

Middle Fork John Day River Intensively Monitored Watershed

Final Summary Report

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Prepared by the Middle Fork IMW Working Group



Forrest Conservation Area. *Courtesy of ODFW.*

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Report Organization

This report represents 10 years of hard work by numerous agencies and individuals, conducting restoration, research, and monitoring activities in the upper Middle Fork John Day River. Each principal investigator and their co-authors wrote a final report, which represents the culmination of their research and monitoring. The reports were compiled, along with pertinent background information, into this final Summary Report. The body of the Summary Report is organized such that projects are represented in the same order in each section of the report. An extensive overview of MFIMW activities, key findings, and recommendations can be found in the Executive Summary. Readers can use bookmarks and navigation, as well as the Table of Contents, to navigate to specific projects. For full details about a specific monitoring project including methods, analyses and results readers can refer to Appendices B-M which are compiled in a separate document. Links, bookmarks, and navigation have been provided, where possible, to ease in viewing this document electronically.

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Acronyms and Abbreviations

7DADM	Seven-day Average Daily Maximum
BRAT	Beaver Restoration Assessment Tool
CBMRCD	Columbia-Blue Mountain Resource Conservation & Development Area
CHaMP	Columbia Habitat Monitoring Program
CTWSRO	Confederated Tribes of the Warm Springs Reservations of Oregon
CREP	Conservation Reserve Enhancement Program
BACI	Before - After - Control – Impact
DPS	Distinct Population Segment
DTS	Distributed Temperature Sensing
EDT	Ecosystem Diagnosis and Treatment model
ELJ	Engineered Log Jam
EPA	Environmental Protection Agency
ESU	Evolutionarily Significant Unit
FCA	Forrest Conservation Area
FLIR	Forward Looking Infrared
IMW	Intensively Monitored Watershed
ISEMP	Integrated Status and Effectiveness Monitoring Program
JDR	John Day River
LCM	Life-Cycle Model
LWD	Large Woody Debris
MFJDR	Middle Fork John Day River
MFIMW	Middle Fork (John Day River) Intensively Monitored Watershed
MPG	Major Population Group
NFJDR	North Fork John Day River
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NRCS	USDA Natural Resources Conservation Service
NWPPC	Northwest Power Planning Council

O/E	Observed/Expected
OCA	Oxbow Conservation Area
ODEQ	Oregon Department of Environmental Quality
ODFW	Oregon Department of Fish & Wildlife
OPRD	Oregon Parks and Recreation Department
OSU	Oregon State University
OWEB	Oregon Watershed Enhancement Board
PIBO	PacFish/InFish Biological Opinion
PNAMP	Pacific Northwest Aquatic Monitoring Partnership
PNW	Pacific Northwest
PSMFC	Pacific States Marine Fisheries Commission
RME	Research, Monitoring, and Evaluation
RST	Rotary Screw Trap
rkm	River kilometer
rm	River Mile
SfM	Structure from Motion
STM	State and Transition Models
SWCD	Soil and Water Conservation District
SWE	Snow Water Equivalence
SFJDR	South Fork John Day River
TIR	Thermal Infrared
TMDL	Total Maximum Daily Load
TNC	The Nature Conservancy
UJDR	Upper John Day River
UMFWG	Upper Middle Fork (John Day) Working Group
UO	University of Oregon
USDA	United States Department of Agriculture
USFS	USDA Forest Service
USGS	United States Geological Survey

Executive Summary

Introduction

In the Middle Fork John Day River (MFJDR) basin in Oregon, nearly two centuries of land management practices have contributed to the decline of federally threatened Mid-Columbia summer steelhead *Oncorhynchus mykiss* and non-listed spring Chinook Salmon *O. tshawytscha*. Beaver trapping, road building, clear-cut logging, fire suppression, channel rerouting, floodplain/wetland drainage, grazing, and mining have all impacted the MFJDR through time. While the most damaging of these practices have been curtailed, their harmful legacies remain, including degraded floodplain function and connectivity, reduced habitat quantity and diversity, increased water temperature, and altered hydrology and sediment routing. These key limiting factors have been identified as negatively impacting steelhead and salmon recovery in the MFJDR (CBMRCD 2005; Carmichael and Taylor 2010). Habitat restoration is a primary strategy to address the limiting factors in Columbia Basin tributaries that hinder salmonid recovery in the Pacific Northwest (PNW), including the MFJDR.



Photo 1. Steelhead. *Courtesy of ODFW.*

Investments in salmonid habitat restoration oftentimes do not include effectiveness monitoring (Roni et al. 2002; Roni P. ed. 2005, Bernhardt et al. 2005), leaving project planners to rely upon anecdotal evidence to infer benefits to fish populations. To address this problem, the Intensively Monitored Watershed (IMW) program was created to monitor fish population responses to restoration actions, provide evidence of restoration effectiveness, and better understand the relationships between fish and habitat. In 2008, the MFJDR joined the IMW program, seeking to study how ongoing stream restoration actions were affecting salmonid populations, and to guide future restoration efforts.

The Middle Fork IMW (MFIMW) is coordinated by a subset of organizations that originally participated in the Upper Middle Fork John Day Working Group (UMFWG). These participants convened in April of 2007 to develop a monitoring approach. In 2008, the National Marine Fisheries Service (NMFS), in coordination with the Pacific States Marine Fisheries Commission (PSMFC), and the Oregon Watershed Enhancement Board (OWEB) began funding the MFIMW.

The goals of the MFIMW are to 1) evaluate the overall benefit of restoration actions to summer steelhead and spring Chinook Salmon in the Upper MFJDR, and 2) understand how specific restoration actions impact instream habitat, temperature, and salmonid metrics at the watershed, sub-watershed, and reach scales.

Over 100 active and passive restoration projects of varying size and scope were implemented over the 10-year period of the MFIMW by organizations that originally participated in the UMFWG. A restoration inventory shows 30 restoration projects implemented along the mainstem MFJDR and 70 projects in the tributaries. This habitat restoration work targets the key limiting factors described above. Many of the restoration projects were multi-faceted, designed simultaneously to address multiple limiting factors, with the intent of maximizing ecosystem 'returns' from these restoration investments.



Photo 2. Setting up weather station. *Courtesy of NFJDWC.*

Key Findings

The MFIMW evaluated the effects of restoration actions on native steelhead and Chinook populations and habitat throughout the Upper MFJDR watershed. A range of parameters were monitored, including but not limited to fish populations, physical instream habitat, and water temperature. Key findings include:

- Evidence strongly indicates that elevated stream temperature remains the most significant limiting factor for steelhead and Chinook populations, overriding the benefits to salmonids from observed instream habitat improvements from restoration actions in the MFJDR.
- Without the simultaneous and effective mitigation of high stream temperatures, restoration actions that targeted quantity and quality of instream habitat were insufficient to generate positive fisheries metric responses at all scales monitored.
- High stream temperatures, and their negative effects on fisheries responses, are the direct result of a warming climate, reduced snow pack, and severely modified riparian habitats. While riparian restoration efforts have been and are being implemented, habitat improvements resulting from these are slow to progress, due to insufficient extent of plantings throughout the watershed and the unexpected magnitude of ungulate browsing.

- Riparian vegetation restoration has great potential to address stream temperature concerns, but riparian maturation takes a great deal of time and careful stewardship to ensure success.
- River restoration is a long-term investment. Restoration actions aimed at improving watershed function, such as riparian restoration and instream habitat improvement, take decades to fully develop and produce detectable improvements in salmonid productivity.
- Various habitat and population changes expected from restoration actions have different response times, from short (a few years) to long (decades), and monitoring should be scaled accordingly.
- During the planning process, it is important to delineate expected response timing and magnitudes from restoration actions to ensure that monitoring goals are realistic and can be achieved within a reasonable time frame.
- Life cycle modeling can aid in predicting the expected magnitudes and timing of fisheries response variables from restoration, and help to prioritize the restoration actions that maximize restoration effect on population metrics.

Response of Salmonid Populations to Restoration Actions

We monitored the response of summer steelhead and Chinook Salmon to restoration actions in the MFJDR. Our hypothesis, based on previous MFJDR observations, was that freshwater salmonid productivity will respond positively to increased quality and quantity of habitat. However, results at the watershed scale indicate that to date, freshwater productivity of salmonid populations has not increased. Evidence indicates that temperature and discharge, rather than restoration actions, were the dominant influences on juvenile salmonid responses in the MFJDR watershed. Salmonid growth was influenced by both temperature and discharge, while low discharge was the dominant factor limiting salmonid survival. Furthermore, we found through distribution surveys that juvenile Chinook habitat quantity was significantly limited by high summer water temperatures. Although our habitat surveys indicate that factors limiting freshwater production were improved through restoration actions in the MFIMW, the most significant limiting factor, stream temperature, has not yet been adequately addressed. Therefore, despite gains made in habitat quality, suitable stream temperatures and habitat quantity remained limited, suppressing significant increases in watershed-scale salmonid productivity.

While improvements to habitat quality were also observed in our Camp Creek surveys, they were not sufficient to create concurrent observable increases in freshwater productivity. Instead, as in the watershed-scale finding, stream discharge and temperature were the most significant influences on juvenile steelhead survival and productivity. In Camp Creek,

we observed increased steelhead density during the early post-restoration period, but higher discharges during that period were most likely responsible, not habitat improvement. Additionally, evidence indicates that elevated stream temperatures in Camp Creek continued to suppress growth and productivity in the post-restoration period, and very likely negated positive fisheries responses to observed habitat quality improvements.

Despite significant habitat quality improvements in MFJDR and Camp Creek, elevated stream temperatures continue to limit the production of salmonid juveniles by limiting habitat quantity and decreasing juvenile salmonid growth and survival. MFIMW life cycle modeling efforts support this finding, concluding that water temperature remains the primary limiting factor in the MFJDR system. The slow progress and limited extent of riparian restoration and lack of reductions in temperature limited freshwater responses throughout the MFJDR watershed. Finally, given the limited time for habitat recovery from active restoration, and the lag time associated with population-scale fish responses, limited fish responses to the recent restoration actions of the MFJDR are reasonable.

Response of Instream Habitat to Restoration Actions

The majority of MFIMW restoration actions were designed to improve instream habitat quality and quantity. These include pool creation and pool modification, floodplain reconnection, fish cover enhancements, increased sinuosity, channel narrowing, and habitat diversification. Therefore, geomorphic and in-stream habitat monitoring was a primary component of the MFIMW, focusing on three spatial scales: project, reach, and watershed level.

We estimated instream habitat trends at the watershed scale by measuring changes in individual stream habitat metrics at established PacFish/InFish Biological Opinion (PIBO) sampling sites in Camp Creek and the mainstem MFJDR. This study demonstrated that stream restoration and land management efforts had a measurable effect on habitat quality at the watershed scale. Overall habitat index improved, large woody debris increased in frequency, and the percentage of undercut banks increased in Camp Creek and the MFJDR. However, percent fines in pools increased in Camp Creek and the MFJDR. These results indicate that most individual aspects of habitat condition in the MFIMW are stable or improving. While habitat conditions in Camp Creek are improving, it remains of poorer quality than reference conditions in the Blue Mountains and Upper Columbia Basin. This comparison highlights the need for additional restoration actions and time for riparian restoration to deliver expected results.

In addition to monitoring broad habitat changes at the watershed scale, finer-scale habitat changes at the reach and individual restoration project scales were also studied. Channel geomorphology, sinuosity, pool depth, bed material, and fish cover were monitored for seven years at

restoration and control reaches. Changes to channel morphology at individual log structure treatments were also monitored. The results show that while restoration reaches did not narrow and deepen or become more sinuous, active restoration measures did produce a significant increase in pool depth, mainly due to deep pools created during the restoration projects. Both treatment and control reaches also experienced a significant decrease in the percentage of embedded gravels, indicating that gravels are becoming more porous and that accumulation of fine sediment in the gravel bed is not a problem. These results indicate that the MFJDR channel is relatively stable and in dynamic equilibrium, and not susceptible to significant net erosion or deposition, even during the 2011 flood, the largest flood ever recorded on the MFJDR.

Interestingly, stream reaches that had experienced passive restoration (i.e., removal of livestock grazing) showed large increases in torrent sedge, a native species, within the active channel. These plants had important influences on channel morphology and habitat by increasing fish cover, creating lateral movement of the channel, and increasing channel complexity. These results suggest that long-term passive restoration is making important contributions to improving geomorphic and fish habitat conditions.

In conclusion, significant overall habitat improvements attributed to watershed-scale land management decisions and stream restoration actions were observed throughout the MFIMW as evidenced by our PIBO surveys. In the MFJDR, log structures did not significantly alter channel morphology. However, cattle exclusion in the MFJDR did successfully improve habitat and channel complexity, as well as fish cover, via increases in sedge vegetation.

Response of Riparian Habitat to Restoration Actions

Riparian planting has become a popular restoration strategy given its ability to provide shade to reduce stream temperatures and contribute large wood to improve instream habitat. Monitoring is important to inform the adaptive management process of riparian restoration, but effectiveness evaluation of riparian planting is often lacking. In the MFIMW, field monitoring was employed to gauge the success of various riparian restoration scenarios and theoretical models were utilized to examine the impacts of these scenarios on future habitat quality.

We studied the effects of wild ungulate browsing on native woody riparian plantings along the MFJDR. To restore shade to highly modified riparian habitats, thousands of seedlings were planted on the Oxbow and Forrest Conservation Areas in 2006. These areas were already fenced to exclude cattle, but not wild ungulates. Results showed that browsing by deer and elk suppressed the growth of most planted hardwoods and concluded that browsing pressure from ungulates severely limits the restoration of

native riparian forests. This limitation must be considered by restoration practitioners during project planning and design phases.

Ecological modeling can complement riparian field studies by using field measurements to predict where restoration plantings are most effective and, thus, inform the prioritization of riparian restoration actions across large landscapes. We modeled historical, current, and future scenarios of riparian plant communities and their effects on salmonid habitat in the upper MFJDR using state and transition models. Alternative management strategies for passive versus active riparian restoration were examined. Simulation results indicate that recovery toward historic conditions occurs under both passive and active strategies, though recovery was slower under passive restoration alone. Simulations also suggested that streams would not fully recover to the historical condition within 50 years (the duration of the modeled simulations), even in the most aggressive active restoration scenario we examined. These results indicate that river restoration investments, particularly those with a long lag time such as riparian restoration, need to be planned and evaluated over several decades. It also suggests that the slow recovery time of riparian restoration may undermine the ability to detect positive fisheries responses from restoration actions within a reasonable time frame, especially in areas where high temperatures are a primary limiting factor, such as in the MFJDR watershed.

Response of MFIMW Stream Temperatures to Restoration Actions

Elevated stream temperature is clearly implicated in salmonid population declines in the MFJDR, and is considered to be the primary limiting factor for salmonids in this system. Some of the restoration projects implemented throughout the MFIMW study area were designed specifically to cool the river, but most were primarily directed to other objectives (e.g., increased habitat, access to low-velocity water during floods). We monitored temperature at both coarse (watershed, subwatershed) and fine (individual project, reach-level) spatial and temporal scales. Field-validated implementations of the physically-based model HeatSource were applied to predict stream temperature changes under various climate and restoration scenarios. Results showed that although some projects did succeed at lowering temperatures in localized areas, others were predicted to increase temperatures, and overall, the elevated summer temperatures due to a lack of riparian shade was not significantly impacted during the study period, with the exception of the Oxbow consolidation of two channels into one.

We used standard temperature loggers to assess temperature trends at the MFJDR watershed scale for over a decade. Between 2005 and 2016, 122 water temperature loggers were deployed in the mainstem MFJDR and 26 of its tributaries. Summer water temperatures, reported as maximum 7-day average daily maximums (7DADMs) were above the EPA recommended 18°C thermal threshold for cold-water salmonids for all locations and all

years. Riparian restoration activities in the MFJDR designed to cool water temperatures are relatively recent, including many within the last 5-7 years. Additionally, these plantings were implemented in a relatively small proportion of the watershed. It was found that these temporal and spatial recovery scales were insufficient to affect a watershed-level change in temperature values.

In addition to the watershed-scale temperature monitoring, we implemented distributed temperature sensing (DTS) to measure stream temperatures at high temporal (minutes) and spatial (0.5 m) resolutions. These data were utilized to calibrate predictive models and investigate the effects of reach-scale restoration projects on stream temperatures.

Floodplain reconnection is an important restoration objective. We investigated whether a MFJDR floodplain reconnection project could mitigate late-summer low flows and elevated stream temperatures through increased mainstem flow by delivery of water stored in the floodplain, from high winter flows, in the summer. This restoration action was shown to be ineffective in the mitigation of summer water temperatures. It should be emphasized, however, that the floodplain reconnection has benefits to salmonid communities during high flow periods.

Tributary inputs of cool water were shown to be critical components of creating thermal conditions suitable to salmonids. We found that the major cooling sources for the mainstem were from tributary contributions, and not from direct entry of groundwater. However, consistent with summer flows being generated from stored groundwater, it was also found that groundwater did provide significant cooling to the MFJD tributaries, which deliver this cool water to the mainstem. At tributary confluences colder contributions to the mainstem provided large areas of thermal refugia.

The mainstem MFJDR experiences very high summer stream temperatures and we investigated the drivers that caused these elevated temperature levels. While tributaries are the primary cooling mechanism to the mainstem MFJDR, our modeling efforts employing HeatSource found that solar radiation is the primary driver of temperature gain along the mainstem MFJDR. The relationship is linear, making it easy to predict the impact of restoration efforts on temperature by simply comparing the pre- and post-restoration surface area of the stream at low-flow. Therefore, wider channels with larger surface (wetted) areas are more susceptible to temperature increases than narrower, deeper channels.

Monitoring of the Phase 2 Oxbow Tailings Project, which decreased channel surface area, confirmed the HeatSource modeling projections. Monitoring of Phase 2 Oxbow Tailings Project showed a decrease in mainstem mean temperature of over 0.6°C (1°F). On the other hand, the Oxbow Tailings Project Phases 3-5 introduced meander bends to an artificially straightened channel and resulted in reduced channel velocities

and an increase in stream channel surface area. HeatSource model projections indicated that these meander bend additions most likely caused increased solar heat inputs into this channel section and increased temperatures (Hall, 2015). Model results considering the impact of shade from stream-bank vegetation found modest and very slow temperature responses, with riparian restoration unlikely to provide significant thermal cooling within a decade on rivers the size of the MFJDR. These results suggest that re-meandering channels, without severe limitation of the wetted area during summer low-flow, may cause temperature increases in the absence of tall riparian vegetation. The results suggest all restoration efforts be assessed for their impact of low-flow stream surface area as a primary predictor of the expected impact on critical stream temperature.

Bridge Creek and the influence of Bates Pond provided an illustrative example of the interplay of temperature, cool water tributary influence to the MFJDR, surface area exposure to solar radiation, and fish habitat use.



Photo 3. Bates Pond fish ladder.
Courtesy of ODFW.

Bridge Creek flows into Bates Pond, a man-made millpond; Bates Pond then outflows into lower Bridge Creek, which empties into the MFJDR soon after. The increased surface water area of Bates Pond elevates water temperature outflow to the extent that lower Bridge Creek is warmer than the MFJDR during much of the summer. This restricts the potential of Bridge Creek to act as thermal refugia both downstream and above Bates Pond since fish will not ascend the fish ladder at the elevated temperatures. If the thermal condition of Bridge Creek within the State Park boundary, including Bates Pond, were improved to replicate temperatures upstream of the park, more steelhead and salmon would be able to utilize Bridge Creek as cool water refugia during periods of heat stress.

Changing environmental and climatic conditions underscore the need to understand the mechanistic linkages between climate, habitat, and fish. For example, increases in air temperature and decreases in stream discharge due to climate change have the potential to increase future stream temperatures. We combined HeatSource and riparian state-and-transition models to predict the interactive effects of climate changes and riparian vegetation to stream temperatures in the upper MFJDR. Simulations suggest a wide range of possible future thermal regimes for the MFJDR. Future 7DADM stream temperatures ranged from 4°C warmer to 8°C colder than current conditions, depending on the extent of riparian vegetation simulated in the model.

Stream surface area exposed to air and shading from tall riparian vegetation had the largest influence on stream temperatures compared to air temperature and streamflow. These model results suggest that constraining channel width and development of tall riparian vegetation has the potential to mitigate the deleterious effects of future climate scenarios. While riparian restoration requires time to achieve anticipated results, investment in this restoration strategy will have critically important, positive effects to salmonid species and their habitats over the long term.

Response of Macroinvertebrates to Restoration Actions

Because macroinvertebrates are the dominant food source for juvenile salmonids in the MFJDR, it is important to understand the causal mechanisms linking stream restoration, macroinvertebrates, and salmonid production. We predicted that restoration actions in the MFJDR would increase overall macroinvertebrate abundance, increase the number of taxa, and produce community compositions more closely resembling those at undisturbed reference sites. To test these predictions, benthic and drift macroinvertebrate communities were compared between control and restored reaches in the MFJDR.

We found that, contrary to our prediction, restoration actions have not significantly affected the macroinvertebrate community composition when compared to reference sites. However, restoration actions did appear to affect the amount of drift macroinvertebrate biomass within the MFJDR from year to year. This was likely due to disturbance of the substrate and drift mobilizations from restoration activities. We also found, again contrary to our hypothesis, that restored reaches had a significantly lower number of drift taxa, probably because the disturbance caused by active restoration may alter the type and number of taxa at that site over the short term. Overall, however, we often observed more variability between years than sites, indicating that annual environmental conditions were more influential than management actions over the short-term period we monitored macroinvertebrate response.

Socio-Economic Benefits of Restoration

We monitored the contribution of restoration projects to the socio-economic health of the local community (often referred to as 'the restoration economy'). This work aims to better understand if and how watershed restoration benefits the local economy. Community indicators assessed the overall socio-economic well-being of Grant County over time. Outcome measures estimated the contribution of MFIMW restoration work to the Grant County economy. The indicators show that Grant County was in socio-economic decline over the past 40-50 years, but that conditions are improving. In particular, jobs and earnings are on upward trajectories, with other indicators supporting that trend. At the same time, restoration work is

bringing work and money into the Grant County economy, contributing to its recovery. The 100 restoration projects documented in the restoration inventory from July 1, 2007 to June 30, 2017 brought a minimum of \$15.6 million dollars into the local economy, along with creating almost 170 jobs and generating additional economic activity in the range of \$20-25 million.

Lessons Learned and Recommendations

Adaptive management is an important tool that should be used to guide restoration actions and be integrated within an IMW framework (Bouwes et al. 2016). As part of the adaptive management process, we asked that researchers and restoration practitioners share lessons learned and future recommendations based on their involvement with the MFIMW. These lessons and recommendations extended beyond what was learned from study findings; they illustrate how the participants would incorporate improved methodologies and strategies into subsequent phases of the IMW process and future IMW programs. During this process, several similar themes emerged from multiple participants. Therefore, lessons learned and recommendations are grouped by the three main topics: Planning, Monitoring, and Restoration. In this context, planning refers to the planning, facilitation, and coordination of the MFIMW process and group itself. We pair lessons learned with accompanying recommendations based on what we gleaned from participant experience. These lessons provide valuable insights for ongoing planning, monitoring, and restoration efforts within the MFIMW and similar IMW efforts.

Planning

Lesson Learned

The monitoring plan designed at the beginning of the study was compromised by unanticipated restoration projects that were implemented during the course of monitoring. There were many organizations implementing restoration actions across the MFIMW study area and a lack of coordination resulted in some restoration projects being implemented in designated control reaches.

Recommendations

Ongoing communication among restoration practitioners and researchers is integral to the long-term success of IMW programs. A communication framework for coordinating these activities is essential to maintaining the integrity of the experimental and monitoring design. A complete review of monitoring activities should be conducted each year prior to the field season and before additional or subsequent restoration occurs.

Lesson Learned

Assessment of the linkages between restoration investments and economic indicators must be designed so that they are relevant to the conditions and situations experienced in local communities.

Recommendation

Identify socio-economic indicators and outcome measures in consultation with local officials and the community.

Monitoring

Lesson Learned

Numerous research studies (e.g., macroinvertebrates and water temperature) were negatively affected by inconsistent temporal and spatial monitoring over their durations. Consistency is the backbone of a successful study design, allowing for long-term quantitative comparisons of restored and control locations.

Recommendation

It is imperative to have a consistent data collection effort across both temporal and spatial scales. Clear and consistent monitoring goals, documentation of site selection, communication among collaborators, data quality assurance/quality control, and ongoing data analyses will help researchers determine which sampling sites are most important to sample consistently over time.

Lesson Learned

The MFIMW was challenged by a lack of control locations with sufficiently similar conditions to be justifiably compared to restoration locations for salmonid productivity monitoring. For instance, the Camp Creek sub-watershed possessed unique geologic, biologic and hydrologic characteristics that were not adequately represented in other tributaries of the MFJDR. Murderer's Creek from the SFJDR was employed as the control watershed for this reason.

Recommendation

It is recommended that restoration and control reaches be allocated within the same watershed, but with careful attention to maintaining independence. Under this scenario, reach-scale monitoring will be most effective if restoration reaches are paired with control reaches that share similar environmental and physical conditions. Alternatively, replicate reaches can be allocated randomly throughout the watershed so that the conditions of the watershed are represented equally across groups.

Lesson Learned

A life cycle model linking fish to habitat variables would have provided a valuable tool at the beginning of the MFIMW effort.

Recommendation

Life cycle modeling can aid in predicting the expected magnitudes and timing of fisheries responses from restoration, and could enhance the probability of success of detecting these responses to restoration actions during IMW monitoring phases. Applying insights gained through these efforts would also help to prioritize restoration actions that maximize restoration effects on population metrics.

Lesson Learned

Natural environmental variability can swamp habitat and fisheries responses to restoration. Increasing baseline or pre-treatment monitoring can reduce noise level by predicting and subtracting among-year variance in the response signal due to environmental fluctuations.

Recommendation

Adequate baseline information is needed to confidently estimate temporal variance of the response variables in pre-treatment conditions. These metrics include salmonid growth, survival, density, and movement, but should also include covariates such as temperature, discharge, and spawner abundance. Ideally, researchers should monitor both treatment and control locations for multiple years prior to restoration. This information would 1) help explain the influence of pre-treatment climate and habitat variables on populations, and 2) provide enough baseline data to be able to factor out environmental variability. Sufficient duration of post-treatment monitoring is also essential to confirm consistency of response variables and covariates in the control location (through the course of study) and to allow time for restorations actions to fully develop and deliver expected responses.

Lesson Learned

Targeting cold-water input locations for habitat improvements (e.g., large wood additions, channel reconfiguration) may have additive or even multiplicative effects on salmonid productivity. There was a missed opportunity to examine the interacting effects of coinciding and favorable habitat variables in the MFIMW.

Recommendation

These strategies can be better understood by continued monitoring of the Oxbow Phase 3, 4, and 5 projects, which occurred at the end of the current MFIMW study.

Lesson Learned

Restoration actions aimed at improving watershed function may take decades to mature. Some processes and cycles that influence salmonid populations span much longer than 10 years, and will not manifest a fish population response within a 10-year period.

Recommendation

Expectations for restoration outcomes need to be tempered with a realistic understanding of the rate at which natural systems can recover from almost two centuries of Euro-American settlement and land use. Slow restorative processes, such as vegetative change, and those that manifest over generations of the target species require planning and monitoring over decadal scales. However, responses to restoration actions such as fish passage, channel reconfiguration, and cover enhancements require less time to observe a fisheries response and can be targeted successfully for shorter term experiments.

Restoration - From the Researchers

Lesson Learned

Channel reconfigurations, which provide habitat and channel complexity to salmonids, can also increase stream temperatures by increasing stream surface area.

Recommendation

Because channel reconfiguration addresses limiting factors such as habitat quality and quantity, managers will need to consider these goals in relation to other factors, such as short-term elevated stream temperatures versus long-term vegetation recovery, during planning and design phases. Prioritizing limiting factors and clearly specifying restoration goals during this phase will maximize the return on costly restoration investments such as active channel reconfiguration.

Lesson Learned

Targeting cold-water input locations for habitat improvements could have been an effective strategy to maximize benefits from costly restoration actions.

Recommendation

The magnitude and location of cold-water inputs into the MFJDR from tributaries and groundwater upwelling should be leveraged in future restoration designs.

Restoration - From the Restoration Practitioners

Lesson Learned

Intense deer and elk browsing pressure prevented riparian plantings from effectively shading the river in some areas.

Recommendation

Invest in elk-proof fencing on major restoration efforts to protect riparian plantings if browsing pressure presents serious risks to restoration outcomes.

Lesson Learned

Installing willow cuttings, planting nursery stock, and transplanting native vegetation that was salvaged from the restoration site was an extremely challenging task for the heavy equipment contractor.

Recommendation

Salvage and re-plant all native vegetation when possible. Hire a full-time vegetation care specialist to work with the contractor on plant salvage and planting operations.

Lesson Learned

Riffle construction in newly constructed channels can be a difficult prospect. Without a sealed riffle crest, water during low flows tended to move subsurface through glide substrates, especially at sites where the start of the glide was at a higher elevation than the riffle crest. If the riffles wash out, habitat for an entire stream segment may be lost.

Recommendation

Channel design should conform to a profile where the riffle crest or head is the highest feature in the substrate. Riffles need fines washed in to ensure the matrix is hardened and stable.



Photo 4. Young cottonwoods. *Courtesy of ODFW.*

Next Steps

Building from the long list summarized in this document, the MFIMW workgroup will prioritize recommendations for Planning, Monitoring, and Restoration over the next year. The agencies and organizations participating in the MFIMW will prioritize among the recommendations and develop a specific and actionable work plan. The work plan will prioritize what is anticipated to be accomplished within the next year, over 2-5 years and within the next 5-10 years.

Many participants are interested in developing an outreach strategy to report the MFIMW key findings to various audiences. These outreach efforts will likely span over a period of time to receive adequate input and develop the appropriate approach and materials to inform the different audiences that are identified. Important work that also awaits us is to make modifications to core priority monitoring efforts to ensure the study design is sufficient to provide data that will continue to help us answer our questions. In addition, the MFIMW will work proactively with NMFS, the Pacific Northwest Aquatic Monitoring Project (PNAMP) and other IMWs in the PNW to reflect on the lessons learned across the broader IMW network and determine how the MFIMW moves forward to provide needed information for decision-makers and practitioners.

Background

Introduction

Salmon and steelhead populations are declining throughout the Pacific Northwest, and stream habitat restoration is a primary strategy to support their recovery. Considerable resources are put toward restoring salmon habitat. Between 2000 and 2014, more than \$700 million was spent on salmon habitat restoration by federal agencies in the Columbia Basin alone, yet only about one-fifth of these resources were applied towards restoration monitoring and evaluation (Wozniacka 2015). Historically, restoration efforts have rarely included effectiveness monitoring (Roni et al. 2002; Roni P. ed. 2005, Bernhardt et al. 2005), leaving project planners to rely upon anecdotal evidence or intuition to infer benefits to fish populations. To address this problem, over 20 watershed-scale restoration efforts with associated effectiveness monitoring programs have been initiated in the Pacific Northwest. Referred to as the Intensively Monitored Watershed (IMW) program, these programs seek to provide quantitative evidence of restoration impacts on salmonid populations and their habitat (Bilby et al. 2005; PNAMP 2005; Nelle et al. 2007).

The goal of an IMW is to improve our understanding of the relationship between anadromous fish and their habitat (Bilby et al. 2005; PNAMP 2005). IMW research can reveal causal mechanisms, allowing us to better predict restoration effects across river systems in a cost-effective manner. Through documenting and sharing the lessons learned from the network of IMWs, resource managers in the Pacific Northwest will be able to implement further restoration with greater confidence, and effectiveness monitoring efforts can be prioritized and directed for maximum value (Bennett et al. 2016).

Beginning in 2008 the National Marine Fisheries Service (NMFS), in coordination with the Pacific States Marine Fisheries Commission (PSMFC) and the Oregon Watershed Enhancement Board (OWEB), funded an IMW in the upper Middle Fork John Day River (MFJDR) basin in Oregon. The goal of the Middle Fork John Day River IMW (MFIMW) is to understand the causal mechanisms between stream habitat restoration and changes in salmonid production at the watershed scale (UMFWG 2011).

MFIMW Development

The MFIMW is coordinated by a subset of stakeholders that originally participated in the Upper Middle Fork John Day Working Group (UMFWG). These participants—agencies, universities, and conservation groups—continued to coordinate MFIMW monitoring efforts and discuss where restoration would be implemented in the study area (Figure 1).



Figure 1. Participating agencies and organizations in the MFIMW.

Participants of the UMFWG convened in April of 2007 and began to develop a MFIMW monitoring plan based on restoration planning efforts that were already underway. Restoration efforts moved forward independently of the monitoring efforts that formally began in 2008. Given that a minimum of 5-10 years is needed to detect a trend in steelhead or salmon populations, the study was anticipated to last at least a decade. The first few years of the MFIMW were used to determine the experimental design, monitoring methods, and metrics. The MFIMW's structure, focus, and study design was informed by the variety of pre-existing collaborative restoration and monitoring projects in the basin. These included monitoring by Oregon Department of Fish and Wildlife (ODFW) of Chinook Salmon *Oncorhynchus tshawytscha* and steelhead *Oncorhynchus mykiss*; PacFish/InFish Biological Opinion (PIBO) monitoring by USDA Forest Service (USFS); and conservation and monitoring efforts by The Nature Conservancy (TNC) and Confederated Tribes of the Warm Springs Reservations of Oregon (CTWSRO).

In 2010 Eco Logical Research Inc. was contracted to complete a study design for monitoring planned restoration activities, improving our ability to detect changes in fish populations and determine whether the changes were caused by environmental factors, restoration, or a combination of these. The resulting [Upper Middle Fork John Day River Intensively Monitored Watershed Draft Experimental Design and Implementation Plan](#) was developed and is available online.

Study Area

The John Day basin lies in the Mid-Columbia Plateau Region in Northeastern Oregon. The basin consists of 5 main subwatersheds: the Lower John Day, the Upper John Day (UJDR), the North Fork John Day (NFJDR), the South Fork John Day (SFJDR), and the MFJDR.

The MFJDR originates in the Blue Mountains of the Malheur National Forest, south of the NFJDR. The MFJDR flows westerly for 75 miles, and merges with the NFJDR about 18 miles north of the town of Monument. The MFJDR is a fourth-field watershed (USGS cataloging unit 17070203) that drains 806 miles² with a perimeter of 158 miles (Figure 2). Watershed elevations range from 2200 feet near the mouth to over 8,200 feet in the headwater areas. The watershed receives approximately 15-25 inches of precipitation each year.

The upper portion of the MFJDR, extending upstream and inclusive of the confluence with the MFJDR and Big Creek, was defined as the MFIMW study area (Figure 3). The upper portion of the MFJDR was chosen because the majority of the restoration actions were occurring in this area and provided a reasonable size to monitor changes. Land ownership in this area is predominantly National Forest with smaller portions that are private. In addition, several large parcels are managed by restoration-focused organizations such as the CTWSRO, TNC, and Oregon Parks and Recreation Department (OPRD). These conservation-focused parcels combine to cover more than 12 miles² of habitat.

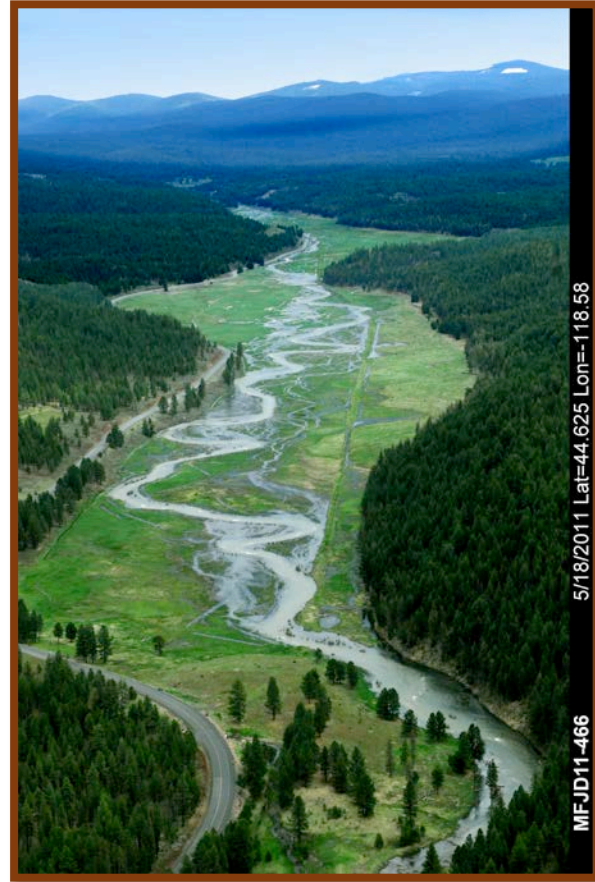


Photo 5. Middle Fork John Day River.
Courtesy of BOR.

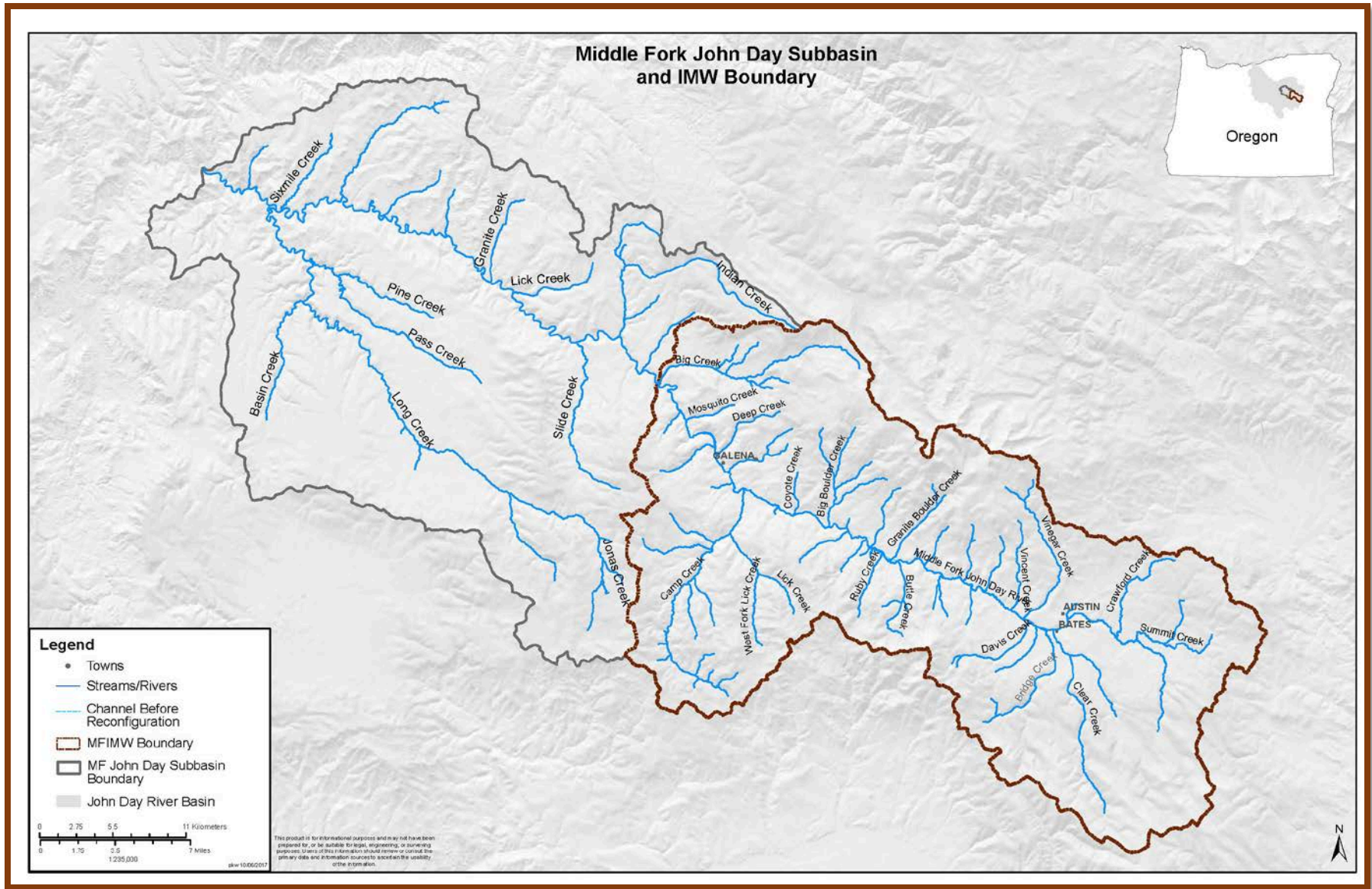


Figure 2. Vicinity map showing the Middle Fork IMW within the Middle Fork John Day River subbasin.

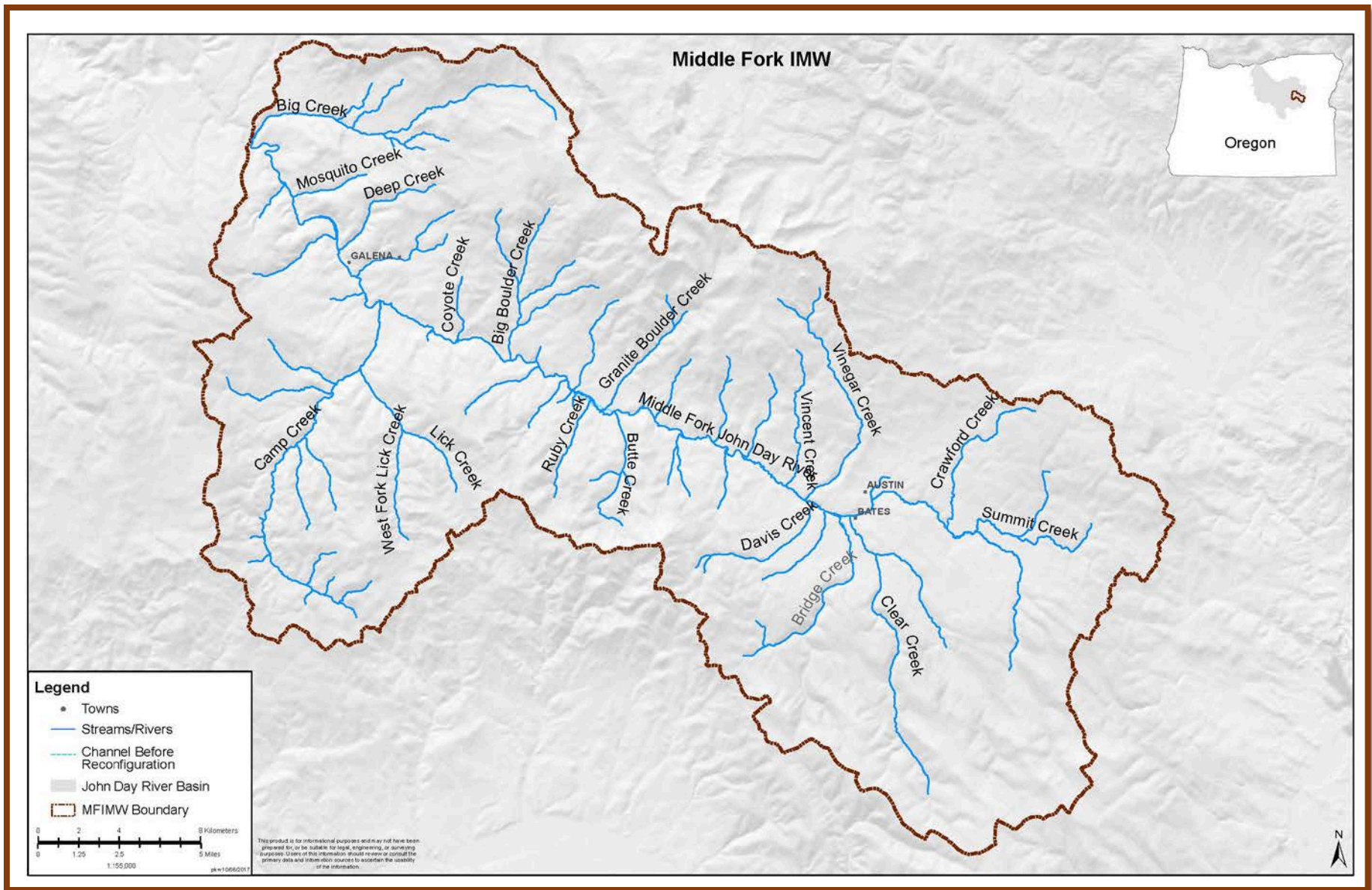


Figure 3. Vicinity map showing the Middle Fork IMW within the Middle Fork John Day River subbasin.

Geomorphology

The geomorphology of river channels and their associated floodplains and valleys strongly influence the process for creating and maintaining salmon and steelhead habitat. The upper MFJDR follows a common geomorphic pattern, characterized by laterally unconfined valleys interspersed with narrower, semi-confined reaches. Most of the land use and visible impacts to streams and floodplains occurs in the upper watershed, which is the focus of the MFIMW.

A [geomorphic framework](#) to inform stream restoration planning for the MFJDR (O'Brien 2017) examined river diversity, evaluated geomorphic condition, and determined the potential for geomorphic recovery. About two-thirds of the watershed was found in good geomorphic condition with the remaining one-third in moderate to poor condition. Most reaches in moderate condition were determined to have a high potential for recovery.

Climate

The John Day Subbasin has a continental climate characterized by low winter and high summer temperatures, low average annual precipitation, and dry summers. Most precipitation falls between November and March as snow. Less than 10% of the annual precipitation falls as rain during July and August, usually from sporadic thunderstorms. The upper elevations receive up to 50 inches of precipitation annually, mostly in the form of snow; lower elevations receive 12 inches or less of precipitation. Most water in the John Day Subbasin is derived from the upper watershed, primarily in the form of melting snow. Discharge is highly variable from peak to low flows (CBMRCD 2005). The hydrologic curve has shifted from historic times, with peak flows greater than in the past and late season flows more diminished. It is suspected that these effects are due to greatly reduced rates of soil infiltration, reduced capacity for ground water/riparian storage, and diminished in-channel storage in beaver ponds (NWPPC 2001). It is further believed that the hydrologic regime changes are due to increasing air temperatures and its impact to snowfall and snowmelt.

To assist in understanding climate impacts on MFJDR discharge regimes, weather information was compiled from the Tipton site, a member of the USDA Natural Resources Conservation Service (NRCS) SnoTel program, located in the headwaters of the upper MFJDR at an elevation of 5,150 feet. Data from the Tipton site includes hourly soil moisture/temperature data, and 24-hour precipitation and snow water equivalence. More [information about the Tipton SnoTel site](#) can be found online. From 2008–2016 the highest precipitation was recorded in water year 2011, while the lowest total annual precipitation occurred in water year 2012, which was followed by 3 consecutive years of low precipitation (Figure 4).

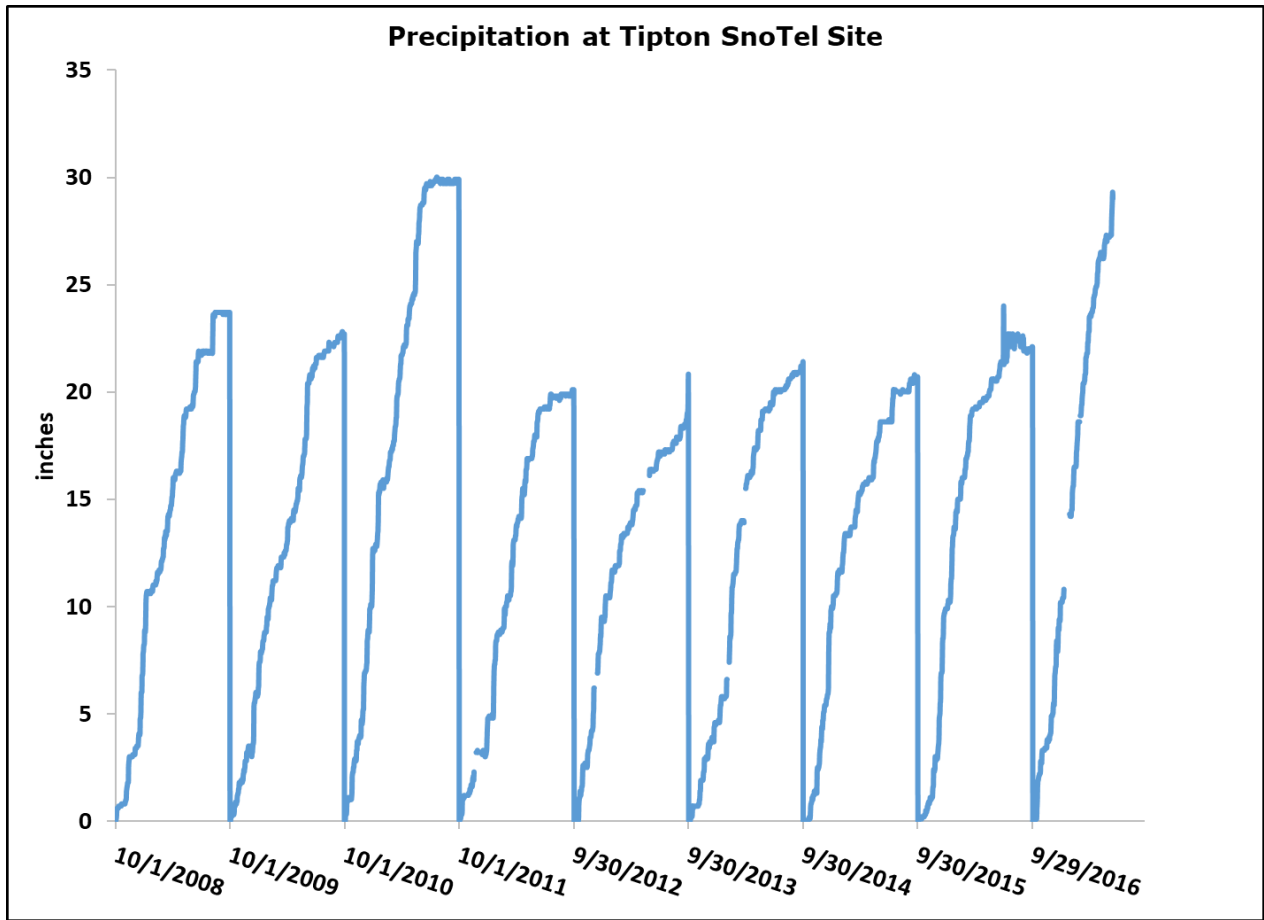


Figure 4. Total annual precipitation at the Tipton SnoTel site for water years 2009-2017.

Another important weather attribute influencing streamflow is snow water equivalence (SWE), defined as the amount of water bound up in the snowpack. SWE was evaluated for water years 2009-2017 (Figure 5). The lowest SWE was observed in 2015 while the highest SWE was observed in 2011.

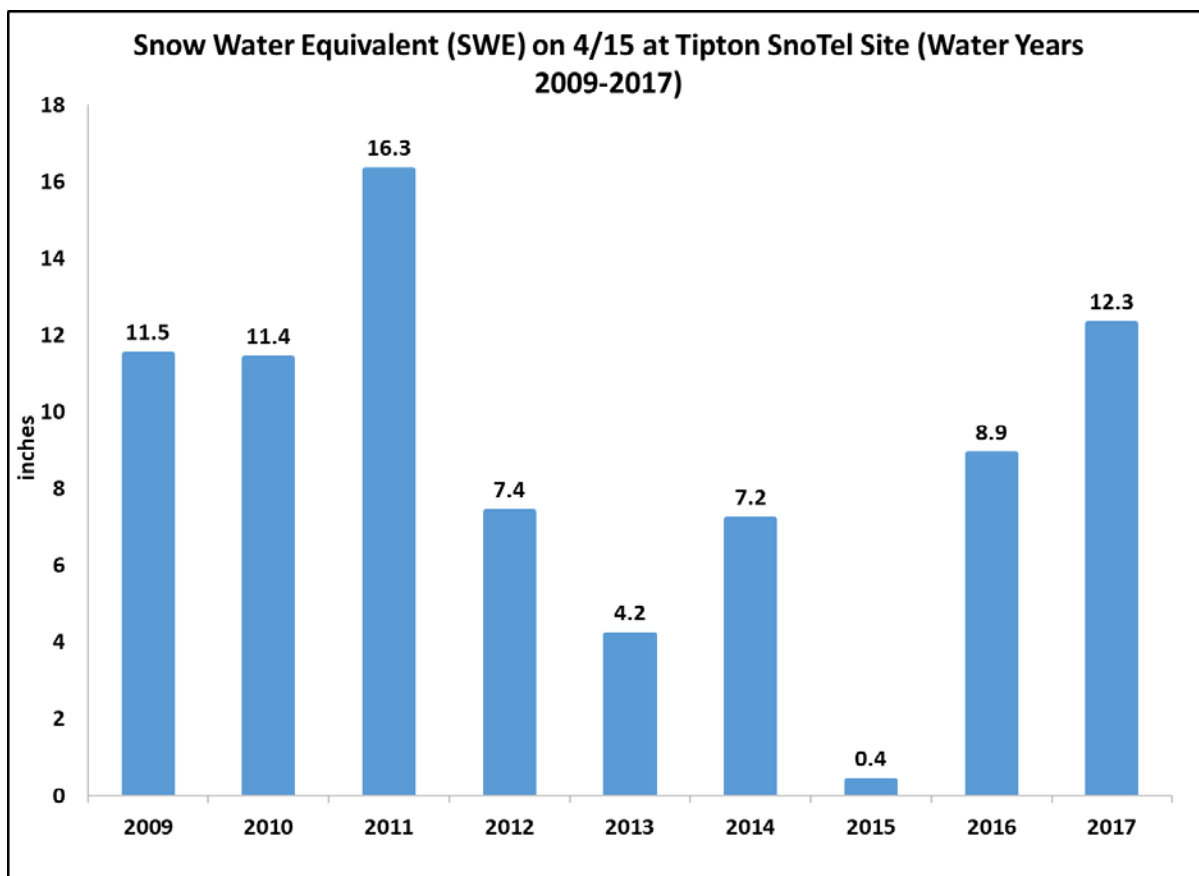


Figure 5. Snow water equivalent (SWE) on April 15 at Tipton SnoTel Site for water years 2009 to 2017.

The hydrologic regime has shifted from the past, with peak flows coming earlier and increasing while late season baseflows are diminishing. Decreased snowpack and increasing spring temperatures, which hasten the onset of snowmelt during spring, shift the timing and magnitude of discharge in the MFJDR. This results in higher peak flows earlier in the spring, and lower base flows during summer. Summer base flows in the Blue Mountains have declined 21-28% between 1949 and 2010, possibly due to changing climate conditions (Safeeq et al. 2013). The years of high and low SWE coincide with the highest and lowest monthly discharge recorded over the last 10 years in the MFJDR (Figure 4; Figure 5; Figure 6). These fluctuations in precipitation directly influence streamflow conditions in the MFIMW (Figure 6).

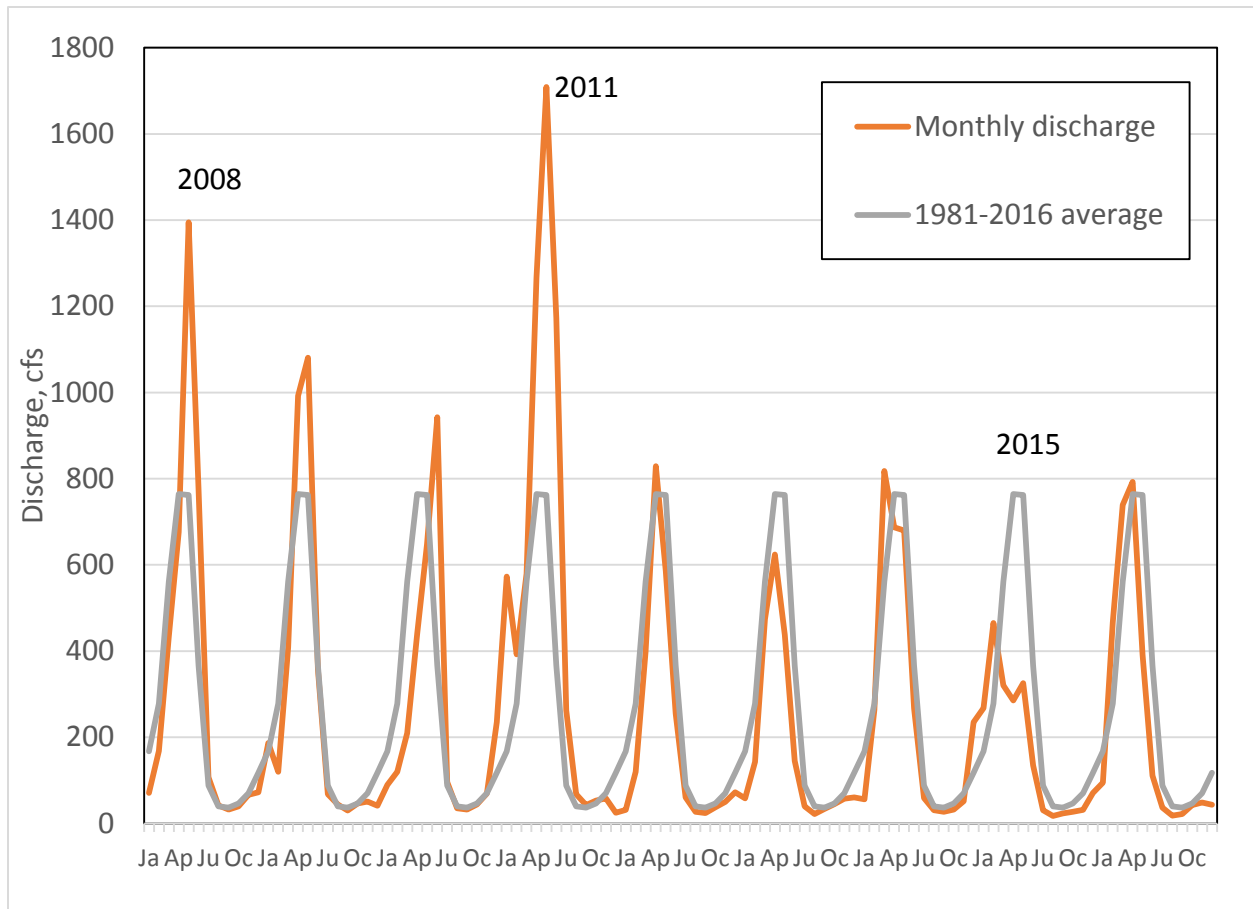


Figure 6. Monthly discharge, Middle Fork John Day River at Ritter. Note higher flows during 2008-2011, and lower flows in later years. Also note that actual discharge is below the long term average during late summer months on most years.

Historic and Current Land Use

Over the past two centuries, the MFJDR incurred significant post-EuroAmerican settlement impact from beaver trapping, road building, clear-cut logging, fire suppression, channel re-routing, floodplain/wetland drainage, grazing, and mining. Fortunately, the most damaging of these practices have since been curtailed and the watershed has good recovery potential. One of the most dramatic changes was dredge mining of a large portion of the MFJDR in the 1930s, near what was then referred to as the Oxbow Ranch, resulting in destruction of floodplain vegetation and soils and a straight, trench-like channel. This change has been largely remedied by building a new meandering channel in the Oxbow Phase 2, 3, 4, and 5 projects in 2012-16.

Implicit in stream restoration is the notion that there is a range of reference “pre-EuroAmerican settlement” ecosystem conditions, and that one can evaluate the degree of departure from this range in order to quantify ecosystem degradation or improvement. However, defining a

specific, pristine “reference” condition for a watershed is untenable because natural disturbance processes have continually shaped river systems over time (Mann 2011). Metrics of restoration success should not be based on an imaginary static condition that once existed, but focused on re-establishing dynamic natural ecosystem structure and function. These functions include riparian biodiversity and natural plant community regeneration, nutrient cycling between the floodplain and channel, maintenance of natural channel morphology through hydraulic processes, and resilience to natural disturbance processes such as floods and fires (Kauffman et al., 1997; Palmer et al., 2005; Williams and Reeves, 2006). Re-establishing and maintaining these natural processes is especially important to ecosystem resilience as the Pacific Northwest faces impacts from a changing climate.

With new perspectives on river ecosystems have come new paradigms in restoration approaches. This new approach is characterized by reestablishing natural processes that in turn do most of the restorative work in rivers and streams (Palmer et. al. 2014). However, this involves un-doing much of the river engineering manipulation that was performed in past decades, whose primary goal was to prevent channel processes from proceeding naturally.

Over the last 30 years, both public and private MFJDR landowners have been voluntarily working to improve watershed conditions. However, some of the measures employed were in fact deleterious and not beneficial to the watershed. Perceived impacts from stream erosion and incision in the MFJDR spurred USFS to install many log weirs in streams on public forest land, especially in Camp Creek, a major MFJDR tributary. While these structures successfully prevented bed erosion and incision, they had negative effects to salmonids such as limiting fish passage, lateral erosion and widening channels, trapping sediment, and inhibiting natural pool formation. Subsequent scientific studies on log weirs revealed that these structures did not mitigate any limiting factors for salmonids, nor increase salmonid abundance, as it had been hypothesized that they might do (Reeve et al. 2006; Beschta et al. 1991; Wissmar et al. 1994). Since log weirs potentially impeded juvenile salmon passage in Camp Creek and limited habitat complexity, their removal was a major focus of restoration in that watershed.

Another common measure implemented in the last 30 years to reduce stream bank erosion was bank stabilization with rip-rap and rock barbs. These structures were installed on several miles of the MFJDR, especially in the Forrest Conservation Area (FCA). Bank stabilization structures were installed to prevent lateral channel migration and minimize erosive processes. While successful in preventing lateral channel migration, these measures unintentionally negatively impacted salmonid habitat in streams, which is actually supported by channel migration. Bank stabilization measures inhibit meander development, preventing the formation of large

meander bend pools, and disrupt the natural processes essential for riparian vegetation on stream banks (Beschta et al. 1991). The removal of log weirs, rip-rap, and rock barbs will reestablish natural processes and with them natural bank conditions, channel sinuosity, and pools.

Formerly a major timber-producing watershed, the upper MFJDR was once home to the company mill town of Bates. The area around the former townsite and mill of Bates has also experienced change. Bates is located at Bridge Creek, the junction of a crucial coldwater tributary with the MFJDR. Bates Pond, the mill pond built by the timber company in the early 1900s, elevates Bridge Creek temperature by increasing the surface area exposed to sunlight and slowing the flow of water before it reaches the MFJDR. Elevated temperatures significantly reduce the ability of Bridge Creek to serve as a source of cold water to the MFJDR, and thermally blocks migrating salmonids' access to upstream spawning and rearing habitats. In 2000, the Bates Pond Fish Ladder partially restored fish passage on Bridge Creek, reopening 7.3 miles of spawning and rearing habitat for steelhead. In 2008, OPRD acquired the Bates mill site and pond from private ownership, creating a state park to commemorate local history. The OPRD is currently engaging local stakeholders and government agencies to find a solution to address the impact of Bates Pond on salmon habitat, while continuing to honor the logging history of the area.

Land ownership changes starting in the 1980s led to changes in resource management across the MFIMW study area. Starting in 1990 with the acquisition of the Dunstan Ranch by TNC, passive restoration was implemented as landowners installed riparian fencing to exclude cattle grazing. Also in 1990, a riparian fence was built on the Oxbow Ranch, which would later become the OCA. In 1996 a conservation easement was placed on the RPB Ranch after it was acquired by RPB, LLC. The shift in land management continued with the acquisition of the 1,022-acre Oxbow Ranch by TNC in 1999; ownership was transferred to CTWSRO in 2001. CTWSRO provided a conservation grazing lease and new riparian fence for John Forrest Meadow in 2000, and acquired this 786-acre property in 2002, renaming it the FCA. CTWSRO enrolled 254 acres across the two properties in a 15-year Conservation Reserve Enhancement Program (CREP) agreement, removing grazing and irrigation from these areas until 2020, and providing new riparian plantings and 180-ft riparian buffers.

Focal Species

Spring Chinook Salmon and summer steelhead are the focal species of the MFIMW. Mid-Columbia summer steelhead are listed as a federally threatened species (U.S. Office of the Federal Register 1999, 2006), while Chinook Salmon are not currently listed. These focal species were selected because of strong interest in anadromous fish recovery throughout the Pacific Northwest region. Below, we summarize life-history information presented in the John Day Subbasin Plan (CBMRCD 2005) and elsewhere.

Steelhead

The John Day subbasin contains one of the few remaining summer steelhead Major Population Groups (MPGs) in the interior Columbia Basin that have not been influenced by direct hatchery introductions. Within this MPG the Interior Columbia Technical Recovery Team defined five populations. Steelhead in the MFJDR compose one population in the Mid-Columbia River Distinct Population Segment (DPS). Spawning, rearing, and migration corridor habitats for summer steelhead are all found in the MFIMW. Summer steelhead are the most widely distributed salmonid species in the watershed, occupying most tributaries and mainstem habitats.

Adult summer steelhead typically enter fresh water during the summer previous to the year they spawn. After returning, most adults spend the first winter downstream of the MFIMW. They begin entering their spawning grounds as the ice and snow melts and typically initiate spawning activity during March. Fry emerge from the gravel early in the summer and rear within the MFIMW as juvenile parr for 1-3 years before smolting during the spring and migrating downstream. They spend 1-2 years in the ocean before returning to freshwater on their spawning migration.

Spring Chinook

The spring run of Chinook Salmon in the John Day is included with the Mid-Columbia River Evolutionarily Significant Unit (ESU). Similar to steelhead, Chinook Salmon in the JDR have not been subjected to direct hatchery introductions. Chinook in the MFJDR compose one of the three populations in the JDR. Adult spring Chinook enter fresh water in April and migrate upstream into the MFIMW during May and June. The adults then hold and reach maturity in freshwater until they spawn in late August through late September. The MFIMW encompasses spawning, rearing, and migration corridor habitats for Chinook Salmon. Chinook distribution is more confined to mainstem habitats and larger tributaries, although juveniles often migrate into cool-



Photo 6. Chinook Salmon parr.
Courtesy of ODFW.

water tributaries during warm summer periods. Chinook emerge from the gravel during early spring and rear in freshwater for one year before smolting the following spring and migrating to the ocean as age-1 juveniles. They spend 1-3 years in the ocean and return as age 3-5 adults.

Limiting Factors

Limiting factors are the conditions that inhibit populations of organisms or ecological processes and functions relative to their restoration and protection potential (CBMRCD 2005). Chinook Salmon and steelhead abundances in the MFJDR basin are limited, in part, by freshwater rearing habitat. The annual number of smolts produced per spawner is regulated by juvenile density, where relatively fewer smolts per adult are produced at greater adult spawner escapement levels within the MFJDR watershed (Bare et al. 2014). This observation of density-regulated abundance within the MFJDR suggests that 1) juvenile salmonid habitat quality and quantity is limiting salmonid production and 2) fish production should increase in response to juvenile habitat restoration. Below, we summarize specific limiting factors for each species, then describe some of the most pressing limiting factors in the MFIMW in greater detail. For additional information related to limiting factors in the MFJDR see CBMRCD 2005 and Carmichael and Taylor 2010.

Steelhead

The limiting factors affecting steelhead in MFJDR include habitat diversity, degraded floodplain, channel structure, altered sediment routing, altered hydrology, and water temperature (CBMRCD 2005; Carmichael and Taylor 2010). Table 1 displays the limiting factors identified for summer steelhead in the Middle Fork John Day Subbasin.

Table 1. Top quartile protection and restoration geographic areas with important restoration attributes as estimated by Ecosystem Diagnosis and Treatment model (EDT) (black), with additional attributes listed by the subbasin planners (gray) for Middle Fork John Day summer steelhead (modified from CBMRCD 2005, pg. 86).

MFJD Summer Steelhead

Geographic area	Geographic area priority		Attribute for restoration				
	Protection Benefit	Restoration Benefit	Flow	Habitat diversity	Sediment load	Temperature	Key habitat quantity
Big Creek	X	X					
Camp Creek	X	X					
Upper MFJDR	X						

Spring Chinook

For Chinook Salmon in the MFJDR, habitat diversity, sediment load, habitat quantity, temperature, and discharge were identified as significant factors limiting productivity (CBMRCD 2005). The plan identified a need for increased habitat complexity, such as areas with large woody debris (LWD). Table 2 contains the limiting factors identified for Spring Chinook in the MFJDR Subbasin.

Table 2. Top quartile protection and restoration geographic areas with important restoration attributes as estimated by Ecosystem Diagnosis and Treatment model (EDT) (black), with additional attributes listed by the subbasin planners (gray) for Middle Fork John Day spring Chinook (modified from CBMRCD 2005, pg. 103).

MFJD Spring Chinook			Attribute for restoration				
Geographic area priority	Protection Benefit	Restoration Benefit	Flow	Habitat diversity	Sediment load	Temperature	Key habitat quantity
Geographic area							
Big Creek	X	X					
Camp Creek	X	X					
Upper MFJDR	X	X					

Temperature

Salmonids are sensitive to stream temperatures above 18°C, resulting in depressed growth and survival, while sustained temperatures above 24°C have direct lethal effects (Bell 1991). The JDR basin Total Maximum Daily Load (TMDL) was approved in December 2010 to develop pollution control targets and improvement plans for impaired waters within the area (ODEQ 2010). TMDL targets of 18°C have been established for instream temperature in the MFJDR subbasins, and the UMFWG identified temperature as the most important stream attribute requiring restoration in the MFJDR. Temperature limits fish distribution, and therefore habitat quantity, during warm summer months. Forward-looking infrared (FLIR) and fish distribution surveys conducted during 2006 on the MFJDR indicated a two-order magnitude difference in parr density between the warm mainstem (19.5°C) and cooler tributary (15°C) habitats, suggesting that parr were using cold tributaries as thermal refugia to escape stressful or lethal temperatures in the mainstem. Surface water temperatures during 2003 FLIR flights on the

mainstem MFJDR exceeded 22°C throughout much of the range occupied by salmonids during cooler seasons of the year (Figure 7). Surveys for Chinook salmon in August and September 2007 revealed high pre-spawning mortality in the MFJDR subbasin due to warm stream temperatures (Ruzycki et al. 2008). Given this pressure on adult salmonids, parr growth and survival is depressed by high temperatures. These temperature and biological observations support other evidence that temperature is a highly significant, if not the primary, limiting factor for salmonid production in the MFJDR.

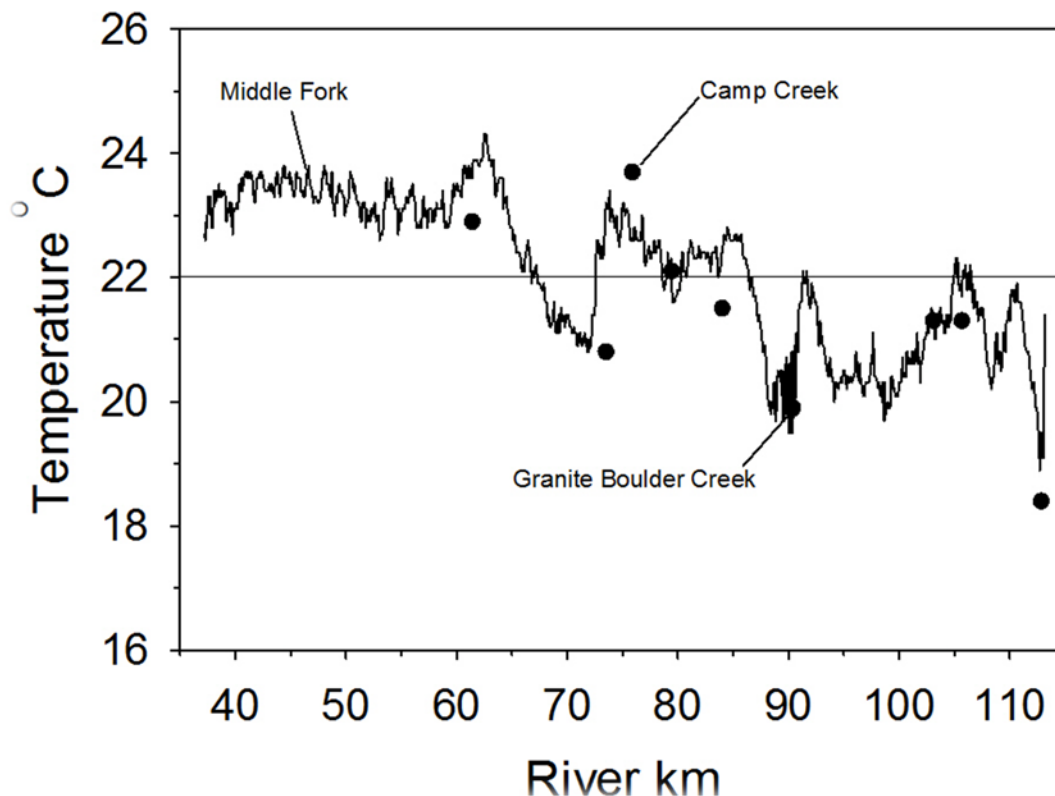


Figure 7. Longitudinal profile of surface water temperatures from thermal infrared surveys conducted during August 2003 by Watershed Sciences LLC. The horizontal line indicates the temperature where models have shown significant decline in parr survival. Temperature and location of important tributaries at their confluence are also shown. The river flows from right to left.

Habitat diversity

Habitat diversity refers to an array of complex habitat types supporting salmonid freshwater life stages. The distribution, dimensions, and quality of stream channel habitat units greatly affect the health of fish populations (Bjornn and Reiser 1991). Fish use pools, riffles, pocket water, off-channel backwaters, and other habitat types depending on species, life-stage, activity-level, and stream conditions.

Key habitat quantity

Key habitat quantity refers to the available physical area of suitable habitat required for each life stage for each species, accumulated across all life stages. Channelization of streams and rivers can affect almost all suitable habitat over the range of life stages. A major loss of just a few habitat types for some of the life stages would produce a limiting factor; for example, the loss of 60% of pool habitat, but no other habitat types, would create a limiting factor.

Sediment load

Sediment load refers to increases in delivery of sediment to the stream channel. Sediment loads from erosion can increase due to land use practices, or from isolation of the channel from the floodplain, eliminating important off-channel sediment storage areas and increasing the sediment load beyond the transport capacity of the stream. Actions such as logging or road construction can destabilize the landscape in high slope areas, increasing the frequency and severity of sediment loading. Increases in the frequency and magnitude of floods, and/or loss of floodplain vegetation, will also increase erosion. Increased sediment delivery to a channel increases the proportion of fine sediments in the bed, which can reduce the survival of incubating eggs in the gravel and disrupt benthic invertebrate production.

Altered hydrology

Reduced summer base flow discharge contributes to elevated water temperatures in the MFJDR. Both increased temperature and alterations in hydrology impact fish movement, survival, and growth. Juveniles migrating from unfavorably high stream temperatures in mainstem reaches to cooler tributary habitat are blocked during times of natural low flows or low flows due to high irrigation demands. Stream surveys of the distribution of salmonids in the MFJDR revealed that when mean daily stream temperatures exceed 22° C in the mainstem, juvenile Chinook either die or escape to cooler tributaries.

Restoration Efforts

Entities involved in restoration designed their restoration efforts to address the limiting factors identified through the Recovery Planning and Subbasin processes. These limiting factors have also helped to guide the development and implementation of the monitoring strategy for the MFIMW.

Many passive and active restoration projects of varying size and scope were implemented over the 10-year period of the MFIMW by various organizations. [The National Oceanic and Atmospheric Administration \(NOAA\) Restoration Center](#) defines active restoration as "on-the-ground" or "dirt-moving" activities, and passive restoration as actions that change management practices and use of landscapes. Examples of active restoration

in the MFIMW include channel re-configuration, riparian plantings, and installation of log structures. Examples of passive restoration include changes in grazing management. A restoration inventory identified 100 projects implemented in the MFIMW during the study period, with 30 of these projects on the mainstem MFJDR and 70 in the tributaries (Figure 8). Several projects were not included in the inventory because we did not have complete information for these projects. Therefore, this inventory is a conservative estimate of restoration in the MFIMW study area.

The USFS and their partners have implemented hundreds of upland restoration actions that were not captured in the formal restoration inventory, but which we wish to acknowledge here as important steps towards natural watershed process reestablishment. Current efforts in the MFIMW uplands focus on improving the health of low-elevation dry forests, reducing fire hazard, restoring functional fish passages, improving habitat for several wildlife species, and improving riparian and stream conditions.

The national Watershed Condition Framework (Potyondy and Geier 2011) addresses a long legacy of fire exclusion and timber practices that have created densely-stocked stands on public forest land. The Framework aims to strategically reduce fuel loads in USFS forests by thinning forests prescribed burning. These efforts also seek to limit insect outbreaks, reduce wildfire severity, and encourage prescribed fire use (Rainville et al. 2008; USFS 2013). Sensitive species whitebark pine (*Pinus albicaulis*) and quaking aspen (*Populus tremuloides*) are focal species of protection efforts. Stewardship contracting, which allows timber receipts to stay within the forest to fund restoration efforts, is a popular strategy on the Malheur National Forest (Rainville et al. 2008).

The restoration inventory in [Appendix A](#) lists each restoration project completed in the past decade, including the lead entity, restoration activities, the completion date, and total cost, if available. Based on the limiting factors described above, restoration projects were divided into 6 categories: fish passage, channel reconfiguration, instream habitat improvement, flow increase, upland management, and riparian fencing and planting. Each restoration project may address multiple limiting factors. Figure 8 and Table 3 summarize the number of projects, outcomes, project examples, and limiting factors addressed by each category of restoration activity. It is important to note that most restoration projects were multifaceted and consisted of several restoration strategies implemented within a given reach.

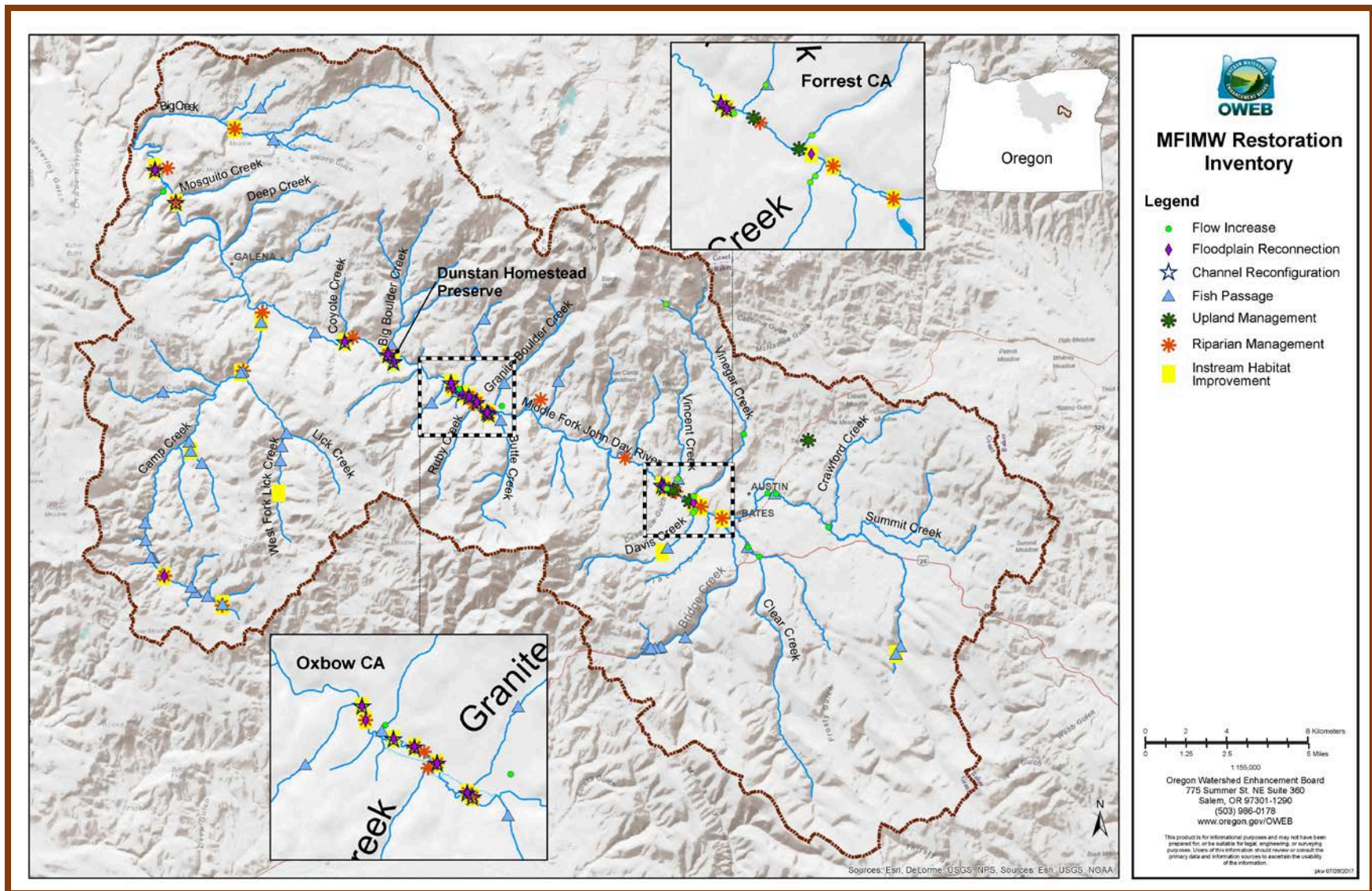


Figure 8. Map showing location of restoration actions. Insets show locations of restoration activities described in Table 3.

Table 3. Summary of restoration projects implemented during the 10-year study period.

Restoration Activity	Total Projects *	Outcomes*	Restoration Action Examples	Limiting Factors Addressed
Fish Passage	44	112 mi of habitat opened or improved, including 93 mi within tributaries to the MFJDR	Culvert removal, side channel reconnection	Temperature, key habitat quantity
Channel Reconfiguration	15	Improved over 35 mi of previously channelized stream, including 10 mi in the mainstem MFJDR	Reconnecting existing channels to old meanders	Temperature, habitat diversity, sediment load
Instream Habitat Improvement	29	Installed hundreds of complex wood structures; when coupled with other actions, worked together to enhance over 35 mi of habitat	LWD, ELJ, off channel habitat and pool development	Temperature, habitat diversity, sediment load
Flow Increase	16	Instream leases on 6 tributaries to the MFJDR provide over 6 cfs of water	Lease or sell water rights to keep water instream during critical low-flow periods	Temperature, altered hydrology
Upland Management	4	Quantified 1,621 acres treated; there are many more upland projects implemented that we were unable to quantify	Juniper removal, road removal or stabilization, aspen enclosures, plantation thinning	Sediment supply, habitat quality and quantity
Riparian Fencing and Planting	25	Planted native trees and shrubs along 15 stream miles and fenced over 21 mi of riparian habitat in the MFIMW study area	Riparian fencing, cattle exclosures, native vegetation planting	Temperature, habitat complexity, sediment loading

*Total Projects and Outcomes reported are likely an underestimation. Outcomes were reported at varying levels of detail. Many projects did not report outcomes.

Several areas of the MFIMW study area were the focus of extensive restoration efforts over the last 10 years (Figure 9). These areas include but are not limited to:

- Oxbow Conservation Area
- Dunstan Homestead Preserve
- Camp Creek Watershed

Oxbow Conservation Area

The Oxbow Conservation Area (OCA) is a 1,022 acre property owned by the CTWSRO. The multiphase Oxbow Tailings Project was initiated in 2011 and completed in 2016. The restoration project aimed to remediate the effects of 1940s gold dredging, in which a house-size dredge reworked all floodplain sediments and pushed the channel to one side of the valley, creating a straightened ditch flowing through a barren landscape of rock piles. To address this, the project included extensive habitat enhancement work: re-sorting dredge tailings and using them to create new, more natural instream habitat; removal/fill of existing channels that lacked fish habitat; extensive transplanting of existing vegetation; tree planting; seeding; fencing; bio-engineering; and installing large wood structures instream.

Phases 1 and 2, completed in 2011 and 2012, focused on merging Granite Boulder Creek (an important source of cold water) directly with the MFJDR, while filling in the artificial 'North Channel' that had been created during dredging. Previously, the creek had emptied into the North Channel, which caused its coldwater contributions to warm substantially by the time the North Channel reached the mainstem MFJDR. Phases 3, 4, and 5 were completed in 2014, 2015, and 2016, respectively. These phases focused mainly on re-meandering straightened portions of the river downstream of Granite Boulder Creek, while simultaneously enhancing and re-naturalizing the floodplain by adding large woody debris and native plants.

Due to the timing of the projects, only a small portion of the completed projects (Phase 1 and 2) was directly monitored. Therefore, limited results are included when the Oxbow Tailings Project is referenced. Modeling based on designs for Phases 3-5 predicts potential results of these phases which are reported in the temperature modeling section, Appendix I. In addition, due to this large-scale project being just completed, the impact of the later phases to fish population response was not assessed. Additional monitoring will help document this project's effects on fish population metrics over time.

The restoration actions at the OCA included construction of approximately 1.3 miles of mainstem channel and creation of more than 2,200 feet of alcoves and side channels to provide important habitat for juvenile salmonids and reconnect the river to the floodplain. The Oxbow Tailings Project comprised placement of 190 complex LWD structures including approximately 2,500 whole trees to enhance instream fish habitat. Dredge-mining had removed most of the topsoil, lowered the water table, and therefore made it very difficult for riparian plants to recruit naturally; as part of this project, considerable efforts were made to improve the riparian vegetation along the stream by installing 8,300 willow cuttings, planting over 17,000 trees and shrubs, and applying 2,150 pounds of native seed.

Dunstan Homestead Preserve

The Dunstan Homestead Preserve is a 1,199 acre property that was acquired by TNC in 1994 and will soon be transferred to the CTWSRO for long-term ownership and management. This property is situated approximately 3 miles downstream of the OCA and occupies 4.5 miles of the MFJDR and its tributaries. Since 2008, numerous restoration actions have been implemented to restore natural river function and processes and to enhance fish habitat in the MFJDR and its tributaries. In addition, cattle were excluded from the riparian area of the Dunstan Homestead Preserve since its acquisition by TNC in 1990.

The collective restoration actions at the Dunstan Homestead Preserve comprised treatment of more than 3,600 feet of the MFJDR, creation of two alcoves, and reconnection of two side channels that had been abandoned due to historic land management practices. Instream fish habitat complexity was improved by installing approximately 60 large wood and boulder structures to provide pool habitats and capture spawning-sized gravels moving downstream. In addition, fish passage was improved by removing one push-up dam and three concrete culverts to provide access to 0.3 miles of fish habitat.

Camp Creek Watershed

Camp Creek is a major tributary subwatershed (40,294 acres) within the MFIMW that hosts steelhead as well as juvenile Chinook rearing habitat and is predominantly within USFS boundaries. The USFS and many partners identified critical limiting factors affecting steelhead from 2004-2008 and developed the [Camp Creek Watershed Action Plan](#) (USFS 2008). This action plan identified biological and hydrologic function degradation from past management activities including logging, roads, beaver trapping, and past overgrazing. Some of the first restoration actions included replacement of stream culverts that had previously impeded fish passage and cut off access to habitat. Another action was removal of 151 legacy log weirs that were installed in the early 1980s along 11 stream miles. Removal of these legacy log weir structures in Lick and Camp Creeks accelerated restoration of channel structure and complexity to improve spawning and rearing habitat. Along with other identified priority fish passage, road, and channel/riparian improvement projects, these actions were key in improving sustainable fish population viability and overall watershed health in Camp Creek.



Photo 7. Log weir in Camp Creek.
Courtesy of ODFW.

Since time immemorial indigenous groups, including ancestors of today's Confederated Tribes of the Warm Springs, have made their homes throughout the Middle Fork John Day River watershed.

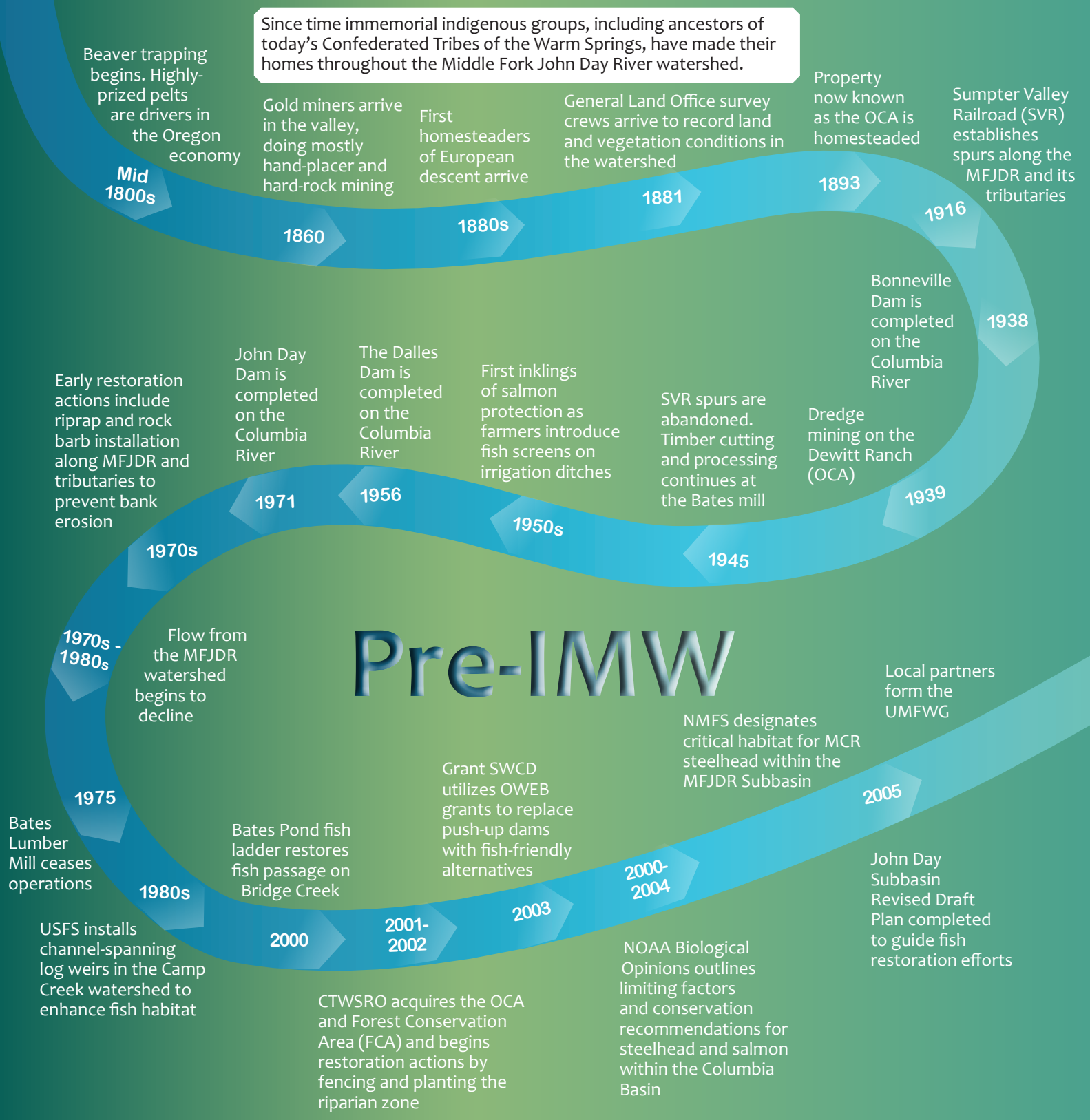
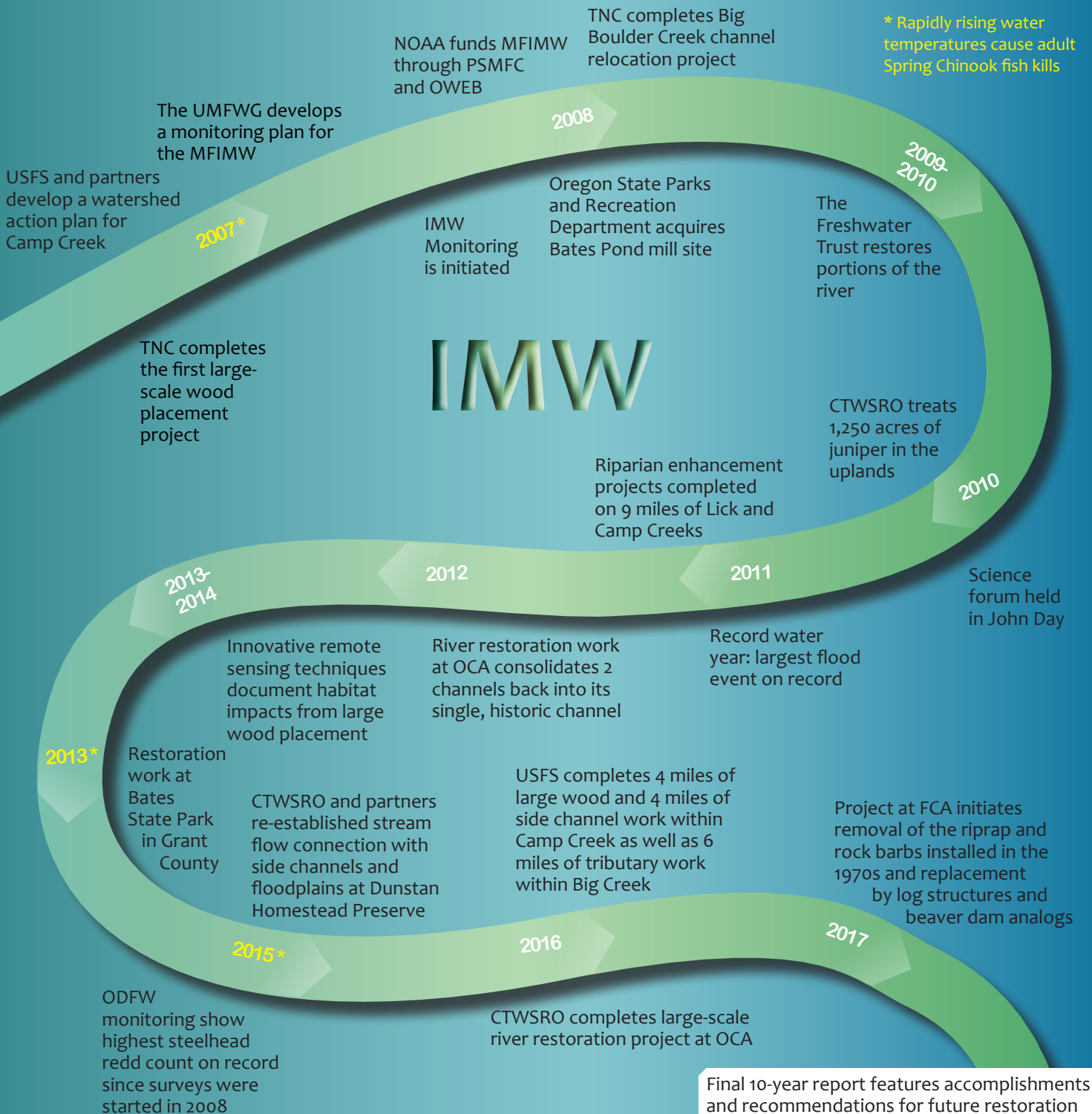


Figure 9. Timeline describing important events in the history of the MFIMW

Middle Fork John Day River Intensively Monitored Watershed (MFIMW)

Restoration Timeline

Since the 1990s, the Middle Fork John Day River (MFJDR) has been the focus of enormous and complex restoration efforts to repair the damage done by previous logging, gold dredging, and cattle grazing. Restoring habitat for Chinook Salmon and steelhead in the MFJDR is key to their population recovery throughout the entire Northwest region. Steelhead in the John Day River were listed as threatened in 1999, and Oregon Department of Fish and Wildlife (ODFW) survey information is available as far back as the 1960's. Fish habitat restoration is a complex process, with climate, ocean, and natural variability potentially influencing local fish population responses. This timeline highlights important cultural, scientific, and restoration milestones throughout the lifespan of the MFIMW.



Objectives and Experimental Design Framework

The objectives of the MFIMW were to evaluate the impact of the combined restoration actions on anadromous salmonid populations and to understand how specific types of actions impact habitat and fish metrics at the watershed, sub-watershed, reach, and restoration project scale. Table 4 and Figure 10 describe the scale of inference for each type of monitoring and/or modeling that was done and, if applicable, what type of restoration actions the monitoring focused on.

Within the MFIMW, several types of restoration and monitoring actions were implemented over a range of time frames. Given this complexity, a hierarchical design framework was used to evaluate the study objectives through multiple research projects. The hierarchical framework included a whole watershed scale evaluation of restoration actions and a nested experiment within the larger framework that targeted specific restoration actions in the Camp Creek subwatershed. The nested experiment, referred to as the Camp Creek and Granite Boulder Creek Experiment, was a Before-After-Control-Impact (BACI) design where restoration efforts in the Camp Creek watershed were evaluated against the control watershed, Granite Boulder Creek. However, analysis showed that Granite Boulder Creek did not possess the adequate physical and biological characteristics for a viable comparison. Therefore, a more suitable watershed, Murderer's Creek from the SFJDR, was substituted for Granite Boulder Creek as a control in this experimental comparison.



Photo 8. Fish Sampling. *Courtesy of ODFW.*

Table 4. Description of the scale of inference for each type of monitoring and/or modeling completed as part of the MFIMW and, if applicable, what type of restoration actions the monitoring targeted.

Monitoring Category	Methods and Approach	Restoration Actions Monitored	Scale of Inference*
Water temperature	Distributed Temperature Sensing (DTS)	Channel reconfiguration, instream habitat improvement, and floodplain reconnection	Project and sub-reach
Water temperature	Continuous temperature loggers	Various throughout watershed	Sub-reach, reach, subwatershed, and watershed
Water temperature	Water temperature modeling (HeatSource)	Simulation of riparian plantings	Watershed (MFJDR)
Groundwater	Level-loggers and wells	Channel reconfiguration, instream habitat improvement, and floodplain reconnection	Reach
Physical in-stream habitat	Variety of geomorphological methods including remote sensing, channel cross sections, and profiles	Channel reconfiguration, instream habitat improvement, and floodplain reconnection	Reach
Physical in-stream habitat	Variety of geomorphological methods including remote sensing, channel cross sections, and profiles	Individual log structures	Individual project (sub-reach, channel unit)
Physical in-stream habitat	PIBO-specific habitat condition monitoring protocol	Instream habitat improvement, riparian fencing, and planting.	Subwatershed (Camp Creek)
Physical in-stream habitat	PIBO-specific habitat condition monitoring protocol	Channel reconfiguration, instream habitat improvement, floodplain reconnection, and riparian fencing and plantings	Watershed (MFJDR)
Economic impact of restoration	Specially developed set of metrics to reflect outcomes and community economic health	Various throughout watershed	County-wide impacts of watershed-wide restoration in MFJDR
Fish	Salmonid productivity metrics including: Adult and juvenile salmonid abundance, distribution, smolts-per-spawner, and survival	Various throughout watershed	Watershed (MFJDR, control watersheds)
Fish	Salmonid productivity metrics including: Adult and juvenile salmonid abundance, distribution, smolts-per-spawner, and survival	Log weir removals	Subwatershed (Camp Creek/Granite Boulder BACI experiment)
Fish	Salmonid life cycle model	Simulation of riparian fencing and plantings, and instream habitat improvement	Population/watershed
Riparian habitat	Wild ungulate browse impact on plant growth and survival	Riparian fencing and plantings on CTWSRO conservation areas	Reach
Riparian habitat	Vegetation state-and-transition models	Simulation of riparian fencing and plantings, and instream habitat improvement	"Chinook reaches" and "Steelhead reaches" compose 33km and 129 km, respectively, of the entire upper MFJD stream network
Macroinvertebrates	Community composition, richness, comparison to reference sites, and % disturbance-adapted taxa	Multiple actions throughout watershed	Watershed (MFJDR, control watersheds) and reach

*See Figure 10, next page.

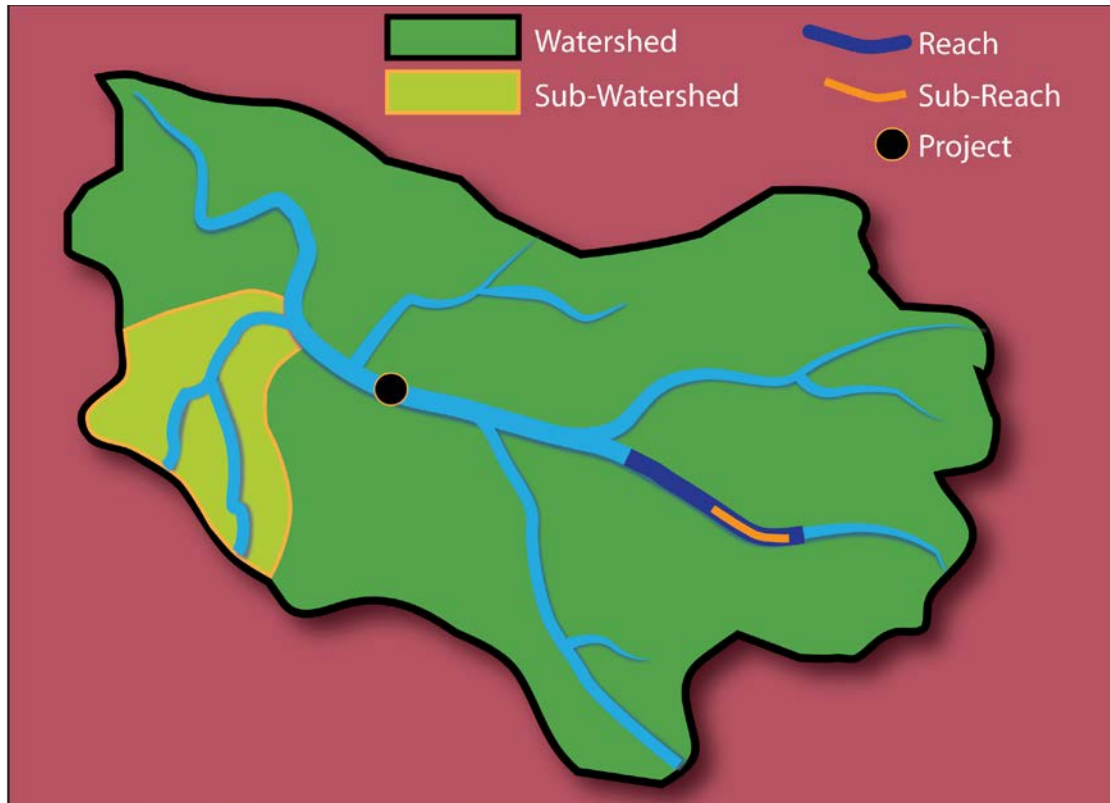


Figure 10. Different scales of inference in the MFIMW that are described in Table 4.

Watershed-scale salmonid productivity

Productivity of steelhead and Chinook populations was defined in this study as smolts produced per adult spawner. At the watershed scale, we measured responses of the MFJDR populations and compared these to two neighboring salmonid populations within the NFJDR and SFJDR. A BACI design was employed to provide spatial and temporal contrast and account for ocean and migration conditions. While some restoration was occurring in the control watersheds, we assumed that the amount of restoration implemented for the MFJDR would be more extensive. The SFJDR was used as the control watershed for steelhead, partially because it has similar steelhead population metrics to MFJDR (Figure 11). The SFJDR watershed, like the MFJDR, is dominated by public lands; unlike the MFJDR, not much large-scale active restoration has been done, although passive restoration with riparian cattle exclusion fencing has been implemented on a number of reaches. The NFJDR watershed was used as an adult Chinook control because, like the MFIMW study area, it is dominated by public lands, with little restoration in the upper watershed. We later decided to include the Upper Mainstem JDR (UJDR) watershed to increase our ability to compare Chinook productivity over time (Figure 12) due to the longer time-series of data on Chinook available in the UJDR.

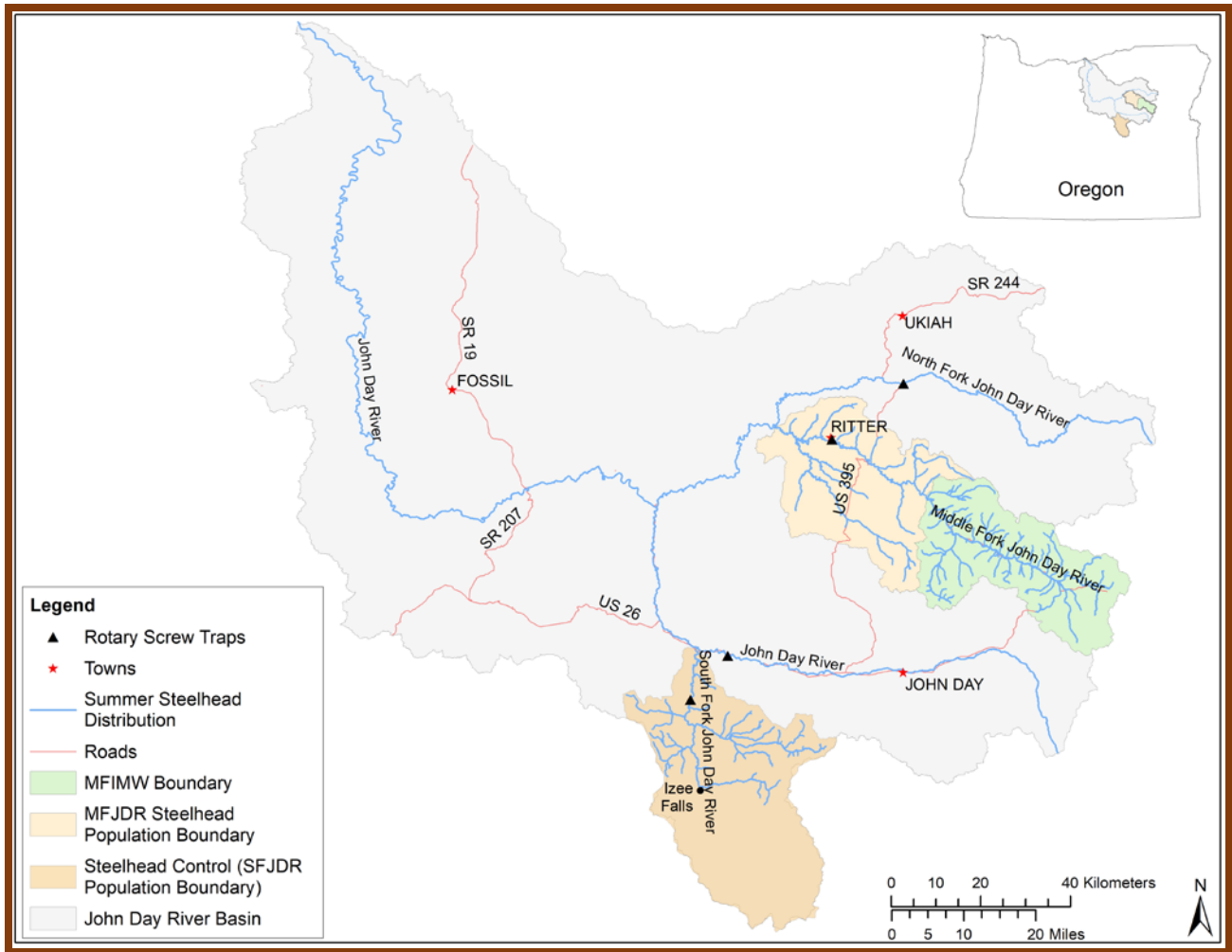


Figure 11. Map of the John Day River Basin showing the Middle Fork IMW, the entire Middle Fork John Day watershed, and the South Fork John Day River (control watershed for steelhead), site of the experimental BACI design.

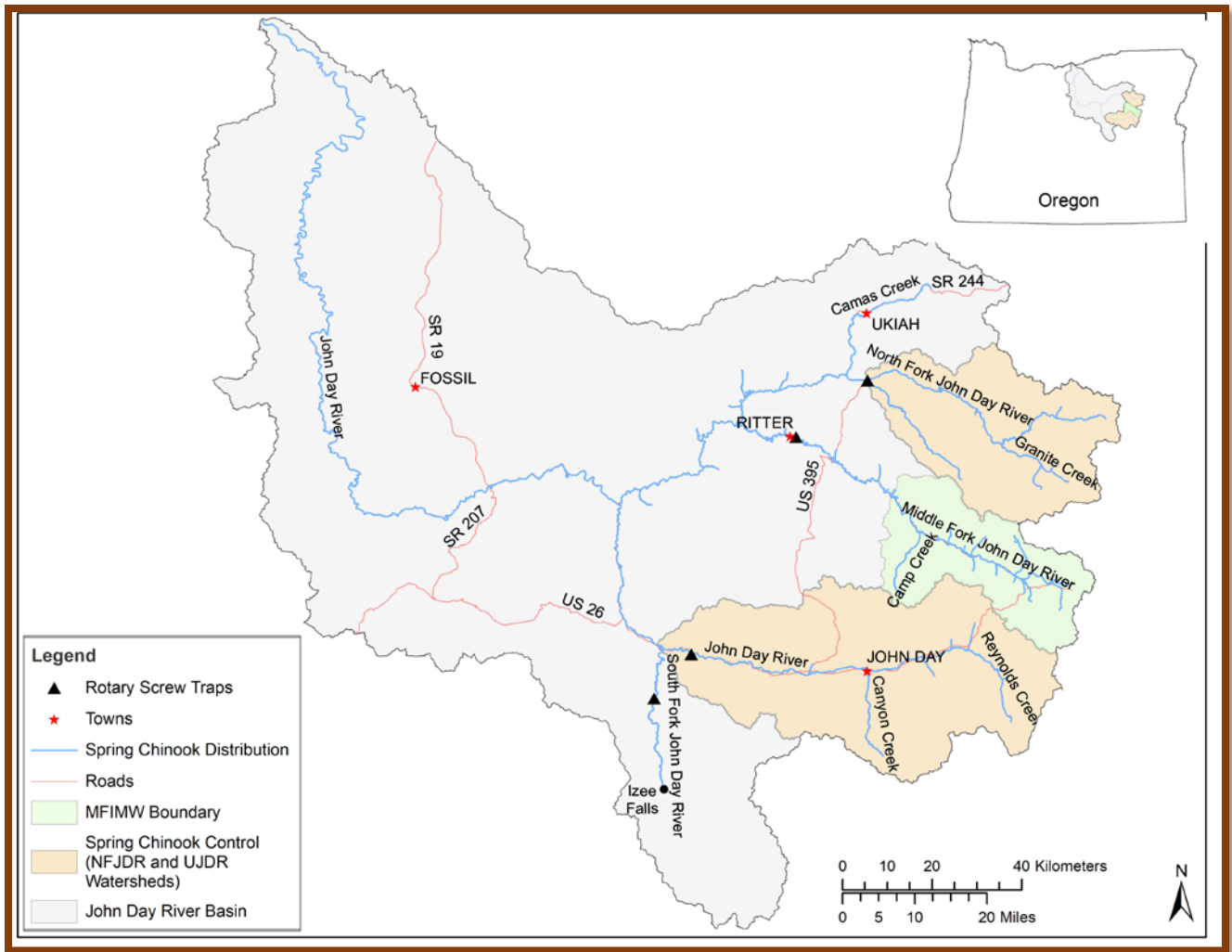


Figure 12. Map of the John Day River Basin showing the MFIMW, the entire Middle Fork John Day watershed, and the control watershed portions for spring Chinook Salmon, North Fork John Day River, and the upper portion of the Upper Mainstem John Day River, site of the experimental BACI design. Monitored control watersheds were delimited at their downstream extent by the locations of our rotary screw traps.

Camp Creek and Granite Boulder Creek BACI juvenile salmonid comparison

Within the MFIMW we compared the juvenile salmonid density, growth, and survival in two contrasting tributaries from 2008 to 2015. Camp Creek, a relatively warm tributary where extensive restoration actions were occurring, was compared to the colder Granite Boulder Creek where few restoration actions had been implemented. Both juvenile Chinook Salmon and juvenile steelhead production were expected to increase in Camp Creek after restoration actions were implemented. Unlike the larger watershed-scale evaluation, the Camp and Granite Boulder Creek comparison targeted the response of specific restoration actions within Camp Creek, investigating causal mechanisms between these specific restoration actions and fisheries outcomes.

During the course of the experiment, the ability of Granite Boulder Creek to act as a suitable control for Camp Creek was evaluated. This included monitoring for yearly temperature and salmonid redd density fluctuations in both Camp Creek and Granite Boulder Creek. A central assumption of a BACI design is the “parallel trajectories” assumption. This states that all environmental and biological covariates that may affect the response variable(s) must correlate in time between experimental and control areas. If this assumption is not met, other control watersheds must be leveraged towards the experimental analysis. Murderer’s Creek, a tributary of SFJDR, was examined as an alternative control watershed for this experiment, and was found to be a stronger candidate for the BACI comparative analysis. The BACI comparative analysis between Murderer’s and Camp Creek is described later in this report.

Steelhead life cycle model development

In a collaborative effort with the Integrated Status and Effectiveness Monitoring Program (ISEMP), a life cycle model (LCM) for steelhead was developed using regional habitat parameters from the Columbia Habitat Monitoring Program (CHaMP) and fish data specific to the MFJDR (McHugh et al. 2017). The modeling framework leveraged CHaMP habitat data to estimate reach-level juvenile rearing and adult spawning capacity as a function of physical habitat. This was scaled up using larger scale basin data (e.g. GIS, remote sensing) to provide an estimate of population carrying capacity for critical steelhead life stages. These values, along with other demographic data for the MFJDR population were built into a LCM to quantify the current status of the steelhead population. Two restoration scenarios were simulated; one that aims to enhance rearing capacity and survival for juveniles by providing cooler summer temperatures and another that aims to increase the population’s juvenile carrying capacity by increasing the structural/hydraulic complexity of select reaches (via large wood and structural additions). These simulations demonstrate a practical approach for

upscaling reach-level mechanistic models to inform population-level assessments and can inform large scale restoration prioritization and strategies for future IMWs.

Steelhead and Chinook population monitoring and associated modeling was the primary focus of monitoring efforts, as described in the preceding section; however, monitoring of habitat components was a key element to supporting the fish efforts. By monitoring ecosystem functions, processes, and structures that are known to impact steelhead and Chinook productivity, the MFIMW would better understand the causal mechanisms of potential changes in salmonid populations. The following section describes the focus of these monitoring efforts.

Geomorphology and physical habitat

Investigators monitored geomorphological responses of stream reaches to restoration actions. Many restoration measures, such as log structures, are expected to interact with flow and sediment to enhance natural geomorphic processes such as lateral movement, bed scour, bar aggradation and bank aggradation. These processes naturally improve aquatic habitat by creating and deepening pools, narrowing channels to create deeper summer flows and shading, mobilizing gravel beds to flush out accumulated fine sediment, increasing channel sinuosity, and modifying channel cross sections to produce a diversity of fast and slow, deep and shallow flows in a reach. Therefore, geomorphic monitoring was an important component of the IMW's research program. The main goal of the geomorphic monitoring was to test the hypotheses of the various restoration actions.

Two primary datasets on physical habitat were collected, each having different goals, hypotheses, and questions. Data was collected at three spatial scales: project level, reach level, and watershed level. The spatial scales are represented by habitat data: 1) collected at PIBO sites in Camp Creek and the mainstem MFJDR; by USFS PIBO staff; and 3) throughout six reaches and at specific project sites along the MFJDR, collected by University of Oregon (UO) investigators.

Physical habitat monitoring at the PIBO sites served two distinct purposes. The first set of 10 sites, in the Camp Creek subwatershed, focused on effects at the sub-watershed scale. This dataset exists to evaluate the physical effects of removal of stream spanning log weirs installed in the 1980's. The 5 control sites never had log weirs while the 5 experimental sites had log weirs removed. It is important to note that in addition to the log weir removals a variety of restoration actions, such as riparian plantings and instream habitat improvements, were implemented across the Camp Creek watershed. Therefore, when combined, these 10 sites collectively describe the habitat conditions status and trends for this watershed. The second set of 15 PIBO sites, located along the mainstem MFJDR, focuses on

watershed-level effects. It exists to evaluate the overall watershed study area's habitat trends. Change detected from these sites can reflect the individual restoration actions and other contributing factors such as: forest management, land use changes, high water events, wildfires, etc.

The third dataset, from UO investigators, focuses on effects of restoration projects mostly at the reach level, but also at the sub-reach and individual structure level, in contrast to the watershed-scale PIBO monitoring discussed above. UO scientists monitored changes in channel geomorphology, sinuosity, pool depth, bed material, and fish cover. The goal of the geomorphology and physical habitat monitoring was to evaluate whether the restoration projects are achieving specific goals for improvement of geomorphology and physical habitat, including changes in channel cross-section area, width, width:depth ratio, and sinuosity. Monitoring techniques included remote-sensing methods such as fine-scale, orthorectifiable aerial photography and structure-from-motion (SfM) using UAVs, and on-the-ground methods such as cross sections, longitudinal profiles, and gravel counts.

The UO monitoring took place over 7 years in six reaches. Three of these were project reaches where active restoration was done and three were control reaches where active restoration did not take place. UO investigators also monitored more fine-scale, localized changes in channel morphology at individual log structures. Processes shaping geomorphology and physical habitat in the study area have been influenced since 2000 by both active restoration and passive restoration.

Vegetation monitoring and modeling

Riparian plantings to provide shade have become a popular restoration strategy on temperature-limited river systems such as the MFJD. Yet this active management strategy often lacks effectiveness monitoring of planting success and survival. Such monitoring can help us understand how better to protect our restoration investments and achieve improved outcomes. In addition, varying strategies for restoring riparian communities are rarely quantified and compared to assess which strategy provides the greatest benefit. Wondzell et al. (2017) focused on addressing these gaps in knowledge by performing direct field monitoring of riparian plantings, and by building a state-and-transition model to compare riparian restoration scenarios. (Appendix I)

Investigators studied the effects of wild ungulate browsing on native woody riparian species (both hardwoods and conifers) planted as part of the overall effort to restore aquatic and riparian ecosystems within the MFJDR. Though browse by domestic livestock is often identified as the major limiting factor to restoration of native woody riparian vegetation, recent work suggests that wild ungulates may equally limit the reestablishment of woody plants. To restore shade and cool water temperatures to the temperature-

limited MFJDR, thousands of seedlings were planted in 2006 on the CTWSRO's Oxbow and Forrest Conservation Areas. However, planting has had limited success, even in areas fenced to exclude cattle. Investigators established small deer and elk browsing exclosures in areas previously planted with native riparian seedlings and cuttings, and remeasured the exclosures to examine how deer and elk browse may limit the success of riparian plantings.

Ecological modeling can complement field studies such as the browse study above by using on-the-ground measurements to extrapolate and predict where our restoration can do the most good. This is important because prioritization of restoration efforts and evaluation of their effectiveness across stream networks or large landscapes is challenging. Predicting potential management effects on riparian and salmonid habitat quality is best done within a common framework that conceptualizes complex ecological relationships which change over time, natural disturbance dynamics, and management actions.

To this end, investigators used state-and-transition models (STMs) to model historical, current, and potential future conditions of riparian plant communities and salmon habitat quality in the MFIMW study area. The goal of the project was to examine the likely long-term (50-year) outcomes of passive and active riparian restoration alternatives in stream reaches with the potential to provide high quality rearing habitat for cold-water dependent salmonids. Models therefore focused on reaches with high intrinsic potential to support spring Chinook.

Investigators used STMs to simulate potential temporal changes in riparian plant communities, stream attributes, and salmonid habitat quality. STMs identify conceptualized states, defined by riparian vegetation structure and composition, and transitions, defined as processes such as plant succession or natural and anthropogenic disturbances, within a channel geomorphic classification system (Montgomery and Buffington 1997, 1998). To apply these models, remote sensing data was used to delineate the stream network into reaches and associate each with a potential vegetation type. Current riparian vegetation composition and structure within each reach was mapped with spatial modeling techniques and high density LIDAR point data acquired in 2008.

Water temperature monitoring

Water temperature has been identified as the primary limiting factor for salmonids to be addressed in the MFJD subbasin, and many of the restoration projects implemented throughout the MFIMW study area were designed specifically to cool this temperature-limited system. The MFIMW monitored temperatures in two main frameworks which encompassed temporal and spatial scales at the opposite ends of the spectrum. The OSU program monitored temperatures at very fine temporal and spatial scales

with a high degree of accuracy using DTS. This was extremely useful for calibrating predictive models and monitoring at the project and sub-reach level. However, the cost and labor to deploy DTS throughout the entire MFIMW study area would have been astronomical. Standard temperature loggers therefore became useful to assess temperature trends over a larger spatial and temporal extent.

The temperature data were used in several other research efforts described within this section. The DTS data helped calibrate a HeatSource model (described in the Water Temperature Modeling section). The HeatSource model addresses the question of how restoration might affect water temperatures and aids in understanding the casual mechanisms between stream habitat restoration and changes in salmonid production at the watershed level. The temperature logger data helped monitor EPA-defined total maximum daily load (TMDL) for water temperature of 18°C in the MFIMW study area. Finally, the temperature logger data was useful to specific research projects such as the macroinvertebrate and fish monitoring, for which the high-resolution DTS data would have been inappropriate.



Photo 9. Water temperature site in Camp Creek. *Courtesy of NFJDBC.*

The coarse-scale temperature data were also used in a standalone fashion. At the observational level, water temperature loggers in the MFIMW were used to consider questions such as:

- Which tributaries appear to have a cooling or warming influence on the mainstem MFJDR?
- What is the temperature pattern in Bridge Creek?
- Does Bates Pond appear to have an effect on temperatures in Bridge Creek?
- How do temperature patterns in the MFJDR compare to the reference watershed SFJDR?

Between 2005 and 2016, 122 water temperature loggers collected data in the mainstem MFJD between Bridge Creek and Big Creek, in key restoration areas, above and below major tributaries, and in 26 tributaries; 74 of these 122 loggers are still collecting data in 2017. These probes measure water temperature hourly and are typically deployed in April or May and extracted in October and November. Seven-day average daily maximum temperatures and proportion of summer days with maximum temperatures above 18°C were calculated for mainstem MFJDR and Bridge Creek loggers.

Distributed temperature sensing

DTS monitoring evaluated localized responses of stream temperature to restoration actions such as channel relocation and reconfigurations. Specific monitoring objectives were: to determine the occurrence of cold water patches that can serve as thermal refugia for fish along the mainstem, evaluate temperature regimes in restored and unrestored mainstem sections, determine tributary contributions to mainstem temperature, and determine floodplain groundwater contributions to summer base flows.

Fiber optic DTS was used in addition to more traditional temperature loggers to assess stream temperature response to restoration because of DTS's ability to measure temperatures at extremely fine-grained spatial and temporal scales. Temperatures in streams can be highly heterogeneous, both spatially and temporally. Patches of cool water in space and time, known as thermal refugia, are important to salmonids which are temperature-sensitive species. Fiber optic DTS is capable of capturing this fine-scale heterogeneity by measuring 1 meter and 1 minute resolution with better than 0.1°C accuracy (Selker et al. 2006). Direct measurement of temperature as a response to restoration is important, but DTS measurements were also used as calibration input for predictive stream temperature models that take many variables into account in order to predict the short- and long-term effects of restoration actions on temperature.

DTS was implemented on the MFJDR at the OCA and FCA to observe peak summer temperatures, supplemented by groundwater contribution, stream discharge, and stream bathymetry across the conservation sites. The foci of this study were sections of the MFJDR where the restoration efforts would have immediate effect and were appropriate for the evaluation of longer temporal scale impacts of restoration such as the growth of woody plants.

Groundwater Monitoring

Groundwater was monitored in three main areas of the upper Middle Fork John Day in order to assess the hydrological impact of re-connection of the MFJDR to its floodplains via restoration activities such as active channel reconfiguration. The UMFWG was particularly interested in groundwater monitoring to inform if certain restoration activities helped increase water storage in the floodplain, how subsurface exchange and hyporheic flow were affected, and if the above mechanisms acted to augment late summer base flows and mitigate elevated water temperatures. Groundwater data also served along with DTS and climatic data to help calibrate the temperature models described in the previous section, as well as floodplain connectivity modeling and evapotranspiration modeling.

Since 2008, groundwater levels in the MFJDR floodplain have been monitored at approximately 40 groundwater monitoring points, each

equipped with a pressure transducer that logs one record per hour continuously. Groundwater wells are arranged in transects of 4-6 wells apiece, spaced 500m apart. Established transects run both perpendicular and parallel to the floodplain, in order to observe gradients of change. These transects are installed throughout the OCA, FCA, and RPB properties.

Water Temperature Modeling

Climate change-induced increases in air temperature, decreases in stream discharge, and loss of stream shade all have the potential to increase stream temperatures in the future. Stream temperatures are also influenced by anthropogenic changes to riparian vegetation that either increase or decrease stream shade. Maximum late-summer stream temperatures in the MFJDR already exceed lethal thresholds for cool-water salmonids in some summers and there is concern that future stream temperature increases will further threaten salmon and steelhead populations. But whereas the state-and-transition modeling described previously considered a variety of restoration scenarios and their long-term effect on riparian and salmon habitat quality, the STMs did not consider the long-term climatic impacts on temperature and stream hydrology. The HeatSource modeling effort described here complements and builds upon the STM accomplishments by also considering the long-term impacts of climate change. These predictive tools will better inform the prioritization of restoration actions in future climate scenarios and enable us to clearly identify the best management decisions that mitigate expected increases in stream temperatures.

The interactive effects of driving factors on streams temperatures are poorly understood. Loss of existing shade from natural or anthropogenic disturbances may exacerbate, or even multiply, the effects of warming air temperatures on streams in future climates. Conversely, increasing shade where it is currently limited or lacking could mitigate expected impacts from increased air temperatures. The advantage of mechanistic models such as HeatSource model is that it uses thermodynamic principles to simulate the stream's heat budget, accounting for heat inputs from various sources. This allowed investigators to examine how future changes in air temperatures, riparian shade, and stream discharge might affect the heat budget of a stream, and therefore its future temperature regime. The study also aimed to quantify relative contribution of each component to the stream's heat budget, allowing investigators to identify which management actions might be most effective in future climate scenarios.

Investigators focused on 37 km of the upper MFJDR, beginning upstream of the confluence with Clear Creek and ending downstream of Camp Creek. The 37-km study segment was extracted from Crown and Butcher's (2010) version of the HeatSource model, previously specifically calibrated for the MFJDR. This 2012 model version was used for analysis,

with conditions in 2002 as the base case for comparison with future stream temperatures.

HeatSource was used to examine alternative future scenarios based on down-scaled projections from climate change models and the composition and structure of native riparian forests. The 36 scenarios examined all possible combinations of future increases in air temperature, stream discharge, and riparian vegetation, given a variety of different scenarios for each individual factor. For stream temperature, there were 3 scenarios with increases of 0, +2, and +4 °C; for stream discharge, 3 scenarios with changes of -30%, 0%, and +30%; and for riparian vegetation, 4 scenarios consisting of post-wildfire with 7% effective shade, current vegetation with 19% effective shade, a young-open forest with 34% effective shade, and a mature riparian forest with 79% effective shade.

Streamflow monitoring

Two USGS gaging stations, one located at the community of Ritter, and one at the confluence of MFJDR and Camp Creek (Fig. 10), monitored water discharge of the MFJDR. Additional stage recorders were established to continually measure water surface elevation from the late spring to late fall. Stream discharge was also measured and used to develop a stage-discharge relationship curve. This data was provided to researchers to understand how discharge varied over the study period and for use in various predictive models and analysis. The location of the stage height recorders was established in conjunction with input from the MFIMW to allow data to be collected that would complement various monitoring efforts. This process resulted in some sites being moved over the course of the MFIMW study period.

Macroinvertebrate monitoring

Macroinvertebrate community composition is one common biotic index used by stream ecologists to identify stream stressors, report on effectiveness of management actions, or set restoration goals. Because macroinvertebrates also serve as an important food source for rearing juvenile salmonids in the MFJDR, they can be viewed as a potentially important causal mechanism linking stream restoration and salmonid production. While most restoration projects in the MFIMW were not planned directly with macroinvertebrates in mind, all projects did aim to increase overall ecological function and provide improved juvenile rearing habitat, and many,



Photo 10. Mayfly. *Courtesy of ODFW.*

such as riparian planting projects, may alter macroinvertebrate abundance and composition as a secondary benefit to their primary aims. The macroinvertebrate monitoring investigated if management actions are affecting the biotic integrity of the MFJDR by comparing benthic and drift macroinvertebrate communities among control, reference, and treatment (restored) reaches. The project also evaluated the strength of the relationship between macroinvertebrate communities, streamflow, and discharge. This relationship is important because many restoration actions aim to alter stream temperature and discharge, and because streamflow and temperature are central components in structuring macroinvertebrate community composition.

A set of 10 macroinvertebrate monitoring sites were selected from 15 existing PIBO monitoring sites (the watershed-level effects sites mentioned in the Geomorphology section) along the mainstem of the MFJDR. Drift and benthic samples were collected from these 10 sites on an annual basis beginning in 2010. The SFJDR was used as the control watershed; benthic samples (but no drift samples) were collected from an additional 10 sites in the SFJDR on an annual basis in 2010.

Investigators used taxa richness, abundance (as measured by dry biomass), and observed/expected (O/E) scores (a metric of how a site's composition compares to a reference site) to assess if benthic and drift macroinvertebrate communities changed following restoration in the MFJDR. To assess associations with streamflow and temperature, investigators used taxa composition (the O/E index), taxa richness, tolerance of taxa to disturbance, and drift macroinvertebrate biomass as response variables. Temperature and streamflow data were drawn from the temperature and streamflow datasets discussed elsewhere in this section.



Photo 11. Rotary screw trap. *Courtesy of ODFW.*

Socio-economic monitoring

A unique component of this MFIMW is monitoring the contribution of restoration projects to the socio-economic condition of the local community. This beneficial effect of the restoration work is what is often called the restoration economy. As ecological restoration activities have become more important and prevalent, their potential as a source of local job and wealth creation in rural communities has been increasingly recognized (Hibbard and Karle 2002). While the central focus of ecological restoration is healthy, functioning ecosystems, the concept of the restoration economy explicitly considers the local economy and community as well. Recognizing the importance of the restoration economy concept, at the inception of the MFIMW 10 years ago, OWEB commissioned the development and field-testing of a set of measures to enable socio-economic monitoring to complement bio-physical monitoring (Hibbard and Lurie 2009, 2010).

To develop metrics for monitoring socio-economic impacts in the local community, a first round of data was collected shortly after the beginning of the MFIMW in 2010. A panel of Grant County opinion leaders and residents helped develop the metrics to reflect locally specific issues and interests. The data collection effort was repeated in 2017. The researchers examined socio-economic impact using two types of metrics:

- Outcome measures estimate the contribution of MFIMW restoration work to the local economy, based on an inventory and analysis of completed projects; and
- Community indicators (e.g., population, employment, earnings) assess the overall socio-economic well-being of Grant County over time based on existing measures that are sensitive to the effects of restoration work.

Monitoring and Research Project Summaries

The following sections contain synopses of the monitoring and research projects implemented during the MFIMW. Each synopsis provides an abstract and a concise summary of the key findings, followed by relevant tables and figures. Readers can refer to Appendices B-M for complete project reports, additional information, and further detail for each monitoring and research project.

Steelhead and Chinook Salmon Monitoring and Evaluation

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Abstract

We monitored the response of steelhead *Oncorhynchus mykiss* and Chinook salmon *O. tshawytscha* to restoration actions in the Middle Fork John Day at several spatial and temporal scales. Monitoring included measures of abundance, survival, distribution, and productivity. Results at the watershed scale indicate limited response by the steelhead and Chinook populations. Freshwater productivity, measured as smolts per spawner, has not increased since inception of the IMW. Similarly, estimates of adult spawners and smolt abundance within the MFJDR, although variable, did not increase significantly when compared to the reference populations in the control watersheds.

Monitoring of juvenile steelhead and Chinook within the MFIMW indicated that abundance varied both seasonally and annually among sites and streams. Survival models for juveniles rearing within the IMW indicate survival was influenced by streamflow and juvenile density, and varied by season.

Our results suggest that although factors limiting freshwater production by salmonids were likely improved through restoration actions in the MFIMW, the primary limiting factor of temperature was not (to date) significantly altered. We continued to observe temperature limitation based on spatial and temporal habitat use by juvenile salmonids. The life-cycle model developed using our MFJDR juvenile steelhead data also confirmed the limiting influence of temperature on production. We conclude that elevated stream temperatures continue to limit the production of salmonid parr by limiting their summer distribution and causing poor early life-stage survival.

Key Findings

- Watershed-scale productivity for both steelhead and Chinook salmon did not increase significantly since the inception of the MFIMW period (Figures 1, 2).

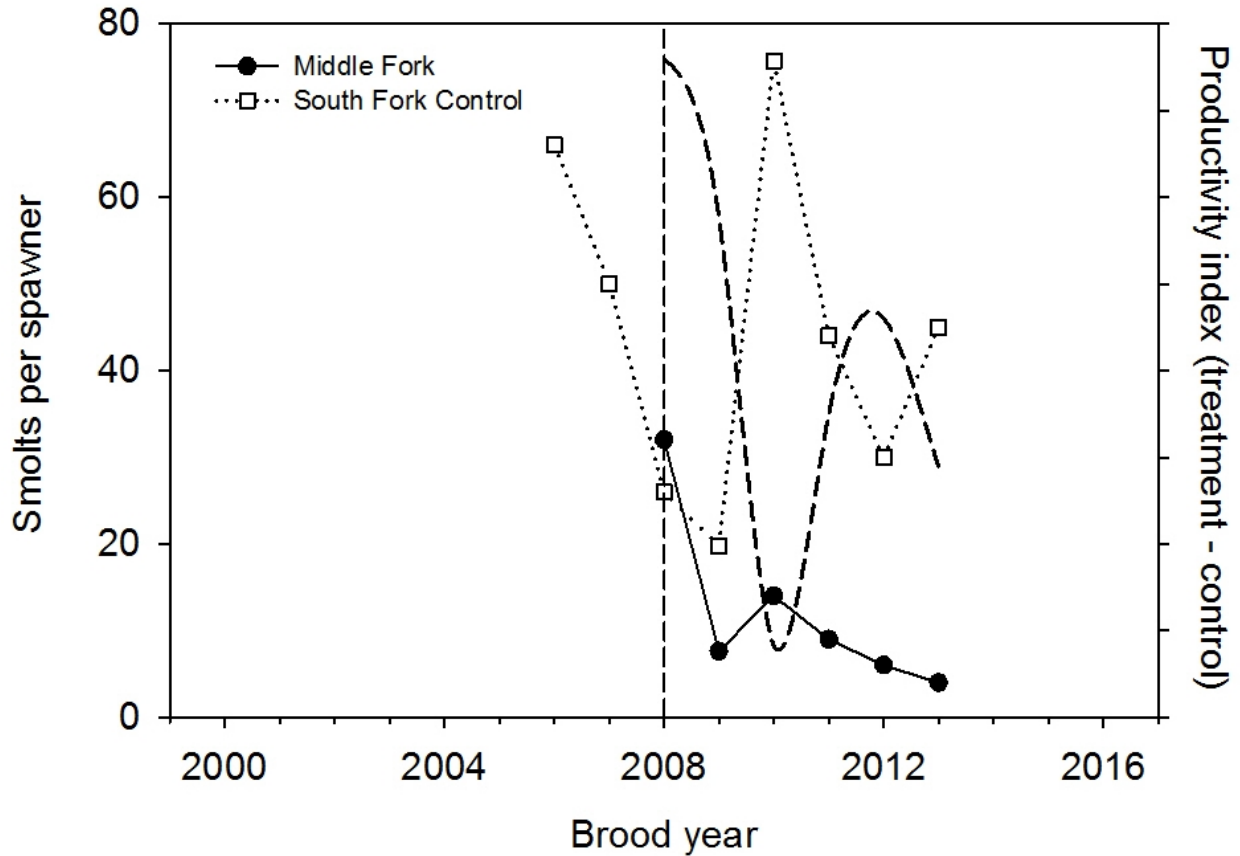


Figure 1. Trends in juvenile freshwater productivity for the Middle Fork and South Fork John Day steelhead populations. An index of the influence of the MFIMW restoration actions is shown (interpolated dashed line) as the difference of productivity of the Middle Fork (treatment) population and the South Fork (control) population. Vertical dashed line indicates initiation of the MFIMW experimental period (2008).

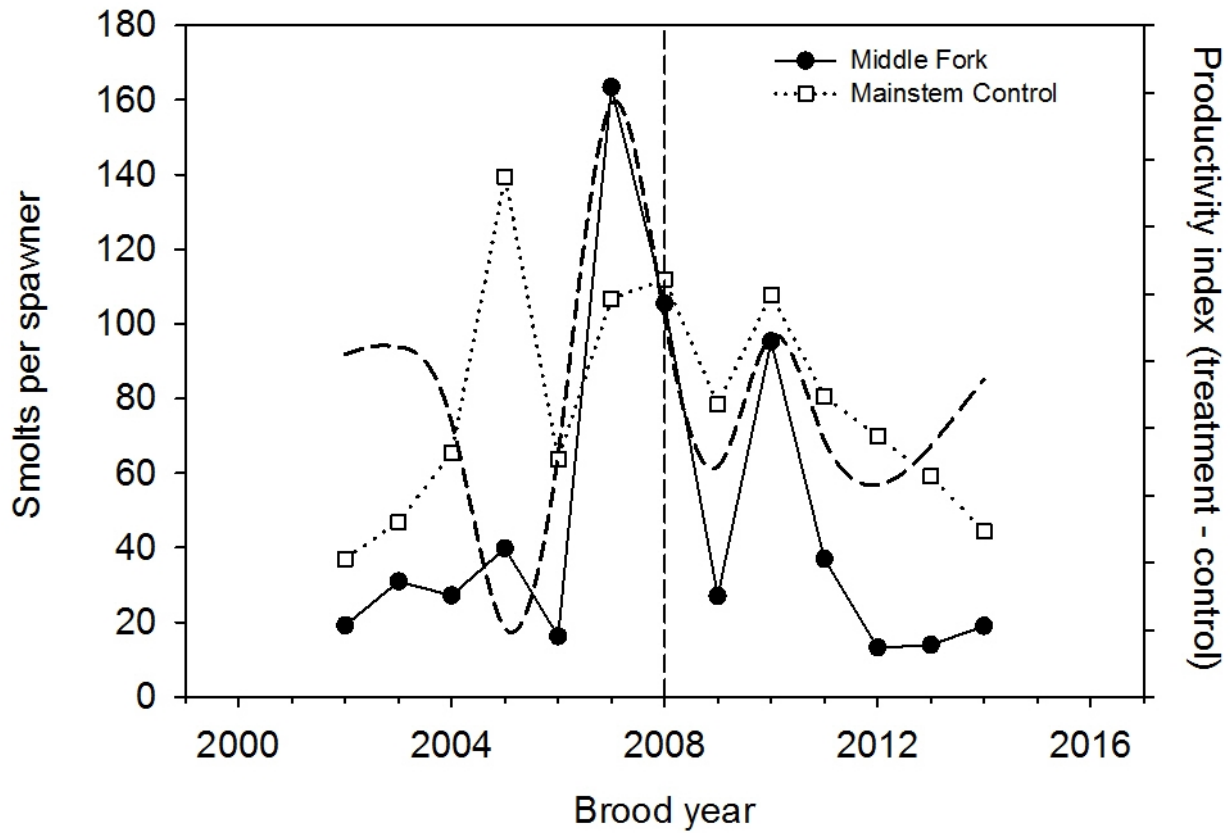


Figure 2. Trends in juvenile freshwater productivity for the Middle Fork and Upper Mainstem John Day Chinook populations. An index of the influence of the MFIMW restoration actions is shown (interpolated dashed line) as the difference of productivity of the Middle Fork (treatment) population and the Mainstem (control) population. Vertical dashed line indicates initiation of the MFIMW experimental period (2008).

- Elevated stream temperatures continue to limit production at the watershed scale by limiting summer parr distribution and causing increased mortality of adult and juvenile Chinook (Figures 3–5).

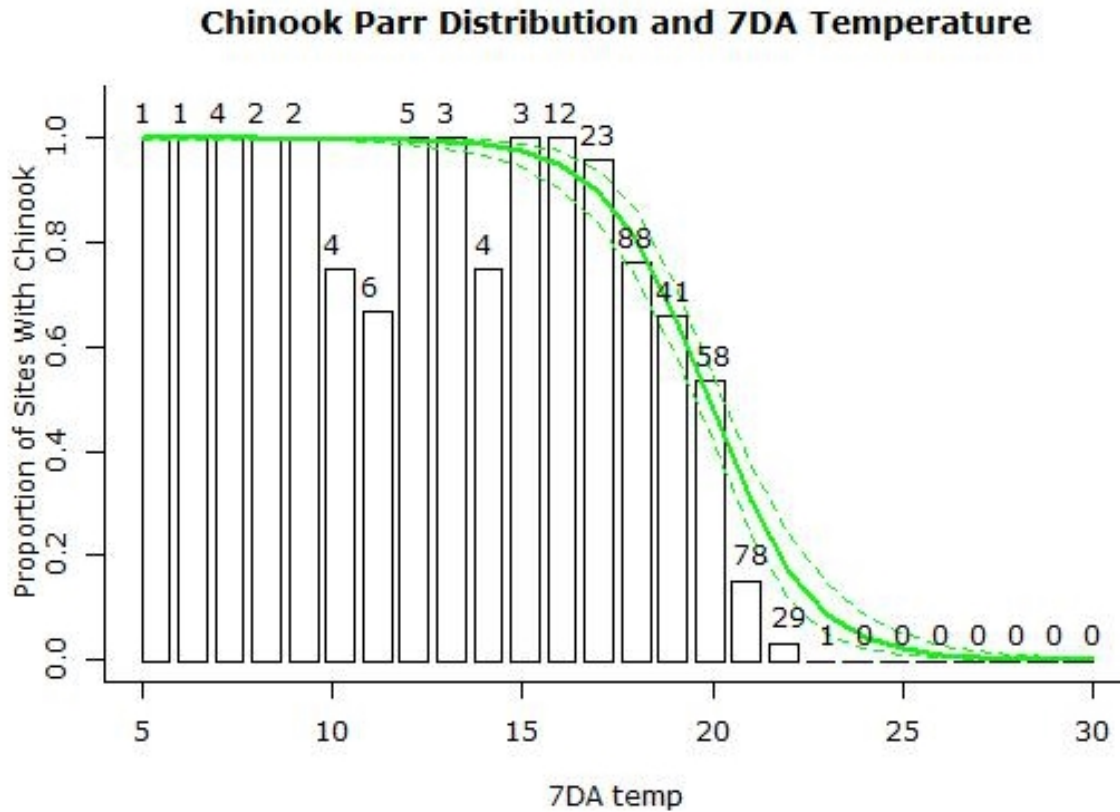


Figure 3. Logistic model results for Chinook presence or absence and 7-day average water temperatures within 1 km of sampling locations at sites within the mainstem MFJDR from 2011 through 2015. Bars are at 1°C intervals and represent sites with observed juvenile Chinook. Sample sizes for each bin are shown at the top of the bars. Model predictions for Chinook presence and $\pm 95\%$ confidence bounds are represented by the green line and dashed green lines respectively.

Steelhead Parr Distribution and 7DA Temperature

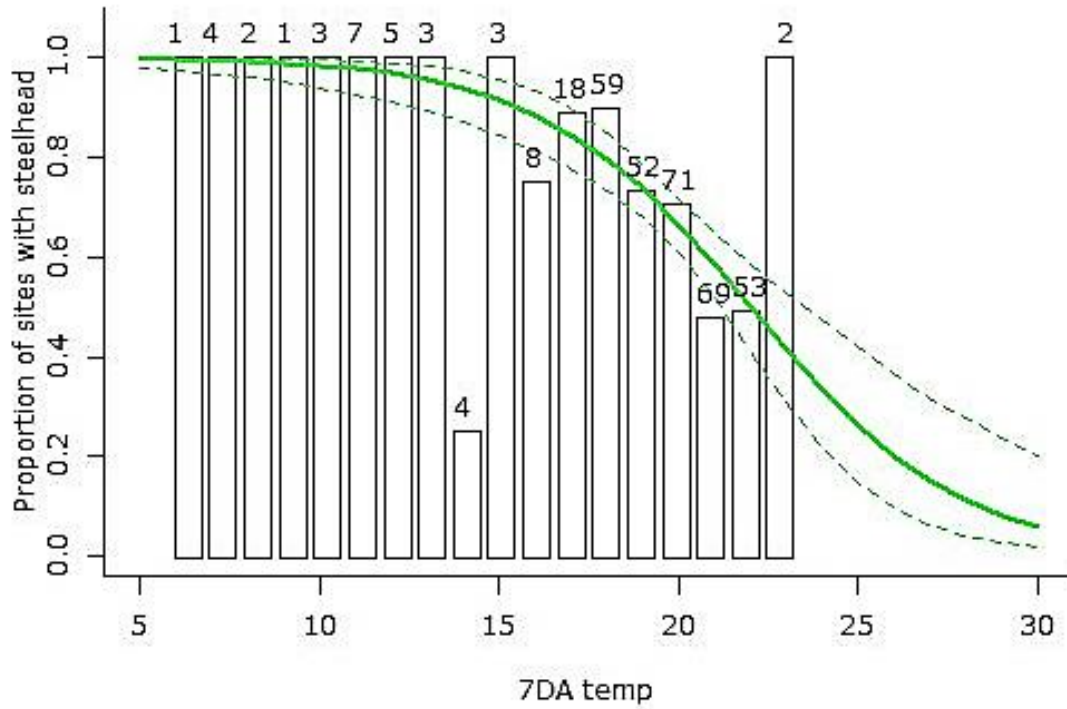


Figure 4. Logistic model results for steelhead presence or absence and 7-day average water temperatures within one km of sampling locations at sites within the mainstem MFJDR from 2011 through 2015. Bars are at 1°C intervals and represent sites with observed steelhead juveniles. Sample sizes for each bin are shown at the top of the bars. Model predictions for steelhead presence and ±95% confidence bounds are represented by the green line and dashed green lines respectively.

Middle Fork John Day Spring Chinook Escapement

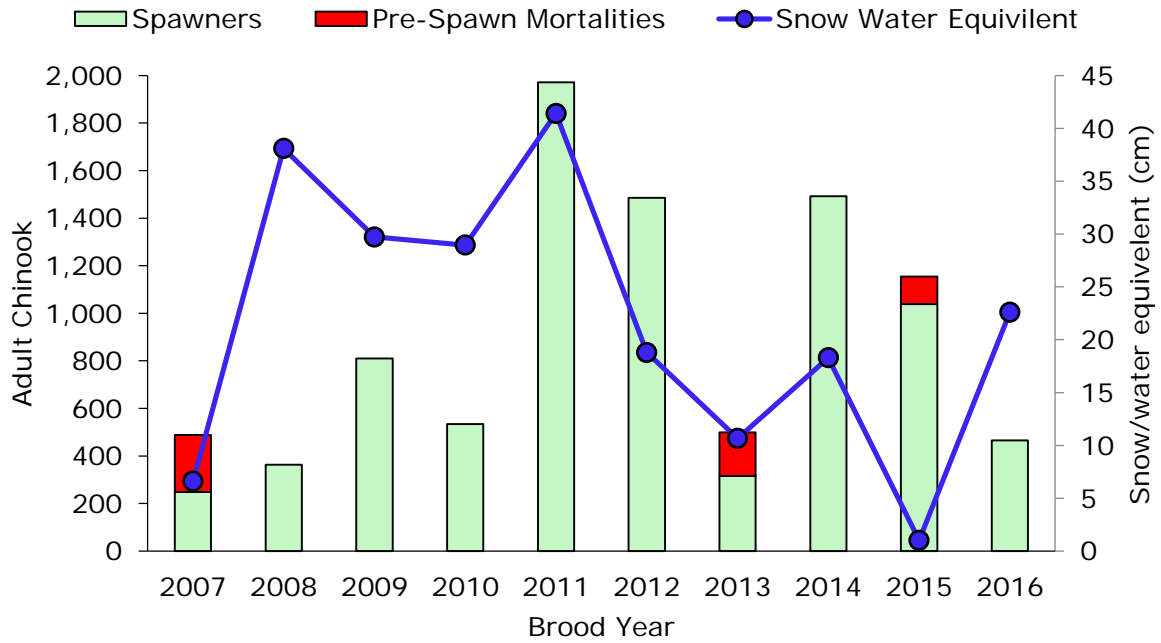


Figure 5. Total adult spring Chinook returns to the MFIMW and pre-spawn mortality estimates for 2007, 2013, and 2015. April 15 snow-water equivalent estimates from the Tipton SnowTel site are shown by year.

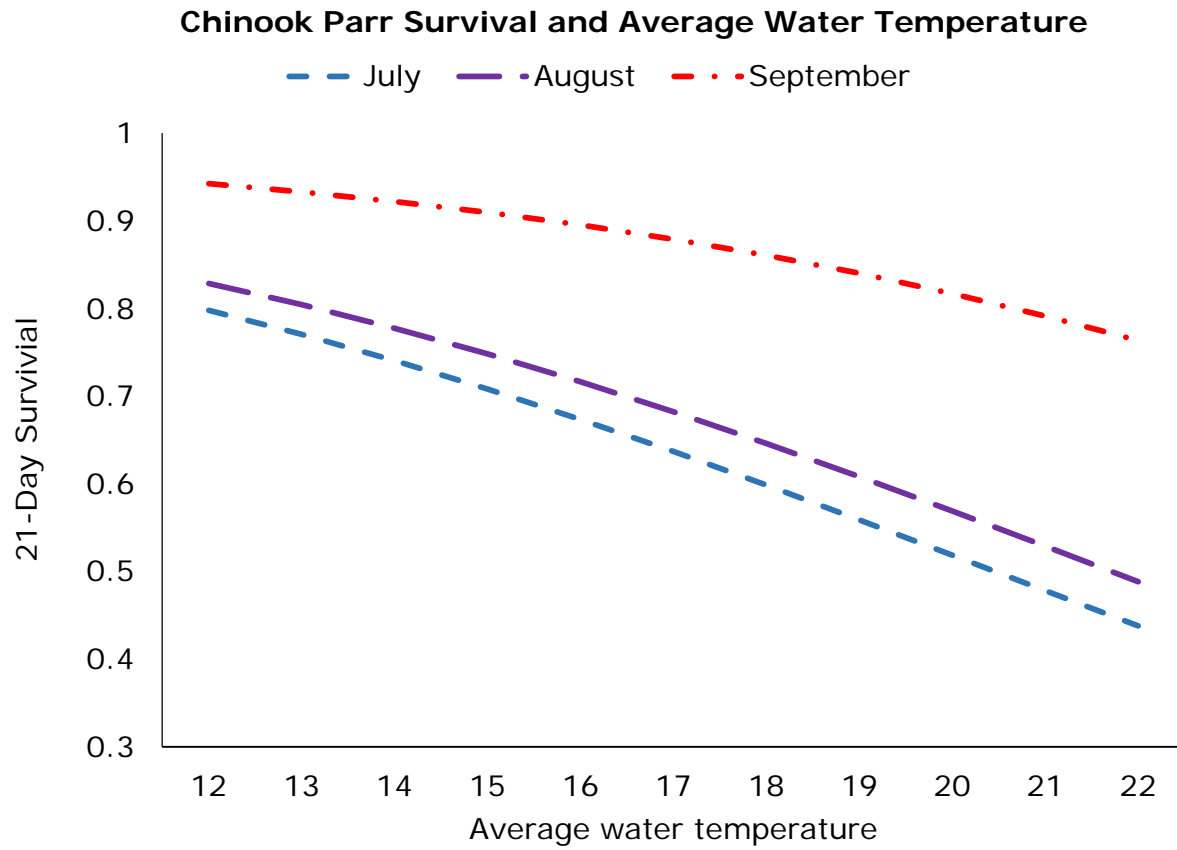


Figure 6. Model predictions of 21-day Chinook parr survival rates throughout the MFIMW relative to water temperature for the July, August, and September intervals.

- Restoration actions had less influence than individual site characteristics and environmental and density dependent conditions on Chinook juvenile Chinook and steelhead survival (Figures 7, 8).

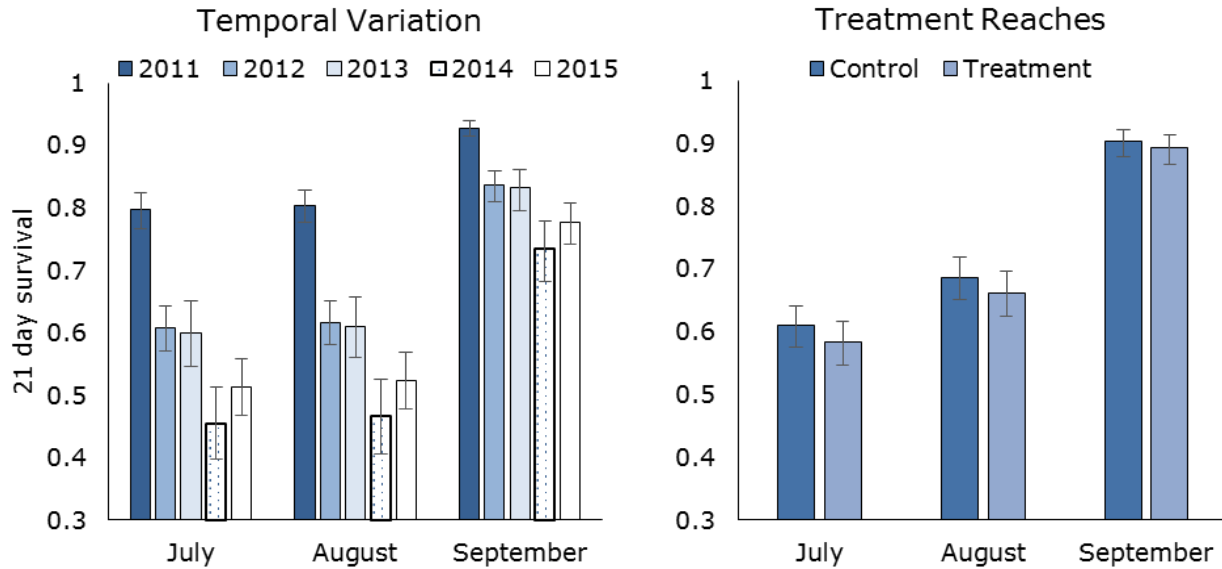


Figure 7. Best fit model parameter estimates of 21-day survival rates of Chinook juveniles at mark recapture sites throughout the MFIMW. Error bars represent 95% confidence intervals.

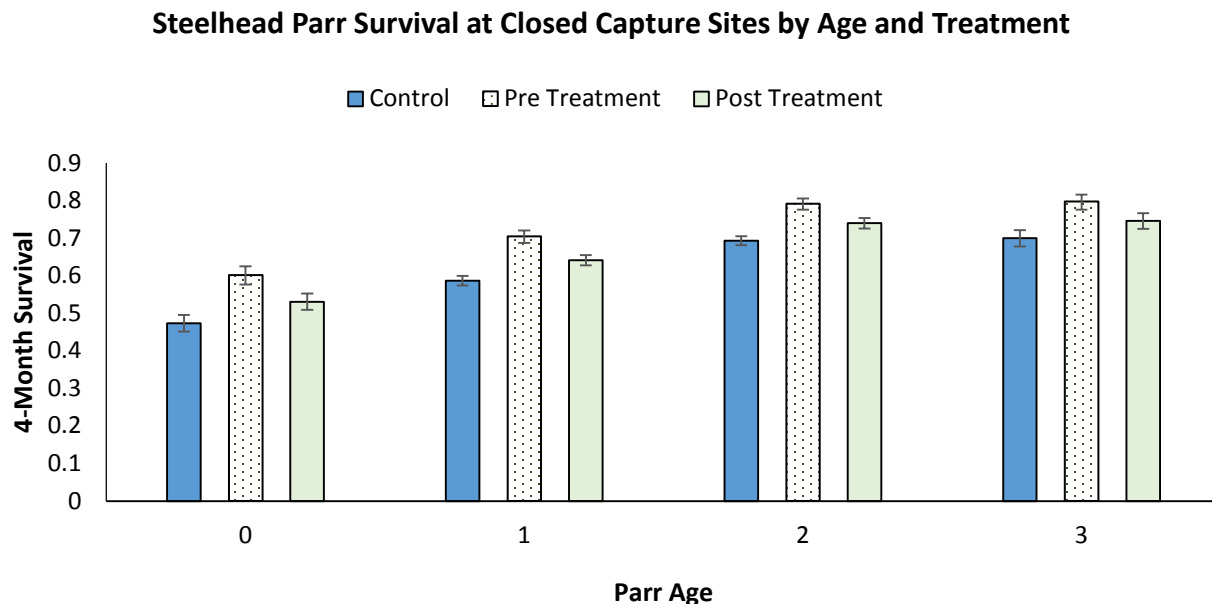


Figure 8. Age-specific steelhead juvenile survival estimates from 2008 through 2015 at locations within control and treatment tributary streams. Control streams include Murderer's Creek and Granite Boulder Creek. Pre- and Post-Treatment shows survival before and after the 2011 treatment in Camp Creek. Error bars represent 95% confidence intervals.

- Steelhead and juvenile Chinook survival was positively related to streamflow (Figures 9-10)

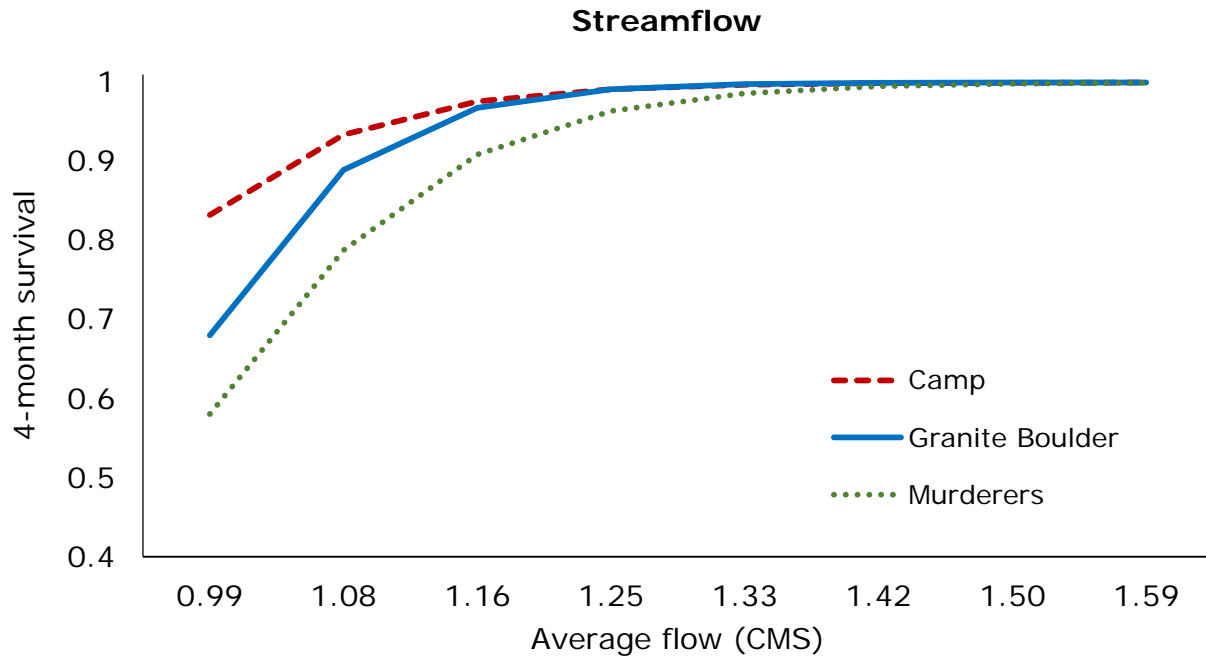


Figure 9. Model predictions for juvenile steelhead survival at three tributary closed capture sites and average streamflow during summer and fall for sites within the MFIMW. Streamflow units are cubic meters per second from the USGS gauge near Ritter, Oregon.

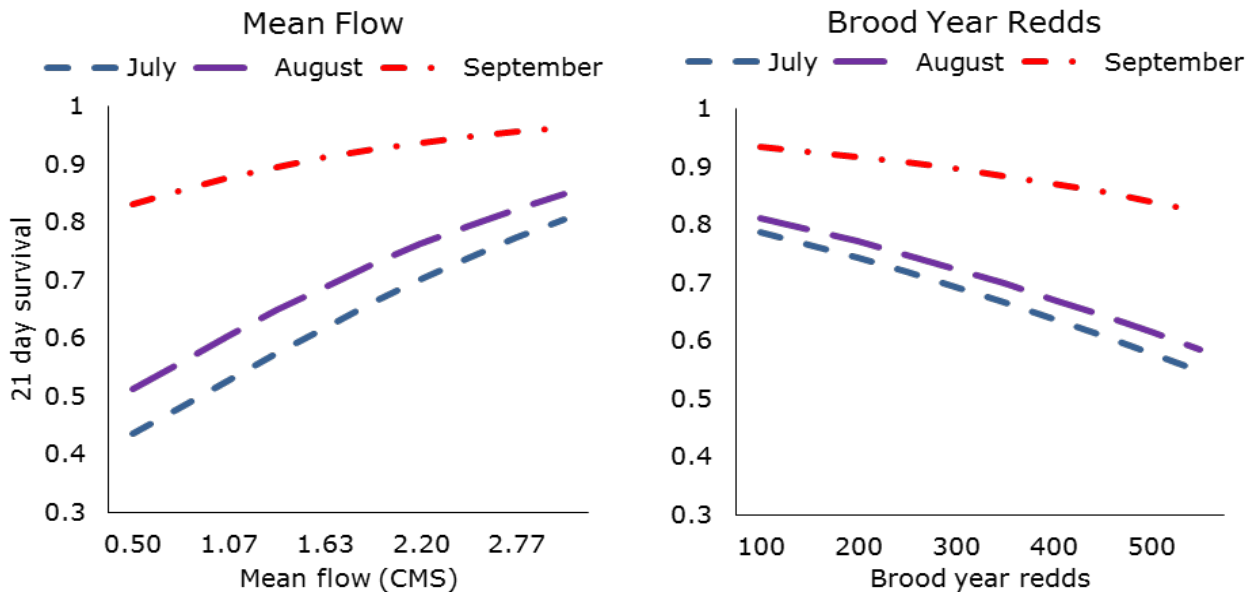


Figure 10. Model predictions of 3-week survival rates of Chinook for juvenile chinook during summer months as a function of stream discharge and brood year redd number as a representation of density dependence.

- Chinook juvenile parr growth varied more among streams and reach condition than by treatment (Figures 11, 12).

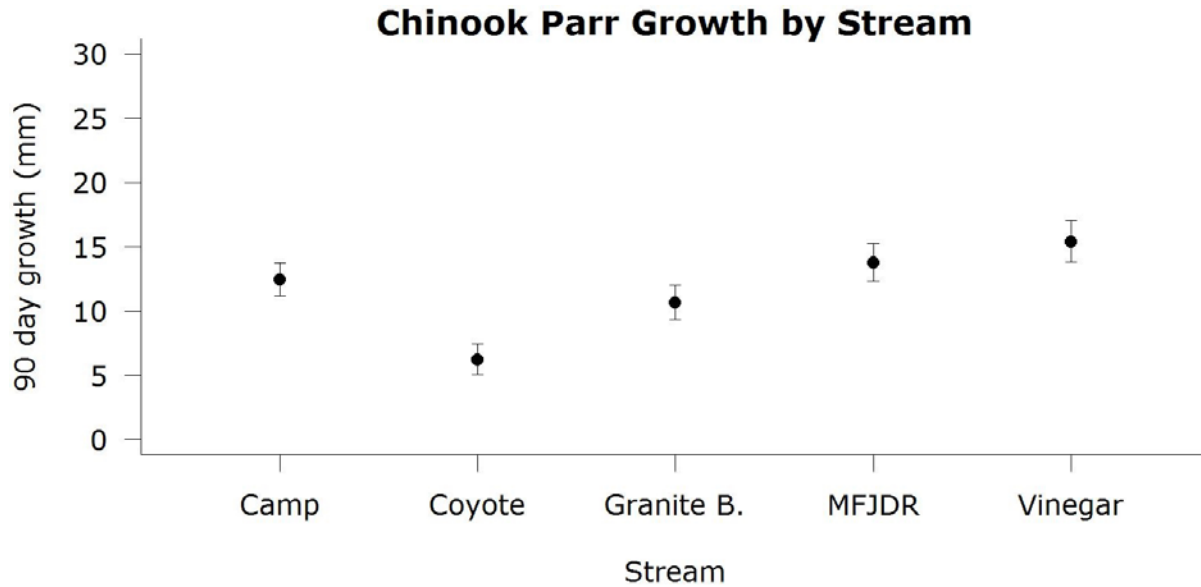


Figure 11. Best-fit model estimates for juvenile Chinook growth at several locations within the MFIMW. Growth estimates were obtained from 2008–2015. These model predictions represent 90-day growth rates for 65 mm juvenile Chinook. Error bars represent \pm 95% confidence intervals.

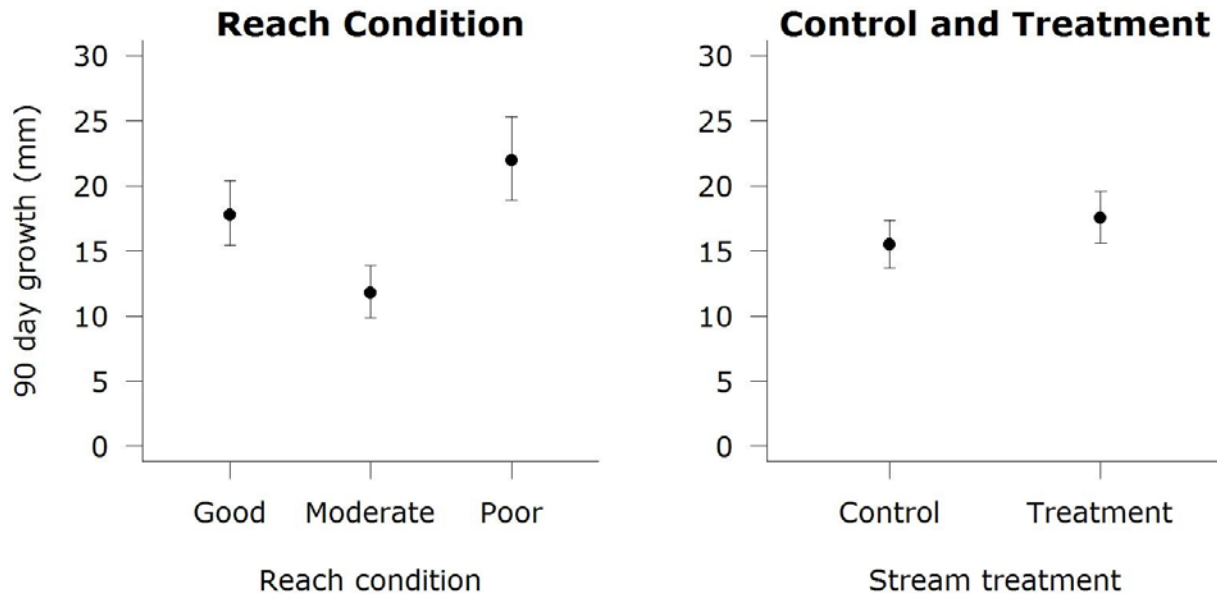


Figure 12. Model estimates for juvenile Chinook growth grouped by reach condition and by treatment. Growth estimates were obtained for Chinook from 2008 to 2015. These model predictions represent 90-day growth rates for 65 mm juvenile Chinook. Error bars represent \pm 95% confidence intervals.

Stream Habitat Condition for Middle Fork John Day River and Camp Creek Watershed

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Abstract

Stream habitat in the MFJDR and its tributaries has been impacted by various historic land management practices. Steelhead and spring Chinook habitat is targeted for restoration efforts in the John Day Basin. Insufficient habitat quantity and diversity have been identified as key limiting factors affecting their recovery (CBMRCD 2005 and Carmichael and Taylor 2010). To detect changes in stream habitat at the watershed scale, the MFIMW commissioned the USFS to establish PIBO sampling sites. We estimated trends by measuring changes in individual stream habitat metrics in Camp Creek and the MFJDR to investigate the effectiveness of restoration efforts implemented throughout the MFIMW. In addition, we used a “habitat index approach” to compare individual aspects of habitat conditions in the Camp Creek watershed to reference sites established in the Blue Mountains Ecoregion and in the Upper Columbia River Basin. These results indicate that most individual aspects of habitat condition in the MFIMW are stable or improving. Overall habitat index, large woody debris frequency, and percent undercut banks in both Camp Creek and the MFJDR showed statistically significant improving trends. The only measure in which we observed an undesired trend in both geographic areas was percent fines in pools, which increased in both Camp Creek and MFJDR. Results show that habitat in the Camp Creek watershed is in poorer condition than reference sites in the Blue Mountains and the Upper Columbia River Basin. The improving trend in the overall habitat index and most individual habitat attributes shows that restoration and current management efforts have a measureable positive impact at the watershed and subwatershed scale. The current status of the Camp Creek habitat condition, while improving, highlights the need for additional restoration actions. Long-term monitoring should continue to track how past and future restoration actions improve habitat as riparian vegetation is established and floodplain processes and functions are restored.

Key Findings

- The improving trend in the overall habitat index score for the majority of PIBO sites in Camp Creek and the MFJDR confirms our hypothesis that the aquatic habitat has improved at a watershed scale after restoration actions were implemented over the last 10 years in the MFIMW study area (Table 1; Table 2).
- Results indicate that most individual aspects of habitat condition in the MFIMW are stable or improving.
- Overall habitat index, large woody debris frequency, and percent undercut banks in both Camp Creek and the MFJDR showed statistically significant improving trends.

Table 1. Trend in stream habitat attributes across the Camp Creek watershed sites.

Explanation of row and column headers:

Overall_Index score

O.E. = Observed/Expected macroinvertebrate score

VegStab = bank stability

UnCutPct = percent undercut banks

LWFrq = large wood frequency

Bank Angle

PTFines6 = percent fines in pool tails

D50 = median substrate size

RPD = residual pool depth

PoolPct = percent pools

Percent Change = Percent change in the mean values between the first and last visit

Desired Direction = direction of change in the mean that would result in an improved habitat condition, which can be either + or –

Actual Change = actual direction of change in the mean, which can be either +, -, or not statically significant (NS)

Metric	2008 Value	2014 Value	Percent Change	Desired Direction	Actual Change
Overall_Index	21.42	27.89	30.2	+	+
O.E.	0.71	0.54	-23.6	+	NS
VegStab	85.26	95.67	12.2	+	+
UnCutPct	10.64	15.2	42.9	+	+
LWFrq	51.54	100.87	95.7	+	+
BankAngle	135.8	133.4	-1.8	-	NS
PTFines6	2.64	6.72	154.3	-	+
D50	0.082	0.0598	-26.8	+	-
RPD	0.24	0.32	32.2	+	+
PoolPct	29.32	30.52	4.1	+	NS

Table 2. Trend in stream habitat attributes across the MFJDR sites.

Explanation of row and column headers:

Overall_Index score

O.E. = Observed/Expected macroinvertebrate score

VegStab = bank stability

UnCutPct = percent undercut banks

LWFrq = large wood frequency

Bank Angle

PTFines6 = percent fines in pool tails

D50 = median substrate size

RPD = residual pool depth

PoolPct = percent pools

Percent Change = Percent change in the mean values between the first and last visit

Desired Direction = direction of change in the mean, which can be either + or -

Actual Change = actual direction of change in the mean, which can be either +, -, or not statically significant (NS)

Metric	2009 Value	2014 Value	Percent Change	Desired Direction	Actual Change
Overall_Index	19.38	22.68	17	+	+
O.E.	0.47	0.51	8.2	+	NS
VegStab	88.42	86.92	-1.7	+	NS
UnCutPct	15.57	23.78	52.7	+	+
LWFrq	15.58	40.64	160.8	+	+
BankAngle	134.67	122.73	-8.9	-	-
PTFines6	2.61	4.98	91.1	-	+
D50	0.0692	0.0677	-2.2	+	NS
RPD	0.58	0.46	19.7	+	NS
PoolPct	44.06	52.6	19.4	+	+

- Percent fines in pools increased in both Camp Creek and the MFJDR.
- Recent restoration actions may have mobilized fine sediments, or results may be caused by impairments in the watershed such as erosion associated with roads that may still need to be addressed.
- Results from the 2014 sampling effort show that habitat conditions in the Camp Creek watershed are poorer than reference sites in the Blue Mountains and the Upper Columbia River Basin (Figure 1).
- Although several restoration projects were implemented in Camp Creek, the aquatic habitat is still well below desired conditions.

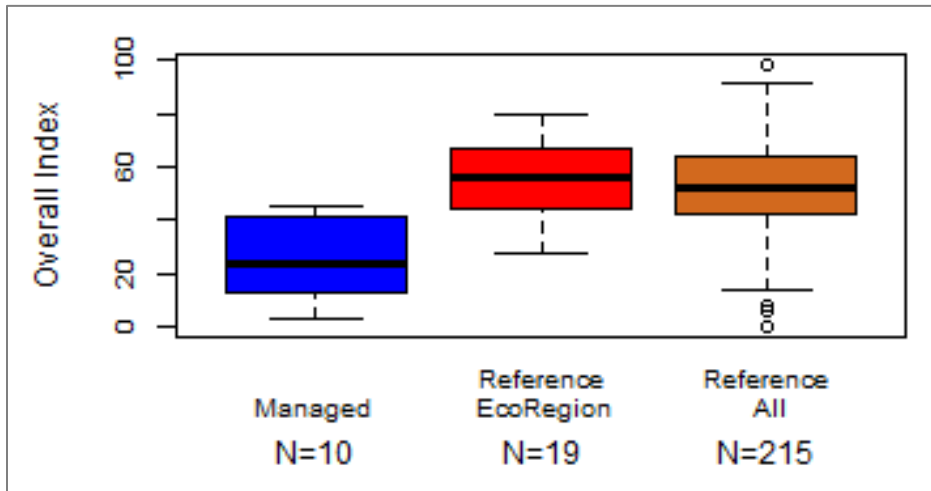


Figure 1. Overall index values across the Camp Creek watershed (managed) sites. Median and range of index values for managed sites, reference sites within the ecoregion, and reference sites for the entire PIBO study area.

Geomorphology and Physical Habitat

P. McDowell, PhD, University of Oregon, Eugene, OR

Abstract

Changes in channel geomorphology, sinuosity, pool depth, bed material, and fish cover were monitored over approximately 7 years in six reaches—three reaches where active restoration projects were installed and three control reaches. Each of the project reaches was the site of an active restoration project built between 2008 and 2011. The primary restoration techniques included removal of rock spurs and bank rip-rap; construction of log structures anchored into the channel banks; addition of unanchored large wood pieces (large woody debris or LWD) in the channel and on the floodplain; LWD anchored on the floodplain to provide floodplain roughness; and enlargement of upstream mouths of intermittent side channels. We also monitored changes in channel morphology at individual log structures. The goal was to test specific restoration goals of the projects, such as increasing pool depth or narrowing channels. In addition to the active restoration projects, removal of livestock grazing spurred increases in vegetation within the active channel that have had important influences on channel morphology and habitat. Channels did not narrow and deepen or become more sinuous in response to restoration as hypothesized. This may be because not enough time has elapsed since restoration for fluvial response to be fully developed. Restoration did produce a significant increase in pool depth. Bed material was generally in good condition at the beginning of the study. Both project reaches and control reaches experienced a significant decrease in the percentage of embedded gravels. The 2011 flood, one of the largest floods ever recorded on the MFJD, did not cause significant net erosion or deposition, indicating the channel is relatively stable and in dynamic equilibrium.

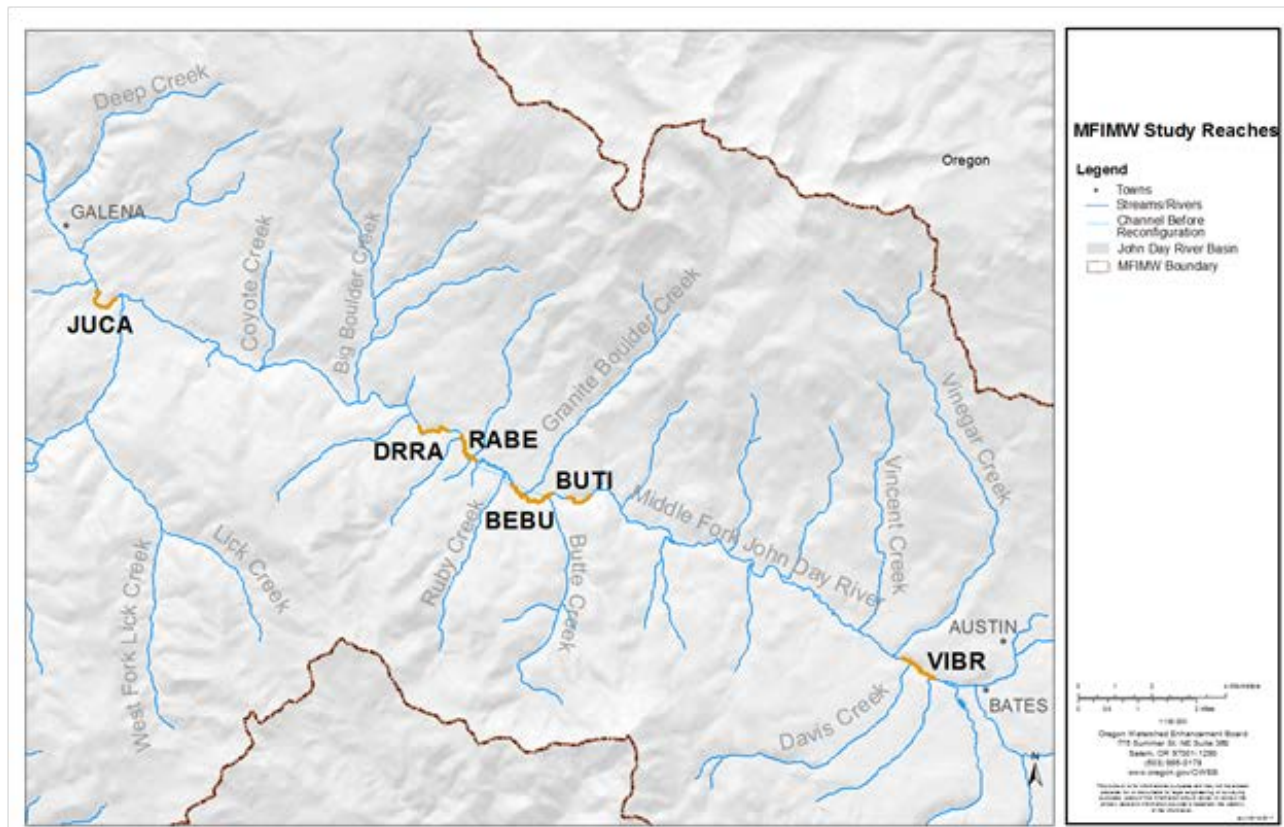


Figure 1. Map of study area showing reaches monitored.

Key Findings

- In addition to the active restoration projects, removal of livestock grazing spurred increases in vegetation (particularly *Carex nudata*) within the active channel that have had important influences on channel morphology and habitat (Table 1).

Table 1. Fish cover in three reaches from log structures and torrent sedge (*C. nudata*) in 2013, based on analysis of high-resolution UAV aerial imagery. Values are fish cover area as a percentage of total summer water area in the channel in the reach.

Reach	Reach type	<i>C. nudata</i> % cover	Log structures % cover
RABE(P)	Project	7.8	4.8
BEBU(P)	Project	12.1	6.0
BUTI(C)	Control	10.1	0

- At present, most of the fish cover is provided by plants – aquatic vegetation (both emergent and submerged) and overhanging bank vegetation (Figure 2). Until large wood inputs have increased to provide more fish cover, careful management of channel vegetation is important in maintaining fish cover.

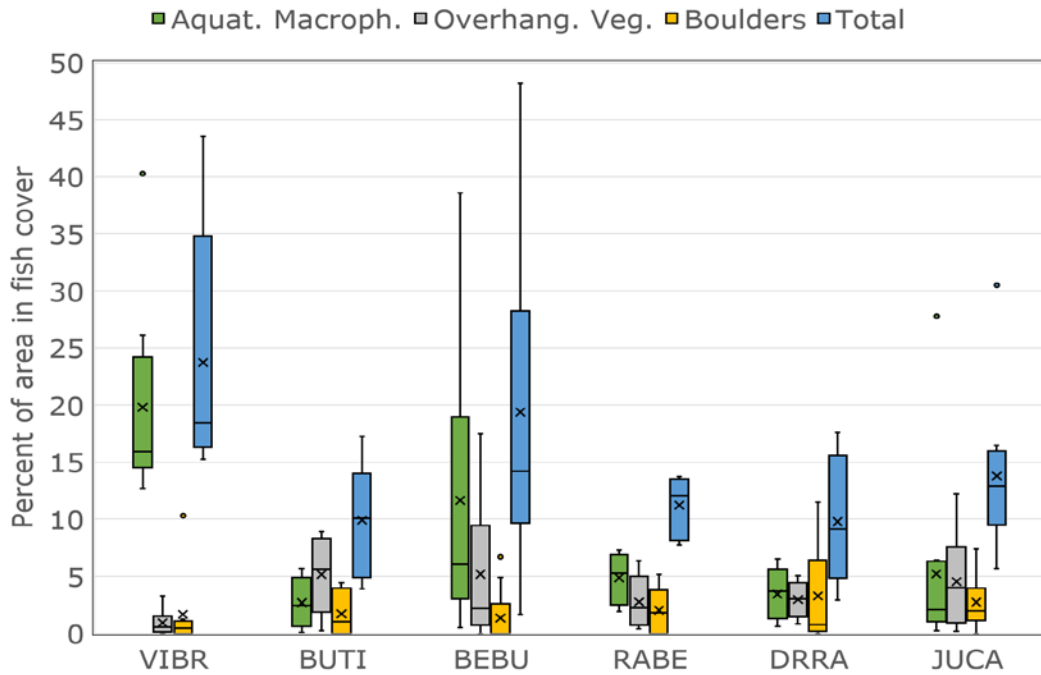


Figure 2. Comparison of major fish cover types in initial year of measurement.

- Channels did not significantly narrow and deepen or become more sinuous in response to restoration as hypothesized (Figure 3; Table 2). Although there were no reach-level net changes in channel dimensions, channels did experience erosion and deposition (Table 3).

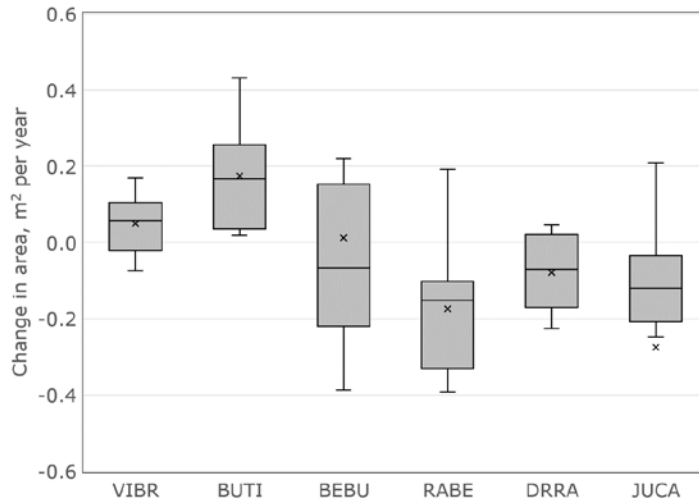


Figure 3. Change per year in cross-section area, over the monitoring period, by reach. Restoration project reaches are VIBR, BEBU, and RABE. (Two large outliers are not shown.) The box extends from the 25th to 75th percentile. The whiskers capture the largest quartile and smallest quartile. The horizontal line represents the median, and the x represents the mean.

Table 2. Sinuosity changes 2006-2013

Reach	Reach type	Sinuosity (2006)	Sinuosity % change	Secondary channel added, m (% increase)
VIBR(P)	Project	1.20	1.90	
BUTI(C)	Control	1.32	0.93	
BEBU(P)	Project	1.46	1.21	
RABE(P)	Project	1.08	0.08	139 (15%)
DRRR(C)	Control	1.14	1.19	
JUCA(C)	Control	1.07	0.24	

Table 3. Summary of dominant modes of channel change for each reach, over the period of study. The dominant modes of adjustment are those displayed by one-third or more of the cross-sections in the reach.

Reach	Reach type	Bank erosion	Point bar aggradation	Lateral migration	Bed aggradation	Bed incision
VIBR(P)	Project	X	X			X
BEBU(P)	Project				X	
RABE(P)	Project	X	X	X		X
BUTI(C)	Control	X				X
DRRR(C)	Control		X		X	
JUCA(C)	Control	X	X	X	X	

- Restoration projects (VIBR, BEBU, RABE) produced significantly increased pool depth (Figure 4).

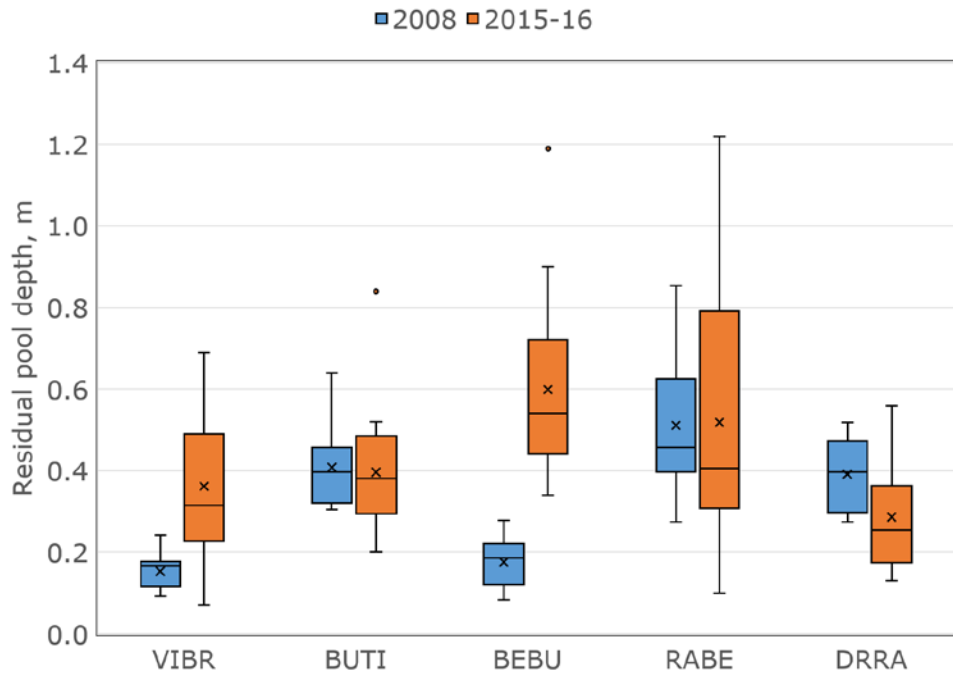


Figure 4. Boxplot of residual pool depth for five reaches, pre-restoration (2008) and post-restoration (2015-16).

- Both project reaches and control reaches experienced a significant decrease in the percentage of embedded gravels (Figure 5).

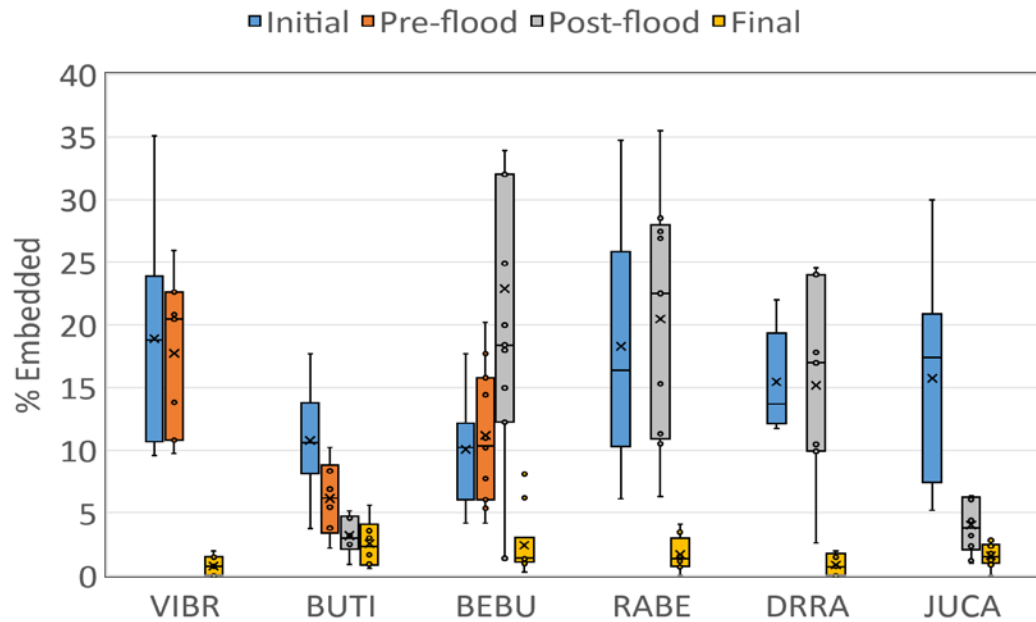


Figure 5. Changes in percent of grains embedded, over the period of study. Data based on surface pebble count method.

- The 2011 flood, one of the largest floods ever recorded on the MFJDR, did not cause significant net erosion or deposition, indicating the channel is relatively stable and in dynamic equilibrium (Figure 6).

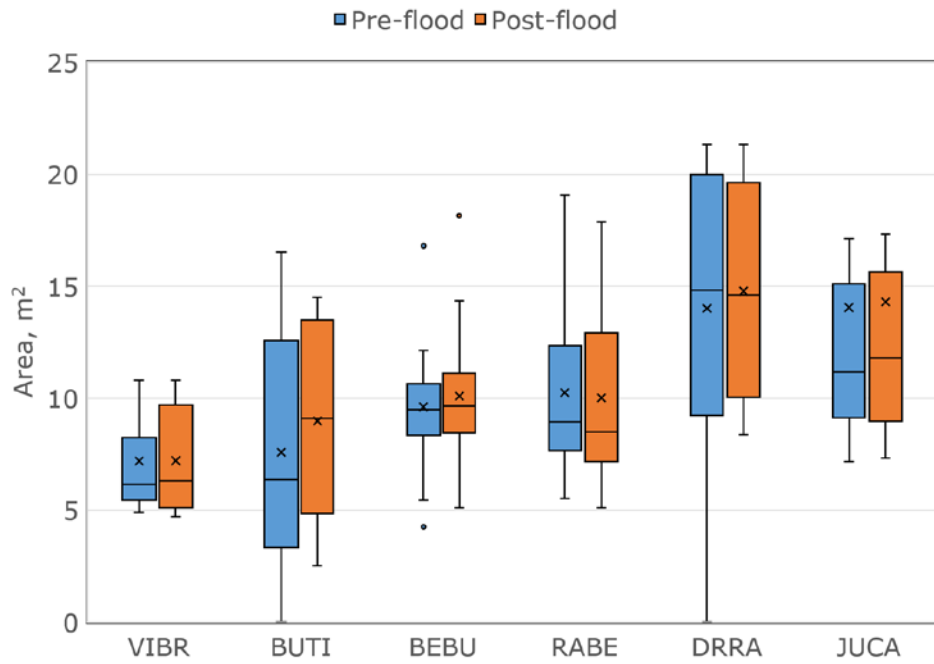


Figure 6. Comparison of pre- and post-flood channel cross-section area.

Influence of Deer and Elk Browsing on the Success of Riparian Restoration Plantings

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B. R. Cochran, Confederated Tribes of the Warm Springs Reservation of Oregon, Warm Springs, OR

Abstract

We studied the effects of wild ungulate browsing on native woody riparian species (both hardwoods and conifers) planted as part of the overall effort to restore aquatic and riparian ecosystems within the Middle Fork John Day River (MFJD). Unconstrained stream reaches along the river have been highly modified to support forage production for domestic livestock. Today, the MFJD is poorly shaded and summer stream temperatures can exceed 28 °C. To restore shade, thousands of seedlings were planted in 2006, but planting has had limited success, even in areas fenced to exclude cattle. We established small browsing exclosures in spring 2009 and remeasured the exclosures after one and two growing seasons. Our results showed that browsing by deer and elk suppressed the growth of most hardwoods. Only ponderosa pine and thinleaf alder showed consistent growth over 2 years. Overall, our results indicate that, in the absence of grazing by domestic livestock, browsing pressure from deer and elk may limit the potential to restore native riparian forests.



Photo 12. Vegetation along streambed. *Courtesy of University of Oregon.*

Key Findings

- MFJD is poorly shaded and summer stream temperatures can exceed 28 °C.
- Planting has had limited success, even in areas fenced to exclude cattle.
- Browsing by deer and elk suppressed the growth of most hardwoods.
- Only ponderosa pine and thinleaf alder showed consistent growth over 2 years.
- In the absence of grazing by domestic livestock, browsing pressure from deer and elk may limit the potential to restore native riparian forests (Figure 1).

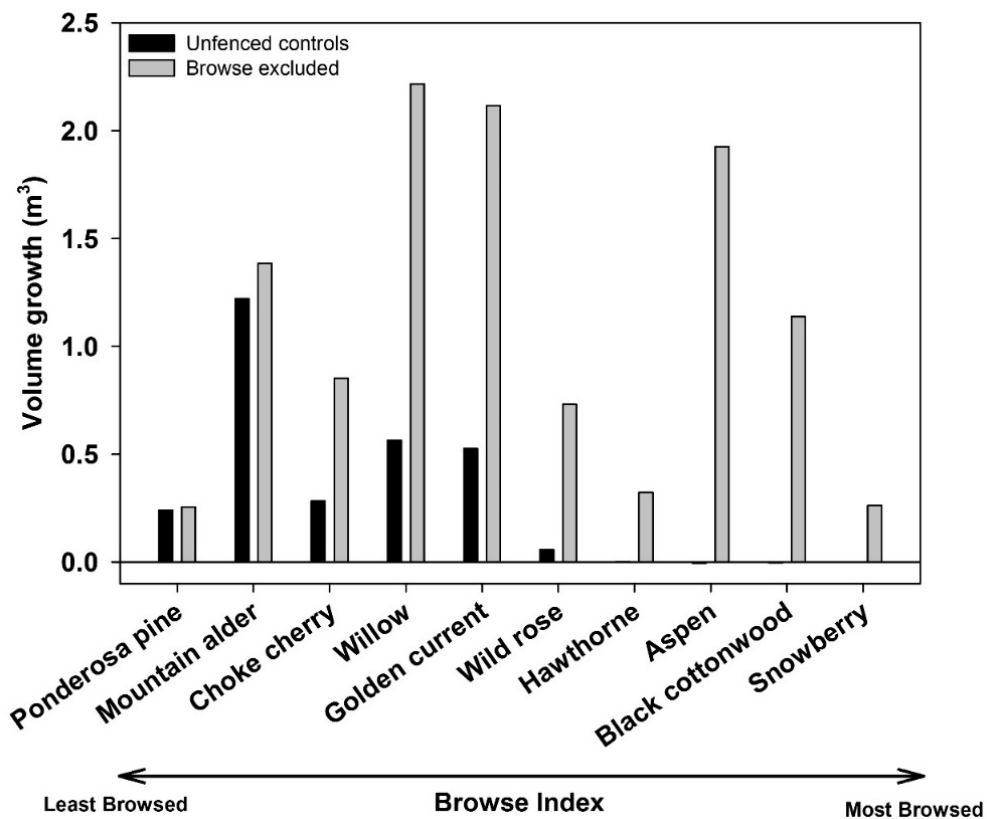


Figure 1. Comparison of volume growth between browsed and unbrowsed native woody riparian species planted on the Forrest and Oxbow Conservation Areas (all plots combined) along the upper Middle Fork John Day River. Species are sorted along a “browse index”, a simple measure of the difference in average volume growth between the browsed and unbrowsed individuals. Black bars are present, but too small to be visible for hawthorne, aspen, black cottonwood, and snowberry.

Projected Response of Riparian Vegetation to Passive and Active Restoration over 50 years

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Abstract

We modeled historical, current, and potential future conditions of riparian plant communities and salmon habitat quality in the Upper Middle Fork John Day River of eastern Oregon using state and transition models. We focused our modeling efforts on stream reaches that had high intrinsic potential to support spring Chinook Salmon or steelhead. Using the models, we examined alternative management strategies for passive versus active restoration of riparian vegetation and salmon habitat quality. The results of our model projections appeared reasonable. However, data were not available for a rigorous validation; thus model results should be interpreted with caution. Specifically, the results of modeled management alternatives should be interpreted as hypotheses of likely management outcomes. Simulation results suggested that recovery toward historic conditions occurs under both passive and active strategies. Recovery was relatively slower under passive restoration. Simulation results also varied by species of interest. Overall, our models suggested that restoration efforts significantly changed riparian and aquatic habitat quality over the time periods of decades. Our simulations also suggested that streams would not fully recover to the historical condition within 50 years (the duration of our simulations), even in the most aggressive restoration scenario we examined. These results indicate that river restoration investments need to be planned and evaluated over long time periods. Expectations for restoration outcomes need to be tempered with a realistic understanding of the rate at which natural systems can recover from more than a century of Euro-American land-use.

Key Findings

- Simulation results suggested that recovery toward historic conditions occurs under both passive and active strategies.
- Recovery was relatively slower under passive restoration.
- Simulations suggested that streams would not fully recover to the historical condition within 50 years (the duration of our simulations), even in the most aggressive restoration scenario we examined (Figures 1-3).
- The current management scenario (Figure 1) includes moderate levels of cattle grazing, high deer and/or elk browse, no wildfire suppression, no forest management prescriptions, no anthropogenic vegetation or channel alteration, low active restoration of channels, and some conifer and riparian hardwoods planting. The results indicate modest improvements in spring Chinook habitat quality, and greater improvements in steelhead habitat, particularly over the next 20 years.

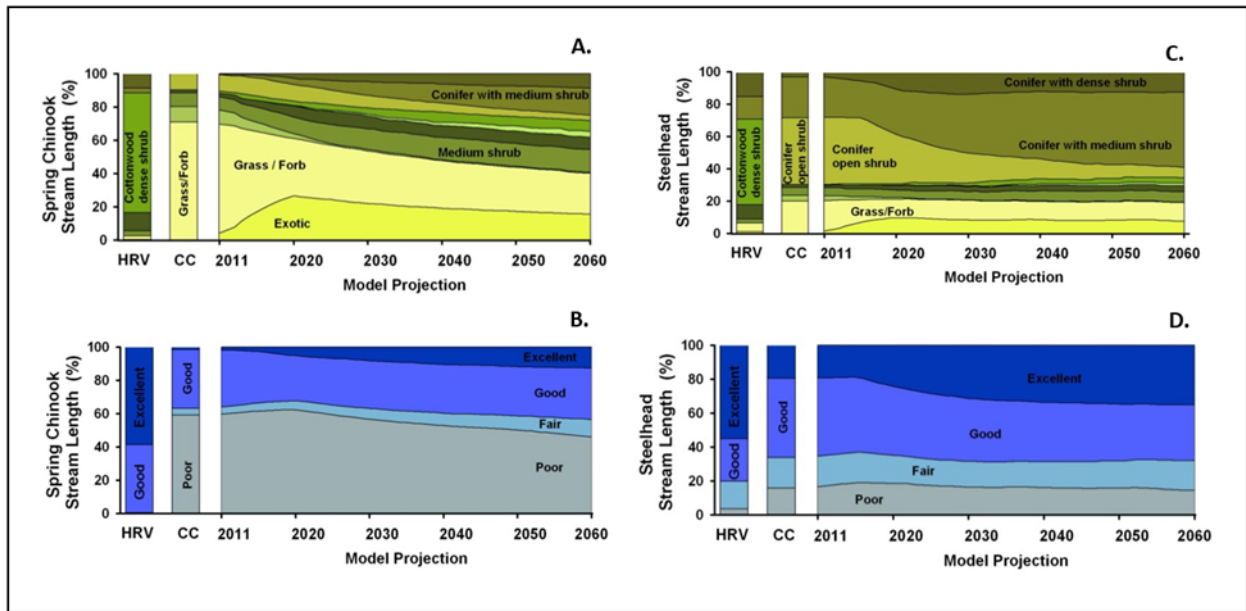


Figure 1. Simulated changes in riparian vegetation and stream habitat quality for portions of the stream network ranked with moderate or high intrinsic potential for spring Chinook (A, B) and high intrinsic potential for Steelhead (C, D). The simulated historic condition (HRV) and LIDAR-derived current condition (CC) are given as bars on the left side of each graph. The time series composing the main body of each graph shows results of a 50-year model simulation initialized with the current condition.

- The light grazing intensity scenario (Figure 2) includes light cattle grazing, high deer and/or elk browse, no wildfire suppression, no forest management prescriptions, no anthropogenic vegetation or channel alteration, low active restoration of channels, and some conifer and riparian hardwoods planting. The results indicate somewhat greater rates of improvement in both spring Chinook and steelhead habitat than in the current management scenario.

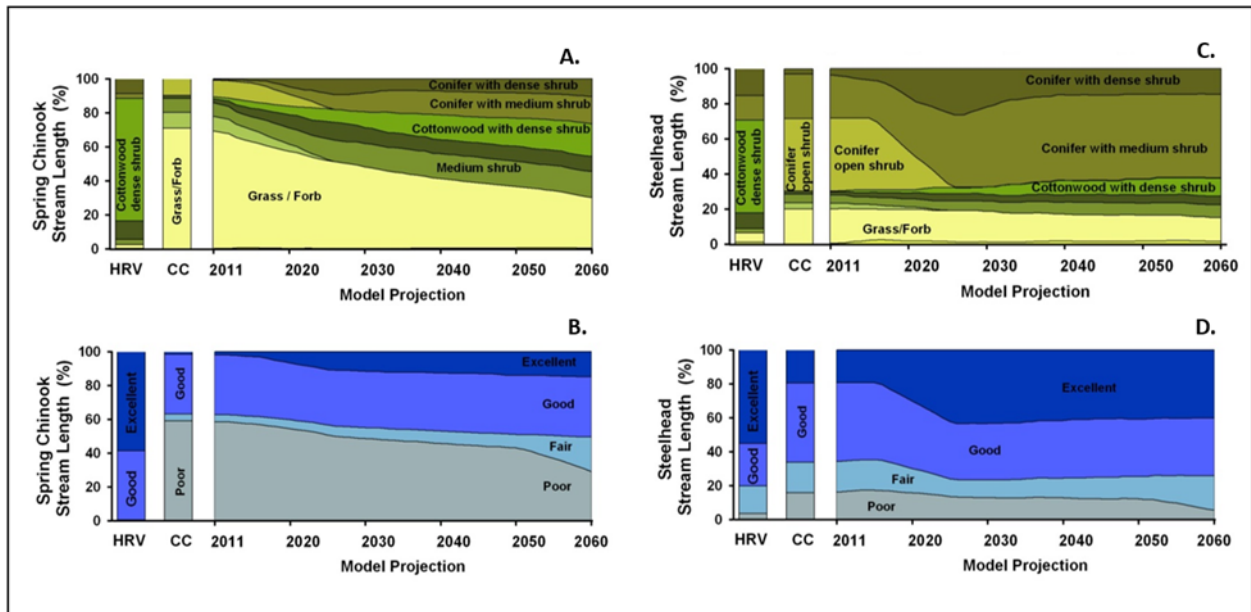


Figure 2. Simulated changes in riparian vegetation and stream habitat quality for portions of the stream network ranked with moderate or high intrinsic potential for spring Chinook (A, B) and high intrinsic potential for Steelhead (C, D). The simulated historic condition (HRV) and LIDAR-derived current condition (CC) are given as bars on the left side of each graph. The time series composing the main body of each graph shows results of a 50-year model simulation initialized with the current condition.

Water Temperature Monitoring

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Abstract

Water temperature has been identified as the primary limiting factor for salmonids to be addressed in the MFJD subbasin. Water temperature loggers were placed in the mainstem MFJD and tributaries in order to provide temperature data to calibrate a Heat Source model and to monitor EPA-defined total maximum daily load (TMDL) for water temperature of 18°C. Between 2005 and 2016, 122 water temperature loggers were in the mainstem MFJD between Bridge Creek and Big Creek and in 26 tributaries. Seven-day average daily maximum (7DADM) temperatures and proportion of summer days with maximum temperatures above 18°C were calculated for mainstem MFJD and Bridge Creek loggers. Summer water temperatures reported as maximum 7DADMs were above the recommended 18°C for coldwater salmonids for all locations and all years. Restoration activities in the MFJD designed to improve water temperatures are recent, within the last 5 years, which is likely too short a time period to see a watershed-level change in temperature values. Water temperature monitoring should continue, with a clear monitoring plan in place, in order to detect changes due to restoration, update temperature models, and check for TMDL compliance.

Key Findings

- Summer water temperatures reported as maximum 7DADMs were above the recommended 18°C for coldwater salmonids for all locations and all years (Figure 1).
- Restoration activities in the MFJDR designed to improve water temperatures are recent, within the last 5 to 10 years, which is likely too short a period to see a watershed-level change in temperature values.

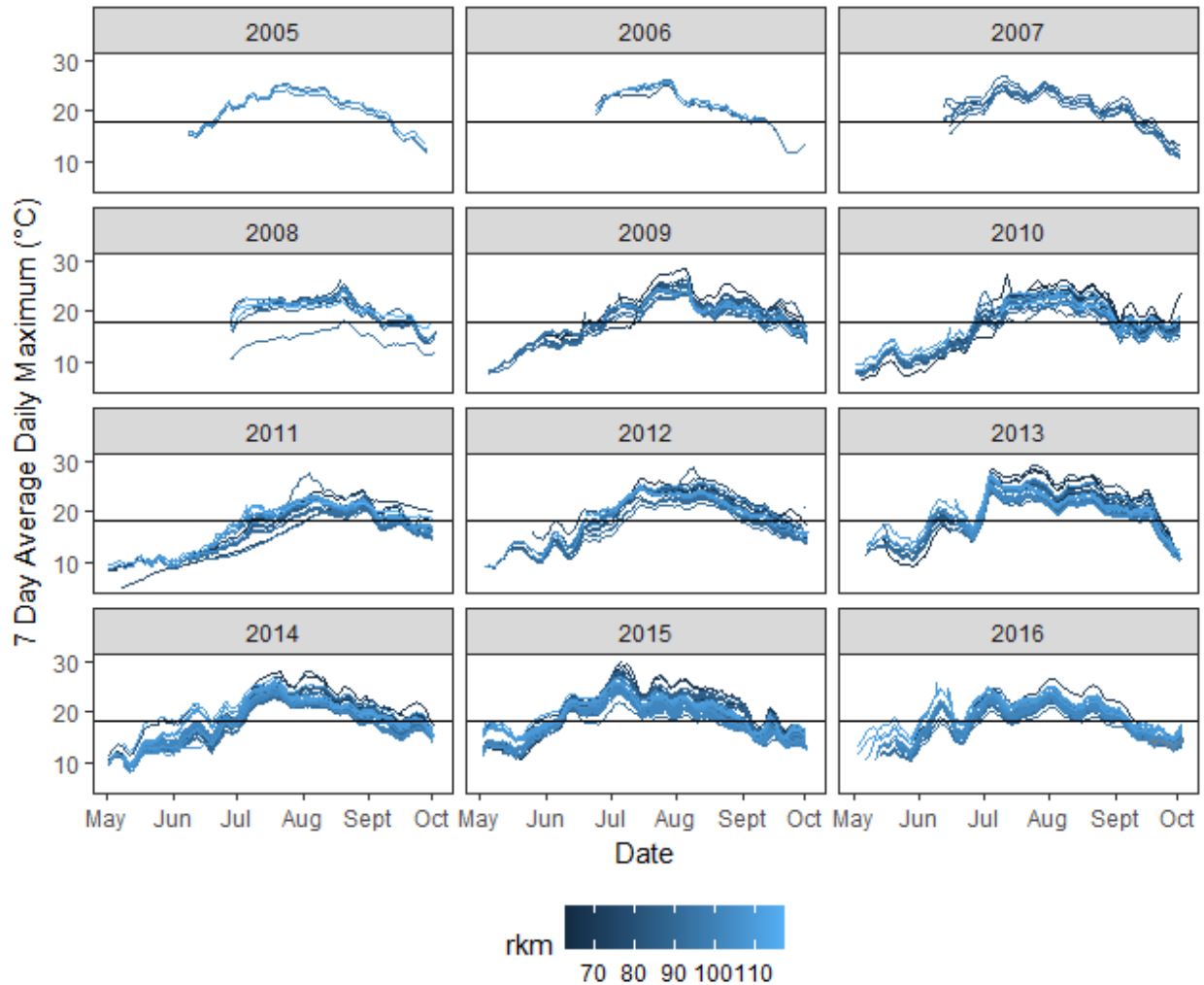


Figure 1. Seven-day average daily maximum (7DADM) temperatures °C for loggers on the mainstem MFJD. Rkm 0 is at the mouth of the MFJD. Black line is 18°C, the EPA cold-water threshold.

- Summer water temperatures reported as maximum 7DADMs increased from upstream to downstream in Bridge Creek, with cooler temperatures occurring further upstream from Bates Pond (Figure 2).

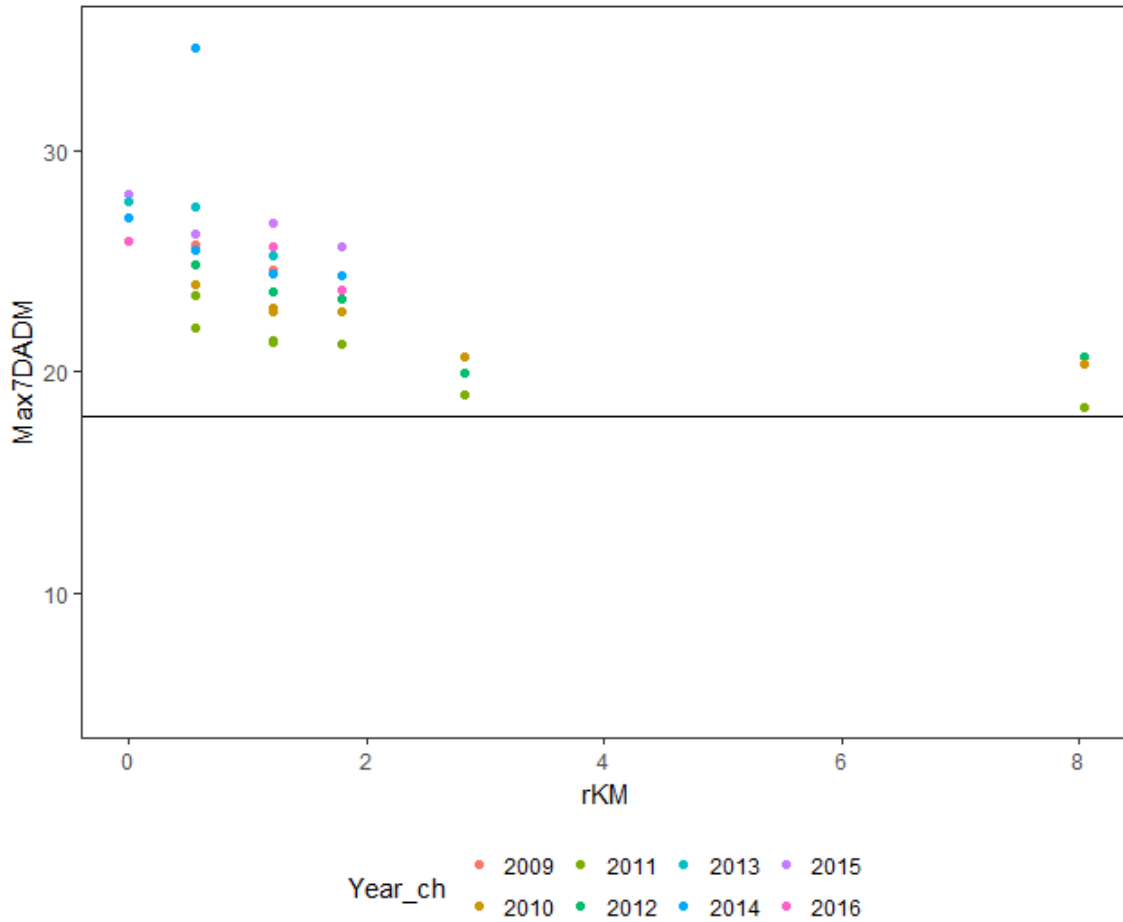


Figure 2. Maximum seven-day average daily maximum temperature (°C) (7DADM) by rkm on Bridge Creek for all loggers and years. Rkm 0 represents the mouth of Bridge Creek; Bates Pond is located at rkm 0.89.

Monitoring and Assessment of Critical Thermal Dynamics in Upper Middle Fork of the John Day River, 2008-2016

Oregon State University MFIMW Team, Oregon State University, Corvallis, OR

Abstract

The Oregon State University (OSU) team conducted hydro-thermal stream monitoring on the Middle Fork of the John Day River (MFJDR) at the Oxbow and Forrest Conservation Areas from 2008 to 2016. Regulation of temperature within these critical habitats is a primary factor in fish survival. Fiber optic distributed temperature sensing (DTS) monitored about 8,000 meters of river channel per summer with 1 meter and 10 minute resolution to observe peak summer temperatures, supplemented by groundwater contribution, stream discharge, and stream bathymetry across the conservation sites. Diurnal cycles during summer observation ranged from absolute minimum of 9° Celsius (C) to absolute maximum of 26°C. Salmonids are sensitive to stream temperatures above 18°C, resulting in depressed growth and survival, while sustained temperatures above 24°C have directly lethal effects (Bell 1991). Groundwater inputs directly into the MFJDR did not significantly decrease stream temperatures, but did reduce tributary temperatures. The primary cooling mechanism of the MFJDR occurred at the confluence of the mainstem and its tributaries, where tributaries supplied cooler, groundwater rich water into the main channel. Physically-based thermal modeling indicated that solar radiation was the primary driver for gains in stream temperature in the mainstem MFJDR; river surface area change associated with restoration actions of the MFJDR mainstem explained 98% of the change in stream temperature. DTS monitoring of the Phase-2 Oxbow Conservation Area (OCA) restoration project (closing the dredged channel and redirecting all flow to the meandering channel) showed a decrease in mainstem temperature by over 0.6°C (1°F), which model results indicate is due to reduced water surface area. Model results of shade to stream temperature provided by riparian vegetation was shown to be a very slow restoration method, unlikely to provide significant thermal effects within a decade on rivers the size of the MFJDR. Finally, while re-connecting the river with the floodplain has many habitat benefits, model results indicate neither an increase to summer low-flow nor a reduction in summer peak temperatures.

Key Findings

- Groundwater inputs did not significantly decrease MFJDR stream temperatures, but did affect tributary temperatures (Figure 1).
- Groundwater and hyporheic contributions were found not to influence the mainstem temperatures (shown through HeatSource modeling and DTS measurements, Hall 2015) or provide detectable cold-water refugia for salmonids (Huff 2009; O'Donnell 2012).
- The primary cooling mechanism of the MFJDR occurred at the confluence of the mainstem and its tributaries, where tributaries supplied cooler, groundwater rich water into the main channel (Figure 2).
- Since surface water surface area is a key metric for change in stream temperature, planned restoration scenarios can be simulated to predict impact on stream temperature by comparing pre- to post-restoration stream surface area.



Photo 13. Wiring monitoring equipment. *Courtesy of CTWSRO.*

BBC Aug 2009: Averaged Maximum & Minimum Temperature with Areas of Groundwater Inflow and Hyporheic Exchange Indicated

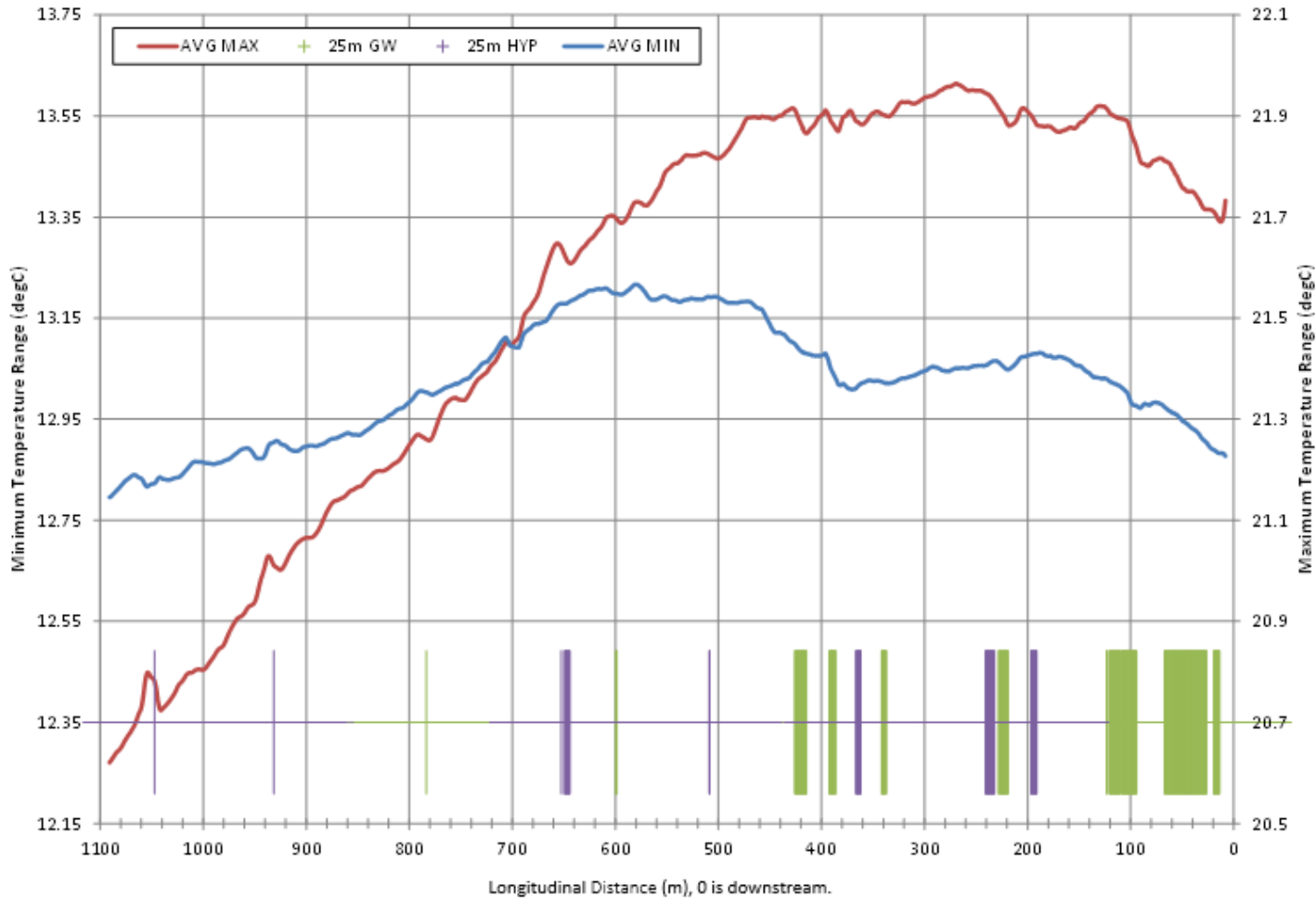


Figure 1. Thermal influences on Big Boulder Creek through DTS observations (Arik, 2011). The upward trend in temperatures in the first 600 m of stream (from 1100 m to 500m) suggests that without groundwater inflows (green bars) and hyporheic exchange (purple bars) the stream would have been over 1° C warmer.

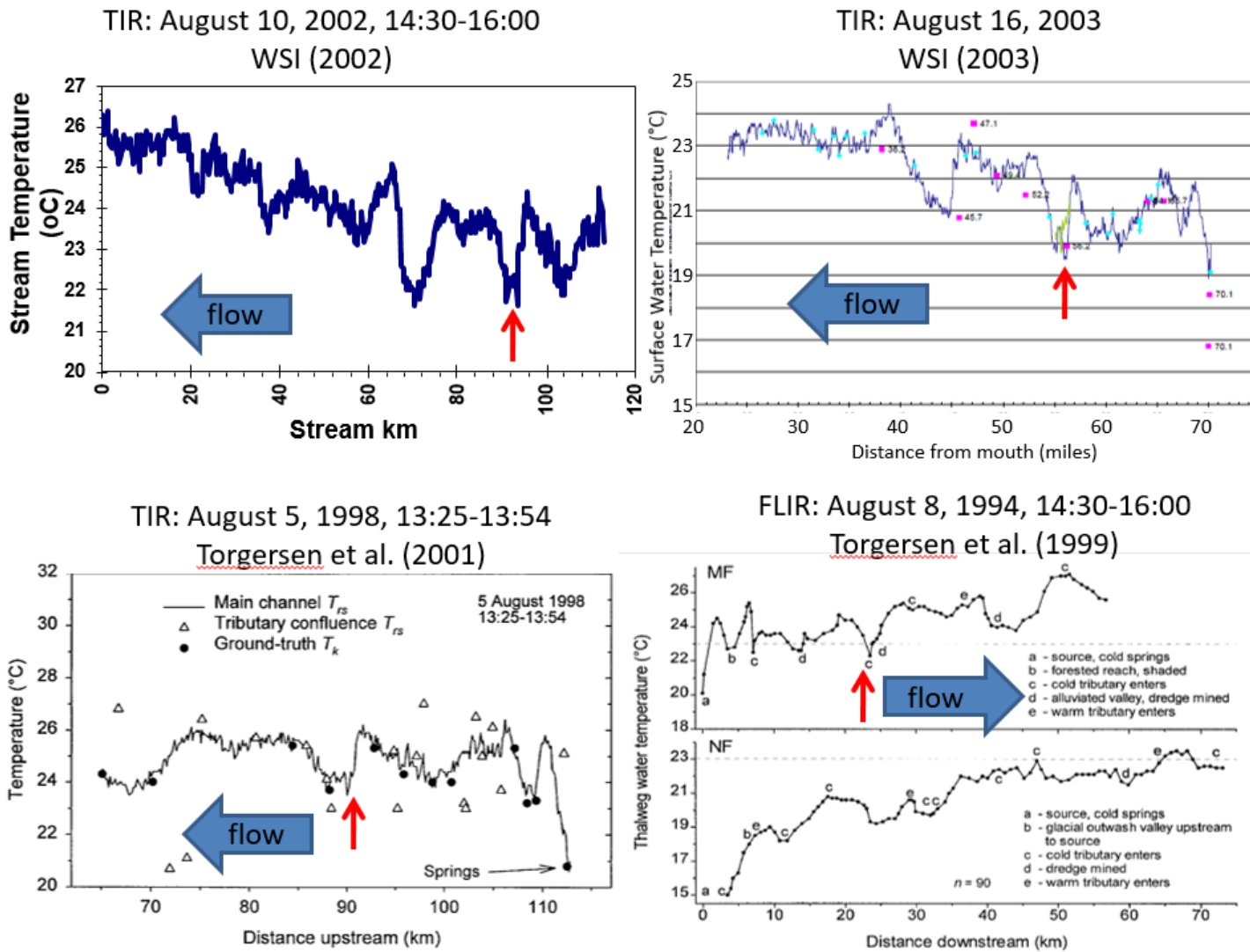


Figure 2. FLIR data taken on four previous studies showing an apparent decrease in temperature between Butte and Granite Creeks (red arrows mark these locations) (O'Donnell, 2012). Fiber optic measurements revealed that these temperature pulses were actually moving down stream, reflecting night-time cold water passing through the system, rather than cooler locations on the river. This illustrates the limitation of repeated afternoon “snapshot” FLIR data for stream restoration planning.

- Physically-based thermal modeling indicated that solar radiation was the primary driver for gains in stream temperature in the mainstem MFJDR; river surface area change associated with OCA Phase 2 restoration actions of the MFJDR mainstem explained 98% of the change in stream temperature (Figure 3).

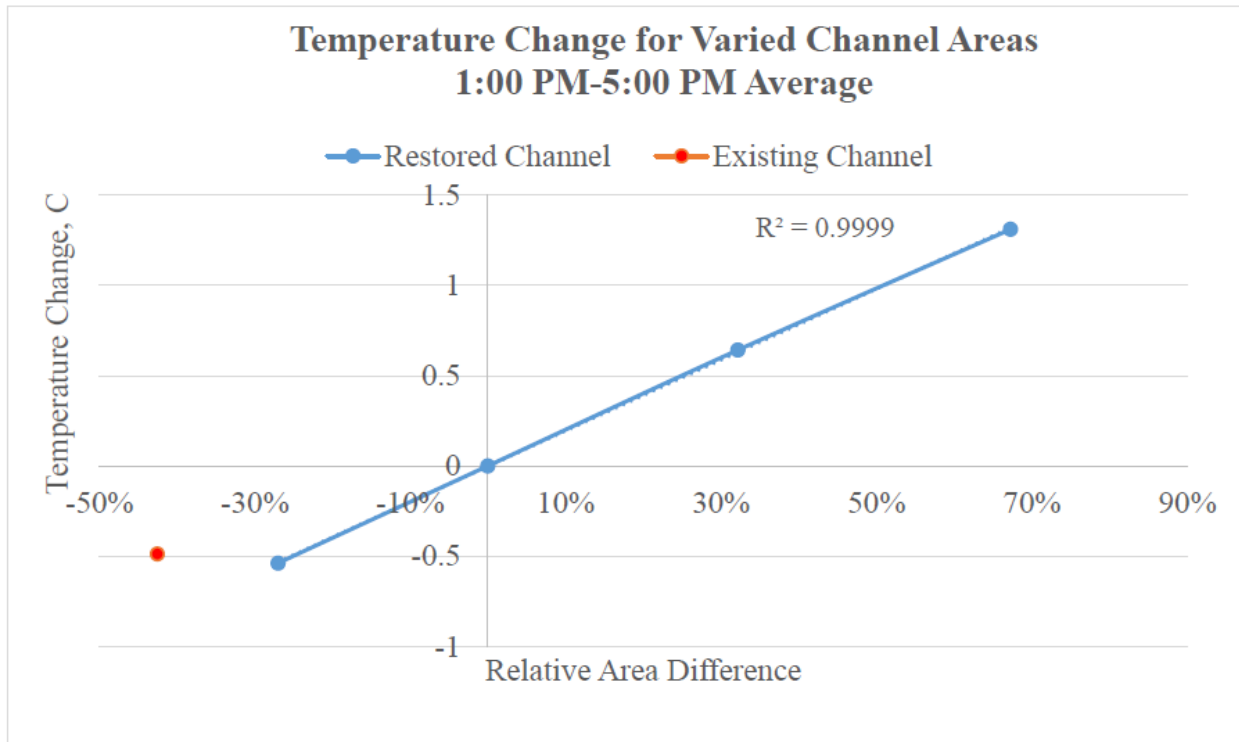


Figure 3. HeatSource model predictions of OCA Phase 3 restoration (a new meandering channel to replace a straight dredged channel) impacts on stream temperature, showing the strong correlation between stream temperature and changes to effective stream area. Increasing stream area is predicted to cause a direct increase in stream temperature and decreasing stream area would be expected to cause a decrease in stream temperature (Hall 2015). The origin is centered on the expected Phase 3, 4, and 5 design parameters which resulted in a surface area of 17,400 m² (whereas the existing channel had a surface area of 10,000m²), which gives rise to higher temperatures than are seen in the pre-restoration channel.

- OCA Phase 3, 4, and 5 restoration projects (a new meandering channel to replace a straight dredged channel) resulted in an increase in stream area through introduction of meander bends and a slowing of velocities due to increased channel length, thus reducing hydraulic gradient.
- Model results of the un-vegetated restored channel indicate an increase in stream temperature at the downstream end of the restored reach.

- If shade cover becomes established or exposed stream area is less than anticipated, a decrease in stream temperature is expected (Hall 2015).
- DTS monitoring showed that the Phase 2 Oxbow Conservation Area (OCA) restoration project decreased mainstem temperature by more than 0.6°C (1°F), which model results indicate is due to reduced water surface area.
- Reduction in peak temperatures and dampening of diurnal fluctuations were achieved through the consolidation of two channels into one in the OCA Phase 2 restoration, demonstrating that stream area reduction is a viable means of reducing peak stream temperatures (Hall 2015).
- Model results show that increasing shade through growth of riparian woody vegetation would be a very slow restoration method, unlikely to provide significant thermal effects within a decade on rivers the size of the MFJDR.
- Model results of varying channel incision scenarios, calibrated by groundwater monitoring of the floodplain, showed that bank storage and release of water along the mainstem river would not increase late season flow or decrease temperature, though habitat improvement and winter flood processes may well justify re-connection of streams to their floodplains (Nash et al. 2017).
- DTS was an essential tool for accurate calibration of HeatSource model results and for identification of all thermal processes along the mainstem and tributaries, which were subsequently used in modeling the Phase 3, 4, and 5 projects (Huff 2009; Arik 2011; O'Donnell 2012; Hall 2015)



Photo 15. OCA alcove, October 2016. *Courtesy of CTWSRO.*



Photo 15. OCA alcove, July 2017. *Courtesy of CTWSRO.*

Future Changes in Mainstem Water Temperatures in the Upper Middle Fork John Day River and the Potential for Riparian Restoration to Mitigate Temperature Increases

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Abstract

Stream temperature regimes are expected to change in response to changes in air temperature and stream discharge that result from global change. Stream temperatures are also influenced by anthropogenic changes to riparian vegetation that either increase or decrease stream shade. The mechanistic stream temperature model, HeatSource, was used to analyze potential changes in stream temperature along a 37-km study segment of the Upper Middle Fork John Day River (MFJDR), located in northeast Oregon, USA. The river currently supports populations of spring Chinook salmon, steelhead, and bull trout, all of which are cold-water dependent species. Both steelhead and bull trout are listed as threatened under the USA Endangered Species Act. Because of their population status, the river has been a focal point of restoration. However, maximum stream temperatures already exceed lethal thresholds in some summers and there is concern that future increases in air temperature will further threaten these populations. HeatSource was used to examine alternative future scenarios based on down-scaled projections from climate change models and the composition and structure of native riparian forests. The 36 scenarios examined all possible combinations of future increases in air temperature ($\Delta T_{\text{air}} = 0, +2,$ and $+4^{\circ}\text{C}$), stream discharge ($\Delta Q = -30\%, 0\%,$ and $+30\%$), and riparian vegetation (post-wildfire with 7% effective shade, current vegetation with 19% effective shade, a young-open forest with 34% effective shade, and a mature riparian forest with 79% effective shade).

Simulation results suggested that the Upper Middle Fork John Day has a wide range of potential future thermal regimes. Specifically, the future 7-day, daily average maximum (7DADM) stream temperature ranged from $\sim 4^{\circ}\text{C}$ hotter to $\sim 8^{\circ}\text{C}$ colder than current conditions under a future climate in which air temperatures were 4°C hotter than today. Shade from riparian vegetation had the largest influence on stream temperatures, with the range in effective shade from 7% to 79% changing the 7DADM from $+1^{\circ}\text{C}$ to -7°C . In comparison, the 7DADM increased by less than $+2^{\circ}\text{C}$ in response to the $\pm 30\%$ change in discharge or $+4^{\circ}\text{C}$ increase in air temperature. Because many streams supporting coldwater dependent species throughout the interior western United States have been anthropogenically altered in ways

that have substantially reduced shade, there is great potential to restore shade over long segments of these streams. The effect of such restoration could be so large that future stream temperatures could be colder than today, even under a warmer climate with substantially lower late-summer streamflow.

Key Findings

- Simulation results suggested that shade from riparian vegetation had the largest influence on stream temperatures, with the range in effective shade from 7% to 79% changing the 7DADM from +1°C to -7°C relative to current conditions. In comparison, the 7DADM increased by less than +2°C in response to the ±30% change in discharge or +4°C increase in air temperature (Figure 1).

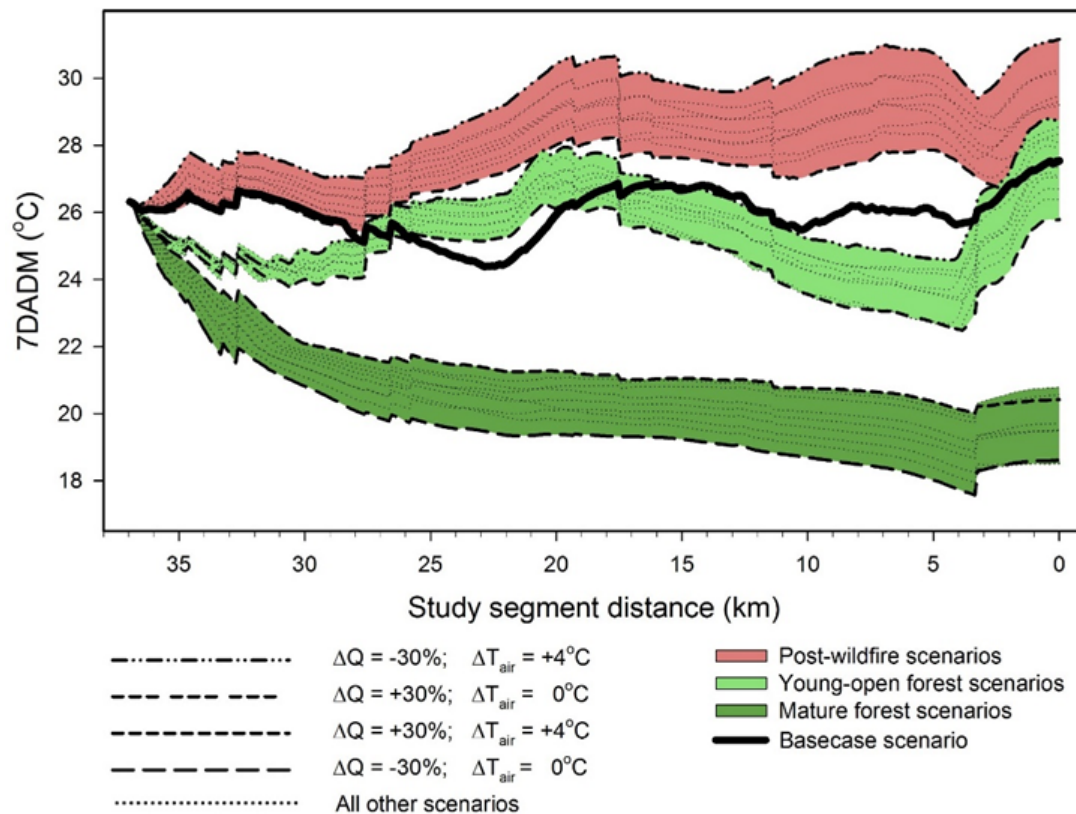


Figure 1. Simulated 7DADM stream temperatures over the length of the study segment. Simulation results are grouped for three riparian vegetation scenarios (pink, light green, and dark green shaded zones) bounded by bold lines representing combinations of T_{air} and Q representing the scenario with the warmest or coldest simulated 7DADM stream temperatures. The remaining simulations for each vegetation scenario are indicated by light dotted lines bracketed by the warmest and coldest simulations within each vegetation scenario. Note that abrupt step changes in temperature result from tributary inputs of warmer or cooler water. Also note that under both the post-wildfire and young-open forest scenarios, the +30% Q simulations result in the coldest stream temperatures. This pattern is reversed under the mature forest scenario where the +30% Q simulation results in the warmest stream temperatures.

Analysis of Benthic and Drift Macroinvertebrate Samples

R. Henderson, Washington State University - Tri-Cities, Richland, OR

Abstract

To assist the MFIMW in evaluating physical and biological responses to stream restoration, we compared macroinvertebrate communities between control and treatment (restored) reaches and streams. With both the benthic and drift macroinvertebrate datasets, we detected significant differences in years using analysis of variance (ANOVAs) and multiple comparisons tests ($p < 0.10$). Between controls and treatment reaches, significant differences were only detected with drift taxa richness. As determined using ANOVAs and multiple comparisons tests with years and the control/treatment streams as factors, there were not any significant differences in O/E scores among the control and treatment streams ($p = 0.78$). However, it is interesting to note that the treatment reaches were able to withstand the climate conditions in recent years better than the control reaches. We suggest exploring if functional group analysis and the use of spatial models would assist in providing conclusive evidence supporting the hypothesis that management actions are affecting the biotic integrity of the MFJDR.

Key Findings

- With both the benthic and drift macroinvertebrate datasets, we detected significant differences in years using analysis of variance (ANOVAs) and multiple comparisons tests ($p < 0.10$).
- As determined using ANOVAs and multiple comparisons tests with years and the control/treatment streams as factors, there were not any significant differences in O/E scores among the control and treatment streams ($p = 0.78$) (Figure 1).

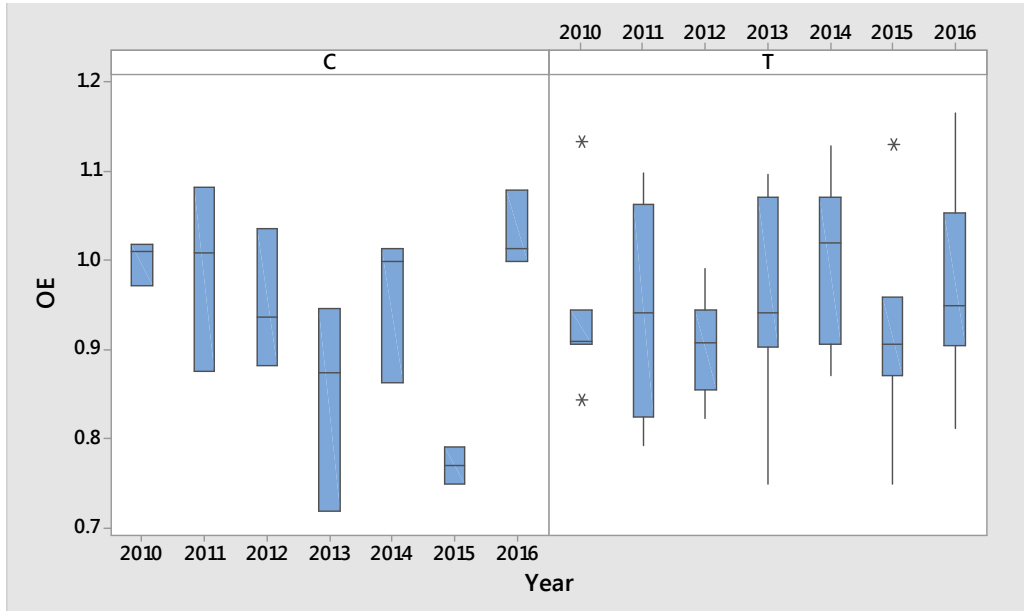


Figure 1. Box and whisker plots of O/E scores for MFJDR control and treatment reaches.

- Between controls and treatment reaches, significant differences were only detected with drift taxa richness, with treatment reaches experiencing a lower taxa richness ($p < 0.10$) (Figure 2).

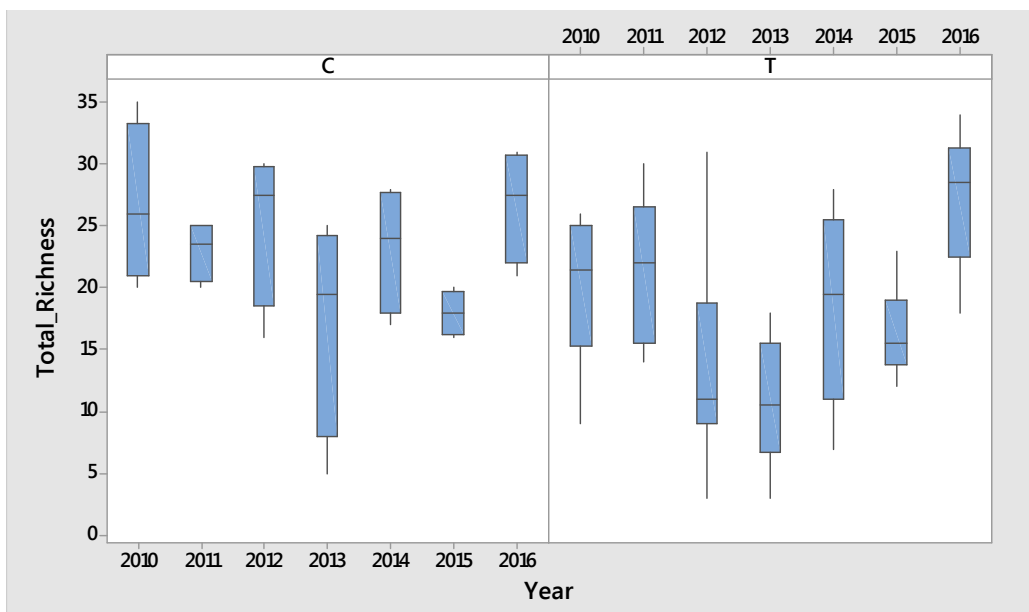


Figure 2. Box and whisker plots of drift taxa richness for MFJDR control and treatment

- Based on the available data, we were unable to detect any significant improvement post-restoration to the MFJDR macroinvertebrate communities between control and treatments, although this may reflect the imbalance between the number of control and treatment samples.

Analysis of the Relationship between Macroinvertebrates, Streamflow, and Temperature in the Middle Fork John Day River, OR

Robin Henderson, Washington State University - Tri-Cities, Richland, OR

Abstract

We tested how strongly aquatic macroinvertebrates were associated with streamflow and stream temperatures in the Middle Fork John Day River (MFJDR). The strength of the relationships with streamflow, temperature, and the MFJDR benthic and drift macroinvertebrate communities, were measured using taxa composition (the Observed/Expected index), taxa richness, tolerance of taxa, and drift macroinvertebrate biomass (g) as response variables. Benthic macroinvertebrate taxa composition, as measured using the Observed/Expected index, and drift macroinvertebrate biomass were only weakly associated with streamflow and temperature variables, suggesting other factors more strongly influenced these factors. In contrast to the benthic Observed/Expected Index and drift macroinvertebrate biomass (g), taxa richness and percent intolerant taxa exhibited a moderate to strong association with streamflow and temperature. Our results have direct implications for understanding the relative importance of streamflow and temperature in regulating the structure and composition of stream assemblages and for improving management decisions with regards to restoration actions.

Key Findings

- Taxa richness and percent intolerant taxa exhibited a moderate to strong association with streamflow and temperature.
- Benthic macroinvertebrate taxa composition, as measured using the Observed/Expected index, and drift macroinvertebrate biomass were only weakly associated with streamflow and temperature variables.
- Temperature and discharge variables co-vary, making it challenging to segregate the biological effects of one set of variables from the other.
- Both streamflow and temperature resulted in the best performing final models, indicating some degree of independent response of biota to these variables (Table 1).

Table 1. Predictor variable importance for drift macroinvertebrate models. The count represents the number of times the predictor variable was ranked as the top predictor variable for drift macroinvertebrate models. Note that predictor importance for the biomass (g) final model could not be determined as there was only one predictor variable in the final model.

Predictor variable	Count
Mean7DayMaxTemp	2
AnnualCVDDischarge	2

- We observed reasonably strong relationships among taxa richness, streamflow, and temperature as well as percent intolerant taxa for benthic macroinvertebrates, but less of a relationship for drift macroinvertebrates.
- Mean October temperature and mean annual streamflow stood out as being important in predicting benthic macroinvertebrates.
- Discharge and number of days > 22°C were important in predicting drift macroinvertebrate response.
- It is difficult to distinguish the separate effects of stream temperature and discharge from one another.
- Benthic EPT taxa richness between the years 2010-2016 has generally increased while the mean October temperature and the mean 7-day maximum discharge also increased (Figure 1).

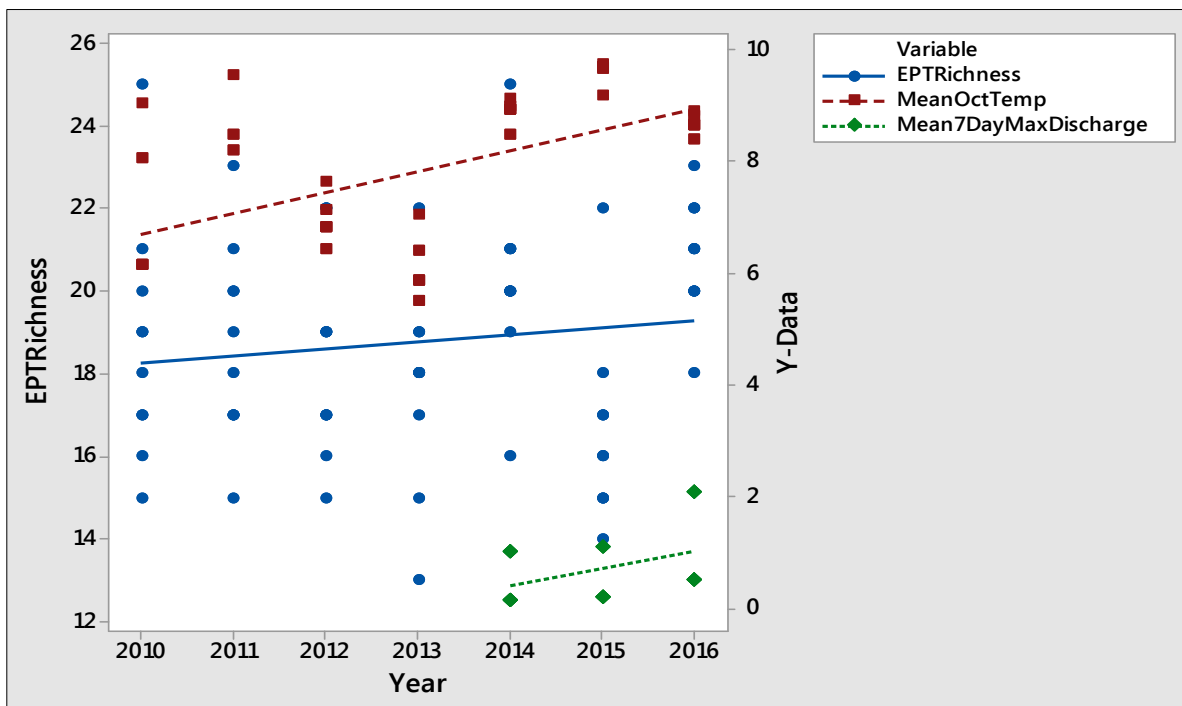


Figure 1. Scatterplot of benthic EPT taxa richness and the top two predictors from the final model, the mean October temperature, and the mean 7-day maximum discharge, by year.

Camp Creek Restoration: A BACI Comparative Analysis

Mark Rogers, Oregon State University, Corvallis, OR

Abstract

The MFIMW employed a hierarchical experimental framework to evaluate restoration actions at both watershed and subwatershed scales. While the watershed scale experiment evaluated the response of multiple restoration types over a large time scale, a subwatershed experiment (Camp and Murderer's Creek Restoration Experiment) evaluated a single restoration action type, the removal of log weir fish passage barriers and large wood additions along Camp Creek (CMP), in a single restoration event in summer 2011. Removal of these barriers were hypothesized to increase age 1 steelhead density, growth, and productivity by lessening interference and exploitative competition within these sites. While the results indicate that age 1 steelhead densities increased following restoration, it was found that discharge, and not restoration actions, was most likely responsible for the observed increases. Furthermore, exploitative competition, estimated by density regulation of summer growth, remained within the system after restoration. Interference completion, estimated by age 1 steelhead survival, also did not change following restoration. Finally, the presence of juvenile Chinook in CMP prior to restoration and no detectable increase in Chinook migration after restoration suggest that log weirs did not significantly limit steelhead habitat utilization in CMP, and their removal most likely did not increase utilization in the CMP ODFW sites. In conclusion, the expected beneficial effects of log weir removal appear to have been overestimated since the changes did not lead to statistically significant improvements in fish passage, competitive effects, nor increases in age 1 salmonid density, growth, or productivity. However, high stream temperatures were shown to dramatically suppress growth and productivity. Therefore, high stream temperatures may have suppressed improvements in steelhead population metrics that would have been detected given a lower temperature regime.

Key Findings

- The BACI design, in conjunction with other analyses, is a valuable tool in stream restoration evaluation. However, BACI assumes "parallel trajectories" and is difficult to apply successfully if this assumption is not met.

- Due to correlation between Age 0 survival (estimated by Age 1 Abundance/spawner) and mean summer discharge of the preceding year, increased discharge is most likely responsible for the observed increase in age-1 density post-restoration in Camp Creek (Figure 1).

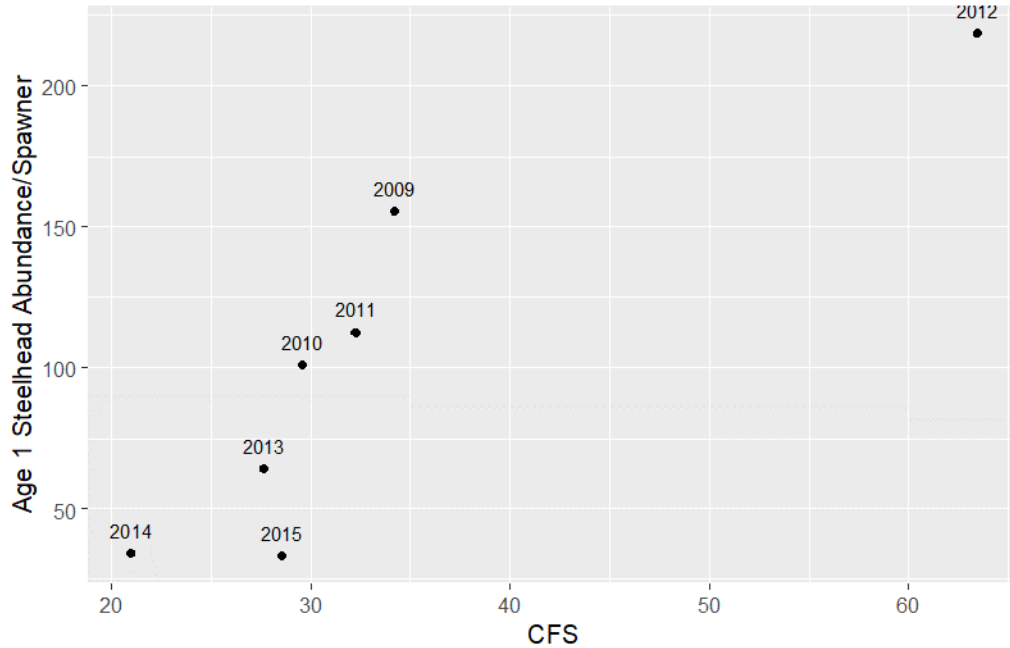


Figure 1. Age 0 survival (estimated by Age 1 Abundance/spawner) vs. mean summer discharge. Discharge values are from the year preceding the abundance measurement (i.e. Abundance: 2012, Discharge 2011).

- Discharge, which had a significant effect on age 1 steelhead densities in Camp (CMP), did not correlate between Camp and Murderer's Creek (MRC), confounding the results of the BACI analysis (Figure 2).

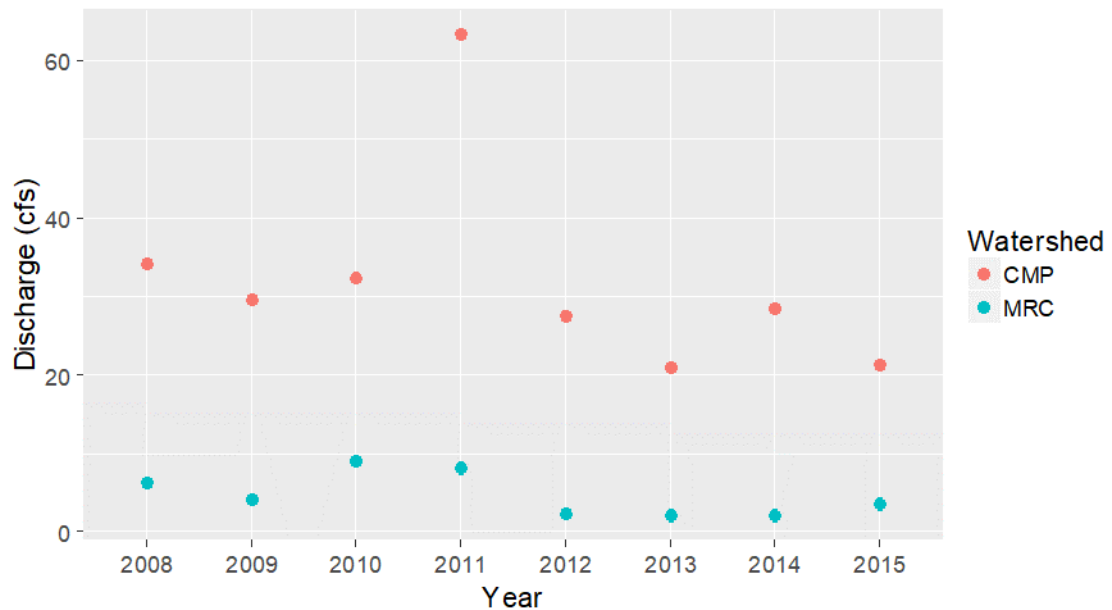


Figure 2. Mean annual discharge of CMP and MRC. Note: The Camp Creek USGS gage (located just upstream of the CMP-MFJD confluence) was applied as a surrogate for discharge measurements in CMP.

- MFJDR stream temperatures were much higher than the SFJDR in the post-restoration period. This created the potential for differential steelhead migration between MFJDR-Camp Creek and SFJDR-Murderer's Creek, violating the assumptions of the BACI analysis.
- Steelhead migration into Camp Creek did not account for the increase in steelhead density observed in the post-restoration period.
- Chinook migration from the MFJDR to Camp Creek did not detectably increase following restoration, indicating that log weirs were not a significant barrier to migration.
- Log weir removals and LWD additions did not significantly lessen competitive effects or increase salmonid density, growth, or productivity.
- High stream temperatures within Camp Creek in the post-restoration period may have overcome any potential productivity gains provided by restoration actions (Figure 3).

Steelhead Life-Cycle Models and Bioenergetics

In a collaborative effort with the Integrated Status and Effectiveness Monitoring Program (ISEMP), a life cycle model (LCM) for steelhead was developed using regional habitat data and fish data specific to the MFJDR (McHugh et al. 2017). Two restoration scenarios were modeled; one scenario aimed to enhance rearing capacity and survival for juveniles by providing cooler summer temperatures and another that aimed to increase the population's juvenile carrying capacity by increasing the structural/hydraulic complexity of select reaches (via large wood and structural additions). The intent was to take a practical approach for upscaling reach-level mechanistic models to inform population-level assessments.

The distribution monitoring conducted to determine the extent of habitat use by both steelhead and Chinook was designed to provide localized temperature tolerance parameters to refine a bioenergetics model. Site occupancy by juvenile Chinook salmon dropped off significantly at 20°C and approached zero at 25°C. Juvenile steelhead were more temperature tolerant. Fifty percent site occupancy occurred at 22°C and we continued to observe some steelhead up to 26°C.

The McHugh et al. (2017) model indicated that restoration designed to reduce temperature was more influential than those designed to increase habitat complexity. While both strategies have the potential to improve the conservation status of steelhead, the benefits of woody structure addition were relatively minor compared to those resulting from stream temperature reduction. Their findings suggest that the benefits of wood addition would be optimized if (1) structures were added at a considerably higher rate than is often done, and (2) these efforts were paired with extensive riparian planting, which would address thermal limitations and offer a natural source for wood recruitment.



Photo 16. Adult steelhead. *Courtesy of ODFW.*

Socio-Economic Indicators Follow-Up Study

M. Hibbard, S. Lurie, and R. Bohner, University of Oregon, Eugene OR

Abstract

Only the Middle Fork John Day River Intensively Monitored Watershed (MFIMW) project includes a socio-economic element that is monitoring the contribution of restoration projects to the socio-economic health of the local community, often called the restoration economy.

This study examined the socio-economic effects of restoration work in the MFIMW in two ways.

- A set of community indicators assessed the overall socio-economic well-being of Grant County over time and put the restoration economy into context. These measures were collected from existing sources that are sensitive to the effects of restoration work.
- A set of outcome measures estimated the contribution of MFIMW restoration work to the Grant County economy. Outcome measures were based on an inventory and analysis of completed projects.

The indicators show that Grant County was in socio-economic decline over the past 40-50 years but that things are improving recently. In particular, jobs and earnings are both up, and other indicators support that trend. At the same time the Grant County economy is doing better, restoration work is bringing work and money into the economy.

Restoration-related planning, management, and monitoring jobs in Grant County nearly doubled between 2000 and 2016.

Key Findings

- Restoration-related planning, management, and monitoring jobs in Grant County nearly doubled between 2000 and 2016 (Table 1).

Table 1. Number of Restoration-Related Planning, Management, and Monitoring Jobs in Grant County: 2000, 2009, and 2016

Organization	2000		2009		2016	
	FTEs	Employees	FTEs	Employees	FTEs	Employees
Grant County Soil and Water Conservation District	4.00	5	7.50	8	8.00	10
North Fork John Day Watershed Council	1.50	2	3.75	4	5.50	6
Confederated Tribes of Warm Springs	2.00	2	6.40	10	18.90	20
Oregon Department of Fish and Wildlife	27.25	29	30.50	33	33.00	37
The Nature Conservancy	1.00	1	2.50	3	0.00	0
USDA Malheur National Forest	6.00	6	7.00	7	10.00	10
USDI Bureau of Reclamation	0.00	0	1.00	1	1.00	1
South Fork John Day Watershed Council	0.00	0	0.50	1	1.20	2
Natural Resources Conservation Service	1.50	2	2.00	2	2.00	2
Monument Soil and Water Conservation District	3.00	3	1.00	1	2.00	2
Oregon Department of Forestry	0.00	0	0.00	0	0.45	3
Oregon Water Resources Department	0.30	2	0.30	2	0.30	2
USDA Farm Service Agency	Unknown	Unknown	Unknown	Unknown	0.10	1
Blue Mountains Forest Partners	0.00	0	1.00	1	1.00	1
Totals	46.55	52	62.45	73	83.5	97

- OWEB capacity grants, basic operating funds for watershed councils and SWCDs, have brought a total of \$1,277,150 to Grant County since 2007. When the multiplier of 5.09 is considered, capacity grants brought about \$6.5 million to the local economy.
- The 100 restoration projects carried out in the MFIMW area in the period from 7/1/07 to 6/30/17 brought a minimum of \$15.6 million dollars into the local economy, along with creating nearly 170 jobs and generating additional economic activity in the range of \$20-25 million (Table 2).

Table 2. Summary of jobs and additional economic activity in Grant County from MFIMW Projects 7/1/07-6/30/17. Dollar amounts are in millions.

Organization	All-projects total cost	Jobs (direct, indirect, and induced)	Additional economic activity generated
OWEB-19 projects	~\$10.3	111	\$12.9-\$16.3
All projects-80	at least \$15.6	168	\$19.6-\$24.8
MNF-48	~\$4.5	49	\$5.7-\$7.2

Lessons Learned and Recommendations

Adaptive management (AM) is an important component of any restoration plan and an AM framework can effectively be incorporated into the IMW structure (Bouwes et al. 2016). As part of the adaptive management process, we asked that researchers and restoration practitioners share lessons learned and future recommendations based on their involvement with the MFIMW. These lessons and recommendations extended beyond what was learned from study findings; they illustrate how the participants would incorporate improved methodologies and strategies into subsequent phases of the IMW process and future IMW programs, given lessons learned from their experiences. This section summarizes these lessons learned and recommendations compiled from each of the MFIMW partner projects, providing an integrated overview of key aspects of the project. Readers should refer to individual reports for details and supporting information.

Several similar themes emerged from multiple participants. Therefore, lessons learned and recommendations are grouped by theme: Planning, Monitoring, and Restoration. In this context, Planning refers to the planning, facilitation, and coordination of the MFIMW process and group itself. Monitoring refers to data collection and evaluation. Restoration refers to practical recommendations for on-the-ground actions. Where possible, we pair lessons learned with accompanying recommendations based on what we gleaned from experience. This section presents a compendium of lessons that are not prioritized, but should provide valuable insights for ongoing planning, monitoring, and restoration efforts to make improvements within the MFIMW and similar IMWs.



Photo 17. Surveying the Oxbow area. *Courtesy of University of Oregon.*

Steelhead and Chinook Salmon Monitoring and Evaluation

K. Handley, Oregon Department of Fish and Wildlife, John Day, OR

J. Ruzycki, Oregon Department of Fish and Wildlife, La Grande, OR

Planning

Lesson Learned

Although this study developed fish survival, abundance, and growth metrics, these metrics were not mechanistically related to habitat variables.

Recommendation

To investigate fish/habitat relationships, design paired study reaches across specific habitat variables to address specific questions

Recommendation

Couple habitat with fish monitoring to answer questions about fish survival, growth, and abundance in a paired experimental fashion using newly developed models that link habitat metrics to fish metrics.

Recommendation

Expand use of bioenergetics and life-cycle models to investigate influential mechanisms.

Monitoring

Lesson Learned

Juvenile fish movement is the most important factor influencing accurate estimates of survival.

Recommendation

Improve understanding of juvenile Chinook movement and distribution during baseline (pre-treatment) conditions.

Recommendation

Include additional sampling events during winter to better understand juvenile salmonid movement throughout the year.

Lesson Learned

Monitoring of out-migrating juveniles needs to be a 24/7 operation when fish are migrating. Episodic migration and flow events can skew estimates.

Recommendation

Operate rotary screw trap site continuously throughout the migration.

Restoration

Recommendation

Restoration actions take decades to achieve results. In the interim timeframe, evaluate restoration actions using habitat response variables and then use predictive models to link to fish responses.

Stream Habitat Condition for Middle Fork John Day River and Camp Creek Watershed

K. Fetcho, Oregon Watershed Enhancement Board, Salem, OR

E. Archer and J. V. Ojala, USDA Forest Service, Logan, UT

Planning

Lesson Learned

Cost and time savings were achieved through collaboration of temperature monitoring, allowing PIBO crews to focus on habitat monitoring.

Recommendation

Evaluate tasks across the scope of the entire project to identify economies of scale.

Lesson Learned

While the MFIMW decided to fund PIBO data collection, no specific entity was identified to analyze the data collected in the different geographic areas.

Recommendation

Collaborative partnerships need a point person to analyze data, streamline workflow, and create efficiencies to meet stated objectives for all partners involved.

Lesson Learned

The PIBO approach offers a consistent framework to detect changes in stream habitat at the watershed scale and to evaluate status and trends over that larger scale.

Recommendation

A useful next step from this study would be to combine all existing PIBO and CHaMP data from the MFIMW. Analyze Camp Creek data with the other randomly established PIBO tributary sites that the USFS Research station has established throughout the MFJDR to better describe changes over a larger watershed scale.

Monitoring

Lesson Learned

The PIBO sites were resampled in 2014 after the initial investment of establishing these sites in 2008/2009, gaining valuable information.

Recommendation

Future sampling of the MFJDR and Camp Creek sites should continue to occur at 5-year intervals. The next sampling event should occur in 2019.

Recommendation

Further data analysis from the control and treatment sites in Camp Creek will help determine changes in physical habitat from restoration actions (e.g., the removal of log weirs and subsequent addition of large woody debris). Analyze the PIBO vegetation data to understand how riparian habitats have changed based on passive and active restoration actions in both geographic areas. Specifically, we suggest answering the following questions after the 2019 resurvey is performed:

- Have riparian plantings improved the vegetation and how does this compare to passive restoration actions (fencing and grazing management) alone?
- Has the change in riparian vegetation affected physical habitat attributes such as bank stability and percent fines in pools?
- Are invasive plant species more predominant; if so, which ones?

Lesson Learned

Long-term data sets that are sampled at regular intervals are essential to detect trends.

Recommendation

Long-term monitoring should continue in the MFJDR and Camp Creek to track habitat changes. Maintain continuity of long-term sampling sites to enable trend detection using an established protocol that generates habitat metrics important to salmonids.

Geomorphology and Physical Habitat

Patricia McDowell, PhD, University of Oregon, Eugene, OR

Planning

Lesson Learned

The initial monitoring plan design was influenced by new restoration projects being implemented during the course of the study that were not anticipated. This precluded a before-after monitoring study.

Recommendation

Develop a long-term restoration plan before designing the monitoring plan that incorporates a communication plan.

Lesson Learned

Passive restoration actions can improve aquatic habitat and help us understand how active restoration improves habitat. Passive restoration in this region mainly occurs through removal or reduction of livestock grazing. Vegetation within the channel and riparian zone is the main driver of response.

Recommendation

It is important to think through potential processes and effects of vegetation change while designing active restoration and coupled monitoring projects.

Lesson Learned

The flood of 2011 was unanticipated. Fortunately we had quite a bit of monitoring from 1 to 2 years before the event, providing essential baseline information.

Recommendation

Develop in advance a plan for monitoring if a large flow event occurs.

Monitoring

Lesson Learned

Our data yielded important insights into the effectiveness of restoration actions. Few actions had immediate effects; most developed over a period of a few years following restoration.

Recommendation

Results from the physical habitat surveys during the MFIMW further support the observation that it takes several years to show measurable results from restoration actions, and monitoring should be supported and evaluated throughout this timeline.

Lesson Learned

This project integrated high-resolution aerial imagery from several sources. These tools greatly enhanced our collection of field data.

Recommendation

Use remote sensing data to complement field measurements.

Restoration

Lesson Learned

Results show that residual pool depth, pool frequency, and frequency of deep pools increased, with the deepest pools associated with log structures.

Recommendation

Incorporate the placement of log structures in existing or constructed pools to maintain depth as a restoration technique.

Influence of Deer and Elk Browsing on the Success of Riparian Restoration Plantings

Lessons learned and recommendations summarized by the MFIMW Summary Report's authors from the original text by S. M. Wondzell and B. R. Cochran.

Restoration

Lesson Learned

Deer and elk browse pressure is preventing riparian plantings from growing tall enough to shade the river in some areas. Establishment of planted native woody riparian vegetation may be jeopardized if planted areas are only fenced to exclude livestock, allowing continued access by deer and elk.

Recommendation

Consider ways to protect woody riparian species from browsing by deer and elk.

Lesson Learned

Data indicate that several native woody riparian species may be especially susceptible to deer and elk browsing when planted in riparian areas. These include black cottonwood, red osier dogwood, blue elderberry, and willow.

Recommendation

When planning riparian plantings, consider the specific needs of plant species. If there is low ability to maintain or protect new plantings from browsing, focus on species known to be resistant to browsing.

Lesson Learned

Some native woody riparian species appear to be much less affected by deer and elk browsing than others. These include Ponderosa pine and thinleaf alder.

Recommendation

Planting species that are less affected by browsing, such as Ponderosa pine and thinleaf alder, may allow the establishment of a forested riparian canopy with a hardwood understory, achieving the desired condition of streamside shade.

Projected Response of Riparian Vegetation to Passive and Active Restoration over 50 years

Lessons learned and recommendations summarized by the MFIMW Report's authors from the original text by S. M. Wondzell, M. A. Hemstrom, and P. A. Bisson.

Planning

Recommendation

Models can be readily modified to explore aquatic, riparian, and terrestrial management scenarios, and explore how policy decisions may influence future habitat conditions.

Recommendation

Expectations for restoration outcomes should be tempered with a realistic understanding of the rate at which natural systems can recover and account for relatively rare episodic events.

Restoration

Recommendation

Our simulations indicated that restoration could be substantially accelerated through active restoration practices. However, active restoration is more expensive. Consequently, the choice between active and passive restoration needs to be made carefully.

Recommendation

Our simulations suggest that active restoration will have a bigger impact on species that have a limited potential spatial distribution, and where a significant proportion of the available habitat is in poor condition.

Water Temperature Monitoring

K. Bliesner, Oregon Department of Fish and Wildlife, La Grande, OR

E. Davis, Confederated Tribes of the Warm Springs Reservation of OR, Warm Springs, OR

J. Rowell, North Fork John Day Watershed Council, Long Creek, OR

Planning

Lesson Learned

Working with the vast amount of temperature data synthesized during this project caused some difficulties in data processing. For example, temperature data collected by various partners was assembled into a large Access database, and the results included more 'outlier' points than expected.

Recommendation

Identify an appropriate platform for storing temperature data and secure funding to purchase, develop, and maintain the platform. Clearly communicate consistent monitoring goals and written protocols for data collection, quality control, and analysis methods. This communication is especially important when multiple organizations are contributing data.

Lesson Learned

Conducting quality control measures years after the data was collected was inefficient.

Recommendation

Perform consistent and timely quality control procedures every season after the data is downloaded. Develop a data collection protocol and quality control procedures in collaboration with all data collection entities to ensure its usefulness.

Recommendation

Additional quality control still needs to be completed on the existing data set. Ensure that future database uploads follow all quality control procedures.

Lesson Learned

Staff turnover and time lags resulted in site selection occurring in a somewhat reactive manner, with documentation often lacking. Moreover, any large-scale natural resources project is subject to unexpected environmental changes and inevitable lost loggers or other unforeseen events.

Recommendation

Establish clear monitoring goals, perform mid-project analysis, document reasoning behind site selection, and maintain communication with collaborators as the study continues. Use an adaptive monitoring approach, with clear documentation to help during times of staff and/or funding changes.

Recommendation

Form a committee of individuals invested in temperature monitoring to develop a Sampling and Analysis Plan for water temperature monitoring to ensure consistent field protocols and data QA/QC measures are followed. Consider a statistical site selection process like GRTS and contributing data to NorWest.

Lesson Learned

Collecting data without linking the data needs to specific management or restoration questions produced datasets collected in an ad-hoc manner, without the time series needed to document changes before and after specific actions.

Recommendation

Link monitoring projects with specific management or restoration questions. For example, identify specific restoration projects that are anticipated to affect water temperature and then document changes pre-/post-restoration.

Lesson Learned

Large amounts of data were collected during this project and additional analyses of the resulting datasets would continue to yield worthwhile information from this study.

Recommendation

Identify statistical analyses that could include air temperatures and flow data to better understand watershed level water temperature changes. For example:

- Complete 7DADM analysis on tributary loggers
- Complete analysis incorporating air temperature and flow data.
- Identify loggers with data before and after MFIMW inception (2008) and calculate differences – similar to SFJDR vs MFJDR analysis.
- Update HeatSource and/or ISEMP models. Use results to identify restoration activities that influence water temperature.

Monitoring

Lesson Learned

Lack of communication among groups about their monitoring activities resulted in unnecessary duplication of effort.

Recommendation

Coordinate among water temperature data collection efforts, including CHaMP and ODFW, to promote collaboration, avoid duplication, and create efficiencies.

Restoration

Lesson Learned

The increased surface water area of Bates Pond elevates water temperature outflow to the extent that lower Bridge Creek is warmer than the MFJDR during much of the summer. This restricts the potential of Bridge Creek to act as thermal refugia both downstream and above Bates Pond since fish will not ascend the fish ladder at the elevated temperatures.

Recommendation

A complete evaluation of the influence of the current and restored Bridge Creek habitat potential should include a temperature analysis using the HeatSource model to understand impacts to fish using a bioenergetics modeling approach to fully understand the restoration alternatives.



Photo 18. Bates Pond. *Courtesy of ODFW.*

Monitoring and Assessment of Critical Thermal Dynamics in Upper Middle Fork of the John Day River, 2008-2016

Oregon State University MFIMW Team, Oregon State University, Corvallis, OR

Planning

Lesson Learned

Though this study lasted nearly a decade, the processes and cycles which influence salmonid populations span much longer time scales.

Recommendation

Develop a plan to collect additional data over decadal scales to accurately assess how changes to vegetative cover (shading) might impact stream temperatures.

Monitoring

Lesson Learned

Temperature was a key variable of interest to all partners throughout the MFIMW. Specifically, DTS with deterministic temperature modeling can be used to predict changes due to hyporheic exchange and inform restoration planning.

Recommendation

Consider results in concert with other findings from the IMW to understand the apparent lack of hyporheic water exchange within the MFIMW.

Recommendation

DTS can be implemented to identify locations and magnitude of groundwater influence.

Lesson Learned

Thermal Infrared/FLIR data can help evaluate stream temperature at a large spatial scale, but if data is not collected throughout the 24-hour cycle, it is difficult to fully evaluate the temperature signature.

Recommendation

Collect data throughout the day to evaluate the full temperature signature.

Restoration

Lesson Learned

We now have information about sources and locations of cold-water inputs to the MFJDR. Groundwater upwelling is the primary cooling influence on tributaries, while the confluence of tributaries with the

mainstem, in turn, provides the primary cooling mechanism for the MFJDR as a whole.

Recommendation

The magnitude and location of cold water inputs into the MFJDR from tributaries and groundwater upwelling can be leveraged in restoration designs.

Lesson Learned

Stream temperatures continue to limit the production of juvenile salmonids. Restoration can increase and/or decrease stream temperatures. Stream area and shade are major contributing factors to stream temperature. Reducing stream area has a more immediate effect, whereas improvements to effective shade should be a long-term goal. Stream area exposed to sun was the primary factor influencing changes in stream temperature.

Recommendation

Restoration should incorporate the reduction of exposed stream area to maximize salmonid productivity and restoration effectiveness.

Lesson Learned

Many factors can limit salmonid productivity including access to floodplains, sinuosity, and channel complexity. Floodplain restoration incentives need to be balanced with late summer discharge expectations to minimize loss of habitat.

Recommendation

Managers need to consider how goals and factors interplay through adaptive management, and prioritize actions as needed to achieve their priority goals.

Lesson Learned

Tributary restoration to improve groundwater connectivity can assist in reducing tributary temperatures.

Recommendation

Future restoration efforts should include temperature analyses in their restoration impacts assessments to maximize benefits to salmonids.

Recommendation

Evapotranspiration for the restored system should be analyzed based on the changes in the riparian system. Greater shade requires larger plants, which consume water.

Future Changes in Mainstem Water Temperatures in the Upper Middle Fork John Day River and the Potential for Riparian Restoration to Mitigate Temperature Increases

Lessons learned and recommendations summarized by the MFIMW Report's authors from the original text by S. M. Wondzell, M. Diabat, and R. Haggerty.

Planning

Lesson Learned

The rate of climate change may be too fast for plantings to produce benefits. Although they are the most resistant to deer and elk browsing pressure, ponderosa pine plantings may take over 100 years to grow to 30 m height in the MFJDR.

Recommendation

Plant faster-growing species such as cottonwood, alder, and aspen to achieve relatively large closed canopy conditions within a few decades. Given these species can be susceptible to animal browsing, invest in efforts to exclude browsers, including deer, elk and beaver.

Restoration

Recommendation

Given the importance of temperature in habitat quality, focus riparian revegetation efforts in streams where shade is currently limited. Use a long-term approach to measure the effects of riparian plantings given uncertainties around climate change.

Analysis of Benthic and Drift Macroinvertebrate Samples

R. Henderson, Washington State University - Tri-Cities, Richland, OR

Planning

Lesson Learned

The sample design was not balanced, minimizing the strength of the relationship between the predictor and response variables.

Recommendation

Ensure sufficient sample size and power to answer research questions. Statistical tests, particularly parametric tests, are most powerful with balanced designs.

Lesson Learned

Selecting a useful predictive model involves evaluating tradeoffs. For example, while a particular predictive model may improve prediction

accuracy, other model qualities like precision, bias, sensitivity, or responsiveness may not increase.

Recommendation

Carefully consider all attributes of the predictive model used to guide stream restoration.

Monitoring

Recommendation

Explore if functional group analysis and spatial models would support the hypothesis that management actions are affecting the biotic integrity of the MFJDR.

Recommendation

Future investigations should increase the number of macroinvertebrate collection sites within control reaches to better explore biotic integrity changes with stream restoration.



Photo 19. Alders planted October 2016.
Courtesy of CTWSRO.

Analysis of the Relationship between Macroinvertebrates, Streamflow, and Temperature in the Middle Fork John Day River, OR

Robin Henderson, Washington State University - Tri-Cities, Richland, OR

Monitoring

Lesson Learned

Because of inconsistent streamflow and temperature data collection, the comparisons in this study have reduced statistical power.

Recommendation

Have a consistent data collection effort across data types, years, and sites to limit noise and variability and increase power of the analysis.

Camp Creek Restoration: A BACI Comparative Analysis

Mark Rogers, Oregon State University, Corvallis, OR

Planning

Lesson Learned

Differential climatic factors among restoration and control watersheds limit attribution of responses to restoration actions. As a result, finding a suitable control watershed that correlates with the restoration watershed is difficult.

Recommendation

Alternative designs should be examined for future watershed scale restoration experiments. The paired-reach BACI design is promising. Alternative BACI designs should be researched through simulation and in the field.

Socio-Economic Indicators Follow-Up Study

M. Hibbard, S. Lurie, and R. Bohner, University of Oregon, Eugene OR

Planning:

Lesson Learned

Analyzing socio-economic outcomes is not a straightforward, formulaic process, and needs to be tailored to the watershed and local community.

Recommendation

Guidelines for how to track and analyze connections between ecosystem restoration and contributions to local economies should be established before restoration actions are implemented. Define what types of data are needed and how to extrapolate from unique characteristics and specific restoration projects.

Recommendation

Define indicators and outcome measures in consultation with local officials and residents, to gauge metrics that are important to them.

Recommendation

Use the measures to inform the general public about the socio-economic contribution of restoration efforts and as an input to public decision-making and action.

Recommendation

Use the measures to help private landowners as they make decisions about engaging in restoration work so they can put these decisions in the context of the local economy.

Lessons Learned from Oxbow Conservation Area Dredge Tailings Restoration Implementation

CTWSRO and USBOR

Lesson Learned

Installing willow cuttings, planting nursery stock, and transplanting native vegetation that was salvaged from the restoration site was a challenging task for the heavy equipment contractor, who was not trained specifically in restoration work.

Recommendation

Require a licensed landscape specialist to work with the contractor on plant salvage and planting operations.

Recommendation

Salvage and re-plant all native vegetation when possible. This ensures that new channels look natural sooner, and the vegetation holds soils and the banks together.

Lesson Learned

Design modeling using a LiDAR imagery surface was not field-checked prior to implementation of new channels. In some cases, LiDAR likely read the top of the dense vegetation instead of actual ground readings, potentially resulting in a mischaracterization of on-the-ground habitat conditions.

Recommendation

Ground-truth the LiDAR data set before the design process is initiated.

Lesson Learned

Exclosure fencing specifically designed to keep out wild ungulates reduced elk and deer browse on vulnerable new riparian plantings.

Recommendation

Install elk-proof fencing to protect investment in riparian plantings.

Lesson Learned

Within the first couple of years, some plantings died on the restored tailings area, likely because of the lack of topsoil and reduced ability to hold soil moisture. Survival increased when irrigation systems were introduced.

Recommendation

Invest in irrigation to keep riparian plantings alive through the first 2 to 3 growing seasons to establish their sustainability.

Lesson Learned

Riffle construction in newly constructed channels is extremely challenging. Without a sealed riffle crest, water during low flows tended to move subsurface through glide substrates, especially at sites where the start of the glide was at a higher elevation than the riffle crest. If the riffles wash out, you will lose the entire habitat for that stream segment.

Recommendation

Channel design must conform to a profile where the riffle crest or head is the highest feature in the substrate. Riffles need fines washed in to ensure the matrix is hardened and stable.

Recommendation

Determine if future flooding flows will assist with sealing riffles substrates. It is possible that high flows may degrade riffle crests that are not adequately constructed.

Lesson Learned

Evaluating information after the completion of the Oxbow restoration project was difficult without the availability of pre-project, refined tributary population assessments.

Recommendation

Wherever possible, acquire appropriate baseline information specific to areas of interest.

Lesson Learned

Base flow channel-width relative to sun exposure plays an important role for temperature restoration.

Recommendation

Add design elements that would cause sediment deposition over time, as well as large wood and gravel placements to narrow the active low-flow channel.

Lesson Learned

Log structures that obstruct the channel help to maintain better pool scour.

Recommendation

To maintain scour and provide other benefits, place large wood structures out into the channel.

Lesson Learned

Role of torrent sedges, substrate size information, and information about pools maintaining at log jams was useful when designing restoration projects.

Lesson Learned

Much of the fish mortalities during salvage operations occurred while transferring fish in buckets to release points.

Recommendation

Ensure there are adequate personnel to transfer fish to decrease transfer time and reduce mortalities.

Lessons Learned and Recommendations from US Forest Service Restoration Efforts

Planning

Lesson Learned

Large wood placement restoration actions were initially planned using Forest Plan standards and guidelines that provide wood loading based on the type of forest. Results of the MFIMW show the value of considering additional information, and the level of planning prior to implementation in 2011 has now increased.



Photo 20. Log placement.
Courtesy of University of Oregon.

Recommendation

Consider stream gradient and valley confinement, riffle lengths, pool quality and quantity in addition to existing large wood loading and recruitment to improve instream conditions.

Recommendation

Place wood that interacts with low flow conditions, and consider side channels and other human features that constrain valley processes. Consider treating the entire reach and valley, rather than patches with log weirs.

Lesson Learned

The USFS evaluated beaver habitat intrinsic potential for the watershed using NetMap and evaluated beaver dam densities using the Beaver Restoration Assessment Tool (BRAT) to target and implement stream restoration actions in reaches showing large heat gains in Camp Creek in 2016.

Recommendation

Valuable tools and information, such as NetMap and BRAT, are available to evaluate various limiting factors or processes impacting riparian and instream conditions. Consider these tools when prioritizing actions in landscapes with riparian community and beaver issues.

Restoration

Lesson Learned

In 2011, a public relations issue was created when the USFS implemented fish passage and habitat restoration actions in Camp Creek using large, visible heavy equipment. A negative public response and a front page newspaper article slowed the implementation of instream restoration actions in 2012.

Recommendation

Be prepared for different public perceptions when implementing large-scale restoration projects and perform adequate community outreach to minimize negative responses from the community.

Lesson Learned

After fisheries abundance and survivability monitoring results were available, we realized that restoration actions were first implemented in reaches with multiple compounding limiting factors in Camp Creek. Wood-limited juvenile rearing was a secondary impact, except in favorable streamflow years. Large temperature gains in upstream reaches likely had a greater impact. Had all the information been available at the beginning, then actions may have been implemented with objectives to restore water table dynamics and improve survivability in the headwater reaches first, because restoring these cooler areas could influence food inputs and conditions for survivability in the lower reaches as they were restored later in the timeline.

Recommendation

Through collaborative working groups and clear communication structure throughout the project, ensure adequate opportunities for all partners to learn where monitoring and restoration actions are planned.

Recommendation

Evaluate landscape restoration actions from ridgetop to ridgetop, considering resistance and resilience to biophysical processes and ecological functions from a top-down context. Integrate planning into the revegetation program. Consider valley characteristics and processes of solar radiation loading. Identify plants that are ecologically appropriate for the site, and plant at distances that can expand without management inputs through passive management.

Lessons Learned and Recommendations from MFIMW Contributors and Workgroup Discussions

See also Provisional Experimental Design and Implementation Plan (2011)

Planning

Lessons Learned

It was challenging to compile all of the information needed for the restoration inventory.

Recommendation

Agree upon a list of required information to be stored in the restoration inventory and update it annually with the restorationists.

Lesson Learned

The MFIMW shows that continued coordination is needed when multiple agencies are implementing restoration actions across such a broad area. When communication is lacking, different levels and types of restoration actions may be applied, potentially confounding experiments.

Recommendation

Provide clear communication structures to develop Implementation and Experimental Design among all partners involved. Provide adequate time for restorationists to buy in to the Experimental Design in order for treatment and control areas to be maintained as best as possible to allow long-term monitoring and statistical analyses.

Lesson Learned

Visiting researchers needed a “base camp” with adequate water, communication infrastructure, and other resources to accomplish their work. For the latter portion of the MFIMW study period, a base camp was created at the CTWSRO Oxbow Conservation Area by bringing in some used RVs, adding amenities such as a propane shower, and ensuring enough staff time and funding to maintain the facility. This base camp was critical for smooth research operations.

Recommendation

For future IMW work, fund and maintain the research station for visiting researchers at the CTWSRO’s Oxbow Conservation Area. Use RVs to complement available local housing or tent camping. The current RV may provide several more years of use, but will need to be replaced eventually.

Lesson Learned

The USGS gage near Camp Creek provided key information for many partner programs to design restoration projects and interpret monitoring results.

Recommendation

Continue to prioritize funding this gage to allow long-term streamflow data collection.

Lessons Learned & Recommendations for Future Restoration Actions on the MFIMW

Lesson Learned

Our MFIMW monitoring group benefitted from collaboration and coordination.

Recommendation

MFJDR restorationists would benefit from a strategic plan that includes collaboration and coordination while also targeting actions suggested herein.

Lesson Learned

Several lines of evidence point to flow and water temperature having the greatest influence on salmonid recovery in the MFIMW.

Recommendation

Future restoration actions should target flow enhancement in the upper reaches of the watershed where cool water originates.

Recommendation

Stream water surfaces need to be protected in tributary and upstream reaches from solar insolation to keep this cool water cool. Specific reaches to consider for restoration include:

- Cool-water tributaries such as Bridge Creek that have been particularly altered and no longer retain their cool water connection to the MFJDR.
- Meadow and pasture reaches of the mainstem MFJDR from Caribou Creek upstream through Phipps Meadow that remain with poorly developed riparian shade and altered channel profiles.

Next Steps

Over the next year various efforts will be performed by the MFIMW to build on the lessons learned and recommendations that are described in this report. Many participants of the MFIMW are interested in developing an outreach strategy to report the MFIMW key findings to various audiences. These outreach efforts will likely span a period of time to receive adequate input and develop the appropriate approach and materials to inform the different audiences that are identified. Some of the audiences that are important to the MFIMW include the funding agencies such as NOAA, OWEB, and BPA. Other important audiences include the local community and restoration practitioners (SWCDs, watershed councils) in the John Day Basin.

Important work that also awaits us is to make modifications to core priority monitoring efforts to ensure the study design is able to provide data that will continue to help us answer our questions. In addition, the MFIMW will work proactively with NMFS, PNAMP, and other IMWs in the PNW to reflect on the lessons learned across the broader IMW network, and determine how the MFIMW moves forward to provide needed information for decision makers and practitioners.



Photo 21. Middle Fork area. *Courtesy of ODFW.*

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Appendices

Appendix A.

List of restoration projects completed in the MFIMW study area. Restoration activities include both active restoration, including “on-the-ground” or “dirt-moving” activities, and passive restoration, which involves changes to management practices and use of landscapes.

Restoration Project Name	Lead Entity ¹	Year Completed	Restoration Activity ²	Total Cost
Clear Creek above MFJDR	TFT	2006	FI	\$100,000
Clear Creek above MFJDR	TFT	2006	FI	\$100,000
MFJDR above NFJDR	TFT	2006	FI	\$100,000
MFJDR above NFJDR	TFT	2006	FI	\$100,000
MFJDR above NFJDR	TFT	2006	FI	\$100,000
MFJDR above NFJDR	TFT	2006	FI	\$100,000
Vinegar Creek above MFJDR	TFT	2006	FI	\$100,000
Big Boulder Channel Relocation	TNC	2008	CR; FR; IHI	\$300,000
FCA CREP	CTWSRO	2008	RM	Not Available
Forrest Dead Cow Gulch realignment	CTWSRO	2008	CR; FR; IHI	\$38,430
OCA CREP	CTWSRO	2008	RM	Not Available
Placer to Davis	CTWSRO	2008	IHI; FR	\$115,000
Vinegar Creek	CTWSRO	2008	RM; UM	\$5,500
Holmes Ditch Diversion	GCSWCD	2008	FP	\$118,112
Davis Creek above MFJDR	TFT	2008	FI	Not Available
TNC Log Jams	TNC	2008	CR; IHI	Not Available
TNC Pine plantings	TNC	2008	RM	Not Available
Beaver 2 aquatic organism passage	USFS	2008	FP	Not Available
Upper Beaver Culvert Replacement	USFS	2008	FP	\$132,900
FCA Instream Habitat Project (CTWSRO Phase I)	CTWSRO	2009	IHI; RM	\$137,788
MFJDR Instream Habitat Imp. (Beaver to Ragged)	CTWSRO	2009	IHI; RM; FR	\$201,005
Stream gravel bar	CTWSRO	2009	CR; FR; IHI	Not Available
Bridge 2 aquatic organism passage	DOT	2009	FP	\$200,000
Bridge aquatic organism passage	DOT	2009	FP	\$200,000
NF Bridge 1 aquatic organism passage	DOT	2009	FP	\$200,000
Butte Creek Culvert Replacement	NFJDWC	2009	FP	\$167,070
MFJD Channel Relocation Restoration Reach 2	TFT	2009	IHI; RM; CR; FR; BS	\$403,072
Beaver 1 aquatic organism passage	USFS	2009	FP	\$65,000
Camp Creek Weir Modification	USFS	2009	FP; IHI	\$5,000
Cougar 1 aquatic organism passage	USFS	2009	FP	\$98,300
Granite Boulder 1 aquatic organism passage	USFS	2009	FP	\$144,000
Lick 1 aquatic organism passage	USFS	2009	FP	\$90,000
Lick 2 aquatic organism passage	USFS	2009	FP	\$70,000
RPB Historic Channel Reconnection Reach II & LWD	USFS	2009	IHI	Not Available

Restoration Project Name	Lead Entity ¹	Year Completed	Restoration Activity ²	Total Cost
Vincent Creek Fish Screen	ODFW	2010	FP	\$40,633
MFJD Channel Relocation Restoration Reach 1	TFT	2010	IHI; RM; CR; FR; BS	\$403,072
Big Boulder Creek (Zaits)	TNC	2010	FP	\$300,000
TNC and Boulder Creek Ranch Aquatics	TNC	2010	IHI; RM; CR; FR; BS	\$386,009
Bridge 3 aquatic organism passage	USFS	2010	FP	Not Available
Bridge 4 aquatic organism passage	USFS	2010	FP	\$300,000
Bridge Creek Culvert Replacements	USFS	2010	FP	Not Available
Camp 3 aquatic organism passage	USFS	2010	FP	\$50,000
Cougar 2 aquatic organism passage	USFS	2010	FP	\$60,000
MFJD Historic Meander Reconnection, Reach 1	USFS	2010	CR; IHI	\$914,000
West Fork Lick 1 aquatic organism passage	USFS	2010	FP	\$300,000
OCA Tailings Restoration - Phase 1	CTWSRO	2011	IHI; RM; CR	\$899,700
Upper Middle Fork Allotment Improvements Phase I	NFJDWC	2011	RM	\$146,672
Camp 2 aquatic organism passage	USFS	2011	FP	\$152,710
Camp and Lick Creek Log Weir Removal Phase II	USFS	2011	FP; IHI	\$104,500
Camp Creek aquatic organism passage	USFS	2011	FP	\$10,000
Charlie aquatic organism passage	USFS	2011	FP	\$60,000
Eagle aquatic organism passage	USFS	2011	FP	\$60,000
Shoeberg aquatic organism passage	USFS	2011	FP	\$70,000
FCA grazing, planting, & invasive control	CTWSRO	2012	RM; UM	\$108,200
OCA grazing, planting, & invasive control	CTWSRO	2012	RM	\$260,823
OCA Tailings Restoration - Phase 2	CTWSRO	2012	IHI; RM; CR; FR; BS	\$1,011,234
Big Rock aquatic organism passage	USFS	2012	FP	\$61,000
Camp Creek Reach 1 Exclosure	USFS	2012	RM	Not Available
Camp Creek Riparian Planting	USFS	2012	RM	\$7,000
Camp Creek Weir Modification	USFS	2012	FP	\$28,750
Cottonwood 1 aquatic organism passage	USFS	2012	FP	\$90,000
Little Trail aquatic organism passage	USFS	2012	FP	\$60,000
Shoeberg 2 aquatic organism passage	USFS	2012	FP	\$64,000
West Fork Camp Creek Weir Modification	USFS	2012	FP	\$28,750
Austin Ranch Voigt Diversion Headgate	CTWSRO	2013	FP	\$12,478
Upper Middle Fork Allotment Improvements Phase II	NFJDWC	2013	RM	\$74,007
Bates State Park restoration project	OPRD	2013	RM; IHI	\$176,658
Hawkins Creek above MFJDR	TFT	2013	FI	Not Available
Camp Creek Watershed LWD	USFS	2013	IHI	\$32,400

Restoration Project Name	Lead Entity ¹	Year Completed	Restoration Activity ²	Total Cost
Placement Project				
MFJDR Channel Relocation Avulsion Repair	USFS	2013	IHI	\$63,866
WF Camp Creek Watershed LWD Placement Project	USFS	2013	IHI	\$32,400
OCA Tailings Restoration - Phase 3	CTWSRO	2014	IHI; CR; FR; BS; RM	\$1,540,773
RPB Easement Fence Installation	CTWSRO	2014	RM	\$85,000
Beaver Creek above MFJDR	TFT	2014	FI	Not Available
Caribou Creek above MFJDR	TFT	2014	FI	Not Available
Davis Creek above MFJDR	TFT	2014	FI	Not Available
Granite Boulder Creek above MFJDR	TFT	2014	FI	Not Available
Vincent Creek above MFJDR	TFT	2014	FI	Not Available
Vinegar Creek above MFJDR	TFT	2014	FI	Not Available
Vinegar Creek above MFJDR	TFT	2014	FI	Not Available
Middle Fork John Day Aspen Restoration	TNC	2014	UM	\$227,753
Camp 2014 LWD, Tree Felling and Weir Modification	USFS	2014	IHI; FP	\$74,900
Camp Creek Riparian Planting	USFS	2014	RM	\$3,000
NF Bridge 2 aquatic organism passage	USFS	2014	FP	\$56,671
Ragged aquatic organism passage	USFS	2014	FP	\$81,960
OCA Tailings Restoration - Phase 4	CTWSRO	2015	IHI; CR; FR; RM	\$446,558
Voigt - Clear Creek Diversion	CTWSRO	2015	FP	Not Available
Camp Creek coarse wood beaver dam analogues	USFS	2015	IHI	\$3,590
Davis aquatic organism passage	USFS	2015	FP	\$145,000
Middle fork John Day River Channel Relocation	USFS	2015	RM	\$15,000
Squaw aquatic organism passage	USFS	2015	FP	\$4,757
Squaw Creek Phase 1 Channel Reconstruction	USFS	2015	IHI; FP; CR	\$202,022
Windlass aquatic organism passage	USFS	2015	FP	\$95,000
Dunstan Preserve Low Flow Enhancement	CTWSRO	2015	CR; FR; IHI; BS	\$377,184
OCA Tailings Restoration - Phase 5	CTWSRO	2016	IHI; CR; FR; RM	\$1,884,098
Big Mosquito Phase 1	USFS	2016	IHI; RM	\$98,300
Camp Creek Headwaters Project	USFS	2016	IHI; RM; FR	\$98,390
Davis Creek LWD	USFS	2016	IHI	\$18,681
Deadwood aquatic organism passage	USFS	2016	FP	\$250,000
East Fork Big aquatic organism passage	USFS	2016	FP	\$131,450

¹Lead Entity: See abbreviations list at beginning of document

²Restoration Activities: BS: Bank stabilization; CR: Channel reconfiguration; FP: Fish passage; FR: Floodplain reconnection; FI: Flow increase; IHI: Instream habitat improvement; RM: Riparian management; UM: Upland management

Appendices B – M are available in a separate document.

Appendix B. Steelhead and Chinook Salmon Monitoring and Evaluation

Appendix C. Stream Habitat Condition for Middle Fork John Day River and Camp Creek Watershed

Appendix D. Geomorphology and Physical Habitat

Appendix E. Influence of Deer and Elk Browsing on the Success of Riparian Restoration Plantings

Appendix F. Projected Response of Riparian Vegetation to Passive and Active Restoration over 50 years

Appendix G. Water Temperature Monitoring

Appendix H. Monitoring and Assessment of Critical Thermal Dynamics in Upper Middle Fork of the John Day River, 2008-2016

Appendix I. Future Changes in Mainstem Water Temperatures in the Upper Middle Fork John Day River and the Potential for Riparian Restoration to Mitigate Temperature Increases

Appendix J. Analysis of Benthic and Drift Macroinvertebrate Samples

Appendix K. Analysis of the Relationship between Macroinvertebrates, Streamflow, and Temperature in the Middle Fork John Day River, OR

Appendix L. Camp Creek Restoration: A BACI Comparative Analysis

Appendix M. Socio-Economic Indicators Follow-Up Study