/ document summary:

Salmon growth can respond to changes in temperature, food availability, food quality, and activity. Climatic variability can affect one or more of these factors, because different climate regimes are associated with different temporal-spatial patterns of temperature, salinity, and other oceanographic features that can alter ocean distribution patterns of salmon and cause shifts in assemblages of other organisms. Consequently, climate variability can simultaneously change the availability or productivity of exploitable prey, and the intensity of competition or predation experienced by salmon at various stages of ocean life. Variability across multiple factors can potentially confound the understanding and prediction of salmon growth or survival. Bioenergetics models can account for changing thermal and food conditions explicitly, and are valuable analytical tools for isolating and evaluating the relative contribution of different factors (e.g., temperature, feeding rate, food availability, food quality) to the consumption and growth of salmon during different life stages. Model simulations, coupled with data on growth trajectories, diet composition, and thermal experience, provide estimates of: 1) consumption rates on each prey (measures of both the importance of various prey to the energy budget of salmon, and the predation impact of salmon on prey species); 2) feeding rate as a proportion of the theoretical maximum consumption rate, a measure of relative food availability; and 3) growth efficiency, a measure of how much food was required to achieve the observed growth rate. We applied bioenergetics models to juvenile pink salmon in the Gulf of Alaska during years of low (2001) versus high (2002) ocean survival to examine feeding and growth performance between years while explicitly accounting for significant variability in stage-specific distribution, diet, growth, and consumption. From these simulations, we determined that higher feeding rates on pteropods, primarily during July–August 2002, explained the higher growth rates and larger body mass of juveniles that were associated with higher stage-specific marine survival for juveniles in 2002. Current bioenergetics models for salmonids provide valuable diagnostic and analytical tools. However, as modeling applications become more predictive and demanding, modifications and improvements will be required to address important topics like behavior, variable activity costs, seasonal and ontogenetic energy allocation, and foraging models.

Restoring Salmon Habitat for a Changing Climate

By: Beechie T, Imaki H, Greene J, Wade A, Wu H, Pess G, Roni P, Kimball J, Stanford J, Kiffney P, Mantua N

2012

Prepared by:

Prepared for:

Funding Source: Moore Foundation, National Marine Fisheries Service

KeyWords: Restoration, climate change, floodplain connectivity

ESUs/ species referenced:

Watershed(s):

Abstract/ document summary:

An important question for salmon restoration efforts in the western USA is ‘How should habitat restoration plans be altered to accommodate climate change effects on stream flow and temperature?’ We developed a decision support process for adapting salmon recovery plans that incorporates (1) local habitat factors limiting salmon recovery, (2) scenarios of climate change effects on stream flow and temperature, (3) the ability of restoration actions to ameliorate climate change effects, and (4) the ability of restoration actions to increase habitat diversity and salmon population resilience. To facilitate the use of this decision support framework, we mapped scenarios of future stream flow and temperature in the Pacific Northwest region and reviewed literature on habitat restoration actions to determine whether they ameliorate a climate change effect or increase life history diversity and salmon resilience. Under the climate change scenarios considered here, summer low flows decrease by 35–75% west of the Cascade Mountains, maximum monthly flows increase by 10–60% across most of the region, and stream temperatures increase between 2 and 6 degrees C by 2070–2099. On the basis of our literature review, we found that restoring floodplain connectivity, restoring stream flow regimes, and re-aggrading incised channels are most likely to ameliorate stream flow and temperature changes and increase habitat diversity and population resilience. By contrast, most restoration actions focused on in-stream rehabilitation are unlikely to ameliorate climate change effects. Finally, we illustrate how the decision support process can be used to evaluate whether climate change should alter the types or priority of restoration actions in a salmon habitat restoration plan.

Benefits of Tributary Habitat Improvement in the Columbia River Basin; Results of Research, Monitoring and Evaluation, 2007-2012

By:	Beechie T, Jordan C, Hillman T, Fisher T, O'Neal J, Paulsen C, Roni P
	2013
Prepared by:	BPA, Reclamation
Prepared for:	
Funding Source:	BPA
KeyWords:	Hatchery Harvest Habitat Hydropower RPA Monitoring Tributary Implementation BiOp Limiting Factor Ret

ESUs/ species referenced:

All 13 Columbia River, Willamette River, and Snake River ESA-listed salmon and trout species

Watershed(s):

Columbia

Abstract/ document summary:

Site-specific and large-scale studies are now confirming the scientific basis for protecting and improving habitat to promote salmon and steelhead survival and abundance. The evidence does not come from a single study, but rather from the increasing weight of the literature supported by a rapidly expanding body of research and data on hundreds of habitat actions throughout the Columbia Basin. Research has established relationships between habitat quality and fish survival and is pinpointing those factors, such as water flows; the number, depth and proportion of pools; gravel sizes; and temperature; that most influence juvenile salmon numbers. An understanding of those relationships, combined with detailed watershed and population assessments, helps biologists target the most critical habitat issues and more accurately estimate the benefits for fish. Managers can then better focus time and resources where they will make the most difference.

Evidence of habitat factors most important in determining fish density and abundance combined with evidence of the most effective habitat actions will help managers make the best investments for fish and for the region. The action agencies are working with project sponsors to readily share and exchange such research findings so they can inform and guide development of future habitat actions.

Large-scale studies that examined the relationships between habitat improvements and habitat quality as documented by PIBO and other programs in the Snake River Basin found many relationships between the two, underscoring benefits of habitat improvement that until recently had been largely documented outside the Columbia Basin. Large numbers of habitat improvements correlated with a roughly 20 percent increase in parr-to-smolt survival, while further analyses showed that about 23 percent of the variation in fish length and 13 percent of the variation in survival could be explained by PIBO habitat measurements. Taken together, the results suggest that habitat and fish data collected by IMWs, CHaMP, PIBO, and similar efforts show a linkage with the performance of listed stocks in streams where the fish spawn and rear.

A classification of habitat types in a large river and their use by juvenile salmonids

By: Beechie T, Liermann M, Beamer E, Henderson R

Prepared by:

Prepared for:

Funding Source:

KeyWords: Juvenile, habitat, alcove, backwater

ESUs/ species referenced:

Chinook, coho, steelhead, chum

Watershed(s):

Skagit

Abstract/ document summary:

We describe six habitat types for large rivers, including pools, riffles, and glides in midchannel and bank edges, bar edges, and backwaters along channel margins. Midchannel units were deeper and faster than edge units on average. Among edge habitat types, backwater units had the lowest velocities and contained complex cover consisting mainly of wood accumulations and aquatic plants. Banks and bars had similar velocity distributions, but banks had more complex cover such as rootwads and debris jams. Because sampling of juvenile salmonids was ineffective in the midchannel units (electrofishing capture efficiency was low, and the units were too deep and fast to snorkel), we focused our sampling efforts on juvenile salmonid use of edge habitats during winter, spring, and late summer. Densities of juvenile Chinook salmon and coho salmon were highest in bank and backwater units in winter, whereas age-0 and age-1 or older steelhead densities were highest in bank units in winter. In summer, only coho salmon densities were significantly different among edge unit types, densities being highest in banks and backwaters. Microhabitat selection (velocity, depth, and cover type) by juvenile salmonids mirrored that in small streams, most fish occupying areas with a velocity less than 15 cm/s and wood cover. Among ocean-type salmon, Chinook and chum salmon fry were captured in large numbers in all edge units and exhibited only slightly higher densities in low-velocity areas (15 cm/s).

Estimated changes to Chinook salmon (Oncorhynchus tshawytscha) and steelhead (Oncorhynchus mykiss) habitat carrying capacity from rehabilitation actions fo the Trinity River, North Fork Trinity to Lewiston Dam

By: Beechie T, Pess G, Imaki H

2012

Prepared by: Northwest Fisheries Science Center

Prepared for: USFWS

Funding Source: USFWS

KeyWords: habitat, capacity, restoration

ESUs/ species referenced:

Chinook, steelhead

Watershed(s):

Trinity

Abstract/ document summary:

This study was conducted by NWFSC under contract to the US Fish and Wildlife Service to estimate potential improvements in salmon and steelhead production from the Trinity River, California. In this report, we assume that the planned actions will be implemented, and then estimate the change in juvenile Chinook salmon and steelhead rearing habitat carrying capacity that will likely result under a range of restoration scenarios. We examine two types of scenarios: (1) a scenario that focuses on changes in habitat quality due to rehabilitation actions, and (2) a set of scenarios that include increasing channel meandering through restoring fluvial processes and the development or construction of side channel habitats. We do not differentiate between habitats created by restored processes and habitats created through rehabilitation actions in our estimated change in carrying capacity for Chinook salmon and steelhead. Rather, we construct a range of scenarios that span relatively modest restoration achievements to those that assume dramatic changes in habitat quantity or quality. For each scenario, we estimated the amount of habitat quantity and quality that will likely be achieved, and then estimate the likely changes in rearing capacity that will result.

Effects of Geomorphic Process Domains on River Ecosystems: A Comparison of Floodplain and Confined Valley Segments

By: Bellmore JR, Baxter CV

Prepared by: USGS, Idaho State University

Prepared for: River Research and Applications

Funding Source: Shoshone-Barnock Tribes, BPA grant #200205900

KeyWords: process domains flodoplain connectivity primary secondary production stream retention aquatic invertebr

ESUs/ species referenced:

Watershed(s):

Salmon

Abstract/ document summary:

The geomorphic template of streams and rivers exerts strong controls on the structure and function of aquatic ecosystems. However, relationships between stream geomorphology and ecosystem structure and function are not always clear and have not been investigated equally across spatial scales. In montane regions, rivers often alternate between canyon-confined segments and unconfined floodplain segments. Yet, few studies have evaluated how this pattern influences aquatic ecosystems. Here, we compared five confined river segments to five paired floodplain segments in terms of allochthonous inputs, aquatic primary producer and invertebrate production, stream retentive capacity, and aquatic invertebrate community composition.

Spatial complexity reduces interaction strengths in the meta-food web of a river floodplain mosaic

By:	Bellmore JR, Baxter CV, Connolly PJ
2015	
Prepared by:	Idaho State University, USBOR, USGS
Prepared for:	Ecology 96(1) pp.274-283
Funding Source:	Reclamation, NSF-EPSCoR
KeyWords:	aquatic habitat food web interaction strength landscape complexity meta-food web predator prey interact

ESUs/ species referenced:

Upper Columbia River spring Chinook, Upper Columbia River summer steelhead

Watershed(s):

Methow

Abstract/ document summary:

Theory states that both the spatial complexity of landscapes and the strength of interactions between consumers and their resources are important for maintaining biodiversity and the balance of nature. Spatial complexity is hypothesized to promote biodiversity by reducing the potential for competitive exclusion; whereas, models show that weak trophic interactions can enhance stability and maintain biodiversity by dampening destabilizing oscillations associated with strong interactions. Here, we show that spatial complexity can reduce the strength of consumer–resource interactions in natural food webs.

The floodplain food web mosaic: a study of its importance to salmon and steelhead with implications for their recovery

By: Bellmore JR, Baxter CV, Martens K, Connolly PJ

Prepared by: USGS, USBOR, Idaho State University

Prepared for: Ecological Applications 23(1) pp. 189-207

Funding Source: Reclamation, NSF-EPSCoR

KeyWords: ecosystem ecology floodplains food webs salmon secondary production side channels steelhead ESA Moni

ESUs/ species referenced:

Upper Columbia River spring Chinook, Upper Columbia River summer steelhead

Watershed(s):

Methow

Abstract/ document summary:

Although numerous studies have attempted to place species of interest within the context of food webs, such efforts have generally occurred at small scales or disregard potentially important spatial heterogeneity. If food web approaches are to be employed to manage species, studies are needed that evaluate the multiple habitats and associated webs of interactions in which these species participate. Here, we quantify the food webs that sustain rearing salmon and steelhead within a floodplain landscape of the Methow River, Washington, USA, a location where restoration has been proposed to restore side channels in an attempt to recover anadromous fishes. We combined year-long measures of production, food demand, and diet composition for the fish assemblage with estimates of invertebrate prey productivity to quantify food webs within the main channel and five different, intact, side channels; ranging from channels that remained connected to the main channel at low flow to those reduced to floodplain ponds.

The response of stream periphyton to Pacific salmon: using a model to understand the role of environmental context

By:	Bellmore JR, Fremier AK, Mejia F, Newsom M
2014	
Prepared by:	USGS, University of Idaho
Prepared for:	Journal of Freshwater Biology, 59, 1437-1451
Funding Source:	Reclamation
KeyWords:	bioturbation ecological model marine derived nutriets salmon periphyton food web restoration life cycle e

ESUs/ species referenced:

Upper Columbia River spring Chinook, Upper Columbia River steelhead, Upper Columbia River bull trout

Watershed(s):

Methow, Entiat, Okanogan

Abstract/ document summary:

In stream ecosystems, Pacific salmon deliver subsidies of marine-derived nutrients and disturb the stream bed during spawning. The net effect of this nutrient subsidy and physical disturbance on biological communities can be hard to predict and is likely to be mediated by environmental conditions.

For periphyton, empirical studies have revealed that the magnitude and direction of the response to salmon varies from one location to the next. Salmon appear to increase periphyton biomass and/or production in some contexts (a positive response), but decrease them in others (a negative response).

To reconcile these seemingly conflicting results, we constructed a system dynamics model that links periphyton biomass and production to salmon spawning. We used this model to explore how environmental conditions influence the periphyton response to salmon.

Our simulations suggest that the periphyton response to salmon is strongly mediated by both background nutrient concentrations and the proportion of the stream bed suitable for spawning. Positive periphyton responses occurred when both background nutrient concentrations were low (nutrient limiting conditions) and when little of the stream bed was suitable for spawning (because the substratum is too coarse). In contrast, negative responses occurred when nutrient concentrations were higher or a larger proportion of the bed was suitable for spawning.

Although periphyton biomass generally remained above or below background conditions for several months following spawning, periphyton production returned quickly to background values shortly afterwards. As a result, based upon our simulations, salmon did not greatly increase or decrease overall annual periphyton production. This suggests that any increase in production by fish or invertebrates in response to returning salmon is more likely to occur via direct consumption of salmon carcasses and/or eggs, rather than the indirect effects of greater periphyton production.

Overall, our simulations suggest that environmental factors need to be taken into account when considering the effects of spawning salmon on aquatic ecosystems. Our model offers researchers a framework for testing periphyton response to salmon across a range of conditions, which can be used to generate hypotheses, plan field experiments and guide data collection.

Aquatic Trophic Productivity Model: A Decision Support Model for River Restoration Planning in the Methow River, Washington

By: Benjamin JR, Bellmore JR

Prepared by: USGS

Prepared for: Reclamation

Funding Source: Reclamation

KeyWords: ATP model RME BiOp Implementation

ESUs/ species referenced:

Upper Columbia River spring Chinook, Upper Columbia River steelhead, Upper Columbia River bull trout, Coho, Pacific lamprey

Watershed(s):

Methow

Abstract/ document summary:

In this report, we outline the structure of a stream food-web model constructed to explore how alternative river restoration strategies may affect stream fish populations. We have termed this model the “Aquatic Trophic Productivity model” (ATP). We present the model structure, followed by three case study applications of the model to segments of the Methow River watershed in northern Washington. For two case studies (middle Methow River and lower Twisp River floodplain), we ran a series of simulations to explore how food-web dynamics respond to four distinctly different, but applied, strategies in the Methow River watershed: (1) reconnection of floodplain aquatic habitats, (2) riparian vegetation planting, (3) nutrient augmentation (that is, salmon carcass addition), and (4) enhancement of habitat suitability for fish. For the third case study, we conducted simulations to explore the potential fish and food-web response to habitat improvements conducted in 2012 at the Whitefish Island Side Channel, located in the middle Methow River.

Response of ecosystem metabolism to low densities of spawning Chinook Salmon

By:	Benjamin JR, Bellmore JR, Watson GA
2016	
Prepared by:	USGS
Prepared for:	Freshwater Science 35(3)
Funding Source:	Reclamation
KeyWords:	gross primary production ecosystem respiration marine derived nutrients salmon migration ecosystem spa

ESUs/ species referenced:

Upper Columbia River spring Chinook

Watershed(s):

Methow

Abstract/ document summary:

Marine derived nutrients delivered by large runs of returning salmon are thought to subsidize the in situ food resources that support juvenile salmon. In the Pacific Northwest, USA, salmon have declined to <10% of their historical abundance, with subsequent declines of marine derived nutrients once provided by large salmon runs. We explored whether low densities (<0.001 spawners/m2) of naturally spawning Chinook Salmon (Oncorhynchus tshawytscha) can affect ecosystem metabolism. We measured gross primary production (GPP) and ecosystem respiration (ER) continuously before, during, and after salmon spawning. We compared downstream reaches with low densities of spawning salmon to upstream reaches with fewer or no spawners in 3 midsized (4th-order) rivers in northern Washington. In addition, we measured chemical, physical, and biological factors that may be important in controlling rates of GPP and ER.

Potential Effects of Changes in Temperature and Food Resources on Life History Trajectories of Juvenile Oncorhynchus mykiss

By: Benjamin JR, Connolly PJ, Romine JG, Perry RW

Prepared by:	USGS
Prepared for:	Transactions of the American Fisheries Society
Funding Source:	USGS, USFS, USBOR
KeyWords:	trout aquatic habitat water temperature life history strategy climate change bioenergetics reproduction m

ESUs/ species referenced:

Upper Columbia River steelhead

Watershed(s):

Beaver Creek

Abstract/ document summary:

Increasing temperatures and changes in food resources owing to climate changemay alter the growth and migratory behavior of organisms. This is particularly important for salmonid species like Oncorhynchus mykiss, where some individuals remain in freshwater to mature (nonanadromous Rainbow Trout) and others migrate to sea (anadromous Steelhead). Whether one strategy is adopted over the other may depend on the individual's growth and size. In this study, we explored (1) how water temperature in Beaver Creek, a tributary to the Methow River, Washington, may increase under four climate scenarios, (2) how these thermal changes may alter the life history trajectory followed by O. mykiss (i.e., when and if to smolt), and (3) how changes in food quality or quantity might interact with increasing temperatures. We combined bioenergetic and state-dependent life history models parameterized for O. mykiss in Beaver Creek to mimic baseline life history trajectories.

Spatio-temporal variability in movement, age, and growth of mountain whitefish (Prosopium williamsoni) in a river network based upon PIT tagging and otolith chemistry

By:	Benjamin JR, Wetzel LA, Martens KD, Larsen K, Connolly PJ
	2014
Prepared by:	USGS
Prepared for:	Canadian Journal of Fisheries and Aquatic Sciences
Funding Source:	Great Northern Landscape Conservation Cooperative, Northwest Climate Science Center, USBOR
KeyWords:	mountain whitefish habitat migration seasonal middle methow

ESUs/ species referenced:

Watershed(s):

Methow

Abstract/ document summary:

Connectivity of river networks and the movements among habitats can be critical for the life history of many fish species, and understanding of the patterns of movement is central to managing populations, communities, and the landscapes they use. We combined passive integrated transponder tagging over 4 years and strontium isotopes in otoliths to demonstrate that 25% of the mountain whitefish (Prosopium williamsoni) sampled moved between the Methow and Columbia rivers, Washington, USA.

Response of ecosystem metabolism to low densities of spawning Chinook Salmon

By:	Benjamin, Joseph R., Bellmore, J. Ryan, Watson, Grace A.
Prepared by:	
Prepared for:	Freshwater Science 35(3)
Funding Source:	US Bureau of Reclamation
KeyWords:	Gross primary production, ecosystem respiration, marine derived nutrients, Pacific salmon, Columbia River

ESUs/ species referenced:

Watershed(s):

Methow River

Abstract/ document summary:

Marine derived nutrients delivered by large runs of returning salmon are thought to subsidize the in situ food resources that support juvenile salmon. In the Pacific Northwest, USA, salmon have declined to <10% of their historical abundance, with subsequent declines of marine derived nutrients once provided by large salmon runs. We explored whether low densities (<0.001 spawners/m2) of naturally spawning Chinook Salmon (Oncorhynchus tshawytscha) can affect ecosystem metabolism. We measured gross primary production (GPP) and ecosystem respiration (ER) continuously before, during, and after salmon spawning. We compared downstream reaches with low densities of spawning salmon to upstream reaches with fewer or no spawners in 3 midsized (4th-order) rivers in northern Washington. In addition, we measured chemical, physical, and biological factors that may be important in controlling rates of GPP and ER. We observed that low densities of spawning salmon can increase GPP by 46% during spawning, but values quickly return to those observed before spawning. No difference in ER was observed between up- and downstream reaches. Based on our results, salmon density, temperature, and the proximity to salmon redds were the most important factors controlling rates of GPP, whereas temperature was most important for ER. These results suggest that even at low spawning densities, salmon can stimulate basal resources that may propagate up the food web. Understanding how recipient ecosystems respond to low levels of marine derived nutrients may inform nutrient augmentation studies aimed at enhancing fish populations.

Using a Food Web Model to Inform the Design of River Restoration - An Example at the Barkley Bear Segment, Methow River, North-Central Washington

By: Benjamin, Josepth R., Bellmore, J. Ryan, Dombroski, Daniel

2018

Prepared by: U.S. Geological Survey

Prepared for: U.S. Geological Survey, U.S. Bureau of Reclamation

Funding Source: U.S. Bureau of Reclamation, U.S. Geological Survey

KeyWords: Methow River, Chinook Salmon, Steelhead Trout, Food Web Model, River Restoration

ESUs/ species referenced:

Upper Columbia River Spring Chinook Salmon ESU, Upper Columbia River Steelhead Trout DPS

Watershed(s):

Methow River

Abstract/ document summary:

With the decline of Chinook salmon (Oncorhynchus tshawytscha) and steelhead (O. mykiss), habitat restoration actions in freshwater tributaries have been implemented to improve conditions for juveniles. Typically, physical (for example, hydrologic and engineering) based models are used to design restoration alternatives with the assumption that biological responses will be improved with changes to the physical habitat. Biological models rarely are used. Here, we describe simulations of a food web model, the Aquatic Trophic Productivity (ATP) model, to aid in the design of a restoration project in the Methow River, north-central Washington. The ATP model mechanistically links environmental conditions of the stream to the dynamics of river food webs, and can be used to simulate how alternative river restoration designs influence the potential for river reaches to sustain fish production. Four restoration design alternatives were identified that encompassed varying levels of side channel and floodplain reconnection and large wood addition. Our model simulations suggest that design alternatives focused on reconnecting side channels and the adjacent floodplain may provide the greatest increase in fish capacity. These results were robust to a range of discharge and thermal regimes that naturally occur in the Methow River. Our results suggest that biological models, such as the ATP model, can be used during the restoration planning phase to increase the effectiveness of restoration actions. Moreover, the use of multiple modeling efforts, both physical and biological, when evaluating restoration design alternatives provides a better understanding of the potential outcome of restoration actions.

Progress and challenges of testing the effectiveness of stream restoration in the Pacific Northwest using intensively monitored watersheds

By:	Bennett S, Pess G, Bouwes N, Roni P, Bilby R, Gallagher S, Ruzycki J, Buehrens T, Krueger K, Ehinger W, Anderson J, Jorda
Prepared by:	
Prepared for:	Fisheries, Volume 41 Issue 2
Funding Source:	
KeyWords:	IMW, monitoring, treatment, control, restoration, BACI, RME,

ESUs/ species referenced:

Watershed(s):

Alsea, Nestucca, Charley, Asotin, Bridge, Elwha, Etiat, Little Anderson, Big Beef, Seabeck, Stavis, Keogh, Waukwaas, Lemhi, Mill, Abernathy, Germany, Methow, John Day, Potlach, Pudding, Caspar, Noyo, Skagit, Twin, Deep, Tenmile, Cummins, Mill, Wind, Trout

Abstract/ document summary:

Across the Pacific Northwest, at least 17 intensively monitored watershed projects have been implemented to test the effectiveness of a broad range of stream restoration actions for increasing the freshwater production of salmon and steelhead and to better understand fish–habitat relationships. We assess the scope and status of these projects and report on challenges implementing them. We suggest that all intensively monitored watersheds should contain key elements based on sound experimental design concepts and be implemented within an adaptive management framework to maximize learning. The most significant challenges reported by groups were (1) improving coordination between funders, restoration groups, and researchers so that restoration and monitoring actions occur based on the project design and (2) maintaining
consistent funding to conduct annual monitoring and evaluation of data. However, we conclude that despite these challenges, the intensively monitored watershed approach is the most reliable means of assessing the efficacy of watershedscale restoration.

Evaluating watershed response to land management and restoration actions: intensively monitored watersheds (IMW) progress report

By: Bilby R, Ehinger W, Jordan C, Krueger K, McHenry M, Quinn T, Pess G, Poon D, Seiler D, Volkhardt G

2004

Prepared by: IMW Scientific Oversight Committee

Prepared for: Washington Salmon Recovery Funding Board

Funding Source:

KeyWords: IMW, monitoring, RME

ESUs/ species referenced:

Watershed(s):

Abstract/ document summary:

Millions of dollars have been dedicated to the restoration of freshwater habitat since the listing of many populations of salmon in the Pacific Northwest in the 1990s. Little is known about the efficacy of these efforts. The most effective means of determining the contribution of restoration projects to salmon recovery is to implement experimental, watershed-scale evaluations. This document describes a series of intensively monitored watersheds (IMW) being established in Washington expressly to measure the effect of habitat restoration on salmon and trout productivity.

The IMW effort in western Washington is split between three sets of smaller, paired watersheds (complexes) focusing on coho salmon, and steelhead and cutthroat trout and the Skagit River estuary focused on ocean type chinook. The sole eastern Washington IMW is a BPA-funded effort on the Wenatchee River being coordinated by NOAA Fisheries. Restoration and monitoring objectives vary among the IMWs according to current condition, land use, and restoration potential and are described in the document. The basic premise of the IMW project is that the complex relationships controlling salmon response to habitat conditions can best be understood by concentrating monitoring and research efforts at a few locations. We have begun implementing a monitoring framework that includes water quantity, water quality, habitat, summer juvenile fish abundance, and smolt production and are identifying specific restoration actions for the purpose of better understanding how salmon and trout respond to current approaches to restore habitat.

We are developing a landscape classification approach with NOAA Fisheries that will aid in applying the information (regarding fish response to habitat restoration) gained from these IMW complexes to more efficiently directing salmon restoration efforts across the state. We have ranked watersheds statewide according to the potential use as IMWs. Ranking criteria included: the feasibility of obtaining quantitative estimates of smolt production, the record of smolt monitoring, fish species present, and influence of hatchery-produced fish. This list may be used to direct other IMW efforts as needed.

Methow Hydraulics for Trophic Model FY2015 Progress Report

By:	Bountry J, Greimann B
2015	
Prepared by:	Reclamation
Prepared for:	USBOR, USGS
Funding Source:	Reclamation
KeyWords:	ATP model food web hydraulics whitefish island twisp floodplain methow salmon habitat RPA Restoration

ESUs/ species referenced:

Watershed(s):

Methow

Abstract/ document summary:

A collaborative Bureau of Reclamation-U.S. Geological Survey (USGS) team has been brought together to incorporate a conceptual geomorphic-habitat model into a process-based trophic model to understand the processes important to anadromous fish habitat. The Methow River Basin was selected as a test basin for this hybrid geomorphic-habitat/trophic model. Analysis is currently being conducted at two scales: subbasin scale and project scale (~1-2 river miles). Analysis for the subbasin scale has been limited to developing a slope and channel width that may be utilized in the future for a more comprehensive look at habitat availability and opportunities for restoration. Prioritization has been placed on analyzing the potential application of the geomorphic-habitat tool at specific restoration project sites. Two-dimensional (2D) hydraulic modeling is a key input to the trophic model analysis. Currently each project site is analyzed independently of other river locations in both the hydraulic and trophic models such that there are no spatial linkages.

Benefits of Tributary Habitat Improvement in the Columbia River Basin; 2014 Update	
By:	BPA
2014	
Prepared by:	BPA
Prepared for:	NOAA Fisheries
Funding Source:	BPA
KeyWords:	Hatchery Harvest Habitat Hydropower RPA Monitoring Tributary Implementation BiOp Limiting Factor Ret

ESUs/ species referenced:

All 13 Columbia River, Willamette River, and Snake River ESA-listed salmon and trout species

Watershed(s):

Columbia

Abstract/ document summary:

This report summarizes relevant RM&E findings from 2014, updating a report from 2013 that synthesized results up to that point. Results from RM&E programs involving tributary habitat continue to indicate that well-designed habitat improvement projects that address limiting factors promote significant increases in fish survival and abundance. RM&E results also provide information on key limiting factors and population bottlenecks, which assists in the selection of future habitat actions. The 2014 research results, combined with earlier analyses of the survival benefits associated with habitat improvements, indicate a range of relatively rapid survival increases from 20 percent to more than 60 percent at various scales and over various life stages.

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

By:	BPA, Reclamation
Prepared by:	BPA, Reclamation
Prepared for:	NOAA Fisheries
Funding Source:	BPA
KeyWords:	Tributary Habitat Hydropower RPA Implementation BiOp Returns Juvenile Passage Restoration RME Effecti

ESUs/ species referenced:

All 13 Columbia River, Willamette River, and Snake River ESA-listed species of salmon and trout

Watershed(s):

Columbia

Abstract/ document summary:

The RM&E program fulfills important obligations under the Columbia Basin Fish and Wildlife Program, which is primarily focused on habitat improvements to help mitigate for impacts of federal hydroelectric dams. It also is a required component of the NOAA Fisheries Biological Opinion for the Federal Columbia River Power System, not only to track progress under the BiOp but also to adaptively improve the value of habitat work by identifying the types of actions that most effectively meet its goals so that managers can focus resources accordingly.

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

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

Endangered Species Act Federal Columbia River Power System 2010 Progress Report - Section 1

By: BPA, Reclamation, USACE

2011

Prepared by:	BPA, Reclamation, USACE
Prepared for:	NOAA Fisheries
Funding Source:	BPA, Reclamation, USACE
KeyWords:	Hatchery Harvest Habitat Hydropower RPA Monitoring Tributary Implementation BiOp Limiting Factor Ret

ESUs/ species referenced:

All 13 Columbia River, Willamette River, and Snake River ESA-listed salmon and trout species

Watershed(s):

Columbia

Abstract/ document summary:

This report meets the requirements of RPA Action 2 and reports RPA implementation progress during the period January 1, 2010, through December 31, 2010. This annual report is organized into three sections. RPA implementation highlights are presented in Section 1, discussing findings that will inform future RPA implementation. This section also presents information in formats requested by the federal-state-tribal Regional Implementation Oversight Group (RIOG). Section 2 addresses progress on RPA implementation by action. Section 3 lists projects implemented during 2010 and includes habitat metrics completed the same year.

Estimating Cohort Survival through Tributaries for Salmonid Populations with Variable Ages at Migration

By: Buchanan RA, Skalski JR, Mackey G, Snow C, Murdoch AR

Prepared by:

Prepared for: North American Journal of Fisheries Management 35:5

Funding Source: BPA, Chelan County PUD, Douglas County PUD

KeyWords:

ESUs/ species referenced:

Upper Columbia spring Chinook and Upper Columbia Steelhead

Watershed(s):

Chiwawa, Twisp

Abstract/ document summary:

Survival of juvenile anadromous Pacific salmonids from their earliest age of seaward movement (“outmigration”) through the tributaries that connect their rearing grounds to larger-order rivers (“cohort survival”) is an important yet often unmonitored factor in the complex life history of these species. Populations with variable age at out-migration (e.g., steelhead Oncorhynchus mykiss) or multiple juvenile rearing strategies (e.g., Chinook Salmon O. tshawytscha) raise particular challenges in survival monitoring. A multiple-state release–recapture model is presented to estimate cohort survival for salmonid species with variable age at out-migration and demonstrated in two case studies. Annual releases of fish tagged with passive integrated transponder (PIT) tags from the same brood year (cohort) and their detections by instream PIT-tag detection arrays in tributaries and at hydroelectric dams are used to estimate survival through tributaries and the age composition of juvenile migrants reaching downstream sites. The 2010 cohort of Chinook Salmon from the Chiwawa River in Washington State had estimated survival of 0.59 to the middle Wenatchee River array in Tumwater Dam Reservoir (river distance of 30 km) and 0.12 to McNary Dam (364 km) on the Columbia River. The age composition shifted from 60.1% subyearlings at the Wenatchee River array to 100% yearlings at McNary Dam, reflecting the use of the Wenatchee River as a nonnatal rearing area, whereas McNary Dam is in the migratory corridor. The 2010 cohort of steelhead from the Twisp River in Washington State had estimated survival from the yearling stage of 0.30 to Rocky Reach Dam (146 km from the Twisp River mouth) on the Columbia River and 0.17 to McNary Dam (439 km). The low survival to the Columbia River resulted from both mortality and adoption of a resident life history and reflects the diverse population structure in the Twisp River.

Evaluating Tributary Restoration Potential for Pacific Salmon Recovery

By:	Budy P, Schaller H
2007	
Prepared by:	USGS, USFWS
Prepared for:	Ecological Applications 17(4) pp. 1068-1086
Funding Source:	
KeyWords:	Meta Analysis Habitat Tributary Restoration Monitoring Salmon Assessment

ESUs/ species referenced:

Watershed(s):

Abstract/ document summary:

Although habitat restoration can play a key role in the conservation of imperiled species, for animals that demonstrate long migrations and complex life histories, reliance on physical restoration of solated habitat patches comes with considerable uncertainty. Nevertheless, within freshwater ecosystems, stream restoration has become a major conservation focus, with millions of dollars spent annually on efforts aimed at recovering degraded habitat and imperiled riverine species. Within this context, we addressed fundamental uncertainties of the focus on tributary restoration for recovery of salmon: (1) Is there potential for improving habitat in tributaries? (2) What magnitude of early survival improvement can be expected based on stream restoration? and (3) Will incremental increases in early survival be sufficient to ensure viability overall? We combined simple mechanistic habitat models, population viability measures, and categorical filters to quantify ''restoration potential,'' expressed as increased total life-cycle survival in response to restored tributary condition, across 32 populations composing five major population groups (MPG).

Mainstem Methow habitat effectiveness monitoring of stream restoration

By: Connolly P

Prepared by: USGS

Prepared for:

Funding Source:

KeyWords: RME Limiting Factor Treatment Control Restoration Survival

ESUs/ species referenced:

Upper Columbia River spring Chinook, Upper Columbia River steelhead, Upper Columbia River bull trout

Watershed(s):

Methow

Abstract/ document summary:

This report summarizes the background, questions, assumptions, hypotheses, objectives and tasks of the pre- and post-treatment monitoring phases for the mainstem Methow River as it undergoes restoration activities. To measure the effects of restoration efforts on habitat quality and productivity, we will use retention (Harvey 1998) and movement (Winker et al. 1995) data in conjunction with abundance and density data. To assess differential biological performance, we will compare age structure, growth, and age at smolting between those fish that stay in natal areas versus those fish that move. To assess retention in, and movement from or into, the restoration reach, we will use a combination of within reach and out-of-reach sampling. We will use PIT tags, a network of instream PIT tag interrogation systems, and smolt traps to assess differences in biological performance and the magnitude of retention in, and movement from and into, the restoration reach.

Mainstem Methow habitat effectiveness monitoring of stream restoration: Study Plan update for FY2011 and FY2012

By: Connolly P, Martens K

2010

Prepared by: USGS

Prepared for:

Funding Source:

KeyWords:

ESUs/ species referenced:

Middle Columbia River steelhead, Upper Columbia River spring Chinook

Watershed(s):

Methow

Abstract/ document summary:

This document presents updates to the January 2009 Statement of Work. Questions, assumptions, and hypotheses have remained unchanged. No new objectives were added. Some new tasks were added and others revised. This document includes a description of progress for 2009 and 2010 to explain why changes are planned for 2011 and 2012.

Potential gains in anadromous salmonid production from restoration of Beaver Creek (Sandy River Basin, Oregon)

By: Cramer S, Vaughan J, Teply M, Duery S

Prepared by: Cramer Fish Sciences

Prepared for: USACE

Funding Source:

KeyWords: Production, spawning, habitat

ESUs/ species referenced:

Lower Columbia River steelhead, Lower Columbia River fall Chinook, Lower Columbia River coho, Lower Columbia River chum

Watershed(s):

Sandy River

Abstract/ document summary:

This report provides estimates of potential gains in production of salmon and steelhead that could result from aquatic habitat restoration actions in Beaver Creek, a tributary to the lower Sandy River, Oregon. These estimates of potential benefits to fish production will contribute to the feasibility stage of a project being considered by the Portland District U.S. Army Corps of Engineers (Corps). The project is being studied under Section 206 of the Water Resources Development Act in cooperation with the local sponsor, Multnomah County. The Portland District U.S. Army Corps of Engineers (Corps) is responsible for conducting a cost-effectiveness and incremental cost analysis of alternatives, which is integral to selecting the preferred construction alternative. Environmental benefits of this project will be focused on improving fish passage and habitat for anadromous salmonids listed under the Endangered Species Act (ESA), including Chinook salmon, coho salmon, Chum salmon, and steelhead.

Elbow Coulee Floodplain Reconnection and Side Channel Restoration Project: 2008-2009 Monitoring Report

By: Crandall J

2009

Prepared by: Confluence Aquatics

Prepared for:

Funding Source:

KeyWords: Habitat RPA Implementation Monitoring BiOp Tributary Snorkel Juvenile Salmon Restoration BACI RME IM

ESUs/ species referenced:

Upper Columbia River spring Chinook, Upper Columbia River steelhead, Upper Columbia River bull trout, Upper Columbia River Coho, Pacific Lamprey

Watershed(s):

Twisp

Abstract/ document summary:

In September 2008, the Elbow Coulee Floodplain Reconnection and Side Channel Restoration Project was implemented in order to: 1) re-establish a primary side channel to the Twisp River at RM 6.6; 2) increase habitat complexity and large woody debris recruitment potential; and 3) increase habitat for native fish, especially rearing-age salmonids. Specifically, a rock breach was constructed in an existing dike at the upper entrance to the primary side channel . The sill (breach) functions as a grade control structure and permits flow to enter the side channel. The sill was designed to activate the side channel when flows in the Twisp River (based on USGS gauge #12448998 data) reached 200-400 c.f.s., which represents a 1.5 – 2 year flow event (i.e. bankfull flow).

Post-project monitoring of the restored side channel and associated floodplain is necessary to gauge project success at meeting goals and to form the basis of adaptive management. Monitoring will consist of both quantitative and visual examinations of side channel form and function. Specifically, monitoring was conducted to assess the: 1) response of the primary side channel geomorphic configuration to restoration activities designed to create long-term habitat benefits; 2) Response of physical characteristics (primarily discharge and water temperature) and the biological community to habitat restoration and the newly re-established aquatic habitats within the primary side channel; and 3) identify steps needed to adaptively manage the project in order to maximize project success.

Methow Subbasin Monitoring Inventory

By:	Crandall J
Prepared by:	Wild fish conservancy, Methow restoration council
Prepared for:	
Funding Source:	
KeyWords:	monitoring, redds, production, returns, juvenile,

ESUs/ species referenced:

Upper Columbia River spring Chinook, Upper Columbia River summer steelhead, Upper Columbia River bull trout, Upper Columbia River coho

Watershed(s):

Methow

Abstract/ document summary:

This assessment reflects an effort by the Wild Fish Conservancy, working in conjunction with the Methow Restoration Council (MRC), to develop an inventory of current salmonid fish population and aquatic habitat monitoring activities in the Methow Subbasin. We employ this inventory to assess the consistency of monitoring efforts in the Methow with the regional population and habitat monitoring criteria contained in the Monitoring Strategy for the Upper Columbia Basin ('Monitoring Strategy', Hillman, 2006) and the Upper Columbia Spring Chinook Salmon and Steelhead Recovery Plan ('Recovery Plan', UCSRB 2007). Results of this effort, including the identification of monitoring data gaps, will assist the alignment of monitoring in the Methow with other monitoring efforts in Upper Columbia (primarily OBMEP and ISEMP) and provide a basis for the creation of a comprehensive Methow Subbasin Monitoring Plan that can be amended into the Recovery Plan.

An assessment of the current and future thermal regimes of three streams located in the Wenatchee River basin, Washington State: some implications for regional river basin systems

By:	Cristea N, Burges S
2009	
Prepared by:	University of Washington
Prepared for:	
Funding Source:	
KeyWords:	temperature, riparian, shade, climate change

ESUs/ species referenced:

Watershed(s):

Wenatchee, Nason, Icicle

Abstract/ document summary:

We examine summer temperature patterns in the Wenatchee River and two of its major tributaries Icicle and Nason Creeks. Through model simulations we evaluate the cooling effects of mature riparian vegetation corridors along the streams and potential increases due to global warming for the 2020s–2080s time horizons. Site potential shade influences are smaller in the mainstream due to its relatively large size and reduced canopy density in the lower reaches, proving a modest reduction of about 0.3◦C of the stream length average daily maximum temperature, compared with 1.5◦C and 2.8◦C in Icicle and Nason Creeks. Assuming no changes in riparian vegetation shade, stream length-average daily maximum temperature could increase in the Wenatchee River from 1–1.2◦C by the 2020s to 2◦C in the 2040s and 2.5–3.6◦C in the 2080s, reaching 27–30◦C in the warmest reaches. The cooling effects from the site potential riparian vegetation are likely to be offset by the climate change effects in the Wenatchee River by the 2020s. Buffers of mature riparian vegetation along the banks of the tributaries could prevent additional water temperature increases associated with climate change. By the end of the century, assuming site potential shade, the tributaries could have a thermal condition similar to today's condition which has less shade. In the absence of riparian vegetation restoration, at typical summer low flows, stream length average daily mean temperatures could reach about 16.4–17◦C by the 2040s with stream length average daily maxima around 19.5–20.6◦C, values that can impair or eliminate salmonid rearing and spawning. Modeled increases in stream temperature due to global warming are determined primarily by the projected reductions in summer streamflows, and to a lesser extent by the increases in air temperature. The findings emphasize the importance of riparian vegetation restoration along the smaller tributaries, to prevent future temperature increases and preserve aquatic habitat.

Physical and Biological Linkages within a Stream Geomorphic Hierarchy: A Modeling Approach

By: D'Angelo DJ, Gregory SV, Ashkenas LR, Meyer JL

Prepared by:

Prepared for: Journal of the North American Benthological Society, Vol. 16, No. 3, pp. 480-502

Funding Source: NSF grants BSR91-19889, BSR86-46851, DEB90-11663

KeyWords: stream, model, simulation, geomorphology, algae, scouring, production, invertebrates,

ESUs/ species referenced:

Watershed(s):

Mack Creek, Lookout Creek

Abstract/ document summary:

Geology and precipitation interact to determine the geomorphology of a stream basin. We propose that stream geomorphology in turn interacts with sunlight, air temperature, precipitation, and geology to produce a distribution of environmental drivers (incident radiation, discharge, water temperature, nutrients) that is largely responsible for determining the distribution of organisms in streams. GEOMOD, a physically explicit stream ecosystem model, was designed to examine this proposal. The model has a geomorphically based hierarchical structure with basin, reach, and channel-unit levels of resolution. We used GEOMOD: 1) to simulate annual cycles of the biota in 3rd- and 5th-order stream sections at the basin level of resolution and 2) to predict organism distributions at the reach and channel-unit level of resolution. Stream physical structure and the 4 environmental drivers were the only factors that differed among the sites. Data from two 150-m sections of 3rd-order Mack Creek (one in old-growth and the other in clear-cut forest) and from a 1.5-km section of 5th-order Lookout Creek in the Cascade mountains of Oregon were used to parameterize the physical structure and initial standing crops and calibrate the drivers. Uniform parameters were determined by curve-fitting. GEOMOD simulated annual magnitudes and cycles for abiotic (e.g., channel dimensions, fine particulate organic matter) and biotic (e.g., algae, invertebrates, fish) variables in Mack and Lookout creeks. With explicit parameterization of reach and channel-unit sequences, GEOMOD also predicted the distribution of organisms among channel units and reaches. Fish distributions were accurately predicted at the reach scale, while algal-invertebrate interactions and scouring effects became clear only when examined at the channel-unit level. These results demonstrate that organism distributions and interactions in highly structured streams such as those in the Pacific Northwest region of the USA can be effectively simulated with a physically explicit model. Although more complicated to design and parameterize than a uniform physical representation, a physical explicit model can be tailored to represent a wide variety of stream types.

Ecological uses for genetic algorithms: predicting fish distributions in complex physical habitats

By: D'Angelo DJ, Howard LM, Meyer JL, Gregory SV, Ashkenas LR

1995

Prepared by:

Prepared for: Canadian Journal of Fisheries and Aquatic Sciences, 52. pp 1893-1908.

Funding Source: NSF grants BSR91-19889, BSR86-46851 and DEB90-11663

KeyWords: genetic algorithms, stream characteristics, trout, stream habitat, fish distribution

ESUs/ species referenced:

cutthroat trout, rainbow trout

Watershed(s):

Mack Creek, Lookout Creek, McKenzie River

Abstract/ document summary:

Genetic algorithms (GA) are artificial intelligence techniques based on the theory of evolution that through the process of natural selection evolve formulae to solve problems or develop control strategies. We designed a GA to examine relationships between stream physical characteristics and trout distribution data for 3rd-, 5th-, and 7th-order stream sites in the Cascade Mountains, Oregon. Although traditional multivariate statistical techniques can perform this particular task. GAs are not constrained by assumptions of independence and linearity and therefor provide a useful alternative. To help gauge the effectiveness sf the GA, we compared GA results with results from proportional trout distributions and multiple linear regression equations. The GA was a more effective predictor of trout distributions (paired t test, $P < 0.05$) than other methods and also provided new insights into relationships between stream geomorphology and trout distributions. Most importantly, GA equations emphasized the nonindependence of stream channel units by revealing that (9) the factors that influence trout distributions change along a downstream continuum, and (ii j channel unit sequence can be critical. Superior performance of the GA, along with the new information it provided, indicates that genetic algorithms may provide a useful alternative or supportive method to statistical techniques.

Transient storage in Appalachian and Cascade mountain streams as related to hydraulic characteristics

By: D'Angelo DJ, Webster JR, Gregory SV, Meyer JL

Prepared by:

Prepared for: Journal of the North American Benthological Society, Vol. 12, No. 3, pp. 223 - 235

Funding Source: National Science Foundation

KeyWords: solutes, transient storage, transport model, retention, discharge, geomorphology

ESUs/ species referenced:

Watershed(s):

Ball Creek, Coweeta Creek, Lookout Creek

Abstract/ document summary:

Hydraulic characteristicsw ere measured in artificials treams and in lst- to 5th-order streams in the Appalachian and Cascade mountains. Appalachian Mountain stream sites at Coweeta Hydrologic LaboratoryN, orth Carolina,w ere on six lst-order streamsa nd a lst- through 4th-order gradient of Ball Creek-Coweeta Creek. Cascade Mountain sites were located on constrained and unconstrained reaches of Lookout Creek, a 5th-order stream in H. J. Andrews Experimental Forest, Oregon. At each site, a tracer solution (chloride or rhodamine WT) was released for 30-180 min and then discontinued. At the downstream end of the release site, the resulting rise and fall of the tracer concentration was measured. These data, along with upstream concentration and measured widths and depths, were used in a computer model to estimate several hydraulic parameters including transient storage and lateral inflow. Estimated transient storage zone size (A,) ranged from near zero in artificial streams to 2.0 m2 in 5th-order streams. As was largest relative to surface crosssectional area (A) at lst-order sites where it averaged 1.2 x A, compared with 0.6 x A and 0.1 x A in unconstrained and constrained 5th-order sites, respectively. Where measured, lateral discharge inputs per metre of stream length ranged from 1.9% of instream discharge in lst-order streams to 0.05% of instream discharge at 5th-order sites. Our results show that surface water exchange with storage zones is rapid and extensive in steep headwater streams and less extensive but still significant at 3rd- through 5th-order sites. An understanding of relationships between stream morphology, storage zone size, and extent of interactions between surface and subsurface waters will assist comparisons of solute dynamics in physically diverse streams.

Difficulties in Estimating Survival for Adult Chinook Salmon in the Columbia and Snake Rivers

By:	Dauble DD, Mueller RP
	2000
Prepared by:	Pacific Northwest National Laboratory
Prepared for:	Fisheries 25(8) pp. 24-34
Funding Source:	BPA
KeyWords:	salmon hydroelectric survival juvenile returns migration monitoring spawning harvest

ESUs/ species referenced:

Watershed(s):

Snake, Columbia

Abstract/ document summary:

The primary method used to measure temporal movement patterns, quantity, and kinds of Pacific salmon migrating to spawning grounds in the Columbia and Snake rivers is passage counts at mainstem hydroelectric dams (ODFW/WDFW 1998). Adult fish passage has been monitored at each mainstem dam by the U.S. Army Corps of Engineers or by public utility districts since Bonneville Dam as built in 1938. These data provide the historical basis for estimating run size, in-river survival, and escapement to spawning grounds. Thus, adult passage counts are important to fisheries managers for establishing harvest limits for in-river fisheries. The National Marine Fisheries Service and others use these same counts to monitor the status of stocks protected under the Endangered Species Act (ESA; NMFS 1994).

Landscapes to Riverscapes: Bridging the Gap between Research and Conservation of Stream Fishes

By: Fausch KD, Torgersen CE, Baxter CV, Li HW

Prepared by:

Prepared for: BioScience Vol. 52 No. 6

Funding Source: NSF, Colorado Division of Wildlife, USFS, USFWS, TU, NSF/EPA Partnership for Environmental Research, Wa

KeyWords: river processes, landscapes, spatial, temporal scales

ESUs/ species referenced:

Watershed(s):

Abstract/ document summary:

Much of our knowledge of the ecology of rivers and streams is based on observations and experiments on organisms and habitat in the short fragments we can view or quickly traverse on foot, and this limited understanding underpins our efforts at conservation of stream fishes.Here,we argue that this understanding is incomplete, like viewing only disjunct parts of a landscape painting through small holes in a curtain draping it. We propose that a continuous view of rivers is essential for effective research and conservation of their fishes and other aquatic biota—a view not just of disjunct reaches but of the entire spatially heterogeneous scene of the river environment, the riverscape, unfolding through time.

Climate change vulnerability assessment

By:	Gale B, Crandell P, Hanson K, Peterson D, Pasley C, Campton D
	2013
Prepared by:	USFWS
Prepared for:	
Funding Source:	
KeyWords:	hatchery, climate change

ESUs/ species referenced:

Upper Columbia River spring/summer Chinook, Upper Columbia River steelhead, Upper Columbia River coho

Watershed(s):

Methow

Abstract/ document summary:

The impact of future climate change to rearing conditions at Winthrop NFH may be manageable with existing adaptation strategies, but alterations to the timing and quantity of water resources may cause unpredictable conflicts between water users (including the NFH) due to increased competition for Methow River water during low flow periods. Decreases to summer flows coupled with increased air temperatures in the area may increase the demands for water from the Methow River, further impacting water quality and quantity. A more thorough understanding of Winthrop NFH's water rights as well as the amount of water diverted by more senior water users in the Methow River basin is needed to accurately determine the impact of declining summer flows.

An additional critical vulnerability of the hatchery programs at Winthrop NFH is the size, status and health of salmon and steelhead populations in the Methow River. All of the programs at Winthrop NFH are intended to be integrated with the natural origin populations meaning that returning hatchery origin adults are expected to mix and spawn with returning natural origin adults. It is critical that work be conducted to adequately predict, monitor, and evaluate the impact of climate induced changes on native fish populations in the Methow River basin.

Lastly, there are a number of regional uncertainties and information gaps that may affect the vulnerability of Winthrop NFH and Methow River natural populations: the response of indigenous pathogens and the spread of novel pathogens in response to a changing climate, climate induced changes to the migratory corridor and impacts on juvenile and adult migrations, and the impact of a changing climate on conditions in the ocean environment.

Beaver Creek Passage Improvement Study Methow Subbasin

By: Grabowski S

Prepared by:	Reclamation
Prepared for:	Reclamation, BPA
Funding Source:	Reclamation
KeyWords:	fish passage habitat RPA BiOp Implementation IMW Restoration RME BACI Effectiveness Monitoring Tribut

ESUs/ species referenced:

Upper Columbia River steelhead, Upper Columbia River spring Chinook

Watershed(s):

Beaver Creek

Abstract/ document summary:

The Beaver Creek Passage Improvement Study was an interagency and landowner effort initially undertaken in 2002 to replace or modify four barriers to migration (push-up dams or small concrete dams to divert water for irrigation) and replace them with a series of rock vortex weirs (RVWs) that were expected to provide passage for adult and juvenile anadromous salmonids, particularly O. mykiss, while maintaining the ability to divert water for irrigation. Some other projects such as culvert removal and pump and headgate replacement were also implemented; some additional diversion replacement and water acquisition actions also occurred. A major objective of passage improvements on Beaver Creek was to reopen and reconnect historically utilized habitat for anadromous salmonids and assess recolonization of Beaver Creek by anadromous salmonids. Some passage based on seasonal stream flows might have been possible prior to replacement of barriers. Another objective was to evaluate upstream passage of smaller juvenile fish. Some novel aspects of the study included coupling new PIT-tag interrogation technology with genetic markers wherein PIT tags indicate movement of fish in the basin while genetics provides information about the reproductive contribution of individuals and the establishment of successful spawning. The intent of this report was to summarize findings from the body of work on Beaver Creek funded by Reclamation. This paper is meant for a general audience, and individual science papers are cited at the end of the report.

Beaver Creek Watershed Summary

By:	Grette Associates, LLC
2015	
Prepared by:	Grette Associates, LLC
Prepared for:	Trout Unlimited, Washington Water Project
Funding Source:	Trout Unlimited, Washington Water Project
KeyWords:	habitat migration fish passage RPA BiOp tributary returns juvenile salmon trout restoration barrier IMW R

ESUs/ species referenced:

Upper Columbia River steelhead, Upper Columbia River spring Chinook

Watershed(s):

Beaver Creek

Abstract/ document summary:

Due to the wide breadth and scope of salmon-recovery efforts in Beaver Creek, numerous reports and peer-reviewed articles are available which describe conditions in the watershed. As a means of guiding and prioritizing ongoing restoration projects in Beaver Creek, TU has prepared this document to summarize past actions, identify monitoring needs, and make recommendations for additional activities which may improve conditions for ESA-listed salmonids. The scope of this summary pertains to the lower portion of Beaver Creek, from the Marracci diversion at river mile (RM) 6.5 [river km (rkm) 10.54] downstream to the Methow River, and Frazer Creek (Study Area). This portion of the watershed has been identified as an area of concern due to the presence of conditions which limit the ability of the habitat to fully sustain populations of ESA-listed salmonids (USBR 2013a).

Since the early 2000s, sixteen habitat restoration and fish passage projects and an increase of at least 3.834 cfs in late-season flows have improved the potential for the Study Area to support the production of ESA-listed salmonids. Together, these projects have provided a strong foundation for implementing additional actions identified in the Biological Strategy as contributing to the ongoing recovery of those fish. However, due to the substantial disturbance and damage caused by the Carlton Complex fires in 2014, habitat conditions in the Study Area are currently in a dynamic state of flux. The principal post-fire impacts to fish habitat in the Beaver Creek watershed are projected to be fine-sediment transport and deposition, and increased stream temperatures resulting from reductions of riparian habitat (loss of shade). As a result, cooperators in the region should continue to coordinate habitat restoration projects in accordance with guidance provided by the RTT and UCSRB but should also be prepared to address conditions where excessive sedimentation, decreased water quality, and increased water temperatures could negatively impact the Study Area.

Based on the information needs identified above and goals for the recovery of ESA-listed salmonids as defined in the Biological Strategy, Recovery Plan, and 2014 Supplemental Biological Opinion, the following list of habitat protection and restoration actions in Beaver Creek are recommended. To provide consistency with the Biological Strategy, these recommendations are grouped under their respective ecological concerns and (subcategories):

(1) Water quantity (decreased water quantity)
a. Continue working with agricultural landowners along Beaver Creek to increase the overall efficiency of existing irrigation systems in the watershed
b. Continue efforts to secure water transactions (lease agreements/purchases) to maintain late-season flows in the Study Area

(2) Channel structure and form (bed and channel form)

Spring Chinook spawning ground surveys in the Methow River basin in 2005

By:	Humling M, Snow C
Prepared by:	WDFW
Prepared for:	Douglas County PUD
Funding Source:	Douglas County PUD
KeyWords:	hatchery, returns, redd, production, carcass, redd, wild, escapement

ESUs/ species referenced:

Upper Columbia River spring Chinook

Watershed(s):

Methow

Abstract/ document summary:

This report summarizes the spring Chinook spawning ground surveys conducted in the Methow Basin in 2005. Comprehensive surveys were conducted on foot within historical spring Chinook spawning habitat.

Effects of Methow River Side Channel Restoration on Fish Abundance Metrics (Draft)

By: Hutcherson J, Watson G, Sutphin Z

2017

Prepared by: Reclamation Technical Service Center (TSC), MSRF

Prepared for: Reclamation

Funding Source: Reclamation

KeyWords: BACI, restoration, salmon, monitoring, research, evaluation, M2, Middle Methow

ESUs/ species referenced:

Upper Columbia River Spring-Run Chinook, Upper Columbia Steelhead, Coho Salmon (reintroduced)

Watershed(s):

Methow

Abstract/ document summary:

This report provides a summation of methodologies used and a qualitative summary of pre-treatment (2009–12), and year one post-treatment (2015–16) data collection efforts. The completion of additional post-treatment data collection efforts, planned through spring 2018 and resulting in three complete years (summer, fall, and spring sampling periods) pre- and three years post-treatment, will permit a more robust quantitative BACI (before-after-control-impact; Smith 2002) analysis to further evaluate side-channel habitat alterations on native salmonids, providing data to guide future restoration, monitoring and evaluation efforts. Since this is the initial complete year of post-treatment sampling efforts across sampling locations, this report is intended to focus on qualitative comparisons across years, sites, and species.

Upper Methow River Reach Assessment

By:	Inter-fluve, Inc
Prepared by:	Inter-Fluve Inc
Prepared for:	Yakama Nation
Funding Source:	Yakama Nation
KeyWords:	Habitat RPA Implementation BiOp Limiting Factor Treatment Restoration RME LWD Side Channel Alcove B

ESUs/ species referenced:

Upper Columbia River spring Chinook, Upper Columbia River steelhead, Upper Columbia River bull trout, Pacific Lamprey

Watershed(s):

Methow

Abstract/ document summary:

This assessment evaluates aquatic habitat and watershed process conditions in the Upper Methow River and identifies habitat restoration strategies. This reach assessment provides the technical foundation for understanding existing conditions and for identifying restoration strategies for the Upper Methow River. Conditions are assessed at both the valley- and reach-scales. The aim is to identify restoration actions that address significant factors limiting the productivity of native salmonids, and to ensure that these actions fit within the appropriate geomorphic context of the river system. An emphasis is placed on understanding the underlying biological and physical processes at work and how human impacts have affected these processes and the habitat they support. Restoration measures focus on recovering, to the extent possible, these impaired processes. Although the proposed restoration measures are expected to benefit a large suite of native aquatic and terrestrial species, there is a particular emphasis on recovery of Endangered Species Act (ESA) listed salmonids, including spring Chinook salmon (Oncorhynchus tshawytscha), steelhead (Oncorhynchus mykiss), and bull trout (Salvelinus confluentus).

This study builds on considerable data collection and assessment work performed by others as part of past studies, including the Methow Subbasin Geomorphic Assessment (USBR 2008). This Reach Assessment updates and further refines previous data collection and assessment efforts and provides a new comprehensive habitat restoration strategy that identifies restoration targets and recommends specific actions to address habitat and stream process impairments.

Twisp River Stream Habitat Assessment River Mile 0 to 7.8

By: Inter-Fluve, Inc

2010

Prepared by: Inter-Fluve Inc

Prepared for: Yakama Nation

Funding Source: Yakama Nation

KeyWords: Habitat Assessment Limiting Facotr Restoration LWD Side Channel Backwater Alcove Groundwater Ecosyst

ESUs/ species referenced:

Upper Columbia River spring Chinook, Upper Columbia River steelhead, Upper Columbia River bull trout, Upper Columbia River Coho, Pacific lamprey

Watershed(s):

Twisp

Abstract/ document summary:

The objective of the Habitat Assessment is to characterize the habitat quantity and quality for salmonid species native to the Twisp River by quantifying in-channel morphologic features, qualitatively describing riparian conditions, and identifying anthropogenic features influencing aquatic habitat. This information is used to inform potential restoration/preservation actions and will provide a baseline for evaluating future habitat trends and for measuring the effectiveness of restoration efforts.

Spring Chinook salmon, Coho salmon, steelhead trout, rainbow trout, bull trout, and west slope cutthroat trout are native salmonid species to the Twisp River. The lower Twisp River is utilized primarily as a migration corridor for steelhead and spring Chinook salmon, but is also used to some degree for spawning and rearing. Bull trout use the lower Twisp River for migration and rearing (BOR 2008). Spawning, rearing, and adult migration habitat is limited by anthropogenic impacts including road building, land clearing, agriculture, and development. These activities have resulted in channel confinement, bank armoring, channel simplification, and reduced quantities of large woody debris (LWD). The results of this assessment highlight habitat deficiencies by reach that will be useful for establishing objectives and performance targets to guide restoration and preservation activities.

Probability of Streamflow Permanence Model (PROSPER): A spatially continuous model of annual streamflow permanence throughout the Pacific Northwest

By: Jaeger, K.L, Sando, R., McShane, R.R., Dunham, J.B., Hockman-Wert, D.P., Kaiser, K.E., Hafen, K., Risley, J.C., Blasch, K.W.

Prepared by:	
Prepared for:	
Funding Source:	Department of the
KeyWords:	Methow River, Flow Permanence, Intermittent, Ephemeral, Perennial, Non-perennial, Streamflow, Stream

ESUs/ species referenced:

Watershed(s):

Methow River Basin, Boise River Basin, Willow-Whitehorse Creek Basin

Abstract/ document summary:

The U.S. Geological Survey (USGS) has developed the PRObability of Streamflow PERmanence (PROSPER) model, a GIS raster-based empirical model that provides streamflow permanence probabilities (probabilistic predictions) of a stream channel having year-round flow for any unregulated and minimallyimpaired stream channel in the Pacific Northwest region, U.S. The model provides annual predictions for 2004–2016 at a 30-m spatial resolution based on monthly or annually updated values of climatic conditions and static physiographic variables associated with the upstream basin. Predictions correspond to any pixel on the channel network consistent with the medium resolution National Hydrography Dataset channel network stream grid. Total annual precipitation and percent forest cover were consistently the most important predictor variables among global and most subregional models, which had error rates between 17 and 22%. Probabilities were converted to wet and dry streamflow permanence classes with an associated confidence. Wet and dry classifications were used to derive descriptors that characterize the statistical and spatial distribution of streamflow permanence in three focal basins. Predicted dry channel segments account for 52–92% of the stream network across the three focal basins; streamflow permanence decreased during climatically drier years. Predictions are publicly available through the USGS StreamStats platform. Results demonstrate the utility of the PROSPER model as a tool for identifying areas that may be resilient or sensitive to drought conditions, allowing for management efforts that target protecting critical reaches. Importantly, PROSPER's successful predictive performance can be improved with new datasets of streamflow permanence underscoring the importance of field observations.

Stream Restoration Databases and Case Studies: A Guide to Information Resources and Their Utility in Advancing the Science and Practice of Restoration

By: Jenkinson RG, Barnas KA, Braatne JH, Bernhardt ES, Palmer MA, Allan JD

2006

Prepared by: The National River Restoration Science Synthesis, University of Idaho, Northwest Fisheries Science Center,

Prepared for: Restoration Ecology 14(2) pp. 177-186

Funding Source: The National River Restoration Science Synthesis

KeyWords: adaptive management database national river restoration science synthesis stream restoration

ESUs/ species referenced:

Watershed(s):

Abstract/ document summary:

The successful application of adaptive management to the science and practice of restoration ecology requires specific knowledge about the outcomes of past restoration efforts. Ideally, project results would be readily available to scientists or other project managers with similar goals or in analogous ecosystems. Recently, there has been a proliferation of Internet-accessible databases, lists, and case studies of stream and river restoration projects. These resources include a wide range of information that could be accessed to aid natural resource and conservation professionals in restoration. In the U.S. Pacific Northwest, the National Marine Fisheries Service's Northwest Fisheries Science Center and, on a national scale, the National River Restoration Science Synthesis are combining existing national and regional databases, along with the individual project descriptions, to create comprehensive, web-based databases of stream restoration projects. In this process, more data ources were discovered than fit the scope of either of these projects. Ten international, 19 U.S. national, and 42 U.S. regional web-accessible sources of restoration project databases and case studies are listed in this study. However, to easily use information that is currently scattered in multiple files and Web sites, databases would optimally use a common, standardized format. We provide a recommended list of information to be included in restoration databases. These efforts may provide a blueprint for development of compatible international databases of stream restoration projects.

Carlton Complex Fire, State and Private Lands, Burned Area Emergency Response Aquatic Resources Report

By: Johnson J, Molesworth J

Prepared by: Yakama Nation, USBOR

Prepared for:

Funding Source:

KeyWords: Habitat BAER Wildfire Limiting Factor Salmon Fisheries Treatment Restoration ESA Monitoring Tributary

ESUs/ species referenced:

Upper Columbia River spring Chinook salmon, Upper Columbia River steelhead, Upper Columbia River bull trout, Upper Columbia River Coho, Pacific lamprey

Watershed(s):

Methow

Abstract/ document summary:

The Carlton Complex Fire affected three ESA-listed fish stocks in the Methow and Okanogan subbasins as well as several non-listed game fish, non-game fish and forage fish species. This report focuses on the acute fire effects and post-fire long-term effects predicted for the ESA-listed stocks and important recreational game fishes.

Based on field observations completed during this BAER assessment, many of the high and moderate severity burns have a high potential for surface erosion from overland flow that may enter headwater channels causing sediment bulking that can be transported during subsequent high flow events. Potential post-fire effects include: increased water temperature, peak flows and channel scour, surface erosion and fine sediment delivery, and landslides and debris flows. Fire effects to fish and habitat are expected to be the greatest in the next few years and to diminish to pre-fire levels within 7 to 10 years. Some of the effects such as increased large wood inputs, fresh bedload and gravel could positively affect aquatic habitat.

With the exception of Beaver Creek, fish bearing tributaries in the Carlton Complex did not suffer a large percentage of moderate to high burn severity. Sediment from post fire effects will likely affect ESA listed fish migrating through the lower Methow River as a result of sediment delivery from steep non-fishing bearing streams. Delivery of fine sediment from debris flows to the Methow and Okanogan Rivers from the Carlton Complex has already occurred. The greatest impact of this will be to spawning areas in Beaver Creek and the mainstem lower Methow. Additional sediment delivery events within 1-3 years are likely. Roughly 16% of the riparian area along Beaver Creek burned, which will likely increase summer low-flow stream temperatures and diurnal temperature fluctuation.

Burned Area Emergency Response treatments that reduce fine sediment delivery, restore natural drainage patterns, allow for fish passage and large wood movement and or accumulation in fish bearing streams and the river are expected to benefit ESA listed spring Chinook, steelhead and bull trout. Objectives are to:

1. Identify fisheries values at risk
2. Assess how overall changes to soil and watershed function caused by the fire may affect critical fisheries values
3. Recommend non-emergency treatments to reduce the risk to fisheries values
4. Identify possible long term treatments to aid habitat recovery and reduce impacts of future events.

Enumeration of Juvenile Salmonids in the Okanogan Basin Using Rotary Screw Traps

By: Johnson P, Rayton M

2007

Prepared by: LGL Limited environmental research associates, Colville Trives Fish & Wildlife

Prepared for: USDOE, BPA

Funding Source:

KeyWords: Screw trap, smolt, monitoring, juvenile

ESUs/ species referenced:

Upper Columbia summer Chinook, Upper Columbia steelhead, Okanogan River Sockeye

Watershed(s):

Okanogan River

Abstract/ document summary:

The Colville Tribes identified the need for collecting baseline census data on the timing and abundance of juvenile salmonids in the Okanogan River basin for the purpose of documenting local fish populations, augmenting existing fishery data and assessing natural production trends of salmonids. This report documents and assesses the pilot year of rotary trap capture of salmonid smolts on the Okanogan River. The project is a component of the Colville Tribes' Okanogan Basin Monitoring and Evaluation Program (OBMEP) which began in 2004.

Trapping for outmigrating fish began on 14 March 2006 and continued through 11 July 2006. Naturally produced summer steelhead and Chinook and sockeye salmon were targeted for this study. Both 8-ft and 5-ft rotary screw traps were deployed on the Okanogan River from the Highway 20 Bridge and typically fished during evening hours or 24 hours per day, depending upon trap position and discharge conditions.

Mark-recapture experiments were conducted using Chinook fry and hatchery-reared steelhead smolts (sockeye were not used in 2006 because the peak of the juvenile migration occurred prior to the onset of the mark-recapture experiments).

Middle Methow Reach Recreational Use Assessment

By: Jonason C

Prepared by:	Wave Trek Rescue
Prepared for:	Yakama Nation
Funding Source:	Yakama Nation
KeyWords:	RPA Implementation Monitoring BiOp Restoration RME IMW Recreation Habitat Middle Methow

ESUs/ species referenced:

Watershed(s):

Methow

Abstract/ document summary:

Reducing the potential for conflicts between river users and salmon habitat restoration projects is a high priority for salmon recovery implementers in the Upper Columbia Region. In the spring of 2011, the Yakama Nation contracted Wave Trek Rescue, a Washington state-based river rescue training and swift water safety consulting company, to assess recreational river use trends in areas targeted for salmon habitat restoration actions. The intent of this report is to provide information about river recreation use within the Middle Methow Reach of the Methow River. This information will be incorporated into the design and implementation of salmon habitat restoration projects associated with the Middle Methow Habitat Project. Currently, a reach-based restoration effort, known as the Middle Methow Habitat Project, is underway between the Yakama Nation, the United States Bureau of Reclamation (Reclamation), and the Methow Salmon Recovery Foundation to improve habitat conditions for endangered salmonids in the Methow sub-basin. This effort has been in the planning phases since 2009, and restoration actions are planned to be implemented over a two-year work-window starting in the summer of 2012. Activities and installations, such as engineered log jams and the removal of dikes, levees and riprap, could have an impact on the hydraulic conditions the recreating public encounters while interacting with the river. Habitat restoration activities could include, among other things: installing engineered log jams, increasing groundwater and/or surface flows in side channels, removing dikes/levees/riprap, and/or modifying riprap with large woody debris. By understanding recreational use trends on the Middle Methow Reach, habitat project implementers can better reduce conflicts between river users and salmon habitat restoration projects.

Two Decades of River Restoration in California: What Can We Learn?

By:	Kondolf GM, Anderson S, Lave R, Pagano L, Merenlender A, Bernhardt ES
2007	
Prepared by:	National River Restoration Science Synthesis
Prepared for:	Restoration Ecology 15(3) pp.516-523
Funding Source:	
KeyWords:	California case studies database evaluation monitoring National River Restoration Science Synthesis restor

ESUs/ species referenced:

Watershed(s):

Abstract/ document summary:

As part of the National River Restoration Science Synthesis (NRRSS), we developed a summary database of 4,023 stream restoration projects built in California since 1980, from which we randomly selected 44 records for in-depth interviews with project managers. Despite substantial difficulties in gathering the data, we were able to draw conclusions about current design, implementation, monitoring, and evaluation practices used in California projects and compare them with national trends. Although more than half of the projects for which we conducted interviews were located in watersheds for which a management or assessment plan had been prepared, these plans had a limited impact on site selection. We also found that the state lacks a consistent framework for design, monitoring, and reporting restoration projects, and that although monitoring is far more widespread than the information in the NRRSS summary database would suggest, there are still problems with the type, duration, and reporting of monitoring. The general lack of systematic, objective assessment of completed projects hinders the advance of restoration science.

Big Valley Reach Assessment

By: Lyon E Jr., Maguire T

Prepared by: Reclamation

Prepared for:

Funding Source: Reclamation

KeyWords: Habitat Assessment Geomorphic Salmon RPA Implementation BiOp Limiting Factor Restoration RME Ecosy

ESUs/ species referenced:

Upper Columbia River spring Chinook, Upper Columbia River steelhead, Upper Columbia River bull trout

Watershed(s):

Methow

Abstract/ document summary:

The primary objectives of this reach assessment are to identify project areas based on environmental baseline conditions, and develop an overall reach-based implementation and sequencing strategy that informs subsequent monitoring and adaptive management activities. The Big Valley reach assessment was conducted by the Bureau of Reclamation (Reclamation) in the fall 2006 and summer 2007. The reach begins at the Wolf Creek alluvial fan about river mile (RM) 55 and ends near the confluence of Cassal Creek about RM 62. The assessment area covers about 1,400 acres of floodplain and river channels. The species of concern found in the Big Valley reach include Upper Columbia River (UCR) spring and summer Chinook salmon (Oncorhynchus tshawysha), UCR steelhead (Oncorhynchus mykiss), Columbia River Bull Trout (Salvelinus confluentus) (Andonaegui, 2000), and non-native brook trout (Salvelinus fontinalis) that are also found in off-channel areas.

Concurrently with the Big Valley reach assessment a collaborative effort was conducted by Reclamation to develop REIs to document environmental baseline conditions that are utilized for project identification, implementation and monitoring. Based on the analysis performed for this reach assessment, about 50 percent of the reach-based ecosystem indicators are in an adequate condition and 40 percent are in an at risk condition for the Big Valley reach. Only one indicator, water temperature, was found to be in an unacceptable risk condition because it did not meet Washington State Department of Ecology water standards. However, the Big Valley reach is located in a “gaining” section of the Methow River that currently provides a thermally favorable environment for salmonids making it one of the most productive spawning areas in the subbasin. The reach exhibits the ecosystem resilience necessary to maintain its current functionality for salmonids, but is threatened by development within the floodplain. Of the eight project areas identified in the Big Valley reach two of them are protection areas and six are primarily restoration areas.

Population-specific Migration Patterns of Wild Adult Summer-Run Chinook Salmon Passing Wells Dam, Washington

By: Mann, Ryan D., Snow, Charles G.

2018

Prepared by:

Prepared for: North American Journal of Fisheries Management, 38

Funding Source: NOAA Fisheries, Pacific States Marine Fisheries Commission

KeyWords: Upper Columbia, Methow River, Entiat River, Wenatchee River, Okanogan River, Summer Run, Chinook Sal

ESUs/ species referenced:

Upper Columbia Summer/Fall Run Chinook Salmon ESU

Watershed(s):

Methow River

Abstract/ document summary:

Summer-run Chinook Salmon Oncorhynchus tshawytscha migrating over Wells Dam, Washington, enter a habitat characterized by blocked upstream access, high tributary water temperature regimes, and robust tribal and recreational fisheries. In 2011, we initiated a 2-year radiotelemetry study to identify population-specific run timing, movement, and mortality of naturally produced fish passing the dam. Five hundred seventeen salmon were radio-tagged at Wells Dam over 2 years of study. The highest proportion (44%) of tagged fish escaped to the Okanogan River, but spawning populations from the Methow River (16%), Wenatchee River (6%), Entiat River (5%), and the Columbia River upstream (14%) and downstream of Wells Dam (14%) were also represented. In general, tributary-spawning fish had significantly earlier run timing than did main-stem–spawning fish. We observed very little movement among spawning tributaries, but a significant proportion of fish (~30%) were detected holding in the tailrace of Chief Joseph Dam on the Columbia River prior to spawning, including fish from populations many kilometers downstream of Wells Dam. Fallback was common in each year of the study, and we calculated that passage at Wells Dam was overestimated by 27.5% in 2011 and 32.0% in 2012 due to fallback and re-ascension. Of the fish that remained upstream, 16% in 2011 and 22% in 2012 were estimated to have died prior to spawning, excluding fish that were known or suspected to have been harvested. In 2012, warm water temperatures (>20°C) in the Okanogan River resulted in a thermal barrier that delayed migration but did not affect spawning distribution within the river compared with 2011, when no significant thermal barrier was detected. Our results highlight some of the complex migration and distribution patterns of natural-origin Chinook Salmon passing Wells Dam and should assist managers in upstream population and fishery modeling efforts.

Juvenile Anadromous Salmonid Production in Upper Columbia River Side Channels with Different Levels of Hydrological Connection

By: Martens KD, Connolly PJ

Prepared by: USGS

Prepared for: Transactions of the American Fisheries Society 143(3) pp.1-11

Funding Source: Reclamation, USGS

KeyWords: habitat restoration side channel off channel hydrological connectivity floodplain juvenile salmon trout RPA

ESUs/ species referenced:

Upper Columbia River spring Chinook, Upper Columbia River steelhead

Watershed(s):

Methow

Abstract/ document summary:

We examined the contribution of three types of side channels based on their hydrologic connectivity (seasonally disconnected, partially connected, and connected) to production of juvenile anadromous salmonids. Juvenile steelhead and Chinook salmon were found in all three of these side channel types and in each year of the study. Upon connection with the main stem at high flows, the seasonally disconnected side channels experienced an emptying out of the previous year's fish while filling with young-of-year fish during the 2- to 4-month period of hydrologic connection.

Effectiveness of a Redesigned Water Diversion Using Rock Vortex Weirs to Enhance Longitudinal Connectivity for Small Salmonids

By: Martens KD, Connolly PJ

2010

Prepared by: USGS

Prepared for: North American Journal of Fisheries Management 30 pp. 1544-1552

Funding Source: Reclamation

KeyWords: fish passage barrier colonization trout juvenile habitat RPA tributary restoration BACI RME IMW model mo

ESUs/ species referenced:

Upper Columbia River steelhead

Watershed(s):

Beaver Creek

Abstract/ document summary:

For nearly 100 years, water diversions have affected fish passage in Beaver Creek, a tributary of the lower Methow River in north-central Washington State. From 2000 to 2004, four dam-style water diversions were replaced with a series of rock vortex weirs (RVWs). The weirs were designed to allow fish passage while maintaining the ability to divert water into irrigation canals. We observed the new appearance of three species (juvenile Chinook salmon Oncorhynchus tshawytscha, juvenile coho salmon O. kisutch, and mountain whitefish Prosopium williamsoni) upstream of the RVWs, indicating successful restoration of longitudinal connectivity. We used passive integrated transponder (PIT) tags and instream PIT tag interrogation systems during 2004–2007 to evaluate upstream passage of small salmonids (240 mm fork length) through one series of RVWs.

Methow River Studies, Washington - Abundance Estimates from Beaver Creek and the Chewuch River Screw Trap, Methodology Testing in the Whitefish Island Side Channel, and Survival and Detection Estimates from Hatchery Fish Releases, 2013

By:	Martens KD, Fish TM, Watson GA, Connolly PJ
Prepared by:	USGS
Prepared for:	Reclamation
Funding Source:	Reclamation
KeyWords:	habitat hatchery RPA juvenile smolt RME BiOp monitoring restoration control treatment IMW BACI side ch

ESUs/ species referenced:

Upper Columbia River steelhead, Upper Columbia River spring Chinook, Upper Columbia River bull trout

Watershed(s):

Methow, Beaver

Abstract/ document summary:

In this report, we document our field work and analysis completed in 2013. During 2013, USGS sampling efforts were focused on resampling of three reaches in Beaver Creek, testing methodology in the Whitefish Island side channel, conducting hatchery survival estimates, and operating a screw trap on the Chewuch River (funded by Yakama Nation). The Beaver Creek sampling effort was a revisit of three index sites sampled continuously from 2004 to 2007 to look at the fish response to barrier removal. Methodology testing in Whitefish Island side channel was done to determine the best method for evaluating fish populations after restoration efforts in side channels (previous sampling methods were determined to be ineffective after pools were deepened). Hatchery survival estimates were completed to monitor fish survival in the Methow and Columbia Rivers, while the screw trap was operated to estimate migrating fish populations in the Chewuch River and track passive integrated transponder (PIT)-tagged fish. In addition, we maintained a network of PIT-tag interrogation systems (PTIS), assisted Reclamation with fish removal events associated with stream restoration (two people for 9 days; 14 percent of summer field season), and conducted a stream metabolism study designed to help parameterize and calibrate the stream productivity model (Bellmore and others, 2014) with model validation.

Methow and Columbia Rivers Studies, Washington - Summary of Data Collection, Comparison of Database Structure and Habitat Protocols, and Impact of Additional PIT Tag Interrogation Systems to Survival Estimates, 2008-2012

By:	Martens KD, Tibbits WT, Watson GA, Newsom MA, Connolly PJ
2014	
Prepared by:	USGS, Reclamation
Prepared for:	Reclamation
Funding Source:	USGS, Reclamation
KeyWords:	RPA monitoring effectiveness IMW RME BiOp Implementation restoration salmon trout habitat survival

ESUs/ species referenced:

Upper Columbia River spring Chinook, Upper Columbia River steelhead ChaMP model ATP fish passage barrier recolonization

Watershed(s):

Methow

Abstract/ document summary:

This report is comprised of three chapters covering different aspects of the work completed by the USGS. The first chapter is a review of data collection that documents the methods used and summarizes the work done by the USGS from 2008 through 2012. This data summary was designed to show some initial analysis and to disseminate summary information that could potentially be used in ongoing modeling efforts by USGS, Reclamation, and University of Idaho. The second chapter documents the database of fish and habitat data collected by USGS from 2004 through 2012 and compares USGS habitat protocols to the Columbia Habitat Monitoring Program (CHaMP) protocol. The third chapter is a survival analysis of fish moving through Passive Integrated Transponder (PIT) tag interrogation systems in the Methow and Columbia Rivers. It examines the effects of adding PIT tags and/or PIT tag interrogation systems on survival estimates of juvenile steelhead and Chinook salmon.

Linking groundwater-surface water exchange to food production and salmonid growth

By: Mejia F, Baxter C, Berntsen E, Fremier A

Prepared by: University of Idaho, Washington State University, Idaho State University

Prepared for: Canadian Journal of Fisheries and Aquatic Sciences

Funding Source: Reclamation

KeyWords: floodplain hyporheic exchange juvenile post-emergent rearing habitat salmon subsidy temperature vertica

ESUs/ species referenced:

Upper Columbia River spring Chinook

Watershed(s):

Methow

Abstract/ document summary:

Materials, energy, and organisms from groundwater may serve as resource subsidies to lotic ecosystems. These resource subsidies may influence energetic conditions and production of food for rearing fish through nutrient inputs and changes in water temperature. We tested the hypothesis that upwelling flows cause higher growth rates in rearing salmon via an enclosure experiment with post-emergent hatchery Chinook salmon across a gradient of groundwater surface water exchange in the Methow River, Washington. We also measured key food web components, surveyed wild fish and used a bioenergetics model to clarify potential energy pathways.

Stream metabolism increases with drainage area and peaks asynchronously across a stream network

By: Mejia, Francine H., Fremier, Alexander K., Benjamin, Joseph R., Bellmore, J. Ryan, Grimm, Adrianne Z., Watson, Grace A.,

2019

Prepared by:

Prepared for:

Funding Source: US Bureau of Reclamation

KeyWords: Asynchrony, Gross Primary Production, GPP, Ecosystem Respiration, ER, River Networks, Production, Respi

ESUs/ species referenced:

Watershed(s):

Methow River

Abstract/ document summary:

Quantifying the spatial and temporal dynamics of stream metabolism across stream networks is key to understanding carbon cycling and stream food web ecology. To better understand intra-annual temporal patterns of gross primary production (GPP) and ecosystem respiration (ER) and their variability across space, we continuously measured dissolved oxygen and modeled stream metabolism for an entire year at ten sites across a temperate river network in Washington State, USA. We expected GPP and ER to increase with stream size and peak during summer and autumn months due to warmer temperatures and higher light availability. We found that GPP and ER increased with drainage area and that only four sites adhered to our expectations of summer peaks in GPP and autumn peaks in ER while the rest either peaked in winter, spring or remained relatively constant. Our results suggest the spatial arrangement and temporal patterns of discharge, temperature, light and nutrients within watersheds may result in asynchronies in GPP and ER, despite similar regional climatic conditions. These findings shed light on how temporal dynamics of stream metabolism can shift across a river network, which likely influence the dynamics of carbon cycling and stream food webs at larger scales.

Reductions in Instream Wood in Streams near Roads in the Interior Columbia River Basin

By: Meredith C, Roper B, Archer E

Prepared by:

Prepared for: North American Journal of Fisheries Management 34. pp. 493-506

Funding Source: USFS Regions 1, 4, and 6; Oregon–Washington and Idaho BLM

KeyWords: habitat alteration, management, large wood, Columbia River, restoration

ESUs/ species referenced:

Watershed(s):

Columbia

Abstract/ document summary:

Despite the success of recent management efforts to reduce streamside logging, instream wood recovery may be limited by the presence of near-stream roads. We investigated the relationships between the presence of near-stream roads and the frequency and volume of different size-classes of wood in streams in the interior Columbia River basin. We developed models to evaluate the average reduction in instream wood for streams near roads (<30 m or 30–60 m). We compared this with the changes in wood frequency and volume related to changes in environmental conditions such as precipitation, bank-full width, gradient, and forest cover as well as to changes in grazing-related management. In order to extrapolate our findings to the entire study area, we used a GIS approach to determine the distance to roads for randomly selected sites throughout the study area. Sites <30 m from a road had 65 (26%) fewer pieces of total wood, 33 (34%) fewer pieces of coarse wood, 31 (37%) fewer pieces of pool-forming wood, and 37 m3 (42%) less wood volume per kilometer than sites >60 m from a road. We also observed significant reductions at sites 30–60 m from a road, but these were about half those documented for sites <30 m. Changes in environmental conditions and grazing intensity had effects similar to those of being near a road. Based on our GIS analysis, approximately 29% of the sites in the study area are within 60 m of a road, and this percentage is even greater if unroaded catchments are excluded. Our results provide strong evidence that the presence of roads has significantly reduced habitat conditions for salmonids in the interior Columbia River basin and illustrate the need for road removal or relocation projects to increase wood in streams.

Upper Methow Big Valley Recreation and Large Wood Assessment For the Yakama Nation Upper Columbia Habitat Restoration Program

By: MIG, Inc.

2014

Prepared by:	MIG, Inc.
Prepared for:	Yakama Nation
Funding Source:	Yakama Nation
KeyWords:	Habitat Restoration Monitoring LWD Recreation Development Assessment LWD Upper Methow

ESUs/ species referenced:

Upper Columbia River spring Chinook, Upper Columbia River steelhead, Upper Columbia River bull trout, Pacific lamprey

Watershed(s):

Methow

Abstract/ document summary:

In support of the Upper Columbia Habitat Restoration Project, Yakama Nation Fisheries hired MIG, Inc. to conduct a study of boating recreation and existing large wood along a series of rivers in north central Washington. This report presents the findings of the recreation assessment of the Big Valley reach of the upper Methow River. This study area This report presents the findings of the recreation assessment of the Big Valley reach of the upper Methow River. This study area runs from the Wolf Creek confluence with the Methow River, upstream to the Weeman Bridge. The goal of this study is to support the work of the Yakama Nation and other project sponsors as they continue to seek ways to balance the ecological benefits of habitat restoration projects for salmonid species with the safety and recreation experience of river users. This study employed a combination of qualitative and quantitative methods to achieve the following objectives:

1. Characterize existing boating recreation use levels and seasonal timing;
2. Describe the “typical” skill level, preferences and behavior of upper Methow River boaters;
3. Establish a baseline characterization of existing large woody material (LW) with respect to rive navigability during the high-use season;
4. Provide an overview of local search and rescue response capability; and
5. Present boater perspectives on potential river hazards and related river management actions.

2005 Upper Columbia River Summer Chinook Spawning Ground Surveys

By: Miller T

Prepared by: WDFW

Prepared for: HCP Hatchery Committee

Funding Source: WDFW

KeyWords: Hatchery Habitat salmon juvenile redd survey spawning returns monitoring tributary

ESUs/ species referenced:

Upper Columbia River summer Chinook

Watershed(s):

Methow, Okanogan

Abstract/ document summary:

Summer Chinook salmon spawning ground surveys in the Methow and Okanogan river basins began in 1956. Spawning survey methodology has ranged from aerial peak counts to comprehensive total ground counts initiated in 1990. The Washington Department of Fish and Wildlife Supplementation Research Team (SRT) has been conducting spawning ground surveys in tributaries above Wells Dam and in the Chelan River since 1998. The objectives of the surveys were to 1) enumerate the total number of summer Chinook redds in the Okanogan and Methow River Basins; 2) collect biological data (e.g., scales, length, egg retention, location) from wild and hatchery summer Chinook carcasses; and 3) recover CWTs from hatchery carcasses. This report summarizes the data collected during the 2005 calendar year.

Matrix of Life History and Habitat Requirements for Feather River Fish Species

By:	Mills T, Bratovich P, Olson D, Pitts A, Atherstone M, Niggemyer A, O'Connell A, Riggs K, Ellrott B
2004	
Prepared by:	California Department of Water Resources
Prepared for:	Oroville Facilities Relicensing FERC Project No. 2100
Funding Source:	
KeyWords:	Juvenile, adult, habitat, temperature

ESUs/ species referenced:

Chinook Salmon

Watershed(s):

Feather

Abstract/ document summary:

Summarizes habitat requirements and life history of Chinook salmon in spreadsheet form. Spreadsheet elements include adult and juvenile Chinook biological attribtes, life history requirements, feeding habits, migration patterns, holding and spawning patterns, and more.

The Number of Redds Constructed per Female Spring Chinook Salmon in the Wenatchee River Basin

By: Murdoch A, Pearsons TN, Maitland TW

Prepared by: WDFW

Prepared for: North American Journal of Fisheries Management 29 pp. 441-446

Funding Source: BPA, Chelan County Public Utility District

KeyWords: redd monitoring salmon returns PIT tag

ESUs/ species referenced:

Upper Columbia River spring Chinook

Watershed(s):

Wenatchee

Abstract/ document summary:

The number of redds in a watershed is routinely used to monitor the population status of Pacific salmon. One limitation of this approach is that spawning escapement estimates derived from redd counts often assume one redd per female. We tested this assumption on spring-run Chinook salmon in the Wenatchee River watershed, Washington. Female spring Chinook salmon were injected with passive integrated transponder (PIT) tags at Tumwater Dam and were monitored annually on the spawning grounds over a 3-year period.

Developing a broader scientific foundation for river restoration: Columbia River food webs

By:	Naiman RJ, Alldredge JR, Beauchamp DA, Bisson PA, Congleton J, Henny CJ, Huntly N, Lamberson R, Levings C, Merrill EN
2012	
Prepared by:	
Prepared for:	PNAS Perspectives Early Edition, 2012
Funding Source:	
KeyWords:	food webs, aquatic communities, habitat, restoration, salmon

ESUs/ species referenced:

Watershed(s):

Columbia

Abstract/ document summary:

Well-functioning food webs are fundamental for sustaining rivers as ecosystems and maintaining associated aquatic and terrestrial communities. The current emphasis on restoring habitat structure—without explicitly considering food webs—has been less successful than hoped in terms of enhancing the status of targeted species and often overlooks important constraints on ecologically effective restoration. We identify three priority food web-related issues that potentially impede successful river restoration: uncertainty about habitat carrying capacity, proliferation of chemicals and contaminants, and emergence of hybrid food webs containing a mixture of native and invasive species. Additionally, there is the need to place these food web considerations in a broad temporal and spatial framework by understanding the consequences of altered nutrient, organic matter (energy), water, and thermal sources and flows, reconnecting critical habitats and their food webs, and restoring for changing environments. As an illustration, we discuss how the Columbia River Basin, site of one of the largest aquatic/riparian restoration programs in the United States, would benefit from implementing a food web perspective. A food web perspective for the Columbia River would complement ongoing approaches and enhance the ability to meet the vision and legal obligations of the US Endangered Species Act, the Northwest Power Act (Fish and Wildlife Program), and federal treaties with Northwest Indian Tribes while meeting fundamental needs for improved river management.

Annual Report of the Integrated Status and Effectiveness Monitoring Program: Fiscal Year 2007

By: Nelle P, Beasley C, Bouwes N, Jordan C, Rentmeester S, Volk C, Ward B

Prepared by: Terraqua

Prepared for: BPA ISEMP

Funding Source:

KeyWords: Habitat, monitoring, limiting factor

ESUs/ species referenced:

Watershed(s):

Wenatchee River, Entiat River, John Day River, and Salmon River

Abstract/ document summary:

ISEMP has been initiated in three pilot subbasins, the Wenatchee/Entiat, John Day, and Salmon. To balance replicating experimental approaches with the goal of developing monitoring and evaluation tools that apply as broadly as possible across the Pacific Northwest, these subbasins were chosen as representative of a wide range of potential challenges and conditions, e.g., differing fish species composition and life histories, ecoregions, institutional settings, and existing data. The work captured in this report reflects the overall progress of the ISEMP in each of the three pilot project subbasins. Each component of work within ISEMP is reported on individually, and in summary that presents all of the overall project components in their programmatic context and shows how the data and tools developed can be applied to the development of regionally consistent, efficient and effective Research, Monitoring and Evaluation.

Multi-Season Snorkel Surveys and Salmonid Observations in the Upper Columbia Basin

By: O'Neal J, Ventres-Pake R, Gross T, Parr J

2015

Prepared by: Tetra Tech, Natural Systems Design

Prepared for:

Funding Source:

KeyWords: Habitat Effectiveness Monitoring Tributary Returns Snorkel Juvenile Restoration Side Channel Chewuch Sal

ESUs/ species referenced:

Upper Columbia River spring Chinook, Upper Columbia River steelhead, Upper Columbia River bull trout

Watershed(s):

Chewuch, Wenatchee

Abstract/ document summary:

Upper Columbia seasonal snorkel surveys are conducted using the BPA Action Effectiveness Monitoring snorkel protocol1, with modifications needed to address environmental conditions at time of the surveys. When high flow conditions made it unsafe to snorkel the entire reach, snorkelers focused on safe areas where fish presence was expected, including off-channel/backwater areas, holding pools, and areas near large woody debris (LWD) structures. Night snorkeling was used at certain visits due to cold water temperatures. Snorkel surveys should be conducted at night during winter and when temperatures are less than 10^{o}C; below this temperature fish are generally inactive and/or hiding during daylight hours (O'Neal 2007, Thurow 1994). Fish were identified to species and fork lengths were estimated to 10 mm increments. Additionally, channel habitat unit type, flow conditions, and associations with habitat structures were recorded for each fish observation.

An estimate of the wetted area snorkeled was determined through concurrent topographic surveys at monitoring reaches. If there was no concurrent topographic survey, wetted widths were measured at top and bottom of site to determine the wetted area using past topographic data. If no topographic information was available, wetted area was determined by multiplying the reach length by the average wetted width. This allowed for fish density calculations and comparisons between monitoring reaches and survey visits. All fish densities are reported in fish per square meter wetted area. In addition, photos and underwater video footage were taken to show site conditions and record fish activity around installed structures.

River Restoration in the Twenty-First Century: Data and Experimential Knowledge to Inform Future Efforts

By: Palmer M, Allan JD, Meyer J, Bernhardt ES

Prepared by: National River Restoration Science Synthesis

Prepared for: Restoration Ecology 15(3) pp. 472-481

Funding Source:

KeyWords: mitigation monitoring restoration rivers streams habitat salmon

ESUs/ species referenced:

Watershed(s):

Abstract/ document summary:

Despite some highly visible projects that have resulted in environmental benefits, recent efforts to quantify the number and distribution of river restoration projects revealed a paucity of written records documenting restoration outcomes. Improving restoration designs and setting watershed priorities rely on collecting and making accessible this critical information. Information within the unpublished notes of restoration project managers is useful but rarely documents ecological improvements. This special section of Restoration Ecology is devoted to the current state of knowledge on river restoration. We provide an overview of the section's articles, reflecting on lessons learned, which have implications for the implementation, legal, and financing frameworks for restoration. Our reflections are informed by two databases developed under the auspices of the National River Restoration Science Synthesis project and by extensive interactions with those who fund, implement, and permit restoration. Requiring measurable ecological success criteria, comprehensive watershed plans, and tracking of when and where restoration projects are implemented are critical to improving the health of U.S. waters. Documenting that a project was put in the ground and stayed intact cannot be equated with ecological improvements. However, because significant ecological improvements can come with well-designed and -implemented stream and river restorations, a small investment in documenting the factors contributing to success will lead to very large returns in the health of our nation's waterways. Even projects that may appear to be failures initially can be turned into success stories by applying the knowledge gained from monitoring the project in an adaptive restoration approach.

Standards for ecologically successful river restoration

By: Palmer MA, Bernhardt ES, Allan JD, Lake PS, Alexander G, Brooks S, Carr J, Clayton S, Dahm CN, Follstad Shah J, Glat DL,

2005

Prepared by:	National River Restoration Science Synthesis
Prepared for:	Journal of Applied Ecology 42 pp. 208-217
Funding Source:	National River Restoration Science Synthesis
KeyWords:	ecosystem rehabilitation floodplain monitoring restoration assessment stream habitat

ESUs/ species referenced:

Watershed(s):

Abstract/ document summary:

1. Increasingly, river managers are turning from hard engineering solutions to ecologically based restoration activities in order to improve degraded waterways. River restoration projects aim to maintain or increase ecosystem goods and services while protecting downstream and coastal ecosystems. There is growing interest in applying river restoration techniques to solve environmental problems, yet little agreement exists on what constitutes a successful river restoration effort.
2. We propose five criteria for measuring success, with emphasis on an ecological perspective. First, the design of an ecological river restoration project should be based on a specified guiding image of a more dynamic, healthy river that could exist at the site. Secondly, the river's ecological condition must be measurably improved. Thirdly, the river system must be more self-sustaining and resilient to external perturbations so that only minimal follow-up maintenance is needed. Fourthly, during the construction phase, no lasting harm should be inflicted on the ecosystem. Fifthly, both pre- and post-assessment must be completed and data made publicly available.
3. Determining if these five criteria have been met for a particular project requires development of an assessment protocol. We suggest standards of evaluation for each of the five criteria and provide examples of suitable indicators.
4.Synthesis and applications: Billions of dollars are currently spent restoring streams and rivers, yet to date there are no agreed upon standards for what constitutes ecologically beneficial stream and river restoration. We propose five criteria that must be met for a river restoration project to be considered ecologically successful. It is critical that the broad restoration community, including funding agencies, practitioners and citizen restoration groups, adopt criteria for defining and assessing ecological success in restoration. Standards are needed because progress in the science and practice of river restoration has been hampered by the lack of agreed upon criteria for judging ecological success. Without well-accepted criteria that are ultimately supported by funding and implementing agencies, there is little incentive for practitioners to assess and report restoration outcomes. Improving methods and weighing the ecological benefits of various restoration approaches require organized national-level reporting systems.

River restoration, habitat heterogeneity and biodiversity: a failure of theory or practice?

By: Palmer MA, Menninger HL, Bernhardt E

Prepared by:

Prepared for: Freshwater Biology, 55 (Suppl. 1), 205-222

Funding Source: David and Lucille Packard Foundation, EPA Collaborative Network for Sustainability (Award #8832206)

KeyWords: diversity, habitat, heterogeneity, invertebrate, restoration, river, stream

ESUs/ species referenced:

Watershed(s):

Abstract/ document summary:

1. Stream ecosystems are increasingly impacted by multiple stressors that lead to a loss of sensitive species and an overall reduction in diversity. A dominant paradigm in ecological restoration is that increasing habitat heterogeneity (HH) promotes restoration of biodiversity. This paradigm is reflected in stream restoration projects through the common practice of re-configuring channels to add meanders and adding physical structures such as boulders and artificial riffles to restore biodiversity by enhancing structural heterogeneity.
2. To evaluate the validity of this paradigm, we completed an extensive evaluation of published studies that have quantitatively examined the reach-scale response of invertebrate species richness to restoration actions that increased channel complexity ⁄HH. We also evaluated studies that used manipulative or correlative approaches to test for a relationship between physical heterogeneity and invertebrate diversity in streams that were not in need of restoration.
3. We found habitat and macroinvertebrate data for 78 independent stream or river restoration projects described by 18 different author groups in which invertebrate taxa richness data in response to the restoration treatment were available. Most projects were successful in enhancing physical HH; however, only two showed statistically significant increases in biodiversity rendering them more similar to reference reaches or sites.
4. Studies manipulating structural complexity in otherwise healthy streams were generally small in scale and less than half showed a significant positive relationship with invertebrate diversity. Only one-third of the studies that attempted to correlate biodiversity to existing levels of in-stream heterogeneity found a positive relationship.
5. Across all the studies we evaluated, there is no evidence that HH was the primary factor controlling stream invertebrate diversity, particularly in a restoration context. The findings indicate that physical heterogeneity should not be the driving force in selecting restoration approaches for most degraded waterways. Evidence suggests that much more must be done to restore streams impacted by multiple stressors than simply re-configuring channels and enhancing structural complexity with meanders, boulders, wood, or other structures.
6. Thematic implications: as integrators of all activities on the land, streams are sensitive to a host of stressors including impacts from urbanisation, agriculture, deforestation, invasive species, flow regulation, water extractions and mining. The impacts of these individually or in combination typically lead to a decrease in biodiversity because of reduced water quality, biologically unsuitable flow regimes, dispersal barriers, altered inputs of organic matter or sunlight, degraded habitat, etc. Despite the complexity of these stressors, a large number of stream restoration projects focus primarily on physical channel characteristics. We show that this is not a wise investment if ecological recovery is the goal. Managers should critically diagnose the stressors impacting an impaired stream and invest resources first in repairing those problems most likely to limit restoration.

Do Habitat Actions Affect Juvenile Survival? An Information-Theoretic Approach Applied to Endangered Snake River Chinook Salmon

By: Paulsen CM, Fisher TR

2005

Prepared by: Fisher Fisheries, Paulsen Environmental Research

Prepared for: Transactions of the American Fisheries Society 134 pp. 68-85

Funding Source: BPA

KeyWords: Habitat Restoration RME survival juvenile model monitoring

ESUs/ species referenced:

Snake River spring-summer Chinook

Watershed(s):

Snake

Abstract/ document summary:

We used 11 years of parr-to-smolt survival estimates from 33 Snake River sites to demonstrate that despite a number of confounding factors higher numbers of past habitat remediation or enhancement actions are associated with higher parr-to-smolt survival of endangered wild Snake River spring/summer (stream-type) Chinook salmon. Information-theoretic weights were applied to help distinguish between statistical models based on their relative plausibility. In the models with the highest estimated weights, actions taken to improve fish habitat showed a positive association with increased parr-to-smolt survival. However, because the actions were not sited randomly on the landscape, and because the actions may also have influenced other potentially important covariates, it is difficult to separate habitat action effects from effects due to other important factors.

Geomorphology and hydraulic modeling for the middle Methow River from Winthrop to Twisp

By:	Piety L, Bountry J, and Klinger R
Prepared by:	Reclamation
Prepared for:	
Funding Source:	Columbia Snake-Salmon Recovery Office in the Pacific Northwest Region of Reclamation
KeyWords:	Middle Methow, hydraulic model, floodplain

ESUs/ species referenced:

Watershed(s):

Methow

Abstract/ document summary:

Specifically, this report describes the geomorphic and hydraulic characteristics of the Middle Methow (M2) reach of the Methow River between Twisp and Winthrop, Washington. An integrated application of surficial mapping and geochronology in combination with numerical hydraulic modeling was undertaken to better understand the geomorphic processes responsible for the evolution of the river and for the formation and development of salmonid habitat features in the M2 reach. The information contained in this report is intended to be utilized as a technical resource for discussions regarding potential rehabilitation opportunities and in determining possible risks, benefits, and/or general constraints on specific projects or treatments.

Juvenile salmon and steelhead occupancy of stream pools treated and not treated with restoration structures, Entiat River, Washington

By: Polivka K, Steel E, Novak J

2015

Prepared by:

Prepared for:

Funding Source: BPA

KeyWords: habitat, RME, monitoring, restoration, juvenile, snorkel, control, treatment, BACI

ESUs/ species referenced:

Upper Columbia river spring/summer Chinook, Upper Columbia river summer steelhead

Watershed(s):

Entiat

Abstract/ document summary:

We observed habitat occupancy by juvenile Chinook salmon and steelhead trout at in-stream habitat restoration structures constructed in the Entiat River, Washington, USA. In 2009–2013, fish abundance measurements during rearing (July–October) showed high temporal variability in pools with restoration structures. Both species were more abundant at restored pools than at natural pools in early summer (July), but this difference was typically absent by September. Fish response to restoration structures also varied across years. When looking only at restored pools, there were strong seasonal fluxes in parameters describing the effects of temperature, water depth, and current velocity on fish abundance. Significant interaction terms such as current velocity × depth and temperature × current velocity were present for both species, suggesting that these may be important physical attributes improved by restoration.

Through extensive sampling in untreated habitat, both within the treated segment and in nearby control segments, we found that when higher Chinook abundance was observed at restored pools, it was apparently attributable to an increase in habitat capacity and not due to depletion of fish from natural habitat in the same segment. Steelhead habitat selection was too inconsistent for conclusions about capacity, but we did not observe evidence that structures depleted untreated habitat.

Predictive models for differentiating habitat use of coastal cutthroat trout and steelhead at the reach and landscape scale

By: Ptolemy R

Prepared by:	Ministry of Environment, British Columbia
Prepared for:	Providence of British Columbia
Funding Source:	Providence of British Columbia
KeyWords:	habitat

ESUs/ species referenced:

coastal cutthroat trout, steelhead

Watershed(s):

Abstract/ document summary:

Steelhead and coastal cutthroat trout are closely related species that are difficult to differentiate as juveniles and are commonly sympatric at the watershed scale. If cutthroat trout spawning and early rearing occur in small streams, it is often difficult to assess which parts of a stream network are dominated by each species. In this study, catch data from 649 sites in coastal British Columbia were used to develop quantitative models of species presence and relative dominance as a function of stream size. An independent data set of 561 streams from the USA was used for the cross validation of models developed with data from British Columbia. The relative dominance of cutthroat trout or steelhead was predicted using logistic regression with stream and channel width, stream order, watershed area, unit runoff, ecoregion placement, and long-term mean annual discharge (LT mad) as predictor variables. The LT mad was the best predictor of Cutthroat Trout and steelhead dominance, with a correct classification rate of 98% for the entire species range. Costal Cutthroat Trout dominated in reaches or streams where LT mad was ≤630 L/s, and steelhead dominated in reaches where LT mad was >1,000 L/s. The models have practical application for predicting stream-bearing length and area used primarily by each species at the landscape scale of productive capacity relative to habitat threats.

The influence of habitat complexity and fish size on over-winter survival and growth of individually marked juvenile coho salmon (Oncorhynchus kisutch) in Big Beef Creek, Washington

By:	Quinn T, Peterson N
1996	
Prepared by:	
Prepared for:	
Funding Source:	Washington Department of Natural Resources, USFS, BPA, H. Mason Keeler Endowment
KeyWords:	juvenile, habitat, survival, restoration,

ESUs/ species referenced:

coho

Watershed(s):

Big Beef

Abstract/ document summary:

Wild juvenile coho salmon were individually marked in October 1990 and 1991 to evaluate the effects of habitat complexity and fish size on over-winter survival in Big Beef Creek, Washington. Habitat complexity was quantified for the habitat unit where the fish were collected and, in 1991, also for the 500-m reach downstream from the collection site. Survival, estimated from recovery of marked smolts at the stream's mouth, differed between years (25.4 and 46.2%) and also varied among habitat units and reaches within years. Survival was at most weakly correlated with complexity of the habitat units but was strongly correlated with the quantity of woody debris and density of habitat units in the 500-m reach, and distance from the estuary. Because distance covaried with habitat complexity, we could not ascertain which factor had the primary influence on survival. In addition, larger fish generally survived at a higher rate than smaller individuals. However, fish tagged above William Symington Lake were smaller in the fall but larger as smolts and had higher survival rates than those tagged below the lake. Taken together, these results reveal complex relationships between size, habitat, and growth that may affect over-winter survival and subsequent life-history events.

Draft Chewuch River Habitat Assessment

By: Reclamation

Prepared by: Reclamation

Prepared for:

Funding Source: Reclamation

KeyWords: Salmon Assessment Habitat Chewuch Ecosystem LWD Off-channel Side Channel Backwater Alcove Ground

ESUs/ species referenced:

Upper Columbia River spring Chinook, Upper Columbia River steelhead, Upper Columbia River bull trout, Pacific lamprey

Watershed(s):

Chewuch

Abstract/ document summary:

A modified Hankin-Reeves Level II habitat survey (USDA Forest Service Stream Inventory Handbook, 2007, Version 2.7, Pacific Northwest Region) was conducted on a 9.5 mile segment of the Chewuch River located from the mouth to the confluence with Boulder Creek at river mile (RM) 9.5. Almost the entire surveyed river segment is located private land. The objectives of the survey were to characterize current fish habitat conditions, compare survey results with the 2000 survey conducted by Pacific Watershed Institute to determine changes and habitat trends, and to make management recommendations and identify restoration opportunities.

Methow Intensively Monitored Watershed 2012 Annual Report

By:	Reclamation
	2013
Prepared by:	Reclamation
Prepared for:	
Funding Source:	Reclamation
KeyWords:	Habitat RPA Implementation BiOp Monitoring Tributary Treatment Control Restoration BACi RME IMW AT

ESUs/ species referenced:

Upper Columbia River spring Chinook, Upper Columbia River steelhead, Upper Columbia River bull trout

Watershed(s):

Methow

Abstract/ document summary:

Reclamation's Methow Intensively Monitored Watershed (IMW) 2012 Annual Report describes research, monitoring, and evaluation (RME) program goals, methods, and results that apply specifically to tributary habitat improvements in the Methow River basin as related to the 2008/2010 Federal Columbia River Power System Biological Opinion (FCRPS BiOp) (NOAA Fisheries 2008). The 2012 Annual Report, our first report, describes the monitoring philosophy and methodology, summarizes the status of project implementation, and presents details of implementation in Appendices. Progress includes 1) development of a collaborative monitoring and reporting program; 2) substantial development of explanatory models and testing of some major hypotheses concerning environmental controls on fish populations; 3) a first version of a database manager software tool; 4) summaries of fish population status that indicate that current freshwater habitat is probably limiting fish population size; and 5) pre-project monitoring results for four large habitat treatment projects.

2014 List of Tributary Habitat Projects Completed for the 2010 Federal Columbia River Power System Biological Opinion

By: Reclamation

Prepared by: Reclamation

Prepared for: NOAA Fisheries

Funding Source: BPA

KeyWords: Hatchery Harvest Habitat Hydropower RPA Monitoring Tributary Implementation BiOp Limiting Factor Ret

ESUs/ species referenced:

All 13 Columbia River, Willamette River, and Snake River ESA-listed salmon and trout species

Watershed(s):

Columbia

Abstract/ document summary:

Habitat improvement projects in various Columbia River tributaries are one aspect of the RPA. Rehabilitation or improvement of altered stream habitat and formation of new habitat are generally accepted methods that benefit fish populations. Reclamation conducts tributary and reach assessments in the river subbasins specified in the FCRPS BiOp to maximize the success of habitat improvement projects benefiting anadromous species listed under the ESA. These assessments analyze the physical and ecological processes at work in the watershed and define environmental baseline conditions that can complement monitoring activities designed to evaluate the physical and biological responses to the improvement projects.

2013 List of Tributary Habitat Projects Completed for the 2010 Federal Columbia River Power System Biological Opinion

By:	Reclamation
2014	
Prepared by:	Reclamation
Prepared for:	NOAA Fisheries
Funding Source:	BPA
KeyWords:	Hatchery Harvest Habitat Hydropower RPA Monitoring Tributary Implementation BiOp Limiting Factor Ret

ESUs/ species referenced:

All 13 Columbia River, Willamette River, and Snake River ESA-listed salmon and trout species

Watershed(s):

Columbia

Abstract/ document summary:

Habitat improvement projects in various Columbia River tributaries are one aspect of the RPA. Rehabilitation or improvement of altered stream habitat and formation of new habitat are generally accepted methods that benefit fish populations. Reclamation conducts tributary and reach assessments in the river subbasins specified in the FCRPS BiOp to maximize the success of habitat improvement projects benefiting anadromous species listed under the ESA. These assessments analyze the physical and ecological processes at work in the watershed and define environmental baseline conditions that can complement monitoring activities designed to evaluate the physical and biological responses to the improvement projects. Objectives of the projects included, but were not limited to, removal of fish passage barriers; the redesign of irrigation structures to allow fish passage; improvement of instream habitat complexity, floodplain connection, and side-channel fish habitat.

Bureau of Reclamation's 2012 List of Tributary Habitat Projects Completed for the 2010 Federal Columbia River Power System Biological Opinion

By:	Reclamation
Prepared by:	Reclamation
Prepared for:	NOAA Fisheries
Funding Source:	Reclamation, BPA
KeyWords:	Hatchery Harvest Habitat Hydropower RPA Monitoring Tributary Implementation BiOp Limiting Factor Ret

ESUs/ species referenced:

All 13 ESA-listed Species

Watershed(s):

Columbia

Abstract/ document summary:

In 2012, 22 fish habitat improvement projects were completed in the following 9 subbasins of the Columbia River Basin: Lemhi River, Pahsimeroi River, Upper Salmon River, Grande Ronde River, Middle Fork John Day River, Upper John Day River, Entiat River, Methow River, and Wenatchee River.
Objectives of the projects included, but were not limited to, removal of fish passage barriers; the redesign of irrigation structures to allow fish passage; the construction of engineered log jams to create pools and fish cover; and the improvement or construction of side-channel fish habitat.

Bureau of Reclamation's 2011 List of Tributary Habitat Projects Completed for the 2010 Federal Columbia River Power System Biological Opinion

By:	Reclamation
2012	
Prepared by:	Reclamation
Prepared for:	NOAA Fisheries
Funding Source:	Reclamation, BPA
KeyWords:	Hatchery Harvest Habitat Hydropower RPA Monitoring Tributary Implementation BiOp Limiting Factor Ret

ESUs/ species referenced:

Watershed(s):

Columbia

Abstract/ document summary:

In 2011, 31 fish habitat improvement projects were completed in the following 8 subbasins of the Columbia River Basin: Lemhi River, Pahsimeroi River, Upper Salmon River, Middle Fork John Day River, Upper John Day River, Entiat River, Methow River, and Wenatchee River. Objectives of the projects included, but were not limited to, removal of fish passage barriers; the redesign of irrigation structures to allow fish passage; the construction of engineered log jams to create pools and fish cover; and the improvement or construction of side-channel fish habitat. In 2011, work was performed in the Grande Ronde River subbasin, but no projects were completed; consequently, that subbasin is not included in this report.

Bureau of Reclamation's 2010 List of Tributary Habitat Projects Completed for the 2010 Federal Columbia River Power System Biological Opinion

By:	Reclamation
Prepared by:	Reclamation
Prepared for:	NOAA Fisheries
Funding Source:	Reclamation
KeyWords:	Hatchery Harvest Habitat Hydropower RPA Monitoring Tributary Implementation BiOp Limiting Factor Ret

ESUs/ species referenced:

All 13 Columbia River, Willamette River, and Snake River ESA-listed salmon and trout species

Watershed(s):

Columbia

Abstract/ document summary:

Twenty-two fish habitat improvement projects were completed in 2010 in the following eight subbasins of the Columbia River Basin: Upper Salmon River, Pahsimeroi River, Lemhi River, Upper John Day River, Middle Fork John Day River, Entiat River, Methow River, and Wenatchee River. Rehabilitation objectives of the projects included, but were not limited to, removal of fish passage barriers; the redesign of irrigation structures to allow fish passage; the construction of engineered log jams to create pools and fish cover; and the improvement or construction of side channel fish habitat. In 2010, reach assessments were completed for the Forrest and Oxbow Conservation Areas on the Middle Fork John Day River and for the Middle Methow River. Geomorphology and hydraulic modeling for the Middle Methow River from Winthrop to Twisp, Washington was conducted as part of the reach assessment.

Reclamation's 2009 Annual Report of Tributary Habitat Projects Completed for the 2008 Federal Columbia River Power System Biological Opinion

By:	Reclamation
2010	
Prepared by:	Reclamation
Prepared for:	NOAA Fisheries
Funding Source:	Reclamation
KeyWords:	Hatchery Harvest Habitat Hydropower RPA Monitoring Tributary Implementation BiOp Limiting Factor Ret

ESUs/ species referenced:

Watershed(s):

Columbia

Abstract/ document summary:

The Action Agencies contribute to the implementation of salmonid habitat improvement projects in some Columbia River Basin tributaries to help meet commitments contained in the 2008 FCRPS Biological Opinion (BiOp) (NOAA 2008). Reclamation provides technical assistance to States, Tribes, Federal agencies, and other local partners for identification, design, and construction of stream habitat improvement projects that primarily address streamflow, access, entrainment, and channel complexity limiting factors. Project summaries in this report not only include results from Reclamation involvement, but also include results from other partners so that pertinent project details are located in one place. Reclamation’s contributions to habitat improvement are all meant to be within the framework of the RPA or related commitments.

Endangered Species Act Federal Columbia River Power System 2008 Progress Report Summary

By: Reclamation, USACE, BPA

Prepared by:	Reclamation, USACE, BPA
Prepared for:	NOAA Fisheries
Funding Source:	Reclamation, USACE, BPA
KeyWords:	Hatchery Harvest Habitat Hydropower RPA Monitoring Tributary Implementation BiOp Limiting Factor Ret

ESUs/ species referenced:

Watershed(s):

Columbia

Abstract/ document summary:

This report summarizes the significant actions implemented by the Action Agencies in 2008 to protect ESA-listed salmon and steelhead affected by the operation of the Federal Columbia River Power System (FCRPS). It describes the status of RPA actions being implemented across the fish life cycle for that calendar year. The actions described in this annual report are focused on achieving biological performance standards, achieving programmatic performance targets, and addressing factors that limit certain life stages for specific evolutionarily significant units (ESUs) or distinct population segments (DPSs) of salmon and steelhead. Adaptive management is the process the agencies use to make annual adjustments to actions based on new scientific information, to meet biological performance objectives effectively and efficiently.

Endangered Species Act Federal Columbia River Power System 2006-2007 Progress Report

By:	Reclamation, USACE, BPA
2009	
Prepared by:	
Prepared for:	NOAA Fisheries
Funding Source:	Reclamation, USACE, BPA
KeyWords:	Hatchery Harvest Habitat Hydropower RPA Monitoring Tributary Implementation BiOp Limiting Factor Ret

ESUs/ species referenced:

Watershed(s):

Columbia

Abstract/ document summary:

Federal agencies, states, and tribes have made considerable progress in recent years working together to recover Columbia Basin fish. While litigation continued on the 2004 National Marine Fisheries Services' (NOAA Fisheries) Biological Opinion (BiOp) on operation of the Federal Columbia River Power System (FCRPS), regional partners were restoring fish habitat, implementing hatchery reforms, controlling predators, and finding out more about the salmon life cycle and the factors that affect salmon survival. This report highlights some of the actions implemented in 2006 and 2007 by the federal Action Agencies (the U.S. Army Corps of Engineers, the Bureau of Reclamation, and the Bonneville Power Administration) under the 2004 BiOp.

Endangered Species Act Federal Columbia River Power System 2011 Annual Progress Report - Section 1

By:	Reclamation, USACE, BPA
Prepared by:	Reclamation, USACE, BPA
Prepared for:	NOAA Fisheries
Funding Source:	Reclamation, USACE, BPA
KeyWords:	Hatchery Harvest Habitat Hydropower RPA Monitoring Tributary Implementation BiOp Limiting Factor Ret

ESUs/ species referenced:

All 13 Columbia River ESA-listed species

Watershed(s):

Columbia

Abstract/ document summary:

This report is organized into three sections. RPA action implementation highlights are presented in Section 1, which identifies findings that will inform future RPA action implementation. This section also presents information in formats requested by the Federal-State-Tribal Regional Implementation Oversight Group (RIOG). Section 2 provides 2011 accomplishments on RPA implementation by action. Section 3 lists projects implemented during 2011 and includes habitat metrics completed.

Endangered Species Act Federal Columbia River Power System 2014-2018 Implementation Plan

By:	Reclamation, USACE, BPA
2014	
Prepared by:	Reclamation, USACE, BPA
Prepared for:	NOAA Fisheries
Funding Source:	
KeyWords:	Hatchery Harvest Habitat Hydropower RPA Monitoring Tributary Implementation BiOp Limiting Factor Ret

ESUs/ species referenced:

Watershed(s):

Columbia

Abstract/ document summary:

In response to the Court Order, however, the Action Agencies, with NOAA's concurrence, have expanded the Implementation Plan to describe specific actions through 2018 to support NOAA's development of a supplemental BiOp. The purposes of this Implementation Plan include:

1. Determine and document strategies, priorities, actions and timetables.
2. Facilitate and measure agency progress toward performance standards and targets.
3. Facilitate agency management of the program and progress reporting.
4. Provide a flexible framework for adapting actions and achieving results.
5. Provide an opportunity for the Regional Implementation Oversight Group (RIOG) and other stakeholders to review the Action Agencies' plans and actions.

Substantial research and extensive planning stand behind the actions described in this Implementation Plan. The BiOp includes measurable performance standards, targets, and timelines that the Action Agencies will use to track their progress and adjust direction if necessary; all these elements ensure transparency and that BiOp commitments will be met. NOAA may therefore reasonably rely on the benefits of the actions described in this Implementation Plan to conclude the suite of actions avoids the likelihood of jeopardizing listed salmon and steelhead or adversely modifying their designated critical habitat. The following Action Agency commitments further underscore the reliability of the mitigation program:

1. The Action Agencies adopted records of decision to implement the BiOp, and BPA has included funding commitments in its rate case proceedings.
2. Each agency has dedicated extensive staff and other resources to carrying out the BiOp.
3. The Action Agencies have joined states and tribes in signing the Columbia Basin Fish Accords, which ensure funding for the duration of the BiOp and reinforce the common goal of delivering benefits for fish.

Hydrogeomorphic classification of Washington State Rivers to Support Emerging Environmental Flow Management Strategies

By: Reidy Liermann CA, Olden JD, Beechie TJ, Kennard MJ, Skidmore PB, Konrad CP, Imaki H

Prepared by:

Prepared for: River Research and Applications 2011

Funding Source: NOAA Fisheries

KeyWords: natural flow regime, habitat template, hydrologic classification, Columbia River, salmon

ESUs/ species referenced:

Watershed(s):

Columbia River

Abstract/ document summary:

As demand for fresh water increases in tandem with human population growth and a changing climate, the need to understand the ecological tradeoffs of flow regulation gains greater importance. Environmental classification is a first step towards quantifying these tradeoffs by creating the framework necessary for analysing the effects of flow variability on riverine biota. Our study presents a spatially explicit hydrogeomorphic classification of streams and rivers in Washington State, USA and investigates how projected climate change is likely to affect flow regimes in the future. We calculated 99 hydrologic metrics from 15 years of continuous daily discharge data for 64 gauges with negligible upstream impact, which were entered into a Bayesian mixture model to classify flow regimes into seven major classes described by their dominant flow source as follows: groundwater (GW), rainfall (RF), rain-with-snow (RS), snow-and-rain (SandR), snow-with-rain (SR), snowmelt (SM) and ultra-snowmelt (US). The largest class sizes were represented by the transitional RS and SandR classes (14 and 12 gauges, respectively), which are ubiquitous in temperate, mountainous landscapes found in Washington. We used a recursive partitioning algorithm and random forests to predict flow class based on a suite of environmental and climate variables. Overall classification success was 75%, and the model was used to predict normative flow classes at the reach scale for the entire state. Application of future climate change scenarios to the model inputs indicated shifts of varying magnitude from snow-dominated to rain-dominated flow classes. Lastly, a geomorphic classification was developed using a digital elevation model (DEM) and climatic data to assign stream segments as either dominantly able or unable to migrate, which was cross-tabulated with the flow types to produce a 14-tier hydrogeomorphic classification. The hydrogeomorphic classification provides a framework upon which empirical flow alteration–ecological response relationships can subsequently be developed using ecological information collected throughout the region.

Theoretical Life History Responses of Juvenile Onchorhychus mykiss to Changes in Food Availability Using a Dynamic State-Dependent Approach

By:	Romine JG, Benjamin JR, Perry RW, Casal L, Connolly PJ, Sauter SS
	2013
Prepared by:	USGS
Prepared for:	Reclamation
Funding Source:	Reclamation
KeyWords:	trout habitat juveniles life history strategy growth rate model

ESUs/ species referenced:

Upper Columbia River steelhead

Watershed(s):

Beaver Creek

Abstract/ document summary:

Marine subsidies can play an important role in the growth, survival, and migratory behavior of rearing juvenile salmonids. Availability of high-energy, marine-derived food sources during critical decision windows may influence the timing of emigration or the decision to forego emigration completely and remain in the freshwater environment. Increasing growth and growth rate during these decision windows may result in an altered juvenile population structure, which will ultimately affect the adult population age-structure. We used a state dependent model to understand how the juvenile Oncorhynchus mykiss population structure may respond to increased availability of salmon eggs in their diet during critical decision windows.

A review of stream restoration techniques and a hierarchical strategy for prioritizing restoration in Pacific Northwest watersheds

By: Roni P, Beechie T, Bilby R, Leonetti F, Pollock M, Pess G

Prepared by:

Prepared for:

Funding Source:

KeyWords: restoration, LWD, floodplain, riparian

ESUs/ species referenced:

Watershed(s):

Abstract/ document summary:

Millions of dollars are spent annually on watershed restoration and stream habitat improvement in the U.S. Pacific Northwest in an effort to increase fish populations. It is generally accepted that watershed restoration should focus on restoring natural processes that create and maintain habitat rather than manipulating instream habitats. However, most process-based restoration is site-specific, that is, conducted on a short stream reach. To synthesize site-specific techniques into a process-based watershed restoration strategy, we reviewed the effectiveness of various restoration techniques at improving fish habitat and developed a hierarchical strategy for prioritizing them. The hierarchical strategy we present is based on three elements: (1) principles of watershed processes, (2) protecting existing high-quality habitats, and (3) current knowledge of the effectiveness of specific techniques. Initially, efforts should focus on protecting areas with intact processes and high-quality habitat. Following a watershed assessment, we recommend that restoration focus on reconnecting isolated high-quality fish habitats, such as instream or off-channel habitats made inaccessible by culverts or other artificial obstructions. Once the connectivity of habitats within a basin has been restored, efforts should focus on restoring hydrologic, geologic (sediment delivery and routing), and riparian processes through road decommissioning and maintenance, exclusion of livestock, and restoration of riparian areas. Instream habitat enhancement (e.g., additions of wood, boulders, or nutrients) should be employed after restoring natural processes or where short-term improvements in habitat are needed (e.g., habitat for endangered species). Finally, existing research and monitoring is inadequate for all the techniques we reviewed, and additional, comprehensive physical and biological evaluations of most watershed restoration methods are needed.

Wood placement in river restoration: fact, fiction, and future direction

By: Roni P, Beechie T, Pess G, Hanson K

2015

Prepared by:

Prepared for: Canadian Journal of Fisheries and Aquatic Sciences

Funding Source:

KeyWords: LWD, habitat, juveniles, restoration,

ESUs/ species referenced:

Watershed(s):

Abstract/ document summary:

Despite decades of research on wood in rivers, the addition of wood as a river restoration technique remains controversial. We reviewed the literature on natural and placed wood to shed light on areas of continued debate. Research on river ecology demonstrates that large woody debris has always been a natural part of most rivers systems. Although a few studies have reported high structural failure rates (>50%) of placed instream wood structures, most studies have shown relatively low failure rates (<20%) and that placed wood remains stable for several years, though long-term evaluations of placed wood are rare. The vast majority of studies on wood placement have reported improvements in physical habitat (e.g., increased pool frequency, cover, habitat diversity). Studies that have not reported improvements in physical habitat often found that watershed processes (e.g., sediment, hydrology, water quality) had not been addressed. Finally, most evaluations of fish response to wood placement have shown positive responses for salmonids, though few studies have looked at long-term watershed-scale responses or studied a wide range of species.

Global review of the physical and biological effectiveness of stream habitat rehabilitation techniques

By: Roni P, Hanson K, Beechie T

Prepared by:

Prepared for:

Funding Source: NOAA, Inland Water Resources and Aquaculture Service

KeyWords: Riparian, floodplain, habitat, LWD, nutrient, riparian,

ESUs/ species referenced:

Watershed(s):

Abstract/ document summary:

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.

Fish-Habitat Relationships and the Effectiveness of Habitat Restoration

By:	Roni P, Pess GR, Beechie TJ, Hanson KM
	2014
Prepared by:	Northwest Fisheries Science Center NOAA Fisheries
Prepared for:	NOAA Techinical Memorandum NMFS-NWFSC-127
Funding Source:	NOAA Fisheries
KeyWords:	Habitat Fish Salmon Restoration Juvenile Returns Effectiveness RME Monitoring

ESUs/ species referenced:

All 13 ESA-listed Columbia River species

Watershed(s):

Columbia

Abstract/ document summary:

A major underpinning of recovery efforts for Pacific salmon listed under the Endangered Species Act is that there is a strong relationship between freshwater habitat quantity and quality and salmon abundance, survival, and productivity in the freshwater environment. This is a major component of Endangered Species Act recovery plans and biological opinions for salmon and steelhead, including the 2008 Federal Columbia River Power System Biological Opinion (BiOp). With regard to habitat, the 2008 BiOp incorporates an expanded tributary habitat program that requires implementation of habitat improvement actions, including actions to protect and improve mainstem and side channel habitat for fish migration, protect and improve spawning and rearing, and restore floodplain function. Because this is a key underpinning of the 2008 BiOp and other biological opinions, it is important to 1) document our understanding of the relationship between habitat quantity and quality and salmon production, 2) quantify the improvements in salmon production and survival that can be expected with different restoration actions, and 3) use models to help identify habitat factors limiting production and quantify population-level responses to restoration. This technical memorandum provides a synthesis of scientific literature and our current level of knowledge on these three topics.

Action Effectiveness Monitoring of Tributary Habitat Improvement: a Programmatic Approach for the Columbia Basin Fish and Wildlife Program

By: Roni P, Scranton R, O'Neal J

Prepared by: NOAA-NFSC, BPA, Tetra Tech

Prepared for: Independent Scientific Review Panel

Funding Source:

KeyWords: action effectiveness monitoring tributary habitat restoration assessment

ESUs/ species referenced:

Watershed(s):

Columbia

Abstract/ document summary:

In their recent review of research, monitoring, and evaluation projects, both the Northwest Power and Conservation Council (Council) and the Independent Scientific Review Panel (ISRP) recommended that the Bonneville Power Administration (BPA) and its partners develop a consistent, rigorous, and cost-effective approach for evaluation of habitat actions implemented under the Council's Fish and Wildlife Program. In response, the following document outlines a coordinated, programmatic action effectiveness monitoring (AEM) program proposed by BPA to meet this need.

This program is built on past habitat monitoring experience in the region. It is designed to be compatible and integrated with other ongoing monitoring efforts (e.g., SRFB AEM, CHaMP, and ISEMP) and a remains a key component of BPA's Research, Monitoring and Evaluation Framework. Overall, consistent with the Council and ISRP recommendations, the proposed AEM approach should provide more useful, standardized information capable of synthesis without requiring a full monitoring and evaluation effort for each individual habitat project. The proposed program includes three major components:
(1) Improving and streamlining on-going currently funded project level AEM,
(2) developing a programmatic third-party approach for AEM of new actions, and
(3) programmatic approach for AEM of past (completed) actions.

The first component includes standardized project annual reporting, monitoring designs, protocols and metrics, and data standardization and management for on-going AEM that is part of existing BPA funded projects. Component 2 includes a AEM of a subset of each of the most common action categories and sub-categories (barriers, fencing, off-channel/floodplain) using a multiple before-after-impact-control (MBACI) design compatible with that used by the Washington Salmon Recovery Funding Board. Specific case studies may still be needed for a few less common action categories (e.g. beaver enhancement, gravel addition) or actions whose response is best evaluated at a watershed scale (e.g., instream flow, road removal). To learn from the thousands of completed riparian planting, barrier removal, and instream habitat actions completed prior to 2012, an extensive post-treatment design (EPT) – a design that samples paired treatment and controls well after the habitat improvement has been occurred – will be used to evaluate a subset of past actions (component 3). The EPT design has been widely used to evaluate historic restoration actions for other programs and provide quick results on action effectiveness. Sample size estimates, years of monitoring, and monitoring metrics are described for each habitat action category and sub-category for components 2 and 3.

Chapter 11: Rosgen Geomorphic Channel Design

By:	Rosgen, D
	2007
Prepared by:	US Department of Agriculture, National Resources Conservation Service
Prepared for:	Stream Restoration Design National Engineering Handbok
Funding Source:	
KeyWords:	restoration, geomorphic, floodplain, habitat

ESUs/ species referenced:

Watershed(s):

Abstract/ document summary:

This chapter outlines a channel design technique based on the morphological and morphometric qualities of the Rosgen classification system. While this approach is written in a series of steps, it is not a cookbook. This approach is often referred to as the Rosgen design approach. The essence for this design approach is based on measured morphological relations associated with bankfull flow, geomorphic valley type, and geomorphic stream type. This channel design technique involves a combination of hydraulic geometry, analytical calculation, regionalized validated relationships, and analogy in a precise series of steps. While this technique may appear to be straightforward in its application, it actually requires a series of precise measurements and assessments. It is important for the reader to recognize that the successful application of this design approach requires extensive training and experience.

2002 Index Watershed Salmon Recovery Monitoring Report

By: Seiler G, Volkhardt G, Murdoch A, Hawkins S, Fuss H, Ehinger B

Prepared by: WDFW, WDOE

Prepared for: Washington Salmon Recovery Funding Board

Funding Source: Washington Salmon Recovery Funding Board

KeyWords: habitat monitoring watershed salmon stream quality restoration survey ecosystem juvenile RME IMW inve

ESUs/ species referenced:

Watershed(s):

Bingham Creek, Big Beef Creek, Deschutes River, Cedar Creek, Chiwawa River

Abstract/ document summary:

In 1999, the Washington Departments of Fish and Wildlife (WDFW) and Ecology (ECY) developed an approach for index watershed monitoring that involved measuring the production of wild downstream migrating juvenile salmon (smolts), habitat, water quality, stream flow, and macro-invertebrate assemblages in selected watersheds. Broad ranging goals included evaluating factors that influence wild salmon production, human activities and natural processes that modify those factors, and monitoring the effects of restoration activities on salmon production and the aquatic environment. To begin achievement of these goals, monitoring of all components except habitat began in 2000 and 2001 in five index watersheds: Deschutes River and Big Beef Creek in Puget Sound; Bingham Creek on the Washington Coast; and Cedar Creek and Chiwawa River in the Columbia Basin. This report describes the results of monitoring that occurred during the second year of the project; between October 2001 and September 2002. It also describes the results of first year smolt monitoring under the index watershed monitoring program.

Temperature, stream flow, water quality monitoring, and macro-invertebrate sampling occurred in all five index watersheds in 2001/02. Water quality parameters measured included turbidity, total suspended solids, fecal coliform bacteria, ammonia-N, nitrate+nitrite-N, total nitrogen, total phosphorus, and soluble reactive phosphorus (orthophosphate). Hardness and dissolved metals copper and zinc) were analyzed at each site for several months when sampling was initiated, but were discontinued when the concentrations were found to be low. Field measurements included dissolved oxygen, temperature, pH, and conductivity. Many of these measures were folded into a Water Quality Index (WQI). Sampling of benthic macro-invertebrates was conducted each fall.

Lower Chewuch River Fisheries Habitat Survey Final Report

By:	Smith JE, Fisher B, Farmer S
	2000
Prepared by:	The Pacific Watershed Institute
Prepared for:	CI Johnson & Associates, Methow Basin Planning Unit
Funding Source:	CI Johnson & Associates, Methow Basin Planning Unit
KeyWords:	Habitat Assessment Fisheries Limiting Factor Snorkel Restoration Salmon Chewuch

ESUs/ species referenced:

Upper Columba River spring Chinook, Upper Columba River steelhead, Upper Columba River bull trout

Watershed(s):

Chewuch

Abstract/ document summary:

Results and data from the baseline habitat survey on the lower 8.8 miles of the Chewuch River mainstem are presented in this report. Recommendation for management changes and restoration opportunities are included to assist in setting priorities for salmonid conservation and restoration in the Chewuch River. A companion study on adult salmonid migration and spawning conditions was also completed and results from the snorkel survey are incorporated into this report.

Monitoring and Evaluation of the Wells Hatchery and Methow Hatchery Programs 2013 Annual Report

By: Snow C, Frady C, Repp A, Goodman B, Murdoch A

Prepared by: WDFW

Prepared for: Douglas PUD, Grant PUD, Wells HCP Hatchery Committee

Funding Source:

KeyWords: monitoring, hatchery

ESUs/ species referenced:

Upper Columba River spring Chinook, Upper Columbia River summer steelhead

Watershed(s):

Methow

Abstract/ document summary:

The Public Utility District No. 1 of Douglas County (Douglas PUD) funds hatchery programs to compensate for inundation of spawning habitat (Wells Hatchery steelhead and summer Chinook inundation programs) and lost harvest opportunities related to the construction of the Wells Hydroelectric Project and for mortality associated with operation and passage at the Project (Methow Hatchery spring Chinook and Wells Hatchery steelhead No Net Impact [NNI] programs) as part of the Anadromous Fish Agreement and Habitat Conservation Plan (HCP) for the Wells Hydroelectric Project (Wells HCP 2002). Douglas PUD also operates programs on behalf of, and funded by, Grant County PUD (Methow Hatchery Spring Chinook and Wells Hatchery steelhead) to meet mitigation obligations specified in Grant PUD's Priest Rapids Salmon and Steelhead Settlement Agreement (SSSA). The Joint Fishery Parties (JFP) developed specific goals for these hatchery programs, which are described in Monitoring and Evaluation Plans (M&E Plan) for PUD Hatchery Programs (Wells HCP HC 2005; M&E Plan2013). More specifically, these programs are intended to:

1. Support the recovery of ESA-listed species by increasing the abundance of the natural adult population, while ensuring appropriate spatial distribution, genetic stock integrity, and adult spawner productivity (Methow spring Chinook Salmon, Methow summer steelhead, Okanogan summer steelhead).
2. Increase the abundance of the natural adult population of unlisted plan (i.e., HCP) species, while ensuring appropriate spatial distribution, genetic stock integrity, and adult spawner productivity. In addition, provide harvest opportunities in years when spawning escapement is sufficient to support harvest (Methow summer/fall Chinook Salmon).
3. Provide salmon for harvest and increase harvest opportunities, while segregating returning adults from natural tributary spawning populations (Wells summer/fall Chinook salmon).

These programs occur at either Wells Hatchery, located on the west bank of the Columbia River adjacent to Wells Dam (Columbia River km 830), or Methow Hatchery, located on the Methow River (Methow River km 83) upstream of the town of Winthrop, Washington. Hatchery programs at these facilities have been categorized within the M&E Plan under three categories; conservation, safety-net, or harvest-augmentation programs. Conservation programs (Methow and Twisp river spring Chinook; Twisp and Okanogan river steelhead) are integrated hatchery programs intended to increase natural production of targeted fish populations. A fundamental assumption of this strategy is that hatchery fish returning to the spawning grounds are reproductively similar to naturally produced fish. Safety-net programs (Methow and Columbia river steelhead) are an extension of conservation programs, intended to provide a demographic and genetic reserve of hatchery adults in years of low returns.

Monitoring and Evaluation of Wells and Methow Hatchery Programs in 2008

By: Snow C, Frady C, Repp A, Murdoch A, Blankenship SM, Bowman C, Small MP, Von Bargen J, Warheit KI

2009

Prepared by: WDFW

Prepared for: Douglas County PUD, Wells Habitat Conservation Plan Hatchery Committee

Funding Source:

KeyWords: salmon trout monitoring hatchery habitat snorkel juvenile adult PIT tag returns HRR NRR survival RME RPA

ESUs/ species referenced:

Upper Columbia River spring Chinook, Upper Columbia River summer steelhead

Watershed(s):

Methow

Abstract/ document summary:

The Public Utility District No. 1 of Douglas County funds hatchery programs intended by the Joint Fishery Parties (JFP) to supplement natural populations of spring Chinook salmon and summer steelhead, and to produce summer Chinook salmon for harvest augmentation. These hatchery programs collect, rear, and release salmonids in accordance with protocols governing the number, origin, and timing of adult salmon and steelhead collected for broodstock, thereby affecting the subsequent number and genetic composition of the juveniles released. The mean number of smolts produced per each redd is a metric used to compare the relative productivity of target species during freshwater rearing. We used rotary screw traps to estimate the number of spring Chinook salmon and summer steelhead smolts emigrating from the Twisp and Methow River basins.

Spawning ground surveys were performed to determine the relative abundance and distribution of summer steelhead within the Methow River basin.Spawning ground surveys were conducted to evaluate the spawn timing, distribution, genetic composition, and tributary-specific spawning escapement estimates of spring Chinook salmon within the Methow River basin. Oncorhynchus mykiss from the upper Columbia River collected 1995 – 2008 (N=1,894) were analyzed for this study. Thirteen collections of adults were obtained at Wells Hatchery (N=865), six of natural origin (i.e., unmarked), three collections with unspecified origin, two collections of adults that were descendants of two hatchery-origin parents (HxH), and two collections of adults that were descendants with one hatchery-origin parent (HxW). In 2007 and 2008, juvenile O. mykiss were collected from smolt traps (N=772) in the Methow, Twisp, and Okanogan Rivers. Additionally, in 2007 and 2008 juveniles classified as residents were collected (N=257) from the Methow, Twisp, and Chewuch Rivers. All individuals were genotyped using 16 fluorescently end-labeled microsatellite marker loci, and data were collected following standardized nomenclature.

Monitoring and evaluation of Wells and Methow hatchery programs in 2010

By: Snow C, Frady C, Repp A, Murdoch A, Small M, Bell S, Dean C

Prepared by:	WDFW
Prepared for:	Douglas County PUD, Wells Habitat Conservation Plan Hatchery Committee
Funding Source:	
KeyWords:	Hatchery, redd, production, returns, rme, SAR, HRR, NRR, survival , wild, harvest

ESUs/ species referenced:

Upper Columba River spring Chinook, Upper Columbia River summer steelhead

Watershed(s):

Methow

Abstract/ document summary:

The Wells HCP Hatchery Committee (HC) developed and adopted a conceptual monitoring and evaluation plan (M&E Plan) for the hatchery programs that consists of 10 objectives (Wells HCP HC 2007). This report summarizes activities and presents data collected during 2010 required to address the program-specific objectives of the M&E Plan and is consistent with the implementation plan. Hence, annual reports are based on activities conducted during the calendar year or, as necessary, directly related activities from previous years. These activities are reported by subject within each chapter of the report. Analysis of the data and results for each objective in the M&E Plan will be presented in a separate five-year report.

Monitoring and evaluation of Wells and Methow hatchery programs: 2012 annual report

By:	Snow C, Frady C, Repp A, Murdoch A, Small M, Dean C
	2013
Prepared by:	WDFW
Prepared for:	Douglas County Public Utilities District, Wells Habitat Conservation Plan Hatchery Committee
Funding Source:	
KeyWords:	Hatchery, redd, production, returns, rme, SAR, HRR, NRR, survival , wild, harvest

ESUs/ species referenced:

Upper Columba River spring Chinook, Upper Columbia River summer steelhead

Watershed(s):

Methow

Abstract/ document summary:

The Wells HCP Hatchery Committee (HC) developed and adopted a conceptual monitoring and evaluation plan (M&E Plan) for the hatchery programs that consists of 10 objectives (Wells HCP HC 2007). This report summarizes activities and presents data collected during 2012 required to address the program-specific objectives of the M&E Plan and is consistent with the implementation plan proposed by the Supplementation Research Team (SRT) of the Washington Department of Fish and Wildlife (WDFW) and approved by the HCP HC (SRT 2011). Hence, annual reports are based on activities conducted during the calendar year or, as necessary, directly related activities from previous years. These activities are reported by subject within each chapter of the report. Analysis of the data and results for each objective in the M&E Plan will be presented in a separate five-year report.

Endangered Species Act Section7(a)(2) Supplemental Biological Opinion

By:	Stelle W
Prepared by:	NOAA Fisheries
Prepared for:	USACE, BPA, Reclamation
Funding Source:	
KeyWords:	Hatchery Harvest Predator Habitat Hydropower RPA Implementation BiOp

ESUs/ species referenced:

All 13 ESA-listed Columbia River species

Watershed(s):

Columbia

Abstract/ document summary:

This document is based on court-remand order requiring the agency to re-examine the 2008 and 2010 BiOps to include more specific identification of habitat actions planned for the 2014-2018 period of the opinion. Purpose is to identify specific mitigation plans for the life of the BiOP; instead of committing to funding projects, they must identify specific projects. The courts currently retain jurisdiction over the matter to ensure the federal defendants follow through with their obligations. Includes ERTG scoring criteria for estuary projects.

Monitoring of Stream Restoration Habitat on the Main Stem of the Methow River, Washington, During the Pre-Treatment Phase (October 2008-May 2012) with a Progress Report for Activities from March 2011 to November 2011

By: Tibbits WT, Martens KD, Connolly P

2012

Prepared by:	USGS
Prepared for:	Reclamation
Funding Source:	Reclamation, USGS
KeyWords:	habitat RPA implementation BiOp juvenile survival treatment control restoration BACI RME IMW ATP mod

ESUs/ species referenced:

Upper Columbia River spring Chinook, Upper Columbia River steelhead, Upper Columbia River bull trout

Watershed(s):

Methow

Abstract/ document summary:

The intent of the summary of information provided in this report is to fulfill the objectives and tasks submitted in a statement of work to Reclamation in November 2010 (Connolly and Martens, 2011). The study design provides data by which to assess potential fish response to a Reclamation habitat restoration effort focused to improve juvenile salmonid rearing habitat in the M2, which runs between the towns of Winthrop and Twisp, Washington. The pre-treatment phase of the study is designed so that specific questions about the response of target fish species (spring Chinook salmon, steelhead, and bull trout) to the restoration actions can be addressed. Effectiveness is being determined by measuring fish productivity and habitat connectivity of the restoration reach and adjoining reaches, and their tributaries. The study includes sampling efforts directed to understand the relationships between stream habitat and the abundance of various fish species and to assess the response of the fish community. To complement these measurements, we will use models to predict response to treatment, and we will update the model with empirically derived data as these data become available. This modeling effort is expected to inform us of data gaps, sensitivity of key variables, and ability to detect response based on variability of the data.

The approach and actions taken or planned by Reclamation to modify off-channel habitat are largely untested as to their effectiveness to improve target fish species' productivity and survival needs. Those documented strategies that identify both physical parameters and biological relationships and benefits have been identified (Reclamation, 2008). To assess biological performance, we plan to compare age structure, growth, and age at smolting between those fish that stay in natal areas versus those fish that move. To assess retention in, and movement from or into, the restoration reach, we have used a combination of within-reach and out-of-reach sampling. We are using passive integrated transponder (PIT) tags, a network of instream PIT tag interrogation systems, and smolt traps to assess differences in biological performance and the magnitude of retention in, and movement from and into, the restoration reach.

Endangered Species Act Federal Columbia River Power System 2014 Annual Progress Report - Section 1

By:	USACE, Reclamation, BPA
Prepared by:	USACE, Reclamation, BPA
Prepared for:	NOAA Fisheries
Funding Source:	BPA
KeyWords:	Hatchery Harvest Habitat Hydropower RPA Monitoring Tributary Implementation BiOp Limiting Factor Ret

ESUs/ species referenced:

All 13 ESA-listed Columbia River species

Watershed(s):

Columbia

Abstract/ document summary:

This report summarizes the actions implemented by the Action Agencies in 2014 to protect ESA-listed salmon and steelhead affected by the operation of the FCRPS. These include actions to implement improvements at dams to increase fish survival, protect and enhance important habitats, improve hatchery and harvest practices, manage and reduce predation, and enhance river conditions for migrating fish. The actions are focused on achieving biological performance standards, achieving programmatic performance targets, and addressing limiting factors for listed salmon and steelhead. The Action Agencies, in coordination with NOAA Fisheries, and as provided for in the 2008 FCRPS BiOp RPA, use adaptive management to improve action effectiveness and efficiency based upon current scientific information. This report describes implementation progress by the Action Agencies during the period of January 1 through December 31, 2014.

This report is organized into three sections: Implementation highlights and accomplishments are presented in Section 1; these will inform future RPA action implementation. Section 2 provides 2014 accomplishments on RPA implementation by action, and Section 3 displays projects implemented in 2014. This FCRPS 2014 Annual Progress Report, which includes the Detailed Description of RPA Action Implementation (Section 2) and Project Tables for RPA Action Implementation (Section 3), is available online. Previous FCRPS annual progress reports and additional information on other salmon and steelhead protection efforts are also available at this website.

Entiat effectiveness monitoring study: monitoring the effectiveness of habitat restoration actions in the lower Entiat River

By: Ward M

2005

Prepared by: Terraqua Inc, Upper Columbia Salmon Recovery Board Regional Technical Team

Prepared for:

Funding Source:

KeyWords: monitoring, control, treatment, restoration, BACI

ESUs/ species referenced:

Watershed(s):

Entiat

Abstract/ document summary:

Bridge-to-Bridge Habitat Restoration Project in the lower Entiat River affects (a) fish habitat, (b) fish habitat utilization, and (c) the productivity of salmonid fishes in the Entiat Subbasin, and will test aspects of the Monitoring Strategy for the Upper Columbia Basin (Hillman 2004) that pertain to effectiveness monitoring. Surveys of fish habitat and fish habitat utilization supported by this Study will be synthesized with separately-funded, yet compatible, agency monitoring programs to include all of the indicators specified for study in Hillman (2004). Coordination with landowners and the local Watershed Planning Unit are built into this Study design.

Ideally, the study will be implemented over a 10 year period. This duration is dependent upon funding. To start, a minimum of five years participation has been solicited from willing private landowners. An extended monitoring time frame is necessary to account for at least two salmonid generations (4-5 years per generation), to capture pre and post-restoration project conditions, interannual variability, long-term channel adjustments resulting from the restoration project, and possible changes to restoration project features that might arise from periodic factors like large runoff events.

Upper Columbia Regional Technical Team 2010 Analysis Workshop Synthesis Report

By: Ward M, Morgan J, Baldwin C

Prepared by: Upper Columbia Regional Technical Team, Terraqua

Prepared for: Upper Columbia Salmon Recovery Board

Funding Source:

KeyWords: restoration, habitat, juveniles, monitoring, RME

ESUs/ species referenced:

Upper Columbia River spring Chinook Salmon, Upper Columbia River summer steelhead

Watershed(s):

Abstract/ document summary:

This document summarizes the workshop held by the RTT. It covers status of VSP for each ESA, implementation, limiting factors and threats, habitat status and trends, habitat action effectiveness, and data gaps/ research needs.

Post Fire and Flood Fish Assessment in Beaver Creek

By: Watson G, Crandall J

2014

Prepared by: MSRF

Prepared for:

Funding Source:

KeyWords:

ESUs/ species referenced:

Upper Columbia River spring Chinook, Upper Columbia River steelhead

Watershed(s):

Beaver Creek

Abstract/ document summary:

Several natural events during the summer 2014 impacted the stream habitat and water quality in the Beaver Creek watershed. On 17 July 2014, the Cougar Flats Fire (a component of the larger Carlton Complex wildfire) burned through much of the lower ten miles of the Beaver Creek watershed. Fire intensity within the area was mostly low to moderate, but the fires burned through a significant portion of the riparian forest in this reach. The adjacent uplands, primarily shrub-steppe habitat, also burned extensively in this area.

A rain event on 14 August significantly increased stream discharge and inputs of ash and fine sediment into Beaver Creek. During this event, stream discharge rose significantly over a period of several hours. Water quality was altered from ash and sediment inputs that turned Beaver Creek into a black, frothy torrent with turbidity exceeding 1000 NTU (J. Johnson, Yakama Nation, personal observation).

A thunderstorm on 21-22 August resulted in localized heavy rains and substantial surface erosion, gully formation, debris flows, and sediment deposits in the Beaver Creek watershed. Frazer Creek, a major tributary to lower Beaver Creek, experienced especially significant levels of erosion and sediment transport during this event. Observations in fire affected portions of Beaver Creek after the fire revealed fish presence as well as limited fire induced fish mortality (J. Molesworth (USRB) and J. Crandall (MSRF), personal observation). No living fish were observed in cursory observations after the August floods and ash/debris flows of 14 and 22 August.

The degree of impact of the fires and floods of 2014 on the fish population in Beaver Creek was assumed to be significant, but quantitative data were lacking to support this assumption. To evaluate the fish response to fire and flood events in Beaver Creek, the Methow Salmon Recovery Foundation (MSRF) collected fish abundance data from a 500 meter reach of Beaver Creek in November 2014. These data were compared to annual fish abundance data collected by the U.S. Geological Survey (Martens et al. 2014) in the same 500 meter reach of Beaver Creek from 2004-2013.

Colonization of steelhead (Oncorhynchus mykiss) After Barrier Removal in a Tributary to the Methow River, Washington

By: Weigel DE

Prepared by: University of Idaho

Prepared for:

Funding Source: Reclamation

KeyWords: trout colonization fish passage barrier habitat RPA juvenile return restoration RME IMW monitoring tribut

ESUs/ species referenced:

Upper Columbia River steelhead

Watershed(s):

Beaver Creek

Abstract/ document summary:

Connectivity is important to the long-term persistence of populations allowing individuals to access essential habitats, and provide demographic support and genetic exchange among local populations. This exchange of individuals among populations increases genetic variation and the evolutionary potential of the species. Barriers to migration create fragmentation and isolation which interrupts these processes. This study explores the effects of small irrigation diversion dams on the migration of steelhead (Oncorhynchus mykiss) in tributaries to the Methow River, and the subsequent colonization of the anadromous life history after re-designing these diversions to allow passage. Passive integrated transponder tags were used with microsatellite markers to identify life history, source of colonizers and successful reproduction. Migratory O. mykiss successfully colonized Beaver Creek and offspring from the first two brood years successfully returned to the stream as adults. Inter-breeding between the fluvial and anadromous life history types was common and offspring from the fluvial parents returned to the basin as adult steelhead. Hatchery O. mykiss did not contribute to the first two brood years during this early colonization process despite high abundances in adult returns. Population genetic diversity and the percent hatchery admixture were significantly different at the lowest two monitoring sites in the stream after barrier treatment. Colonization was still progressing upstream one generation after barrier treatment (4-5 years). Migration estimates prior to treatment of the diversion dams indicated that there was no migration for at least a generation in Beaver Creek. Comparisons with migration to no migration sites in reference streams (Libby and Gold creeks) found significant differences in distance, number of obstructions, obstruction height to depth ratio and stream gradient. However, when examining Beaver Creek in comparison to sites with migration in the reference streams, only the number of obstructions was significantly different. Diversion dams on Beaver Creek were preventing migration and the treatment of these barriers resulted in the re-colonization of the migratory life histories. The fluvial life history was important in the colonization process and acts as a genetic reserve for the wild genotypes.

Colonization of Steelhead in a Natal Stream after Barrier Removal

By: Weigel DE, Connolly PJ, Martens KD, Powell MS

2013

Prepared by: Reclamation, USGS, University of Idaho

Prepared for: Transactions of the American Fisheries Society 142(4) pp. 920-930

Funding Source: Reclamation

KeyWords: habitat colonization trout salmon restoration fish passage barrier juvenile migration monitoring tributary R

ESUs/ species referenced:

Upper Columia River steelhead

Watershed(s):

Beaver Creek

Abstract/ document summary:

Colonization of vacant habitats is an important process for supporting the long-term persistence of populations and species. We used a before–after experimental design to follow the process of colonization by steelhead Oncorhynchus mykiss (anadromous rainbow trout) at six monitoring sites in a natal stream, Beaver Creek, after the modification or removal of numerous stream passage barriers. Juvenile O. mykiss were collected at monitoring sites by using a backpack electrofisher. Passive integrated transponder tags and instream tag reading stations were used in combination with 16 microsatellitemarkers to determine the source, extent, and success ofmigrant O. mykiss after implementation of the barrier removal projects.

Fluvial rainbow trout contribute to the colonization of steelhead (Oncorhynchus mykiss) in a small stream

By: Weigel DE, Connolly PJ, Powell MS

Prepared by:	USGS, USBOR, University of Idaho
Prepared for:	Environmental Biology of Fishes
Funding Source:	Reclamation
KeyWords:	colonization parentage genetic barrier removal fitness life history polymorphism strategy monitoring fish p

ESUs/ species referenced:

Upper Columbia River steelhead

Watershed(s):

Beaver Creek

Abstract/ document summary:

Life history polymorphisms provide ecological and genetic diversity important to the long term persistence of species responding to stochastic environments. Oncorhynchus mykiss have complex and overlapping life history strategies that are also sympatric with hatchery populations. Passive integrated transponder (PIT) tags and parentage analysis were used to identify the life history, origin (hatchery or wild) and reproductive success of migratory rainbow/steelhead for two brood years after barriers were removed from a small stream.

Flow regime, temperature, and biotic interactions drive differential declines of trout species under climate change

By: Wenger SJ, Isaak DJ, Luce CH, Neville HM, Fausch KD, Dunham JB, Dauwalter DC, Young MK, Elsner MM, Rieman BE, Ha

2011

Prepared by:

Prepared for: PNAS Vol. 108, No. 34, pp. 14175-14180

Funding Source: Grant 2008-0087-000 of the NFWF's Keystone Initiative for Freshwater Fishes, USGS Grant G09AC00050, U

KeyWords: global change, hydrology, invasive species, niche model, distribution, modeling

ESUs/ species referenced:

cutthroat trout, brook trout, brown trout, rainbow trout

Watershed(s):

Abstract/ document summary:

Broad-scale studies of climate change effects on freshwater species have focused mainly on temperature, ignoring critical drivers such as flow regime and biotic interactions. We use downscaled outputs from general circulation models coupled with a hydrologic model to forecast the effects of altered flows and increased temperatures on four interacting species of trout across the interior western United States (1.01 million km2), based on empirical statistical models built from fish surveys at 9,890 sites. Projections under the 2080s A1B emissions scenario forecast a mean 47% decline in total suitable habitat for all trout, a group of fishes of major socioeconomic and ecological significance. We project that native cutthroat trout Oncorhynchus clarkii, already excluded from much of its potential range by nonnative species, will lose a further 58% of habitat due to an increase in temperatures beyond the species' physiological optima and continued negative biotic interactions. Habitat for nonnative brook trout Salvelinus fontinalis and brown trout Salmo trutta is predicted to decline by 77% and 48%, respectively, driven by increases in temperature and winter flood frequency caused by warmer, rainier winters. Habitat for rainbow trout, Oncorhynchus mykiss, is projected to decline the least (35%) because negative temperature effects are partly offset by flow regime shifts that benefit the species. These results illustrate how drivers other than temperature influence species response to climate change. Despite some uncertainty, large declines in trout habitat are likely, but our findings point to opportunities for strategic targeting of mitigation efforts to appropriate stressors and locations.

Application of new approaches to water quality temperature criteria Chiwawa River case study

By: Western watershed analysts, BioAnalysts

Prepared by:	Western watershed analysts, BioAnalysts
Prepared for:	IDEQ
Funding Source:	
KeyWords:	temperature, climate change

ESUs/ species referenced:

Watershed(s):

Chiwawa

Abstract/ document summary:

The EPA Region 10 has developed draft guidance for how states and authorized tribes may adopt water quality standards for temperature that will support native salmonid populations and meet the requirements of the Clean Water Act and Endangered Species Act (EPA, 2001). The guidance requires estimation of the natural thermal potential (NTP) of mainstem river and tributary reaches within sub-basins through modeling or other estimation procedures. EPA defines NTP as the thermal regime that existed prior to Euro-American Settlement. The guidance also recommends “species-life stage numeric criteria” that the EPA believes represent thermal conditions that are protective of native salmonids that would apply where and when the different life stages occur. Maps are to be prepared that describe the potential distribution of each guild and life-stage within sub-basins. The species-life stage numeric criteria would then apply until “thermal potential numeric criteria” are developed from the NTP in a process that may accommodate some level of anthropogenic impact. The thermal potential numeric criteria would then replace the species-life stage numeric criteria as a spatially explicit distribution of temperatures across the sub-basin.

This case study was developed to examine application of the EPA guidance in a real watershed. Key requirements for the case study include:

• Choose a test watershed that is generally representative of watersheds in Idaho, Oregon, and Washington, with anadromous salmon and bull trout fisheries, and that is known to have data readily available to support the required modeling and fish distribution mapping requirements.
• Assemble the required watershed data, track the sources of the data, and track the effort required to acquire and assemble it.
• Model the current thermal regime of the mainstem and tributaries, and model the NTP through estimation of current versus historical conditions of streamflow, channel morphology, groundwater, meteorology, and riparian vegetation. Include parameter sensitivity analysis, error analysis, and model validation procedures.
• Map existing and potential species-life stage occurrence and time of occupancy in the mainstem and tributaries.
• Integrate and reconcile the NTP with the species-life stage numeric criteria.
• Illustrate how the temperature criteria would be applied across the test watershed.
• Discuss application of the Guidance and temperature criteria to real watershed conditions, including assessment of relative difficulty of application.

Estimation of Juvenile Salmon Habitat in Pacific Rim Rivers Using Multiscalar Remote Sensing and Geospatial Analysis

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We conducted a regional classification and analysis of riverine floodplain physical features that represent key attributes of salmon rearing habitats. Riverine habitat classifications, including floodplain area and river channel complexity, were derived at moderate (30 m) spatial resolution using multispectral Landsat imagery and global terrain data (90 m) encompassing over 3 400 000 km2 and most North Pacific Rim (NPR) salmon rivers. Similar classifications were derived using finer scale (i.e. ≤ 2.4-m resolution) remote sensing data over a smaller set of 31 regionally representative flood plains. A suite of physical habitat metrics (e.g. channel sinuosity, nodes, floodplain width) were derived from each dataset and used to assess the congruence between similar habitat features at the different spatial scales and to evaluate the utility of moderate scale geospatial data for determining abundance of selected juvenile salmon habitats relative to fine scale remote sensing measurements. The resulting habitat metrics corresponded favorably ($p<0.0001$) between the moderate scale and the fine scale floodplain classifications; a subset of these metrics (channel nodes and maximum floodplain width) also were strong indicators ($R2>0.5$, $p<0.0001$) of floodplain habitats defined from the finer scale analysis. These relationships were used to estimate the abundance and distribution of three critical shallow water floodplain habitats for juvenile salmon (parafluvial and orthofluvial springs, and shallow shore) across the entire NPR domain. The resulting database provides a potential tool to evaluate and prioritize salmon conservation efforts both within individual river systems and across major catchments on the basis of physical habitat distribution and abundance.