Appendix C Washington

The Washington State Intensively Monitored Watersheds (IMW's) include the Asotin and Lower Columbia-Abernathy IMW's. Recent summaries are below including the Lower Columbia and Asotin Creek Intensively Monitored Watersheds.

Links to reports for the Asotin Creek IMW can be found below:

Eco Logical Research IMW page

AsotinCreekIMW_Revised Study Plan_July2015_Bennettetal

Executive Summary of the Washington State Intensively Monitored Watersheds (IMWs) in support of a region-wide synthesis document (*in development)* for the Pacific State Marine Fisheries Commission (PSMFC)

This summary is being provided to the Pacific States Marine Fisheries Commission (PSMFC) as one in a series of reports supporting a Pacific Northwest synthesis of the NOAAA/PSMFC – funded intensively monitored watersheds (IMWs) program. This program has funded two IMWs in Washington State; the Abernathy IMW complex in the Lower Columbia River Salmon Recovery Region, and the Asotin IMW complex in the Snake River Salmon Recovery Region. In addition, three other complexes have been funded in this cooperative program; the Lemhi and Potlatch IMWs in Idaho, and the Middle Fork John Day IMW in Oregon. Washington State greatly appreciates this collaborative process that has attempted to glean the answers to specific questions related to limiting factors, distribution, abundance and productivity, as well as certain life histories of salmonids.

In particular, these studies have attempted to address how certain restoration treatments, once implemented, may affect or modify the treated watersheds which in turn contributes to the anticipated improvements in habitat quality, and ultimately salmonid production.

While there are two IMW complexes funded by the PSMFC in Washington State, it should be noted that Washington has had other IMWs supported by other programs. The Pacific Coast Salmon Recovery Fund (PCSRF), another NOAA program, funds the western states on a yearly basis and has done so for over a decade. The states apply in the spring for an award that may be received late summer, in order to be entered into agreement(s). Funding from this program are provided to three additional IMWs, the Hood Canal Complex, the Skagit, and the Strait of Juan de Fuca complex. These three along with the Lower Columbia were the original four IMWs in western Washington funded by the SRFB in order to address certain limiting factors.

These projects may use a Before After / Control Impact design, Staircase, or other such design as appropriate for the localized conditions. In the case of Washington State, the two IMWs are significantly different from each other in numerous ways. They are located in both western and eastern Washington with significant differences in rainfall, topography, geomorphology, riparian condition and vegetation, and not the least access to anadromous fish species. The Abernathy Creek mouth drains into the Columbia River without any hydroelectric facilities impeding access. The Abernathy IMW complex is located below Bonneville Dam the Columbia River. The Asotin IMW complex drains into the Snake River at river mile xx, above four dams on the Snake and four on the Columbia respectively.

Abernathy Intensively Monitored Watershed (IMW) complex in the Lower Columbia River Salmon Recovery Region

This interim report for the PSMFC period is from July 1 – September 30, 2017, the 90-day *extended period* of time granted for the Recreation and Conservation Office (RCO), who in turn granted the same 90 day period to its sub-awardee, the Lower Columbia Fish Recovery Board (LCFRB), in order to complete final designs for the Abernathy IMW complex. The attached document summarizes final design for aquatic habitat restoration in Project 9B of the IMW Treatment Plan for Abernathy Creek (HDR 2009), in Cowlitz County, WA. It is a Final Product from HDR, Inc. It, along with the Project Design Specifications, will be used for advertising the project for competitive bid through a procurement process, once construction funds have been identified and secured. The LCFRB, technical, and local citizen teams are expected to provide the appropriate ranking to the project, prior to soliciting Requests for Proposals (RFP) or Request for Qualifications and Quotations (RFQQ).

The Lower Columbia Fish Recovery Board (LCFRB) agreement can be found in the Recreation and Conservation Office's PRISM database (15-1444), and can accessed through PRISM as a read-only file. Their contract period with RCO ended September 30 2017, and is in *Closed Completed* status. Their 90-day extension from July 1, 2017 through September 30 2017, was identical with our RCO contract with NOAA-PSMFC, ending on that same date. If appropriate, and additional IMW funding is allocated to the states in 2018, the LCFRB are expected to apply for a portion of the new funds. Following previous discussions with the Snake River Salmon Recovery Region, and entertaining a similar process, both regions will determine a fair and appropriate distribution of the next allocation, with supplemental scopes of work and budgets. that date, we can amend the contracts, adding both time and resources if they are made available.

It should be noted this reporting period for PSMFC is only for the 90 –day extended period from July 1, 2017 and ending September, 2017. The LCFRB chose to not accept funds (approximately $30,000) from the new allocation that was made available late summer, 2017. The original intent of those funds was for the preparation of bid documents. The LCFRB felt there would be a significant time lag, from the commencement of the resources October 1, 2017 and its current ending date of June 30, 2018 in order to prepare bid documents for the project. The LCFRB believed there be a required revision of those older bid documents due to the time lag, and that it would be more cost-effective to delay an acceptance of PSMFC funds until a future time. It is the intention of the LCFRB to apply for any subsequent PSMFC funds made available during the 2018 calendar year.

The purpose of this project is to enhance habitat for steelhead and ESA-listed coho salmon. Projects that result from this effort will be consistent with the Lower Columbia Salmon Recovery and Fish & Wildlife Subbasin Plan, the Lower Columbia Fish Recovery Board (LCFRB, 2004) 6-Year Habitat Work Schedule, and goals of the Abernathy and Germany Creeks Intensively Monitored Watershed (IMW) Treatment Plan (HDR 2009).

Annual water quality and quantity monitoring occurs at stream gages located at the mouth of each creek. Seasonal patterns in flows and temperature are synchronized among watersheds. Monthly stream flows for water year 2017 were relatively high (>75th percentile) with respect to the time series. Stream temperatures for water year 2017 were relatively low (< 25th percentile) in the winter months but relatively higher (>75th percentile) in the summer months. Annual summer flow metrics are correlated among the watersheds suggesting a synchrony in watershed condition that supports assumptions of the before-after control-impact study design.

An evaluation of the ecosystem responses to the salmon carcass analog (SCA) treatments was conducted using nitrogen isotopes to trace the uptake of marine derived nutrients by the stream ecosystem. This analysis was completed and reported in a Master's Thesis (Western Washington University) in 2017. Results indicated that the SCA were consumed by both invertebrate taxa and juvenile coho salmon, but did not show nutrient uptake from the analogs in periphyton and organic matter. Nutrient uptake from the analogs occurred as a temporal, pulsed event that did not last more than two months following the treatment. Neither the fall or spring SCA treatments resulted in increased numbers, fork length, or weight of smolts for Coho Salmon, Steelhead Trout, or Chinook Salmon.

A preliminary analysis of site-scale habitat change to the instream habitat projects is presented in this report. To account for annual variation in habitat, we compared metrics at restoration project sites to metrics from randomly selected sites across the watershed. Preliminary results were available for two locations where the timing of the restoration projects has allowed for post-treatment monitoring. Results at the project locations showed variability among years but did not show changes that suggested the restoration treatments had influenced stream habitat at the project location. This result was surprising and we propose several avenues of future work to further develop approaches useful for evaluating habitat change at each project site.

Lower Columbia Intensively Monitored Watersheds Annual Assessment – 2017

This annual assessment provides an update on the lower Columbia River Intensively Monitored Watershed study for the contract period between October 2016 and September 2017. The IMW stream complex in the lower Columbia River includes Mill, Abernathy, and Germany creeks which flow into the Columbia River near Longview, Washington. The study was set up with a Before-After Control-Impact design and the analysis will make use of this design in addition to environmental covariates that are identified using the pre-restoration time series. Mill Creek is the reference stream for which no restoration is planned and Abernathy and Germany creeks are the treatment streams.

Watershed-scale nutrient enhancement in the form of salmon carcass analogs (SCA) was completed in the fall in Germany Creek (2011-2013) and in the spring in Abernathy Creek (2013-2015). The intensity of treatment ranged between 0.09 and 0.13 kilograms of analog per meter-squared of stream channel. As of 2017, the completed instream habitat treatments in Abernathy

Creek include 7.6 kilometers of instream habitat, 1.3 kilometers of off-channel and side-channel habitat, and 0.05 km2 of riparian area. Three additional projects are currently funded but not yet constructed. An additional two projects are designed but not yet proposed for funding. Funding needed to complete these remaining two projects is estimated to be $1.3 million.

As of 2017, the completed instream habitat treatments in Germany Creek include 2.3 kilometers of instream habitat, 0.2 kilometers of off-channel and side-channel habitat, and 0.15 km2 of riparian area. Three projects are currently funded but not yet constructed. Concepts for remaining projects in Germany Creek were described in the 2009 Treatment Plan which estimated that approximately $1.4 million dollars would be needed to complete construction of projects in Tier 1 reaches of Germany Creek after design is completed.

Target fish species for this study are Coho Salmon, Steelhead Trout, and Chinook Salmon. Annual life cycle monitoring data are collected for each species. Smolt production in 2017 was at or below the long-term average in all three watersheds with the exception of Chinook fry production in Mill Creek, which was higher than the long-term average. Adult spawner abundance of Chinook Salmon and Steelhead Trout in 2017 were among the lowest numbers observed in the time series, a result likely due to low ocean survival. Adult spawner abundance of Coho Salmon in 2016 were near the long-term average for the time series (2017 spawner data for Coho Salmon are still being collected at the time of the report).
Annual habitat monitoring includes collection of a standardized set of habitat measurements (intensive sampling) in approximately 20 randomly selected locations within each watershed. In 2017, 26, 27 and 25 sites were surveyed in Germany, Abernathy and Mill creeks, respectively. Our initial analysis of the habitat data includes four metrics typically used to represent habitat complexity – very large wood, percent pool, percent gravel, and bankfull width-depth ratio. Within years, our results show notable spatial variation of habitat attributes among sites. Among years, our results show correlation of habitat attributes among watersheds, suggesting that large scale processes are generating synchronous annual changes in these watersheds.

Asotin Intensively Monitored Watershed (IMW) complex in the Snake River Recovery Region

This summary and the attached *Asotin Creek Intensively Monitored Watershed: A 2017 Progress Memo, December 31, 2017 (see below)* serve as the PSMFC interim report for the latter half of 2017. The progress report is for the Asotin IMW located in the Snake River Salmon Recovery Region. While the PSMFC contract calls for 6-month interim reporting, July 1- December 31, 2017, our RCO sub-awardees are required to provide a more comprehensive end-of-year annual summary for our Salmon Recovery Funding Board (SRFB) Monitoring Panel to review, and to provide recommendations to the SRFB. I make efforts to not over-burden my monitoring contractors, and to utilize their reports in multiple forums, where possible.

Please note at this time stage we are only providing contractual support for the Asotin IMW, to the sub-awardee EcoLogical Resources, as well as a sub-contract to the WA Department of Fish and Wildlife (WDFW) for their monitoring assistance in the Asotin IMW. There have been other incidental costs associated with this project, such as power support through the local utility, and support for a phone line for transmitting the telemetry signal for the passive monitoring arrays that track tagged fish. These costs may be modified in the future, as the contractor is considering a refinement to this tracking method. I do not expect this to require a scope of work (SOW) modification to the RCO agreement with NOASA-PSMFC, and be minimal if any budget line items changes. Stephen Bennett, the contractor's principle investigator was expected to present at the Upper Columbia Science Symposium in Wenatchee, WA 1/25/18.

The EcoLogical Resources agreement can be found in the Recreation and Conservation Office's PRISM database (15-1443), and can accessed through PRISM as a read-only file. Their contract period with RCO is through 6/30/18, identical with our RCO contract timing with NOAA-PSMFC. If appropriate and additional funding is allocated to the states, following that date, we can amend the contracts, adding both time and resources if they are made available.

As mentioned, the SRFB Monitoring Panel will be reviewing the Asotin annual report. The Panel does comprehensive review of all the reports, comments collectively, have their suggested edits compiled by the Panel chairman, which and then forwarded to the principle investigator. There may be other email or conference calls between all parties to resolve any outstanding issues. Following these interactions between the Panel and the P.I. which could be a month or so, a final version of the document is then prepared. Some elements of the final document may be submitted as partial or in full for consideration for publishing in the appropriate journal(s).

As noted in previous communications, Stephen Bennett, PhD. is the principle investigator for the Asotin IMW complex, and has been since its inception. He maintains a high standard of conceptualizing the project, coordination of field collection and data analysis, reporting on his findings in written and oral forums, and subsequently adaptively managing the project. His reporting is detailed, and he strives to inform disparate audiences of the project process and progress. Additional details of the Asotin IMW complex are in preparation, to be included in the PSMFC IMW synthesis document. Others will be provided for the next interim reporting

Asotin Creek Intensively Monitored Watershed:

2017 Progress Memo, December 31, 2017

Charley Creek treatment section 2017

Prepared for:

Recreation and Conservation Office

Prepared by:

Stephen Bennett, Eco Logical Research Inc., Providence, Utah

SUMMARY

Background

The Asotin Creek Intensively Monitored Watershed (IMW) was implemented in 2008. The focal species are natural reproducing summer steelhead. Based on previous habitat assessments and preliminary IMW monitoring it was decided that riparian function and instream habitat complexity were impaired. The restoration proposed was fencing, native plant revegetation, and weed control to enhance riparian function in the **long-term**, and the addition of large woody debris (LWD) in the **short-term** to increase habitat diversity and promote a more dynamic channel (e.g., increase sediment sorting, pool frequency, and floodplain connection). We implemented the IMW using a staircase experimental design where restoration actions were implemented in different years starting in 2012 and ending in 2016 in three different streams. Each stream is divided into three 4 km long sections and one or more sections has been restored in each stream with the remaining sections acting as controls. We completed the restoration actions in 2016 and have built 654 large woody debris structures at an average density of 4.7 structures per 100 m in the treatment sections (~39% of the study area has been restored and 61% remains as controls). We are using extensive habitat sampling and fish PIT tagging and resighting to estimate habitat changes and changes juvenile steelhead abundance, growth, survival, movement, production, and productivity in each experimental section.

Analyses Approaches

We continue to develop and refine tools/models to help us analyze the data we have including:

- The Staircase statistical model which allows us to more accurately assess responses to restoration because it can differentiate variance components (year, stream, section, response) and interactions. We have completed the development of model and can update the model each year to accommodate the changing year after treatment component of the staircase design. We have analyzed the juvenile steelhead abundance data with the model and will be using the model to analyze other fish and habitat responses
- Geomorphic unit delineation tool (GUT) which allows us to use the topographic data to look at fine scale changes in geomorphic unit assemblages; We have run the GUT tool on all sites for three years of data and will be running the remaining sites to complete all sites from 2011-2017.
- The Barker model for calculating true survival, site fidelity, and probability of captures. We have now completed and run for all sites, seasons, and years from 2008-2016. We will update the survival estimates and analyze them with the staircase model (see above) when we have our age data analyzed for 2017 fish captures.
- We have developed a Bayesian based model for aging all of our fish using a subsample of known ages and acquired from scale samples and fish lengths. We use the age model to estimate the age of tagged fish that were not aged with scales so that we can determine the brood year of migrants and calculate smolts per spawners as well as assess treatment responses by age class.
- Net rate of energy intake model has been run for North Fork and South Fork sites for three periods: 1 year pre-restoration, 1 year post-restoration, and 2016. We have since updated the NREI model based on field validation and are currently running the model on all topographic data in all streams from 2011-2017.

- We have begun to summarize productivity of treatment and control sites pre and post restoration by estimating the number of migrants (smolts) by age class and then back-calculating the brood year they came from using PIT tag detections at the interrogation sites at the mouths of each IMW study stream. We used the same interrogation sites and redd surveys to estimate the number of female steelhead entering each tributary and spawning in each treatment and control section.

Trends

Habitat

- We continue to see habitat responses that are in line with many of original hypotheses.
- The frequency of wood in the treatments is staying high relative to the control sections.
- The frequency of pools and bars has increased in treatment areas compared to control areas.
- Other habitat characteristics such as width or thalweg variability have not responded as strongly.
- The rate of habitat change is more dramatic in the North Fork compared, minor but consistent in the South Fork, and less consistent and significant in Charley Creek. This fits our understanding to the dominant reach types in these three streams: the North Fork is a wandering Gravel bed stream with higher stream power and more natural capacity for adjustment. The South Fork and Charley are more confined planeform and bedrock controlled systems with a lower capacity for adjustment.
- We have produced geomorphic unit analyses that confirm coarse scale data such CHaMP habitat data and or rapid habitat surveys. The delineation of geomorphic units is a consistent unbiased manner will allow us to better understand what factors are driving the fish response.

Fish

- We have observed positive trends in fish abundance and are beginning to see difference in the fish response by stream. Like the habitat changes, the fish response in the North Fork appears to be greater than the other two streams despite being treated last (i.e., we are observing a Year 3 response in North Fork, Year 4 in Charley, and Year 5 in South Fork).
- We will be analyzing growth and survival data using the staircase model from 2008-2017 in the coming months
- Smolts/spawner data summaries have been completed for 2010-2015 and we are working on updating smolts/spawner estimates for 2016 and 2017.

General

- We have implemented a robust design, completed a large restoration treatment, maintained a high quality data stream for both habitat and fish for 10 years, developed a series of geomorphically and empirically based set of tools to summarize raw data, and developed a staircase statistical model to analyze these data and separate multiple sources of variance from the true treatment response.
- We are now in the phase of the project where we need to complete enough years of post-treatment monitoring to complete the smolts/spawner table (by annually back-calculating the brood year of smolts and continuing to monitor adult escapement), develop models that can explain what factors are driving the responses we see (i.e., causal mechanisms), and assessing if the responses are consistent, persistent, and how they vary between stream types.

ACKNOWLEDGMENTS

The Asotin Intensively Monitored Watershed (IMW) is a collaborative multi-agency initiative sponsored by the Snake River Salmon Recovery Board (SRSRB). The SRSRB provides oversight and technical review of all the Asotin Creek IMW activities through support from the Regional Technical Team (RTT) and National Oceanic and Atmospheric Administration (NOAA) staff. The majority of the IMW takes place on Washington Department of Fish and Wildlife (WDFW) and US Forest Service (USFS) land, and both agencies have supported the development and implementation of the project. Funding for the primary research components of the IMW are from the NOAA Pacific Coastal Salmon Recovery Fund (PCSRF). Funding for the restoration activities comes from PCSRF through the State of Washington's Salmon Recovery Funding Board (SRFB), BPA, Conservation Commission, USFS, and WDFW. We are particularly grateful for support we receive from Ethan Crawford of WDFW in the form of field staff and data on fish-in fish-out from the Clarkston office to assist the IMW project, and Bonneville Power Administration (BPA) which supports WDFW's efforts to collect fish in-fish out data in Asotin Creek. Bob Dice, the manager of the Clarkston Wildlife Office, has also provided the IMW with accommodation, transportation, and access since the start of the project. We also wish to thank the Koch and Thornton families for graciously providing us access to private property along Charley Creek to conduct monitoring and restoration. Brad Johnson, Palouse Conservation District has also been an indispensable part of the IMW team working with the local landowners and agencies to help secure land access, operating permits, and local support and sponsorships for the IMW. The Asotin County Public Utility Department has provided us with office space and storage for field gear. Del Groat (now retired) of the USFS has provided generous donations of time and large wood for the restoration treatments and Billy Bowles, also with USFS, has helped with safety training for field crews. Bruce Heiner, WDFW Habitat Engineer and Barry Sutherland, USDA Natural Resources Conservation Service (NRCS) Fluvial Geomorphologist provided comments on the earlier versions of the restoration plan. The following groups have provided direct support to the IMW in either goods or services and we wish to thank them for their help with this important fisheries conservation project: Avista Power, Clearwater Power, Collier Electric, Inland Metals Electric, TDS Telecom, WDFW, and USFS.

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BACKGROUND

In 2008, Asotin Creek was chosen as a location to implement an Intensively Monitored Watersheds (IMW) project in southeast Washington (Figure 1). We are implementing the IMW experiment within an adaptive management framework and have revised aspects of the experimental design, restoration plan, and monitoring based on the iterative evaluation process of adaptive management (Bouwes et al. 2016). An experimental study design has been developed and refined for the Asotin Creek IMW that includes treatment and control sections within the Asotin Creek tributaries of Charley Creek, North Fork Asotin Creek (North Fork), and South Fork Asotin Creek (South Fork; hereafter referred to together as "study creeks"). The study creeks generally exhibit homogenized and degraded habitats, with poor riparian function and low frequencies of large woody debris and pool habitat which is thought to be limiting salmonid production (SRSRB 2011). A detailed Restoration Plan was developed that proposed ***riparian enhancement and large woody debris additions as restoration treatments in the Asotin Creek IMW*** (Wheaton et al. 2012).

The Asotin Creek IMW is funded from NOAA's Pacific Coastal Salmon Recovery Fund (PCSRF) and the Pacific States Marine Fisheries Commission (PSMFC). The NOAA funds are used to fund the ongoing fish and habitat monitoring and data collection and analysis. These funds are administered via the Governors Salmon Recovery Office. A separate project funded by the Bonneville Power Administration (BPA) and implemented by the WDFW provides fish-in, fish-out monitoring for the Asotin watershed (Crawford et al. 2016). Funding for the restoration actions has primarily come from Pacific Coast Salmon Recovery Fund (PCSRF) through the State of Washington's Salmon Recovery Funding Board (SRFB) and donations of wood from US Forest Service, accommodation and equipment from WDFW and SRSRB. Eco Logical Research Inc. is the primary contractor that manages the Asotin Creek IMW and implements the restoration. The intent of this progress memo is to give a brief update of i) status of the IMW (what has been done), ii) data trends and advances in analysis, and iii) challenges and further analyses in 2018.

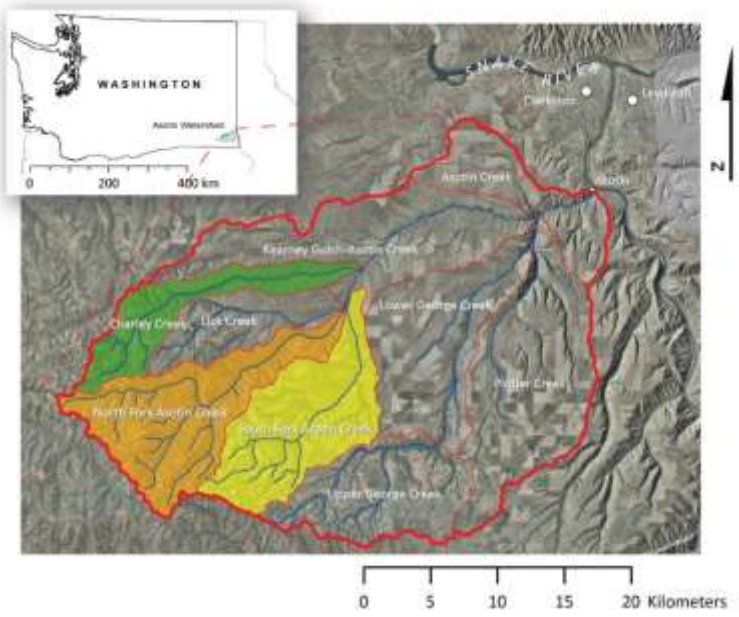

Figure 1. Location of Asotin Creek within Washington and the Asotin Creek Intensively Monitored Watershed study creek watersheds (i.e., three colored watersheds) within Asotin Creek.

ASOTIN IMW STATUS

We began the Asotin IMW in 2008 and it has been running for ten years (Figure 2). We secured funding to install the majority of the monitoring infrastructure (e.g., PIT tag arrays, water height gages, and temperature probes) in 2009. The Asotin IMW also relies on the intensive monitoring of fish-in fish-out conducted by WDFW to provide detailed information on age, condition, size, migration timing, and spawning distribution of steelhead in the Asotin watershed (Crawford et al. 2016). A total of four PIT tag interrogation sites, a smolt trap, and adult weir provide valuable data to the IMW for assessing restoration effectiveness (Appendix A**Error! Reference source not found.**). We have completed the restoration for he IMW treating a total of 14 km (~ 39% of the study area) with high densities of large woody debris structures averaging ~ 4.7 structures per 100 m. We implemented the IMW using a staircase experimental design where restoration actions were implemented in different years starting in 2012 and ending in 2016 in three different streams. Each stream is divided into three 4 km long sections and one or more sections has been restored in each stream with the remaining sections acting as controls (Appendix A). See Bennett et al. (2015) for details on activities from 2008-2015.

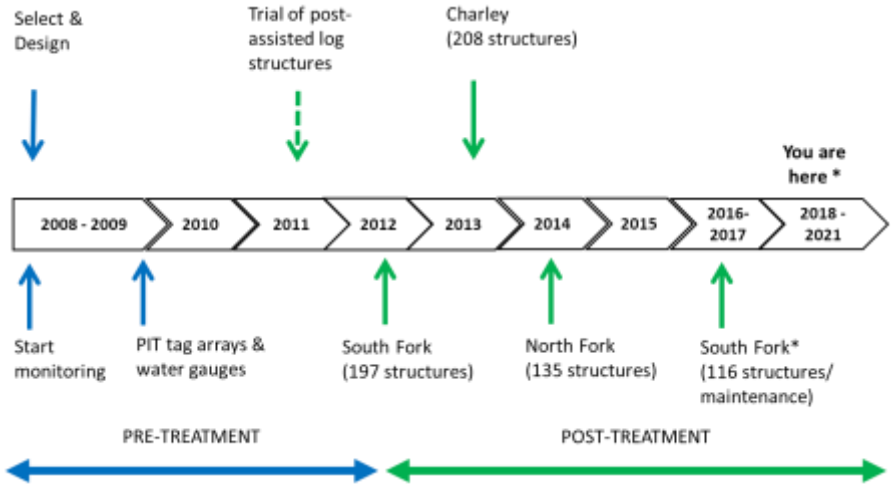

Figure 2. Timeline of Asotin Creek IMW design, monitoring, and restoration implementation. The initial restoration design of 12 km of wood treatments was completed from 2012-2014. Another restoration treatment to extend South Fork was implemented in 2016 along with adding more wood to existing structures to enhance their function in 2016 and 2017. Monitoring of habitat and fish is expected to continue to at least 2021.

RESTORATION ACTIONS

We built 197 structures in the South Fork, 208 in the Charley Creek, and 135 in North Fork treatment sections from 2012-2014 (Table 1). The total number of pieces of LWD added to each treatment section was 1500 pieces in the South Fork (structures built in 2012 and 2016), 497 pieces in Charley Creek, and 568 pieces in North Fork. The majority of structures built were deflector PALS in all streams. In 2016 we added another 116 LWD structures to the upper 2 km of South Fork Section 1. The total length of stream restored with LWD is 14 km which equates to 38.9% of the IMW study area (i.e., 14/36 km). On average the LWD structures are approximately 21 m apart or 4.7 LWD structures/ 100 m. In addition to the installation of LWD structures we conducted a round of maintenance in 2016 where we added LWD the existing treatments built between 2012-2014. Approximately 600 pieces of LWD were added to the existing treatments focusing on structures that where less effective at promoting hydraulic and/or

geomorphic change. Figure 3 shows an example of a stream reach before treatment and after treatment and Figure 4 shows examples of the common structure types we built.

Table 1. Summary of the type and count of large woody debris (LWD) structure built in each stream by year constructed. PALS = post-assisted log structure, Seeding = unsecured LWD placed in channel, Key LWD = LWD too large to move by hand (e.g., > 10 m long and > 0.4 m diameter).

Type	South Fork (2012)	Charley (2013)	North Fork (2014)	South Fork (2016)	Total
Bank attached PALS	115	129	75	67	386
Mid Channel PALS	17	38	31	17	103
Debris Jam PALS	2	10	15	18	45
Seeding	50	30	14	14	108
Key LWD	12	0	0	0	12
Total	**196**	**207**	**135**	**116**	**654**

Figure 3. Example of treatment section before restoration (left) and after restoration (right) in South Fork Section 1. Treatment took place in summer of 2016.

Figure 4. Example of the three most common post-assisted log structure (PALS) built in the new treatment section of the South Fork Asotin Creek in summer of 2016. Top left = series of Bank-attached PALS, top right = Mid-channel PALS, and bottom picture = Debris Jam PALS.

Ongoing maintenance

In 2017, with remaining funds, we added more wood to the sections of the IMW project that had been previously treated in order to maintain high levels of large woody debris (LWD) in treatment sites compared to control sites (Figure 5). We also acquired a permit from WDFW to fell live trees along each treatment section to increase wood densities (Figure 6). We added approximatley 400 pieces of LWD to both North Fork and South Fork Asotin Creek and 200 pieces of LWD to Chalrey Creek. Monitoring funded by the IMW shows that the exisitng and new restoration structures are producing positive habitat responses. The structures are forcing floodplain connection, creating pools, backwaters, sediment deposition, gravel bars, and recruiting trees as the channel increases in sinuousity (Figure 7-10).

Figure 5. Example of felling a tree and adding large woody debris to an existing structure in North Fork Asotin Creek treatment section 1 to maintain high large woody debris density.

Figure 6. Example of felling a tree on an existing structure in North Fork Asotin Creek treatment section 1 to maintain high large woody debris density.

a) **b)**

Figure 7. a) Debris jam built in 2016 and viewed in summer of 2017. Note large dam pool upstream. b) Upstream of debris jam large sediment deposit covered with cottonwood seeds.

Figure 8. Example of post-assisted log structure built in 2016 in South Fork section 1 creating a large gravel and cobble bar downstream of the structure.

Figure 9. Example of trees that have been recruited into the stream by the strategic design of a post-assisted log structure.

MONITORING, DATA MANAGEMENT, AND TRENDS

Stream Discharge and Water Temperature

Prior to the start of the IMW in 2008 there were several years of low peak stream discharge and high temperatures (Figure 10). Water temperatures were cooler at the start of the IMW which is correlated with higher peak flows observed from 2008 through to 2012. However, since we began restoration in 2012, peak flows have decreased and average 7-day maximum temperatures have increased. Consistent low peak flows since the start of restoration in 2012 are suspected of limiting the effectiveness of the LWD structures to cause large changes to the channel and floodplain connection. Thankfully we observed the third largest peak flow in 17 years in the spring of 2017 and for the first time since restoration saw some extensive overbank flow, side-channel reconnection, and substantial sediment movement and sorting (Figure 11).

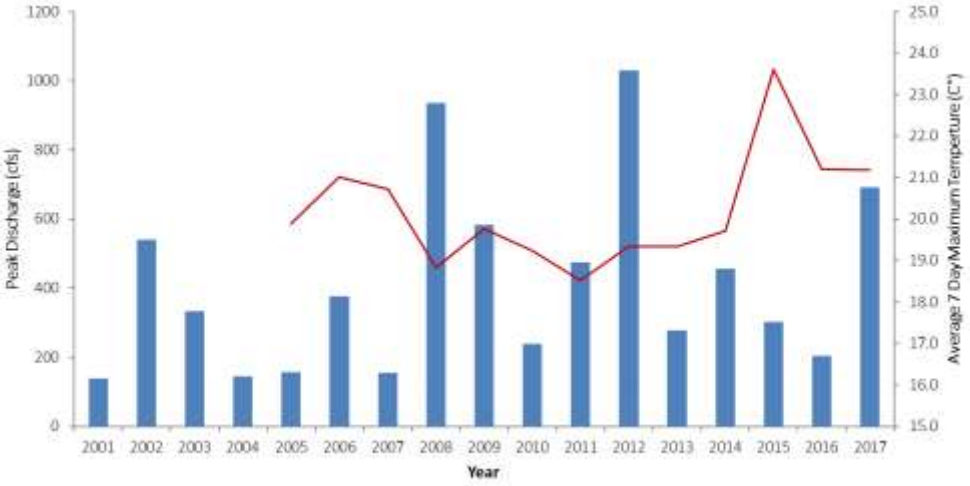

Figure 10. Asotin Creek mainstem a) average discharge (blue bars) and summer temperature (July and August – red line) by year and b) peak discharge and 7-day max summer temperature by year. Peak flows measured at USGS gauge 13334450 and water temperature measured at WDOE gauge 35D100.

Figure 11. South Fork Asotin Creek treatment section 1 in the spring of 2017 overflowing the banks and reconnecting with the floodplain. We had not observed overbank flow in the South Fork since the IMW started in 2008. Note the high-density of large woody debris that is causing the response.

Habitat Trends

The restoration actions have increased the amount of LWD ($\geq$ 0.1 m diameter and $\geq$ 1.0 m long) in the treatment sections relative to the control sections by almost 200% (mean LWD/100 m in control = 10.7 and in treatment = 31.9; Figure 12). The changes in habitat since the addition of LWD have generally been positive. For example, our habitat surveys are showing the frequency of pools has increased 38% in

treatment sections relative to control sections (mean pools/100 m in control = 2.4 and in treatment = 3.4; Figure 13Figure 13). We have begun to analyze the topographic data we collect as part of the Columbia Habitat Monitoring Protocol (CHaMP) using the geomorphic delineation tool which uses algorithms to identify topographic features and geomorphic units. For example, concavities in the streambed are characteristic of pools whereas convexities in the topography are characteristic of sediment deposits (i.e., bars). We are now seeing increases in the area of pools in the topography which match our visual observations of habitat units, and also increases in bars and transitional areas (i.e., units that are not a specific geomorphic type; Figure 14 - 16). These data may help us better describe what is commonly been described as "habitat diversity" but has previously been difficult to measure. Other habitat metrics have not yet responded to the restoration. For example, the variability in the thalweg and residual pool depths are either not increasing as expected or are increasing in both treatment and control areas.

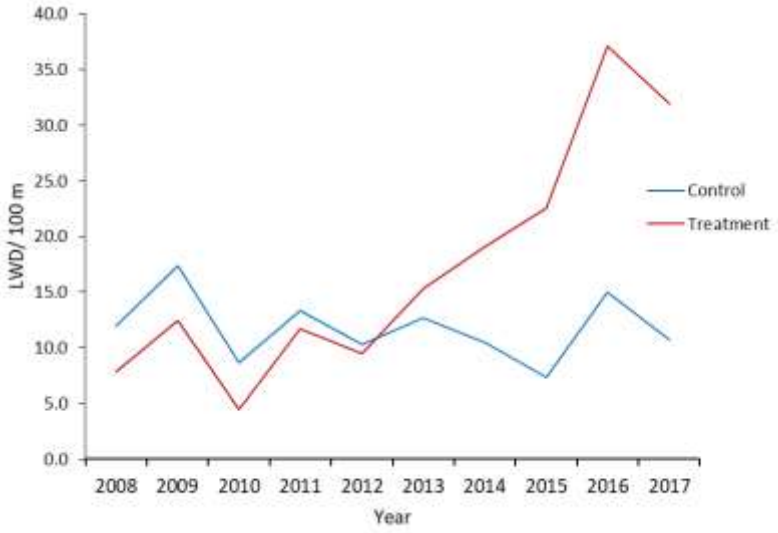

Figure 12. Frequency of large woody debris (LDW/100 m) in treatment and control sections, all study creeks combined: 2008-2017.

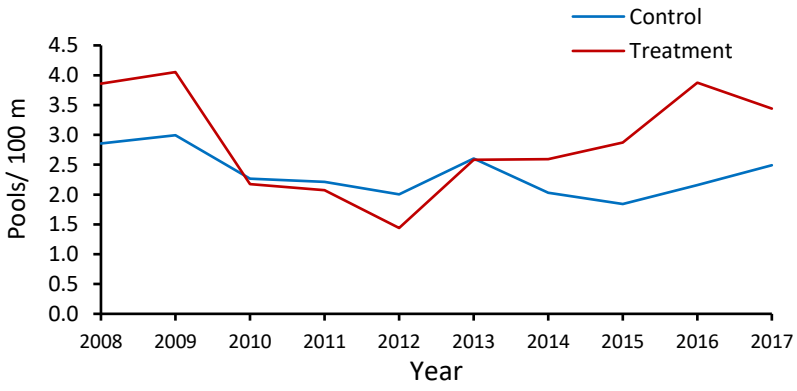

Figure 13. Average frequency of pools (pools/100 m) in treatment and control sections, all study creeks: 2008-2017.

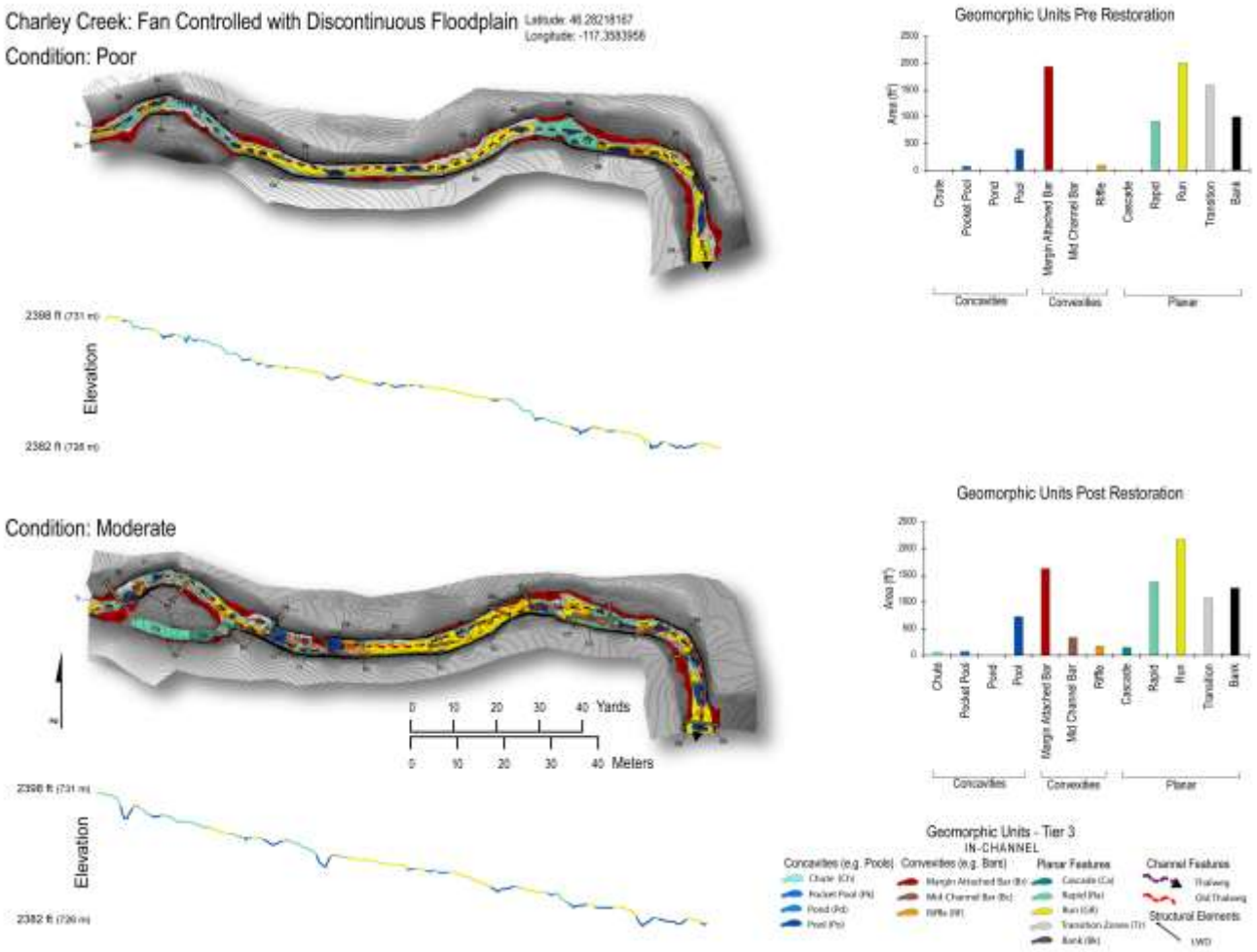

Figure 14. Geomorphic unit delineation of Columbia Habitat Monitoring Protocol (CHaMP) topographic data for a Charley Creek treatment site before restoration (top panel) and after restoration (bottom panel). Graphs show area of geomorphic units organized by concavities (i.e., pools), convexities (i.e., bars), and planar topographic features (i.e., runs, rapids, etc.). Geomorphic units are delineated by the geomorphic unit tool (GUT) developed by Joe Wheaton and the Ecohydraulics Laboratory at Utah State University (http://www.joewheaton.org). Area of pools and bars has increased since restoration.

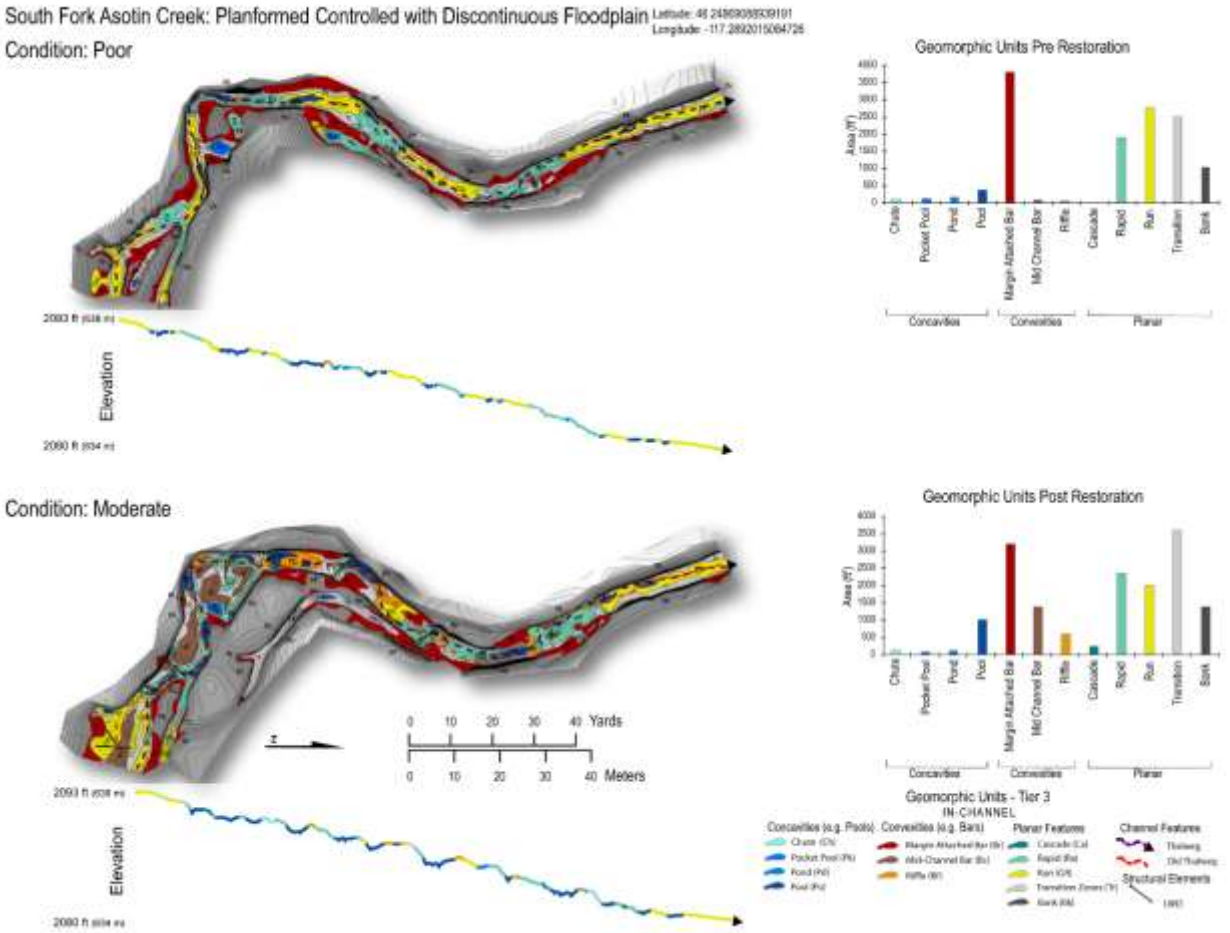

Figure 15. Geomorphic unit delineation of Columbia Habitat Monitoring Protocol (CHaMP) topographic data for a South Fork Asotin Creek treatment site before restoration (top panel) and after restoration (bottom panel). Graphs show area of geomorphic units organized by concavities (i.e., pools), convexities (i.e., bars), and planar topographic features (i.e., runs, rapids, etc.). Geomorphic units are delineated by the geomorphic unit tool (GUT) developed by Joe Wheaton and the Ecohydraulics Laboratory at Utah State University (http://www.joewheaton.org). Area of pools and bars has increased since restoration.

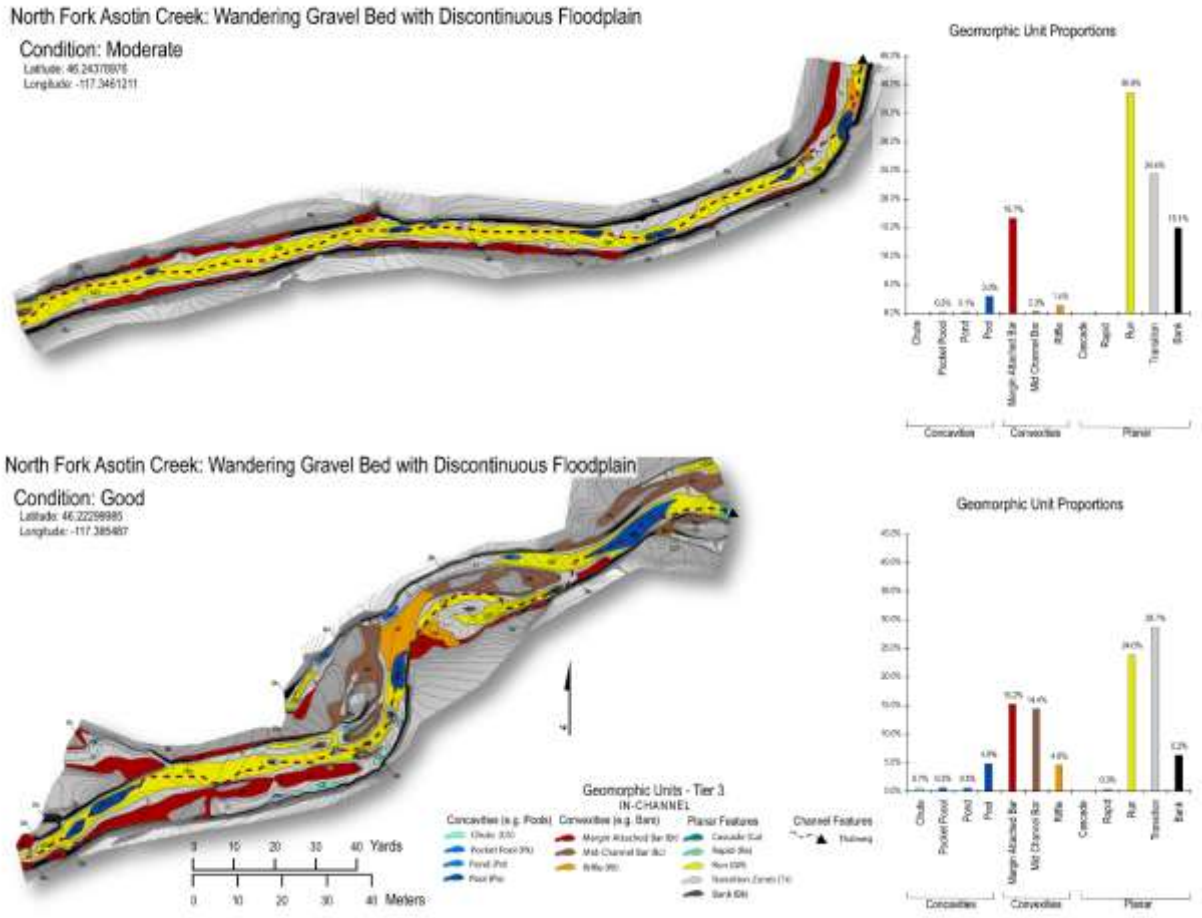

Figure 16. Geomorphic unit delineation of Columbia Habitat Monitoring Protocol (CHaMP) topographic data for a North Fork Asotin Creek site before restoration (top panel) and a different site after restoration (bottom panel). Graphs show area of geomorphic units organized by concavities (i.e., pools), convexities (i.e., bars), and planar topographic features (i.e., runs, rapids, etc.). Geomorphic units are delineated by the geomorphic unit tool (GUT) developed by Joe Wheaton and the Ecohydraulics Laboratory at Utah State University (http://www.joewheaton.org). Area of pools and bars are higher in restored site.

Fish Capture

Since 2008 we have tagged 40,536 juvenile steelhead ≥ 70 mm in the three study creeks of the IMW (Table 2). We capture relatively few bull trout and Chinook and have only tagged 39 bull trout and 169 Chinook since the start of IMW. WDFW has tagged 39,405 juvenile steelhead at the smolt trap and from hook and line sampling on the mainstem Asotin Creek (see Crawford et al. 2015). The majority of the juvenile steelhead we capture and tag are age 1 (~ 60%) and very few fish are age 3 or older (< 10%).

Table 2. Summary of the number of juvenile steelhead (> 70 mm) PIT tagged in Asotin Creek from 2005 to 2017 at the smolt trap on the Asotin mainstem by WDFW and in the IMW study creeks by Eco Logical Research Inc.

Stream	2005	2006	2007	2008	2009	2010	2011	2012	2013*	2014*	2015*	2016*	2017	Total
Asotin (WDFW)	2,462	1,552	1,895	1,862	946	2,605	4,002	4,679	3,944	5,607	2,334	4,339	3,178	**39,405**
Charley	-	-	-	424	1296	1,955	1,283	1,136	1,246	1,180	1,048	1,086	1,205	11,859
North Fork	-	-	-	372	470	1,397	906	931	1,797	1,549	2,035	2,244	1,792	13,493
South Fork	-	-	-	549	737	1,862	1,275	1,499	1,939	1,848	1,892	1,782	1,801	15,184
IMW subtotal	-	-	-	1,345	2,503	5,214	3,464	3,566	4,982	4,577	4,975	5,112	4,798	**40,536**
Total	**2,462**	**1,552**	**1,895**	**3,207**	**3,449**	**7,819**	**7,466**	**8,245**	**8,926**	**10,184**	**7,309**	**9,451**	**7,976**	**79,941**

Fish Abundance

Recapture rates during mark-recapture surveys have been high throughout the tagging efforts averaging approximately 30% in Charley Creek and South Fork Creek and 20% in North Fork. The density of juvenile steelhead is very similar across all three study creeks and generally tracks across years. When comparing the density of fish, the South Fork tends to have the highest densities of juvenile steelhead and the North Fork tends to have the lowest. However, when comparing the frequency of fish, the North Fork tends to have the highest frequency and the Charley Creek has the lowest. We have chosen to use fish/100 m as the primary metric for assessing fish response because our restoration actions may increase the area of stream per linear length of stream and therefore, changes in the total number of fish per length may be a more appropriate measure than density.

We analyzed the juvenile steelhead abundance data using the staircase model to look at the restoration response (Figure 17 and 18). When we assessed the overall response across all streams we found 23 - 47% increase in juvenile abundance in treatments compared to controls (Figure 17). The response varied depending on what type of response we looked for. We did not know where the response would be high in the first year and then fade away, ramp up over time, or any other combination of possible responses. Therefore, we looked for reasonable alternative response types. Specifically we tested for a traditional BACI response which is just a yes/no response pre versus post restoration (Impact 0/1). We also looked to see if the first or second year had the biggest response (Year 1 or Year 2), or if the response ramped up over time. So far there appears to be no dominate response type but Year 2 stands out from the other response types (though not statistically different from the other responses). This could be due to the

dominance of age 1 and 2 fish in the system which could secure responses to be more pronounced every 2 years, or be due to structures taking two years to be more effective at causing geomorphic change, or a combination of these factors.

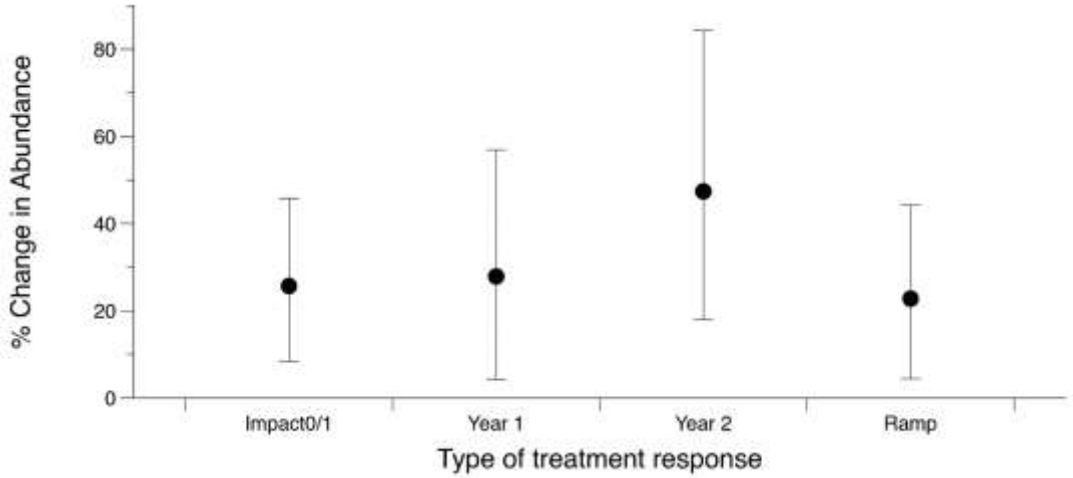

Figure 17. Results from the staircase model analysis comparing change in juvenile steelhead abundance in the treatments compared to the controls before and after restoration. Estimates are the percent change in juvenile steelhead abundance (fish/100m) across all three study streams combined in the Asotin Creek IMW: 2008-2017. Confidence intervals are 90% (α = 0.1). The different estimates are for analysis looking for different treatment responses (we did not presume what the response would look like): Impact0/1 is equal to a traditional BACI where mean of pre-restoration abundance is compared to mean post-restoration. Year 1 is a response that is expected to be greatest in year 1 after restoration. Year 2 is a response expected to be the greatest in year 2 after restoration. Ramp is a response that increases incrementally after restoration (i.e., expected response is smaller in year 1 compared to year 2, and smaller in year 2 compared to year 3).

We also used the staircase model to look at responses of the individual streams (Figure 18). There is a positive trend in abundance in treatment areas compared to control areas in all the streams. However, like the habitat changes, the fish response in the North Fork appears to be greater than the other two streams despite being treated last (i.e., we are observing a Year 3 response in North Fork, Year 4 in Charley, and Year 5 in South Fork). This would tend to suggest that it is geomorphic change that is causing the change in abundance and not other factors such as cover or refugia from high flows since there are similar densities of LWD structures in each stream. The

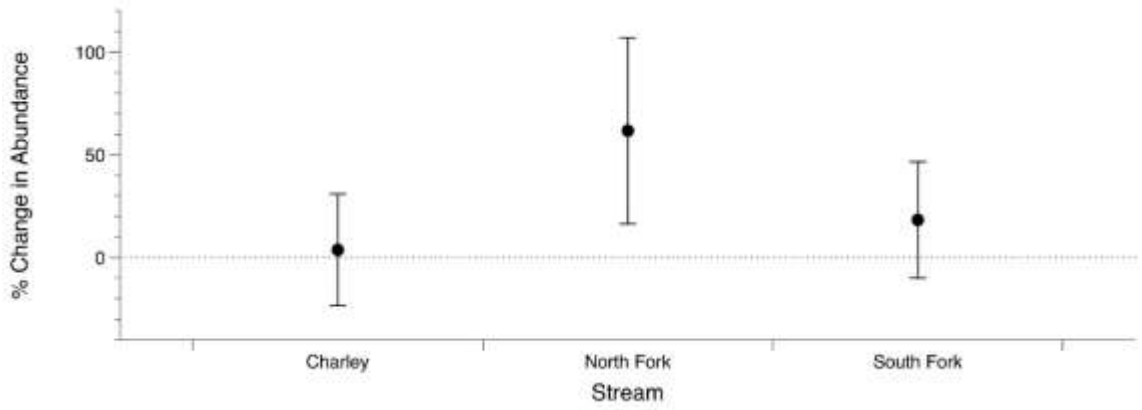

Figure 18. Results from the staircase model analysis comparing change in juvenile steelhead abundance in the treatments compared to the controls before and after restoration. Estimates are the percent change in juvenile steelhead abundance (fish/100m) within each study stream in the Asotin Creek IMW: 2008-2017. Confidence intervals are 90% (α = 0.1). The estimates were derived using the Impact 0/1 response contrasts because there is not strong evidence for choosing any specific response. All estimates of a response were positive and ranged from 3.8% (Charley Creek, p = 0.19), 61.7% (North Fork, p = 0.002), and (South Fork, p = 0.19).

Growth, Movement, and Survival

We continue to collect data and calculate growth by age class and site within each stream. We also assess fish movement, and seasonal survival. We will use the staircase model now we have fully developed it to analyze these important population parameters.

Productivity and Smolts/Spawner

We have developed a novel method to assess the productivity of the study area and treatment and control sections by estimating the migrants leaving the study area and the adult escape using the PIT tagging efforts of juvenile steelhead in the IMW study area and the tagging of adult returning and captured at the WDFW weir in the lower Asotin Creek. Future reports will describe this method in detail but briefly we used the following approach:

Migrants (Smolts)

- We estimate the total population of juveniles each year using our mark-recapture estimates at four fish sites in each stream (Figure 19).
- We calculate a tagged to untagged ratio by using the known number of fish we tagged each year divided by the population estimate for each stream and year
- We summarize the fish detections at each PIT tag array at the mouth of the three study streams by tag site, age, and year they left the tributary and expand these counts by the array efficiency (Figure 20)
- Assume the survival rate for marked and unmarked fish is the same
- Expand the tag detections by the tagged to untagged ratio
- We calculate the age of all tagged juveniles using a Bayesian model that uses a subsample of ages determined by scale analysis and known lengths to estimate the probability a fish of X length is a particular age.
- We can then attribute the attribute a proportion of total migrants estimated to have left into the appropriate brood year based on their age at the time they migrated (Figure 21).

- These analyses can be done at the stream level and at the treatment and control section (the ultimate goal; Figure 22)

Adult escapement

- We perform a similar approach to estimate the adult escapement except we focus on females because they wander between tributaries less and drive productivity (i.e., more egg limited than sperm limited)
- WDFW estimates a total population of male and females entering Asotin Creek each year and they PIT tag all fish they capture at the weir that are not already tagged
- We can count the number of females entering each study stream using the PIT tag arrays and expand by the antenna efficiency and tagged to untagged ratio from WDFW population estimates

We have built the databases to perform all these calculations and produced initial estimates of population estimates, adult escapement, and migrants by stream and treatment and control section from 2010-2015. These data will provide a wealth of information about these streams, naturally reproducing summer steelhead populations, and the effectiveness of large woody debris stream restoration.

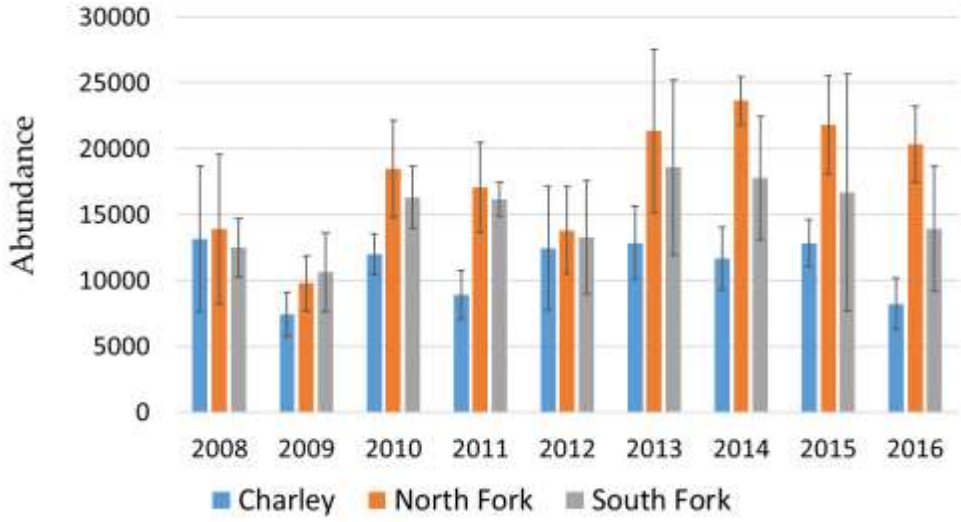

Figure 19. Estimate of the total population of juvenile steelhead in each IMW study stream

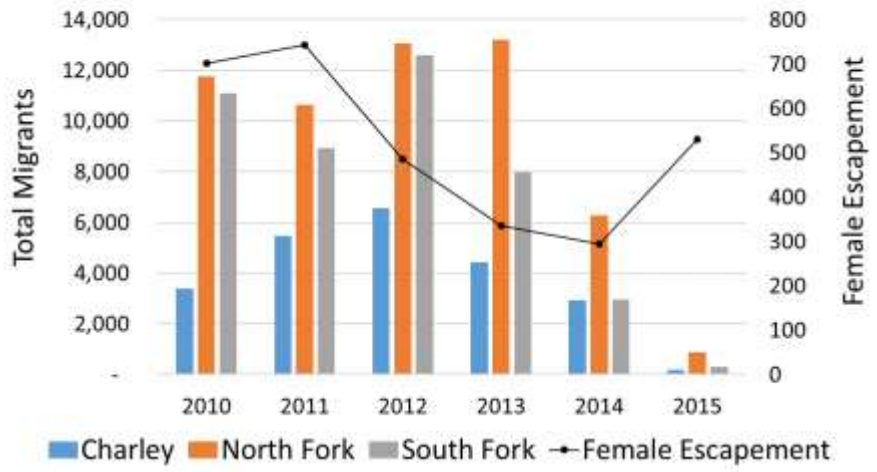

Figure 20. Total migrants leaving each study stream by brood year and female escapement. The brood years 2014-2015 are not complete counts of all migrants but will be completed in future summaries.

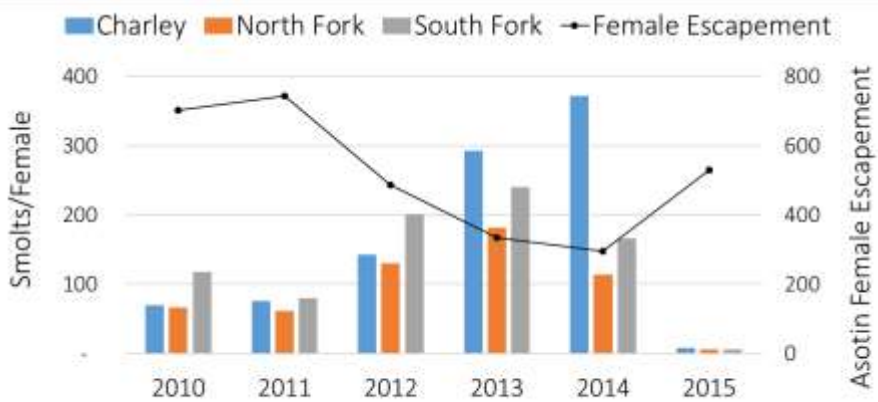

Figure 21. Smolts per female and total female escapement for Asotin Creek IMW study streams: 2010 -2015. Strong density dependence is evident from 2010 – 2014. Brood years 2014 and 2015 are not complete counts of all migrants but will be completed in future summaries.

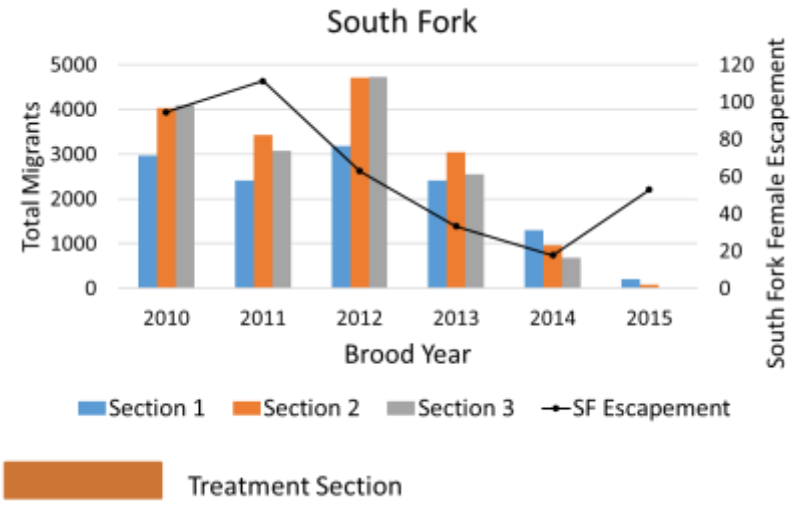

Figure 22. Migrants per treatment and control section and the total female escapement in South Fork Asotin Creek: 2010 - 2015. Brood years 2014 and 2015 are not complete counts of all migrants but will be completed in future summaries.

CHALLENGES

We have suit of tools and models to assess the restoration actions – and analysis will be the focus of our efforts in 2018. Although we have made progress on developing tools and analyses methods, data management, and data preparation continue to hinder our analysis efforts. It takes a considerable amount of time to collect the monitoring data and updating model outputs every year takes time – it would require a considerable effort to automate these efforts. However, we plan to reduce our habitat sampling efforts in 2018 and dedicate more of that time to data preparation and data analysis. We will maintain the same level of effort for fish sampling because it is critical to complete our productivity analysis.

FUTURE ANALYSES

Below is a summary of the tasks for 2018:

- Estimate total number of smolts emigrating from IMW study creeks and Asotin Creek by brood year
- Estimate the distribution adult steelhead in the IMW study creeks by year and section
- Calculate smolts per spawner for IMW study creeks
- Recalculate survival by age class using refined Barker model approach (only need to calculate 2017 survival)
- Complete running NREI for all sites and years
- Analyze CHaMP data and incorporate into analyses
- Develop models to explain variability in population parameters
- Publish experimental design using hierarchical-staircase approach (this is 95% complete)
- Publish life history of juvenile steelhead in Asotin Creek

APPENDIX A. MONITORING DESIGN AND EXPERIMENTAL DESIGN

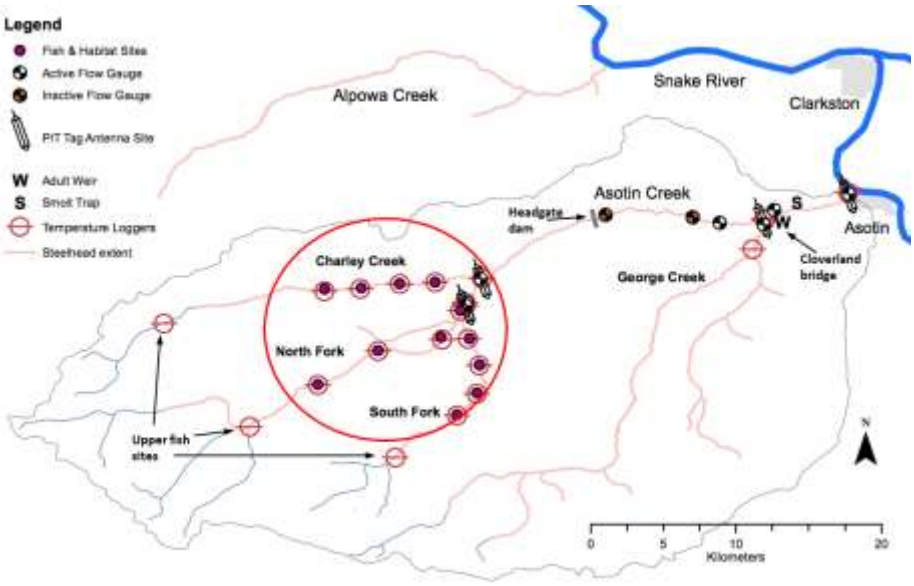

Figure 23. Monitoring infrastructure including fish and habitat sites in Charley Creek, North Fork, and South Fork Creek, temperature and discharge gauges, PIT tag antenna arrays, and the WDFW adult weir and smolt trap for fish-in fish-out monitoring.

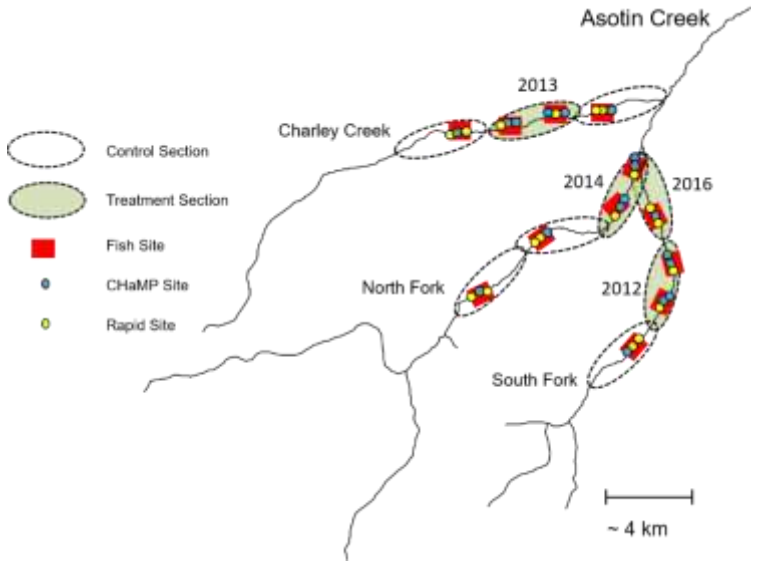

Figure 24. Experimental design of Asotin Creek Intensively Monitored Watershed. Each study stream has three 4 km long sections. One section in each stream has been restored using post-assisted log structures (shaded green): South Fork (2012), Charley Creek (2013), and North Fork (2014). Section 1 of South Fork (lower section) was restored in 2016. All other sections not colored will be controls throughout the project. Fish sites and habitat survey sites are nested within each section. CHaMP = Columbia Habitat Monitoring Protocol, Rapid = custom rapid habitat survey.

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LOWER COLUMBIA INTENSIVELY MONITORED WATERSHED STUDY 2017

ANNUAL REPORT

Mara Zimmerman[1], Bill Ehinger[2], Amelia Johnson[3], Kirk Krueger[1], Tim Quinn[1],

[1]Washington Department of Fish and Wildlife, Olympia, Washington

[2]Washington Department of Ecology, Lacey, Washington

[3]Lower Columbia Fish Recovery Board, Longview, Washington

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EXECUTIVE SUMMARY

This annual assessment provides an update on the lower Columbia River Intensively Monitored Watershed study for the contract period between October 2016 and September 2017. The IMW stream complex in the lower Columbia River includes Mill, Abernathy, and Germany creeks which flow into the Columbia River near Longview, Washington. The study was set up with a Before-After Control-Impact design and the analysis will make use of this design in addition to environmental covariates that are identified using the pre-restoration time series. Mill Creek is the reference stream for which no restoration is planned and Abernathy and Germany creeks are the treatment streams.

Watershed-scale nutrient enhancement in the form of salmon carcass analogs (SCA) was completed in the fall in Germany Creek (2011-2013) and in the spring in Abernathy Creek (2013-2015). The intensity of treatment ranged between 0.09 and 0.13 kilograms of analog per meter-squared of stream channel.

As of 2017, the completed instream habitat treatments in Abernathy Creek include 7.6 kilometers of instream habitat, 1.3 kilometers of off-channel and side-channel habitat, and 0.05 km^2 of riparian area. Three additional projects are currently funded but not yet constructed. An additional two projects are designed but not yet proposed for funding. Funding needed to complete these remaining two projects is estimated to be $1.3 million.

As of 2017, the completed instream habitat treatments in Germany Creek include 2.3 kilometers of instream habitat, 0.2 kilometers of off-channel and side-channel habitat, and 0.15 km^2 of riparian area. Three projects are currently funded but not yet constructed. Concepts for remaining projects in Germany Creek were described in the 2009 Treatment Plan which estimated that approximately $1.4 million dollars would be needed to complete construction of projects in Tier 1 reaches of Germany Creek after design is completed.

Target fish species for this study are Coho Salmon, Steelhead Trout, and Chinook Salmon. Annual life cycle monitoring data are collected for each species. Smolt production in 2017 was at or below the long- term average in all three watersheds with the exception of Chinook fry production in Mill Creek, which was higher than the long-term average. Adult spawner abundance of Chinook Salmon and Steelhead Trout in 2017 were among the lowest numbers observed in the time series, a result likely due to low ocean survival. Adult spawner abundance of Coho Salmon in 2016 were near the long-term average for the time series (2017 spawner data for Coho Salmon are still being collected at the time of the report).

Annual habitat monitoring includes collection of a standardized set of habitat measurements (intensive sampling) in approximately 20 randomly selected locations within each watershed. In 2017, 26, 27 and 25 sites were surveyed in Germany, Abernathy and Mill creeks, respectively. Our initial analysis of the habitat data includes four metrics typically used to represent habitat complexity – very large wood, percent pool, percent gravel, and bankfull width-depth ratio. Within years, our results show notable

spatial variation of habitat attributes among sites. Among years, our results show correlation of habitat attributes among watersheds, suggesting that large scale processes are generating synchronous annual changes in these watersheds.

Annual water quality and quantity monitoring occurs at stream gages located at the mouth of each creek. Seasonal patterns in flows and temperature are synchronized among watersheds. Monthly stream flows for water year 2017 were relatively high (>75th percentile) with respect to the time series. Stream temperatures for water year 2017 were relatively low (< 25th percentile) in the winter months but relatively higher (>75th percentile) in the summer months. Annual summer flow metrics are correlated among the watersheds suggesting a synchrony in watershed condition that supports assumptions of the before-after control-impact study design.

An evaluation of the ecosystem responses to the salmon carcass analog (SCA) treatments was conducted using nitrogen isotopes to trace the uptake of marine derived nutrients by the stream ecosystem. This analysis was completed and reported in a Master's Thesis (Western Washington University) in 2017. Results indicated that the SCA were consumed by both invertebrate taxa and juvenile coho salmon, but did not show nutrient uptake from the analogs in periphyton and organic matter. Nutrient uptake from the analogs occurred as a temporal, pulsed event that did not last more than two months following the treatment. Neither the fall or spring SCA treatments resulted in increased numbers, fork length, or weight of smolts for Coho Salmon, Steelhead Trout, or Chinook Salmon.

A preliminary analysis of site-scale habitat change to the instream habitat projects is presented in this report. To account for annual variation in habitat, we compared metrics at restoration project sites to metrics from randomly selected sites across the watershed. Preliminary results were available for two locations where the timing of the restoration projects has allowed for post-treatment monitoring.

Results at the project locations showed variability among years but did not show changes that suggested the restoration treatments had influenced stream habitat at the project location. This result was surprising and we propose several avenues of future work to further develop approaches useful for evaluating habitat change at each project site.

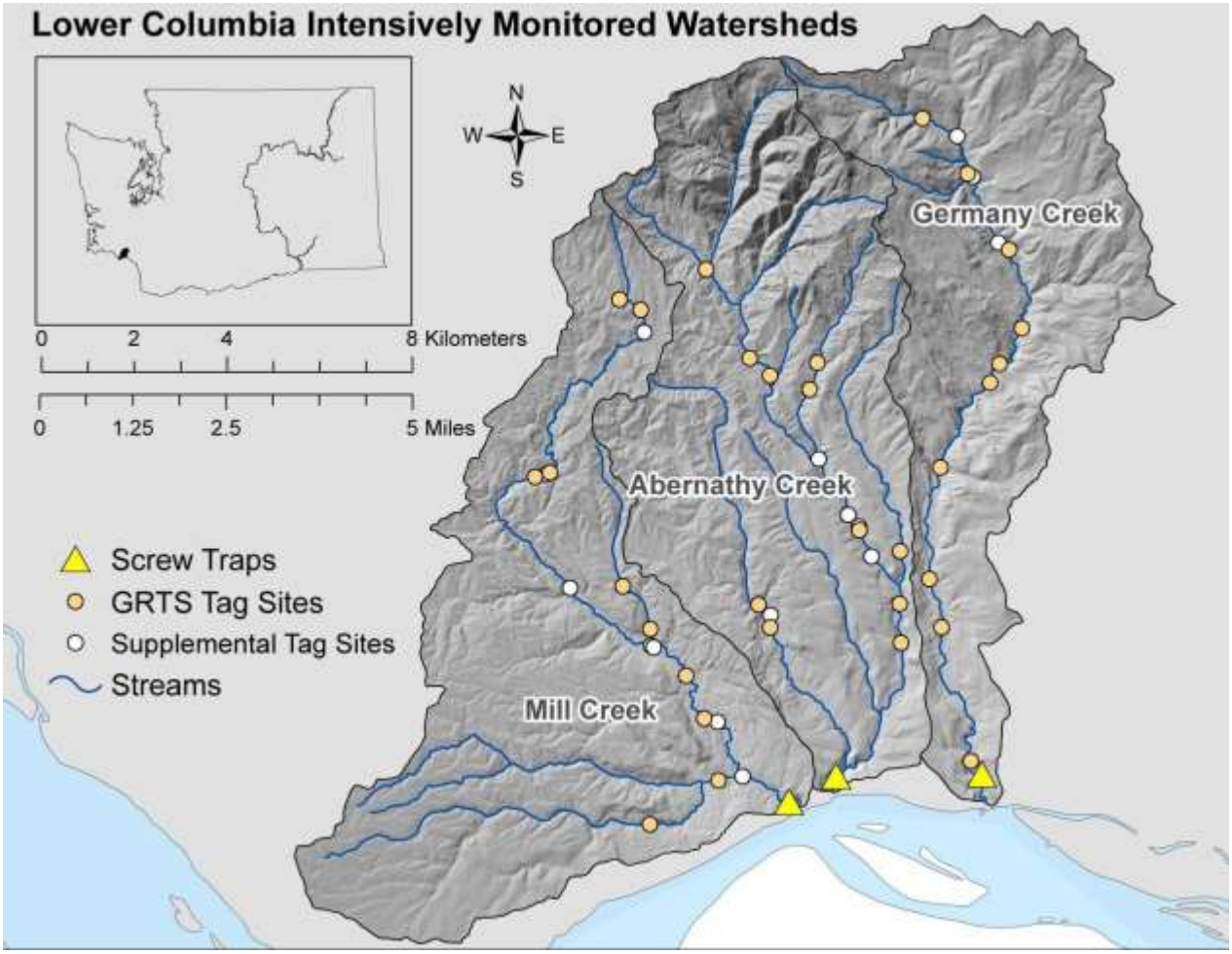
INTRODUCTION

Since the 1990s, many salmon populations in the Pacific Northwest have become listed under the U.S. Endangered Species Act and millions of dollars have been dedicated to the restoration of freshwater habitat (NRC 1996). Despite the substantial investment of funding and effort towards the restoration of freshwater habitats, little is known about the efficacy of these efforts for increasing salmon production (Roni et al. 2002, Katz et al. 2007). Fish responses to restoration actions are difficult to isolate because restoration projects typically happen as localized projects in large watersheds where annual variation in salmon abundances is influenced by multiple co-varying factors. Understanding the cumulative effect of local habitat projects on the anadromous salmonid life cycle requires a carefully selected study design and a long-term investment in research.

The purpose of the Intensively Monitored Watersheds (IMW) program is to determine whether and how restoration activities increase salmon and steelhead production. The rationale and need for the IMW program was outlined in the Washington Comprehensive Monitoring Strategy and Action Plan for Watershed Health and Salmon Recovery (Crawford et al. 2002). In 2004, a group of agency and industry scientists selected four locations in western Washington for inclusion in the collaborative IMW research program (Bilby et al. 2004). A Before-After Control-Impact study design was selected to maximize the ability to detect changes in salmon production as a result of habitat restoration treatments while minimizing the probability of detecting spurious inter-annual effects (Intensively Monitored Watersheds Scientific Oversight Committee 2007). Watersheds selected for this program had a history of monitoring data and were small enough that scientists anticipated restoration actions of sufficient scale could be completed to cause a population response.

The lower Columbia River watershed complex is comprised of three adjacent tributaries (Mill, Abernathy, and Germany creeks) which drain into the Columbia River near the town of Longview, Washington (Figure 1). A detailed description of the landscape and fish populations in each watershed is provided in earlier reports (Bilby et al. 2005; Kinsel et al. 2009; Zimmerman et al. 2012; Zimmerman et al. 2016a). These watersheds are characteristic of the southwest region of Washington State and were selected due to their relatively small watershed size and availability of baseline smolt data. Land use in these watersheds, as with many watersheds in southwest Washington, is primarily private or state owned timber lands (Krueger et al. 2010; Krueger et al. 2012). Percent of impervious surfaces is very low (2-2.8%; LCFRB 2010a). At present, less than 1% of the existing forested landscape is in a late-seral stage. While lands in the headwaters of all three watersheds continue to be managed for commercial timber harvest, implementation of new forest practices through the Department of Natural Resources' Habitat Conservation Plan (state lands) and Forest Practices Rules (private lands) is expected to substantially improve stream conditions over time. Specifically, standards of the Washington State Forest and Fish Law, passed by the Washington State Legislature in 1999, are expected to restore passage, protect riparian conditions, reduce fine sediment inputs, lower water temperatures, improve flows, and restore habitat diversity (LCFRB 2010c).

Figure 1. Map of Mill, Abernathy, and Germany creeks in southwest Washington. Rotary screw traps are operated annually at the mouth of each creek. Summer surveys of fish and habitat are conducted at spatially representative (Generalized Random Tessellation Stratified) and Supplemental sites.



The original study plan for the IMW watersheds in western Washington was described in Bilby et al. (2004) with details specific to the lower Columbia River IMW developed by the Intensively Monitored Watersheds Scientific Oversight Committee (2007). In the lower Columbia River, an integrated watershed analysis and Ecosystem Diagnostic Treatment model were developed as part of the recovery planning process (LCFRB 2010a; LCFRB 2010b). Results of these analyses were used by the Lower Columbia River Fish Recovery Board to identify possible limiting factors in the Mill, Abernathy, and Germany creek watersheds. A Treatment Plan was completed in 2009 (HDR Inc and Cramer Fish Sciences 2009) and laid out three phases of restoration. In response to the Treatment Plan, an updated study plan for the lower Columbia River complex was completed in 2012 (Zimmerman et al. 2012) and again in 2015 (Zimmerman et al. 2016a). The study plan outlined hypotheses regarding fish and habitat responses to restoration actions to be tested with the annual time series of monitoring data collected with the IMW research team.

Two types of restoration activities have been or are being implemented on Abernathy and Germany creeks. A watershed-scale nutrient enhancement project was completed in Germany Creek (fall treatment) in 2013 and Abernathy Creek (spring treatment) in 2015. Reach scale physical habitat projects have been implemented and are planned in response to dedicated funding provided by the Salmon Recovery Funding Board for restoration in IMW watersheds. In 2013, the SRFB designated $2 million per year over a three year period for restoration treatments in IMW complexes. Between 2014 and 2016, this allocation was used to fund habitat projects in the Lower Columbia IMW streams.

This document provides an update on current activities and results from the lower Columbia River IMW stream complex for the contract period between October 2016 and September 2017. In order to address the comprehensive nature of the IMW work, the main document is organized into five sections – (1) Limiting Habitats and Life Stages, (2) Restoration Actions, (3) Monitoring Approach, (4) Key Findings, and

(5) Discussion. In addition, we have provided supplemental information in seven appendices including Appendix A which addresses specific questions posed by the SRFB Monitoring Panel regarding the lower Columbia River IMW study and Appendix C which explains the history and future funding potential for restoration projects in Germany Creek.

LIMITING HABITATS AND LIFE STAGES

This section addresses the processes that contribute to current versus historical numbers of anadromous salmonids in the IMW study streams.

The 2009 Treatment Plan described a long list of limiting factors in the Abernathy and Germany creek watersheds (HDR Inc and Cramer Fish Sciences 2009). Additional discussion and refinement of this list occurred among members of the IMW TOG during summer of 2016. Rather than consider individual limiting factors, the TOG discussions focused on watershed processes. Watershed processes in the Lower Columbia IMW watersheds have been impacted by historical land use that has disrupted sediment transport processes and disconnected the riparian and instream ecosystems. Although recent laws requiring the development of riparian buffers, reduction of road densities, and culvert repairs should lead to 'healing' of watershed processes in the long term, habitat treatments are needed in the short-term to increase channel complexity, re-establish connectivity between instream channels and off- channel areas, and improve fish access to tributaries.

- Complexity is defined as the diversity in flows, substrate, and bathymetry of the channel,
- Connectivity is defined as the inundation of off-channel areas at winter flows, and
- Fish access is defined as improved upstream passage for adults in major tributaries such as Sarah and Erick creeks (Abernathy).

Existing information from habitat and life cycle monitoring supports this assessment of the stream habitat. Pre-treatment monitoring suggests that large wood is extremely limited and plane-bed channel

type is common in these watersheds (Zimmerman et al. 2016b). To date, the analysis of the Coho Salmon life cycle indicated that spring smolt production is a density-dependent function of spawners

and that apparent overwinter survival determines the numbers of spring smolts. Both overwintering and summer habitat appear to be important contributors to the ultimate production of spring smolts. For example, overwinter survival is determined by juvenile location and growth during the summer months and smaller tributaries and headwater areas disproportionately contribute to the spring smolts when compared to juveniles that over-summer in lower main stem reaches of Abernathy Creek (Johnson et al. 2015). Complexity of the channel (especially the conversion of plane bed to forced pool-riffle) in mainstem reaches should increase the quality of summer rearing habitat for juvenile Coho Salmon improving their growth and potentially their overwinter survival. Historical numbers of Coho Salmon in Mill, Abernathy and Germany creeks combined is estimated between 10,000-30,000 adult spawners (LCFRB 2010c). In contrast, spawner abundance over the past decade has ranged from approximately 400 to 3500 among all three watersheds. Increased connectivity of off-channel areas should provide flow refugia for juvenile Coho Salmon during winter flow events improving their retention in the watershed. Currently, most of the rearing habitat consists of pools within the mainstem and tributaries with limited alcove, beaver pond, and backwater channel units. Finally, improved access for Coho Salmon spawners to major tributaries (e.g., Erick and Sara creeks) should provide additional rearing habitat, improving the number of juvenile Coho Salmon that are retained in freshwater through the winter and survive to spring smolts.

Historical numbers of Steelhead Trout spawning in Mill, Abernathy and Germany creeks combined is estimated to be around 2,000 adult spawners. In contrast, spawner abundance over the past decade has ranged from approximately 200 to 650 among all three watersheds. Similar to Coho Salmon, spring smolt production of Steelhead Trout is a density-dependent function of spawners. However, bottlenecks to the Steelhead life cycle are not well understood and are influenced by the complexities of age-specific survival and age-specific migration. Steelhead smolts in the IMW watersheds are primarily two years in age, but a consistent proportion of one and three year smolts are observed each year. Additional analyses are needed to explore the relationship between inter-annual variation in age structure,

density-dependent growth, and freshwater productivity of juvenile Steelhead Trout.

Historical numbers of Chinook Salmon in Mill, Abernathy and Germany creeks combined is estimated to be between 5,000-7,500 adult spawners (LCFRB 2010c). In contrast, spawner abundance over the past decade has ranged from approximately 175 to 2,500 spawners among all three watersheds, and more than 90 percent of these spawners are of hatchery origin. The abundance of outmigrant Chinook Salmon is a density-independent function of the number of spawners (e.g., more spawners = more outmigrants). Juvenile Chinook Salmon spend little to no time rearing in the IMW streams, which contrasts with other populations of tule fall Chinook Salmon in the lower Columbia River. For example, in the Coweeman River, a consistent proportion of juveniles rear in freshwater for two to eight months and outmigrate as subyearling smolts (~ 90 mm fork length) each year (Lamperth et al. 2014). Increased channel complexity and connectivity should reduce scouring and sedimentation of Chinook Salmon redds during high flow events, improving egg-to-fry survival. Increased channel complexity (e.g., conversion of plane bed to forced pool-riffle) may also create pools and improve conditions for freshwater rearing of juvenile Chinook Salmon (Mossop and Bradford 2006).

Historical numbers of Chum Salmon spawning in Mill, Abernathy and Germany creeks combined is estimated between 6,500-40,000 adult spawners (LCFRB 2010c). Today, Chum Salmon in these watersheds are typically too few to produce a reliable estimate of abundance; less than ten Chum Salmon spawners are observed on typical years. However, high returns of Chum Salmon to the Columbia River in 2015 and 2016 resulted in detectable numbers of spawners and outmigrants in Abernathy and Germany creeks (neither life stage was detected in Mill Creek). Although data are too sparse to conduct a thorough analysis, the proximate limitation to current chum abundance is certainly too few eggs in the gravel. Ultimately, some combination of factors, which likely included degradation of spawning habitat, contributed to the current scarcity of Chum Salmon in Mill, Abernathy, and Germany creeks.

RESTORATION ACTIONS

This section describes the implementation of restoration projects in Abernathy and Germany creeks.

In-stream restoration projects and their primary treatment objectives are summarized in Tables 1 and 2. Further details for each project are available in Appendix B-2 and on the Recreation Conservation Office PRISM website (https://secure.rco.wa.gov/prism/search/projectsearch.aspx).

In Abernathy Creek, 9 of the 14 projects identified for implementation were constructed through 2017 (Table 1). Of the remaining five projects, three are funded but not yet constructed (15-1127, 16-1533, and 17-1115), and two have completed designs but need to be proposed for construction funding (Erick Creek Culvert Replacement and Abernathy Creek Reach 9B). The two project designs were funded through Pacific State Marine Fisheries Commission grants, Erick Creek in 2016 and Abernathy 9B in 2017, and both incorporate feedback from the IMW Technical Oversight Group and the Lower Columbia Fish Recovery Board Technical Advisory Committee. The Abernathy Creek Reach 9B project was selected for design in 2017 based on recommendations described in the 2016 Treatment Plan Update. The project area for this design extends the spatially intense treated area in upper Abernathy Creek by including both the Abernathy 9B and 9C project sites, as well as main channel stream sections from the confluence of Abernathy Creek and Sarah Creek to the upstream end of the Wisconsin project site (Figure 2). Once constructed, this project will primarily address instream habitat complexity and off- channel/side-channel reconnection treatment needs, as well as riparian planting and management.

Completed habitat treatment through 2017 includes 7.6 kilometers of instream habitat, 1.3 kilometers of off-channel and side-channel habitat, and 0.05 km^2 of riparian area (Appendix B-2). The funding needed to complete the remaining two projects (Erick Creek Culvert Replacement and Abernathy Creek Reach 9B) is $1.3 million.

In Germany Creek, one project was proposed for funding, but no additional projects were constructed in 2017 (Table 2). Completed habitat treatment through 2017 includes 2.3 kilometers of instream habitat, 0.2 kilometers of off-channel and side-channel habitat, and 0.15 km^2 of riparian area (see Table 3 in the

Treatment Plan Update). In the current funding landscape, future projects in Germany Creek will need to be competitive in the Lower Columbia Fish Recovery Board process for selecting restoration projects within the lower Columbia River region (see Appendix C). This requirement will likely limit the spatial extent of projects in Germany Creek to Tier 1 reaches identified in the 2009 Treatment Plan. The 2009

Treatment Plan estimated that restoration projects identified in Tier 1 reaches of Germany Creek would cost approximately $1.4 million (2009 dollars) after project design was completed.

Nutrient enhancement in the form of salmon carcass analogs were conducted in the fall in Germany Creek (2011-2013) and in the spring in Abernathy Creek (2013-2015,

c "Cost" refers to additional costs to construct projects in proposed "Project Status". Costs are provided as estimates only.

[d] The listed funding for project 17-1027 is anticipated, but receipt of this funding is dependent upon the approval of the Washington State capital budget.

Table 3). The intensity of treatment ranged between 0.09 and 0.13 kilograms of analog per meter- squared of stream channel (Appendix B-1). In Germany Creek, a total of 29,000 kg of SCA material was distributed over 56 km of stream channel (excluding the 2010 treatment in which the analogs disintegrated within a few day of distribution in the water). In Abernathy Creek, a total of 30,000 kg of SCA material was distributed over 43 km of stream channel. As an approximate comparison, the amount of nitrogen available from the SCA material was 5-10 times more than that provided by salmon and steelhead carcasses during the treatment years (Sturza 2017).

Table 1. Habitat restoration projects for Abernathy Creek, 2009 to present. Project status included completed (C), funded (F), and proposed (P). Primary treatments are Off-Channel/Side Channel (OF/SC), Floodplain Reconnection (FR), Instream Habitat Complexity (IHC), Fish Passage (FP). Acquisition projects are not included in this table.

Additional details are available in the Updated Treatment Plan (see Table 4 in plan).

PRISM ID	Project Name	Project Status[b]	Construction Complete[b]	Primary Treatment	Cost[c]
10-1300-01	Abernathy Creek Tidal Restoration[a]	C	2013	OC/SC	
11-1329	Abernathy Creek Bridge Removal Project	C	2012	FR	
11-1386	Abernathy Creek Two Bridges	C	2012	FR	
12-1333	Abernathy 5A Side Channel Project	C	2015	OC/SC	
PCSRF	Abernathy Sitka Spruce	C	2015	IHC	
14-1296	Abernathy Creek Davis Site	F	2017	OC/SC	
PCSRF	Abernathy Creek Wisconsin Site Project	C	2016	IHC	
14-1311	Abernathy Creek Cameron Site	F	2016	IHC	
14-1310	Abernathy Creek Midway Project	F	2016	IHC	
15-1127	Abernathy Creek Headwaters Implementation	F	2018	IHC	
16-1533	Sarah Creek Habitat & Passage Enhancement	F	2020	FP & IHC	
17-1115	Erick Creek Instream Habitat Restoration	F	2019	IHC	$455,183[d]
PSMFC	Erick Creek Culvert Replacement	P	Future	FP	$939,000
PSMFC	Abernathy Creek Reach 9B[e]	P	Future	IHC	$349,000

[a]The majority of project 10-1300-01 occurred below the smolt trap location. As a result, the study design has not incorporated a direct evaluation of fish responses to this project.

[b] "Project Status" refers to the status of the sponsor's contract with the Washington State Recreation and Conservation Office where as "Construction Complete" refers to the year that the on the ground work was completed. Several projects with construction completed are still in funded project status due to the time lapse between field implementation and final reporting. Completion dates for projects in proposed "Project Status" are provided as estimates only.

[c] "Cost" refers to additional costs to construct projects in proposed "Project Status". Costs are provided as estimates only.

[d] The listed funding for project 17-1115 is anticipated, but receipt of this funding is dependent upon the approval of the Washington State capital budget.

[e] This designed project includes Abernathy 9B and 9C, which were prioritized for implementation in the 2016 Treatment Plan Update.

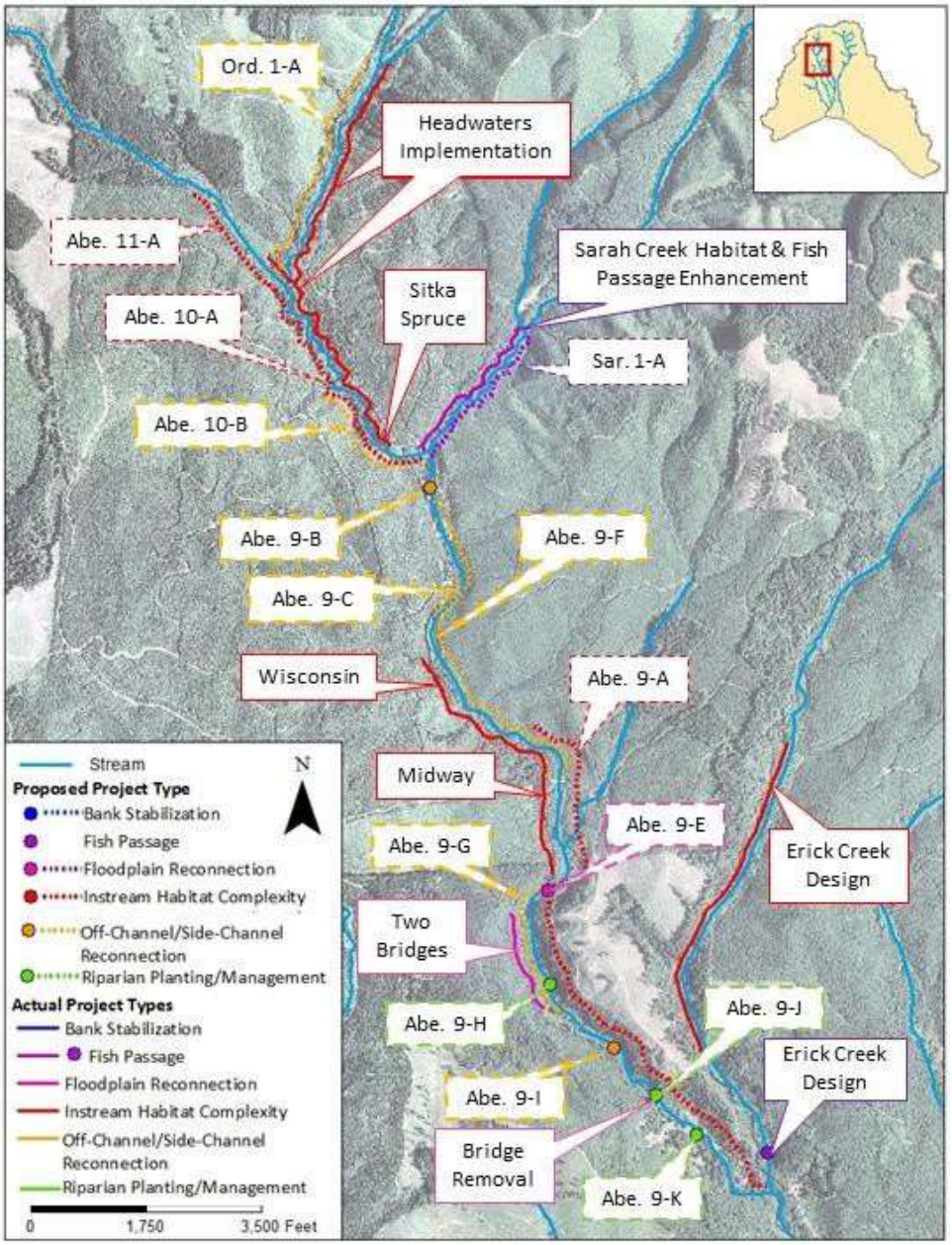


Figure 2. Proposed and funded habitat treatment projects in upper Abernathy Creek (Abernathy Reach 9, 10, and 11, Sarah Creek Reach 1, and Ordway Creek Reach 1). "Proposed" projects are from the 2009 Treatment Plan and "Actual" projects are all funded work through 2016 (see Figure 4 in the Treatment Plan Update for more details). The Abernathy 9B Reach design addresses proposed projects Abernathy 9-B and 9-C on this map, as well as main channel work from the mouth of Sarah Creek to the upstream end of the Wisconsin project site.

Table 2. Habitat restoration projects for Germany Creek, 2009 to present. Project status included completed (C), funded (F), and proposed (P). Primary treatments are Off-Channel/Side Channel (OF/SC), Floodplain Reconnection (FR), Instream Habitat Complexity (IHC), Fish Passage (FP). Acquisition projects are not included in this table.

PRISM ID	Project Name	Project Status[b]	Construction Complete[b]	Primary Treatment	Cost[c]
04-1563	Germany Creek Conservation and Restoration 1	C	2006	IHC	
09-1378	Germany Creek Conservation and Restoration 2[a]	C	2012	IHC	
15-1039	Germany Creek Restoration Smith Site	F	2019	IHC	
15-1040	Germany Creek Andrews Site	F	2019	IHC	
17-1027	IMW Godinho Restoration	F	2020	IHC	$174,000[d]

[a] The majority of this project occurred below the smolt trap location. As a result, the study design has not incorporated a direct evaluation of fish responses to this project.

[b] "Project Status" refers to the status of the sponsor's contract with LCFRB where as "Construction Complete" refers to the year that the on the ground work was completed. Several projects with construction completed are still in funded project status due to the time lapse between field implementation and final reporting.

[c] "Cost" refers to additional costs to construct projects in proposed "Project Status". Costs are provided as estimates only.

[d] The listed funding for project 17-1027 is anticipated, but receipt of this funding is dependent upon the approval of the Washington State capital budget.

Table 3. Watershed-scale application of salmon carcass analogs in the fall and spring in Germany and Abernathy creeks, 2010-2015. The primary treatment was enhancement of marine derived nutrients (MDN).

Watershed	Project Name	Project Status [a]	Year Complete [a]	Primary Treatment
Abernathy	Salmon Carcass Analogs (Spring Treatment)	C	2013-2015	MDN
Germany	Salmon Carcass Analogs (Fall Treatment)	C	2010-2013	MDN

[a] "Project Status" refers to the status of the sponsor's contract with LCFRB where as "Construction Complete" refers to the year that the on the ground work was completed.

MONITORING APPROACH

This section describes components of our monitoring approach for the IMW study – hypotheses, study design, and annual monitoring tasks.

Hypotheses

The IMW study tests the general hypothesis that increasing the complexity and connectivity of the stream network will cause an increase in the freshwater productivity (i.e., smolt output) of salmon and steelhead. The study is designed to evaluate whether responses to stream restoration occur and why (or why not). We assume that the synchrony of habitat forming processes is consistent among the reference and treatment streams and that restoration treatments will generate changes in stream habitat. We hypothesize that changes in stream habitat resulting from the restoration treatments will simulate the complexity and connectivity in the stream network needed to increase survival and growth of juvenile salmon and steelhead. Our results should provide important insight into these hypotheses and their underlying assumptions.

Study Design

The IMW study asks whether site-specific habitat changes translate into population change following restoration treatments. Site-specific changes are tracked through project effectiveness monitoring that quantifies whether and what kinds of reach-scale changes occur following the restoration action.

Further, the IMW studies are uniquely designed to allow for a robust assessment of project effectiveness by evaluating fish and habitat responses at the population or watershed scale. Although several life stages are included in the population-level monitoring, the number and size of emigrating smolts represents the cumulative effect of all freshwater conditions. Inter-annual variability in the number and body size of smolts is caused by a number of interacting factors. In order to isolate the contribution of the habitat restoration from these factors, the Lower Columbia River IMW study was set up to leverage the advantages of a Before-After Control-Impact design (Smith 2002; Roni et al. 2005).

This design includes the selection of control (hereafter, reference) and impact (hereafter, treatment) watersheds. Mill Creek was selected as the reference watershed and Abernathy and Germany creeks were selected as the treatment watersheds. If annual fish metrics are correlated between the two watersheds prior to restoration occurring, this design provides additional statistical power to detect responses of the treatment watersheds by accounting for co-variation between the treatment and reference watershed due to non-restoration related factors. Alternately, measures of environmental conditions such as stream flows, pool frequencies, or large woody debris counts were incorporated into the sampling efforts to account for failures to meet the assumptions of the experimental design (Bendetti-Cecchi 2001; Steinbeck et al. 2005) and to strengthen the analyses by revealing mechanisms that may affect freshwater production.

The planned analysis to test for watershed-scale effects of restoration relies on consistent and accurate time series data for fish population, habitat, and water quality prior to and following implementation of the restoration projects. Annual monitoring that contributes to these time series includes fish life cycle metrics, instream habitat characteristics, and water quality and quantity. The planned analysis to test for

project-scale effects of restoration relies on pre- and post-treatment monitoring of habitat characteristics at the project locations as well as simultaneous monitoring of habitat characteristics at the watershed-scale to provide context for interpreting any changes observed at the project locations. Annual measurement of habitat may also allow selected attributes to be used as covariates to improve our ability to detect changes in fish abundance or survival, thus shortening the necessary duration of the post-treatment monitoring period.

Annual Monitoring Tasks - Fish

Annual monitoring of fish life cycle metrics are collected at the spawner and spring outmigrant life stages for Coho Salmon, Chinook Salmon, and Steelhead Trout (Adult spawner **abundance**

- *Smolt abundance*

Table 4. Annual monitoring tasks associated with fish life cycle metrics. Progress on these tasks for the lower Columbia River IMW study is shown for all years as well as the current reporting period (October 1, 2016 to September 30, 2017).

Task	Annual Time Frame	Years	2016-2017
Chinook spawner surveys	September - November	2005-2017	Completed
Coho spawner surveys	October – January	2006-2017	Completed
Steelhead spawner surveys	March – June	2005-2017	Completed
Smolt Trap operation	January - June	2001-2017	Completed
Parr surveys & PIT tagging	August - September	2005-2017	Completed

). Observations of Chum Salmon are noted at the spawner and outmigrant life stages; however, the numbers of Chum Salmon are typically so low that additional metrics (e.g., spawner abundance estimates) are not calculated beyond raw counts. Additional information on the density and abundance of summer parr are collected for Coho Salmon and Steelhead Trout. Data collection methods follow standard monitoring protocols of the American Fisheries Society (Crawford et al. 2007a; Crawford et al. 2007b; Volkhardt et al. 2007) and have been described in detail in earlier reports (Kinsel et al. 2009).

Metrics initially selected to evaluate long-term trends in fish populations include:

- *Adult spawner abundance*
- **Smolt abundance**

Table 4. Annual monitoring tasks associated with fish life cycle metrics. Progress on these tasks for the lower Columbia River IMW study is shown for all years as well as the current reporting period (October 1, 2016 to September 30, 2017).

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Smolt Trap operation	January - June	2001-2017	Completed
Parr surveys & PIT tagging	August - September	2005-2017	Completed

Annual Monitoring Tasks – Habitat

The IMW habitat sampling plan and field methods are adapted from the US EPA, Environmental Monitoring and Assessment Program (EMAP, http://www.epa.gov/emap) as described in Peck et al. (draft, http://www.epa.gov/emap/html/pubs/docs/groupdocs/surfwatr/field/ewwsm01.html) and Crawford (2008a, 2008b, 2009) for the Washington Salmon Recovery Funding Board (SRFB). These methods are recommended in the Washington Comprehensive Monitoring Strategy for Watershed Health and Salmon Recovery (Crawford et al. 2002) and meet the preliminary criteria of the Pacific Northwest Aquatic Monitoring Partnership (PNAMP; http://www.pnamp.org/). Samples consist of measures and counts made at and between 21 equally spaced cross-sections. Cross-sections are positioned along a length of stream that is the longer of either 40 bankfull widths or 300 m. These methods are highly repeatable which facilitates very low among-surveyor variability which is especially important for long-term projects in which many different surveyors participate.

Sampling sites within a watershed were identified using a random, spatially balanced design (Stevens and Olsen 2004) that was stratified by stream order (Strahler 1957). This allows statistically valid descriptions and comparisons of watersheds and among sites within and among watersheds. Some sampling sites were changed after 2006 to include a greater number of locations where fish presence is likely. That is, we redefined the sampling frame to exclude some very small reaches that are distant from the outlet, but retained random site selection within the new sampling frame. Preliminary analysis in 2006 suggested that repeated measures sampling, rather than a rotating panel, would allow the collection of more samples in each year and likely provide better change detection via repeated measures analysis. In 2007 and subsequent years about 20 sites are sampled every year in each watershed in each complex. In each year as logistically feasible, additional random sites are sampled to increase spatial coverage of samples within watersheds. Sampling times among watersheds rotate on about a weekly schedule to minimize seasonal bias (e.g., stream drying as summer progresses). This sampling plan provides an accurate description of habitat conditions in each watershed in every year.

Additionally, because sample sites are randomly selected it is possible to parse and stratify samples to address specific questions; for example one can select sites within and downstream of restored reaches (and similar sites within reference reaches and reference watersheds) to more certainly detect downstream effects of restoration actions, if they occur.

The measured habitat attributes include bankfull width, wetted width, bar width, bankfull height, water depths, counts of substrate by size classes, occurrence of mesohabitat types (e.g., pool) and sub-types (e.g., plunge pool), counts of instream and bridging wood by length and diameter classes, presence of

backwaters, side channels, and fish, compass bearing and distances between cross-sections, and channel shape. A wide range of metrics can be calculated from these measured attributes to describe habitat conditions in each watershed. **Metrics** initially selected to evaluate long-term trends in habitat include:

- **Very Large Wood Debris (VLWD) density** was selected to represent channel roughness. This metric is estimated using counts of LWD that are > 5 m long and > 0.3 m in diameter between each of the 21 transects. VLWD density estimates are described for each sample site in each year as the sum of the VLWD counted within a sample site. We assumed that VLWD would be relatively temporally stable and that counting errors would be infrequent.
- **Percent pools** was selected to represent the quality of salmonid rearing habitat. This metric is the percent of the 21 cross-sections within each sample reach that intersects a pool. It is possible for one pool to be crossed by more than one cross-section and for more than one pool to intersect a single cross-section. Pools are identified as relatively deep, slow moving portions of water following Lazorchak et al. (1998), Crawford 2008b, Krueger et al. 2010, and Krueger et al. 2012)
- **Percent gravel** was selected to represent the quality of salmonid spawning habitat. This metric is the proportion of approximately 205 substrate samples collected at each site during each year that are classified as fine gravel (2-16 mm) or coarse gravel (16-64 mm). We assumed that percent gravel would be relatively dynamic because fine substrate can mobilize at relatively low and frequent flows.
- **Bankfull width-to-depth ratio** was selected to represent channel complexity. This metric is the mean of the estimate made at each of the cross-sections at a site during each year. We assumed that bankfull width-to-depth ratio would be relatively temporally stable because it is describing changes in bank and bed form.

Table 5. Annual monitoring tasks associated with habitat metrics. Progress on these tasks for the lower Columbia River IMW study is shown for all years as well as the current reporting period (October 1, 2016 to September 30, 2017).

Task	Annual Time Frame	Years	2016-2017
Basin-Scale Reaches (GRTS)	June - September	2006-2017	Completed
Project Reaches	June - September		Completed

Annual Monitoring Tasks – Water Quality and Quantity

Annual monitoring of water quantity and quality data occurs at stream gages operated near the mouth of each creek and includes continuous flow, temperature, turbidity, and monthly water chemistry analysis (Table 6). Data collection follows standard operating protocols established by the Washington Department of Ecology (http://www.ecy.wa.gov/programs/eap/quality.html). To describe flow and temperature characteristics of a given water year (October through September), we plot the mean monthly values in context of the 25th, 50th, and 75th percentiles for each month. Water flow metrics of interest with respect to salmonid rearing in these watersheds include the magnitude of summer rearing flows (mean daily flow in the month of September) and the duration of summer low flows (minimum 60-

day average between the months of June and October). Therefore, **metrics** initially selected to evaluate long-term trends in water quality and quantity include:

- **Summer flows (magnitude)** – the amount of flow during the summer rearing period is represented as the mean daily flow in the month of September, and
- **Summer flows (duration)** – the duration of flow during the summer rearing period is calculated as the minimum 60-day average between the months of June and October.

Table 6. Annual monitoring tasks associated with water quality and quantity metrics. Progress on these tasks for the lower Columbia River IMW study is shown for all years as well as the current reporting period (October 1, 2016 to September 30, 2017).

Task	Annual Time Frame	Years	2016-2017
Stream flow (cfs)	October - September	2005-2017	Completed
Stream temperature (˚C)	October - September	2005-2017	Completed

Annual Monitoring Tasks – Project Effectiveness

Project effectiveness monitoring of the salmon carcass analog (SCA) treatments was conducted at three locations in each watershed (lower, middle, and upper main stem). Two additional tributaries (Weist, Cameron) were included in the sampling to provide in-basin controls for Abernathy Creek. Ecosystem responses were evaluated via bi-monthly sampling. We used stable isotope content of sample tissue to measure the uptake of marine derived nutrients ($\delta^{15}N$) into multiple levels of the stream ecosystem (organic matter, invertebrate function group, juvenile coho salmon). We evaluated fish responses at project locations by tracking the overwinter growth of juvenile coho salmon and population level changes in smolt abundance and survival of all salmon and steelhead. **Metrics** used to evaluate ecosystem responses to the SCA treatments were:

- **Stable isotope ($\delta^{15}N$) content** - riparian vegetation, periphyton, invertebrate functional feeding groups, juvenile coho salmon
- *Size and weight of juvenile coho*
- **Smolt abundance and size** (all species)

Table 7. Project effectiveness monitoring tasks associated with ecosystem responses to salmon carcass analog treatments. Progress on these tasks for the lower Columbia River IMW study is shown as the years that monitoring was conducted during and following treatment, including work completed in the current reporting period (October 1, 2016 to September 30, 2017).

Project	Treatment Years	Treatment Monitoring	Post-Treatment Monitoring
Germany Creek (fall)	2010-2013	2010-2014	2017

Abernathy Creek (spring)	2012-2015	2012-2016	2017
Mill Creek	Reference	2010-2016	2017

Project effectiveness monitoring of instream projects is conducted at the location of each project site using the same habitat monitoring protocols followed at the watershed scale (Table 8). The data are

collected in the same manner as the annual monitoring of randomly selected habitat reaches in each watershed. Our methods expand on those suggested by Crawford (2008a, 2008b, 2008c, 2009). Using the same methods for intensive monitoring project effectiveness monitoring has several important advantages. First, surveyors are already trained and experienced using the methods which reduces sampling error. Second, our habitat database is already designed to store and manage those data.

Thus, all habitat data are reliably stored and readily available for analysis. Third, and perhaps most importantly, because intensive monitoring data and project effectiveness monitoring data are directly comparable we can make valid comparisons of environmental changes at project locations with those at other locations within and among watersheds. At each project site, we collect habitat data for at least one year prior to treatment as well as multiple years after treatment. These data will be compared with watershed scale trends as well as statistically valid or ecologically meaningful (e.g., downstream) reference sites, which can provide strong inferences regarding the effects of treatments within and downstream of treatment projects. **Metrics** used in our initial analyses of habitat in treatment reaches paralleled those selected to evaluate trends at the watershed scale:

- *Very Large Wood Debris (VLWD) density*
- **Percent pools**
- **Percent gravel**
- **Bankfull width-to-depth ratio**

Table 8. Project effectiveness monitoring tasks associated with habitat responses to instream habitat projects. Progress on these tasks for the lower Columbia River IMW study is shown as the years that monitoring was conducted pre-treatment and post-treatment, including work completed in the current reporting period (October 1, 2016 to September 30, 2017).

Project	Project Number	Monitoring Site	Construction Completed	Pre-Treatment Monitoring	Post-Treatment Monitoring
Abernathy Creek Two Bridges	11-1386 R	ABR900	2012	2005, 2007-2011	2013-2017
Abernathy 5A Side Channel Project	12-1333 R	ABR051	2014	[a]	[a]
Abernathy Sitka Spruce	13-1152 R	ABR901	2015	2011-2015	2016-2017
Abernathy Creek Wisconsin Site	12-1672 R	ABR009	2016	2011-2015	2016-2017
Abernathy Creek Cameron Site	14-1311 R	ABR020	2016	2006-2015	2016-2017
Abernathy Creek Midway Project	14-1310 R	ABR030	2016	2006-2015	2016-2017

Abernathy Creek Headwaters Implementation	15-1127 R	ABR115	2018	2005, 2007-2017	---

[a]Monitoring site ABR051 is located just downstream from the Abernathy 5A side channel project. Project monitoring is not available directly at this site because the current habitat monitoring protocols did not lend to monitoring the creation of a side channel.

KEY FINDINGS

This section describes overall and annual observations for each of the monitoring tasks – fish life cycle, habitat, water quality and quantity, and project effectiveness.

Fish Life Cycle Monitoring – Annual Time Series

The smolt time series begins in 2001 for Coho Salmon and Steelhead Trout and in 2005 for Chinook Salmon. Over the time series, Coho Salmon smolt abundance has been consistently highest in Mill Creek and lowest in Germany Creek (Figure 3). The 2017 outmigration of Coho Salmon smolts retained the among-watershed pattern and was at or below the long-term average in all three creeks. Previous analysis indicated that Coho Salmon smolt production in the treatment watersheds was not correlated with the reference watershed prior to project implementation and that a before-after analysis will be most appropriate to evaluate population-level responses to the habitat treatments (Zimmerman et al. 2015). This analysis will benefit from identifying environmental covariates that help to explain a portion of the inter-annual variation in the number of smolts. Over the time series, Steelhead smolt abundance has been highest in Germany Creek and lowest in Mill Creek. The 2017 outmigration of Steelhead smolts differed from the typical among-watershed pattern with the highest smolt production occurring in Abernathy rather than Germany Creek. Previous analyses indicated that Steelhead Trout smolt production in the treatment watersheds was correlated with the reference watershed prior to project implementation and that a before-after control-impact analysis will be most appropriate to evaluate population-level responses to the habitat treatments (Zimmerman et al. 2015). Similar to Coho Salmon, this analysis will benefit from identifying environmental covariates that help to explain a portion of the inter-annual variation in the number of smolts. Over the time series, outmigrants of Chinook Salmon have been more numerous in Mill than Abernathy or Germany creeks. This difference reflects variation in the number of spawners among the three watersheds. Chinook mostly outmigrate at the “fry” life stage with minimal freshwater growth observed prior to outmigration. The 2017 outmigration was near or above average in each of the creeks. Chum Salmon are rarely observed in these watersheds; however, spawner numbers in 2015 and 2016 were high enough to result in detectable levels of reproductive success measured as fry outmigrants. Although no estimates of outmigration could be derived in 2016 (due to constraints imposed by the ESA take permit for trap operation), the 2017 outmigration of Chum Salmon fry was estimated to be 58,500 (CV = 11%) in Abernathy Creek and 49,000 (CV = 16%) in Germany Creek. Neither spawning nor juvenile production of Chum Salmon was observed in Mill Creek.

For the purpose of the IMW study, the adult time series began in 2005 for Chinook Salmon and Steelhead Trout and 2006 for Coho Salmon. At the time of this report, the most recent estimates of spawners abundance available are 2016 for Coho Salmon and 2017 for Steelhead Trout and Chinook Salmon. The Coho Salmon time series has historically been presented as redd counts; however, these counts are being converted to total spawner abundance using the methodology outlined in Zimmerman et al. (2016b - see Appendix B). The methodology expands the observed redds by a fish per redd ratio derived from mark-recapture estimate of abundance coupled with a census redd count in Abernathy Creek. Over the time series, redd counts have been consistently higher in Mill and Abernathy creeks than Mill Creek and the

numbers are highly synchronized among years (Figure 4). On a given year, spawner estimates for Coho Salmon are an average of five times (range two to thirteen) times the

number of redds observed. Factors that contribute to this expansion ratio are male:female ratios and visibility of redds, both of which vary among years. Over the time series, spawner abundance of Steelhead Trout has been consistently higher in Abernathy and Germany creeks than in Mill Creek. The 2017 returns of Steelhead retained these relative differences among watersheds and all three watersheds were among the lowest numbers observed in the time series. Over the time series, spawner abundance of Chinook Salmon has been consistently higher in Mill Creek than the other two creeks. The 2017 returns of Chinook were the lowest numbers observed in the time series. Low spawner numbers of winter Steelhead and Chinook salmon in 2017 were observed throughout the lower Columbia River tributaries and was not a result unique to the IMW streams; the spatial extent of the pattern suggests that low numbers likely resulted from poor survival in the ocean.

Thirteen percent of Coho Salmon were of hatchery origin in 2016, which was lower than the average of eighteen percent proportion of hatchery spawners (pHOS) observed over the past decade. In comparison, 57% (Germany) to 91% (Mill) of the Chinook Salmon were hatchery origin, consistent with the watershed pHOS averages of 82% to 90% observed since 2008 when mass marking of hatchery releases first allowed the origin of returning fish to be determined. Hatchery composition for Steelhead Trout is not known. Steelhead carcasses are rarely recovered from the spawning grounds and the spawn timing of hatchery Steelhead released by the USFWS research program at the Abernathy Fish Technology Center is similar to that of wild fish (i.e., hatchery and wild can not be distinguished by the timing of redd construction).

Habitat Monitoring – Annual Time Series

Within years, habitat metrics have high variability among sites (Figure 5). This result is expected due to the wide range of channels types, sizes and conditions of the randomly selected sites and demonstrates the variability of habitat that is available for spawning and rearing of anadromous fishes. Within each watershed, mean habitat metrics among sites were also highly variable among years. For example, median values of percent pool habitat and percent gravel varied three-fold among years. Among-year variability was strongly synchronized among watersheds (Figure 6) and suggests that large-scale processes are largely responsible for temporal variability. Large scale processes affecting the characteristics of reach-scale habitat include winter flows of sufficient magnitude or duration move substrate or wood and affect shape of the stream channel or summer flows that limit the amount of water available (affecting pool quantity). The strong inter-annual correlations between reference and treatment watersheds support our study design and suggest that the long-term monitoring and use of reference watersheds likely provide robust project monitoring inferences. Often, the cause of variability within a site among years can be reliably determined using the intensive, annual sampling data, but this can be very time consuming. For example, variability in VLWD may be due to burial and exhumation of VLWD as sediment is transported through a stream site or may occur due to channel migration. These mechanisms have not yet been documented in the Lower Columbia IMW streams and a reliable assessment of the relative importance of site and time require further analyses, likely via mixed model analysis.

Stream flows observed in the IMW streams follow a seasonal pattern (Figure 7). Median winter flows are between 150 and 200 cfs, 20-fold higher than the median summer flows (5 to 10 cfs). High winter flows occur between the months of November to March, a declining hydrograph between March and August, and base summer flows in the months of August and September. The seasonal pattern in flows is highly synchronized among the three watersheds and the metrics of summer flow derived from these data are also highly correlated (Figure 9). In water year 2017 (October 2016 to September 2017), mean monthly stream flows were higher than the long-term median flows in all months except August. Flows during the late winter and early spring, which correspond to fry emergence and smolt outmigration, were well above the 75th percentile.

Stream temperatures observed in the IMW streams also follow a seasonal pattern (Figure 8). Median summer temperatures are between 15 and 17˚C, 9 to 10 ˚C warmer than the median winter temperatures (6 to 7˚C). Stream temperature is measured at the mouth of the creek and likely varies spatially among areas of each watershed. The lowest temperatures occur in the months of December to February. Monthly temperatures steadily increase between February and July and the warmest temperatures are observed in the months of July and August. The seasonal pattern in temperature is highly synchronized among watersheds. In water year 2017, stream temperatures were at or below the 25th percentile during the winter (see month of January) but at or exceeded the 75th percentile during the summer (see month of August). Winter temperatures will affect the development rate of eggs in the gravel (Coho, Chinook) and the overwinter metabolism of Coho and Steelhead parr. Summer temperatures will affect the metabolism of Coho and Steelhead. Depending on the availability of food resources, different metabolic rates may result in variable juvenile growth; future analyses that examine the connection between annual variation in stream temperature versus parr (summer) and smolt (spring) body size may be worth pursuing.

Project Effectiveness Monitoring – Instream Projects

The preliminary evaluation of habitat changes at the project sites included four habitat metrics (very large wood, pools, gravel, and bankfull width-depth ratio). We examined the time series of each metric at the project site and used the randomly selected sites to provide context for the annual variation at the watershed scale. If the metric values change at the project site relative to the watershed scale, the annual value at the project site should increase (or decrease) relative to the annual range observed at the watershed scale. For example, if the metric value was close to the median of the watershed scale values prior to restoration, we might expect that the metric value would deviate towards the upper (or lower) range of the watershed scale values following treatment of the project site (i.e., project site will change rank order with respect to all monitored sites within a watershed).

Based on our current approach to analyzing these data, our results do not show notable changes in habitat at the project sites. This result is surprising because visual inspection of each of the field sites reveals obvious changes to the channel complexity that have resulted from each of the restoration projects and can be visually contrasted with the plane bed channel characteristics that were previously observed at each site.

The Abernathy Two Bridges site has the longest duration of post-treatment monitoring data (Figure 1Figure 10). In-stream construction was completed in 2012 at this site. Percent gravel in this reach has decreased since the construction was completed, but changes in gravel measures at the project site follow those observed at a watershed scale. As a result, changes in percent gravel at the project site most likely reflects watershed scale processes rather than reach-scale response to the restoration treatment. In 2015 and 2016, both VLWD and percent pools at this site appear to have increased in rank value relative to the annual variation observed at the watershed scale.

The Sitka Spruce site has one year of post-treatment monitoring data (Figure 11). In-stream construction was completed in 2015 at the Sitka Spruce site. Considerable amounts of wood were added at both project sites; however, our monitoring data did not detect an increase in VLWD density between the

pre-treatment and post-treatment years. Similarly, the pool, gravel, and bankfull width-depth ratio metrics show little change between the pre- and post-treatment years, especially relative to the variability observed throughout the watershed.

Unfortunately, pre- and post-monitoring data are not available for the Abernathy 5A Side Channel project because established habitat monitoring protocols did not lend themselves to evaluating the addition of a side channel. Further discussion of this issue is provided in the 'Uncertainties and Challenges' section later in the report.

Project Effectiveness Monitoring – Nutrient Enhancement

A detailed analysis of the ecosystem response to the SCA treatments is provided in Sturza (2017, see Appendix D). A summary of key results are provided in this sub-section based on selected text from Sturza (2017):

'Seasonal trends of δ15N in periphyton, macroinvertebrates, and juvenile coho, as well as seasonal trends of juvenile coho fork length and weight were compared between fertilized and unfertilized watersheds. We detected SCA effects on seasonal trends of macroinvertebrate and juvenile coho δ15N for the fall and spring treatments, indicating SCA nutrients were incorporated by these communities. We detected SCA effects on the seasonal trends of juvenile coho fork length and weight for the spring treatment, but not for the fall treatment. We could not detect SCA effects on seasonal trends of

periphyton δ15N for either the fall or spring treatment, potentially due to smaller than needed sample sizes. Overall, the effect of fall SCA application was to disrupt the seasonal trend of δ15N values among trophic levels by causing an increase in δ15N during the late fall/early winter when values are normally decreasing. The effect of spring SCA application was to enhance the seasonal trend, causing increases in δ15N values greater than those seen in the absence of SCA applications. Comparing juvenile coho sizes and abundances between years with and without SCA application and between fertilized and unfertilized

watersheds indicated that neither the fall or spring treatment had a significant effect on coho growth and survival. ‘

Figure 3. Time series of smolt abundance in Mill, Abernathy, and Germany creeks, 2001-2017. Data are annual estimates and 95% confidence intervals. Horizontal line is the geometric mean of annual estimates across years. The 2005 Chinook abundances in Abernathy and Germany creek are outside the range of the graph but influence the geometric mean. Chinook outmigration estimates are not available for 2001-2004 (trap not operated during outmigration period) or 2016 (due to ESA take permit restrictions).

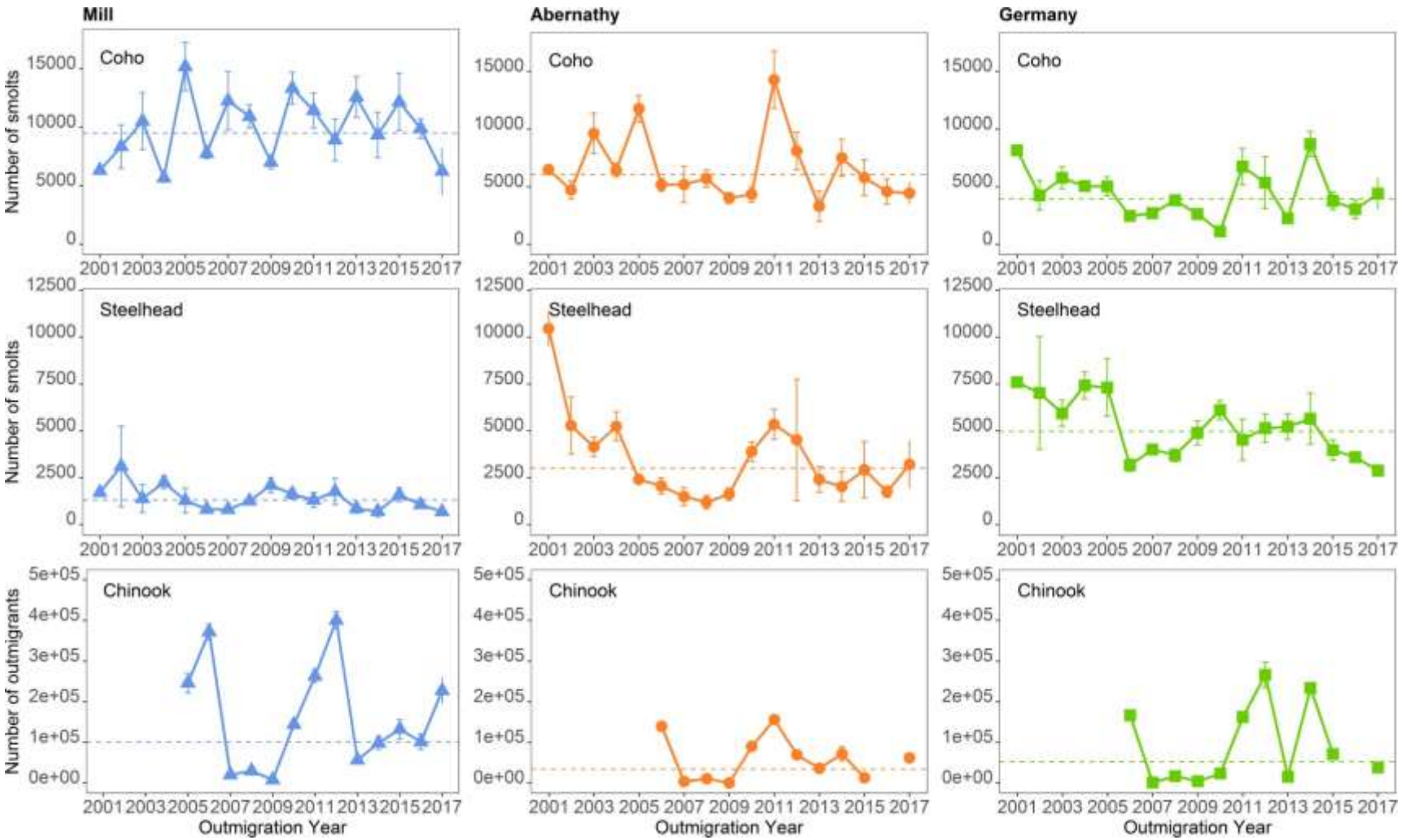


Figure 4. Time series of adult spawners for Mill, Abernathy, and Germany creeks, 2005-2017. Data are annual estimates. Coho data are shown as number of spawners (solid line) and number of redds (dashed line) – additional years of coho spawner data will be available in the future. Estimates are preliminary and may change slightly once finalized.

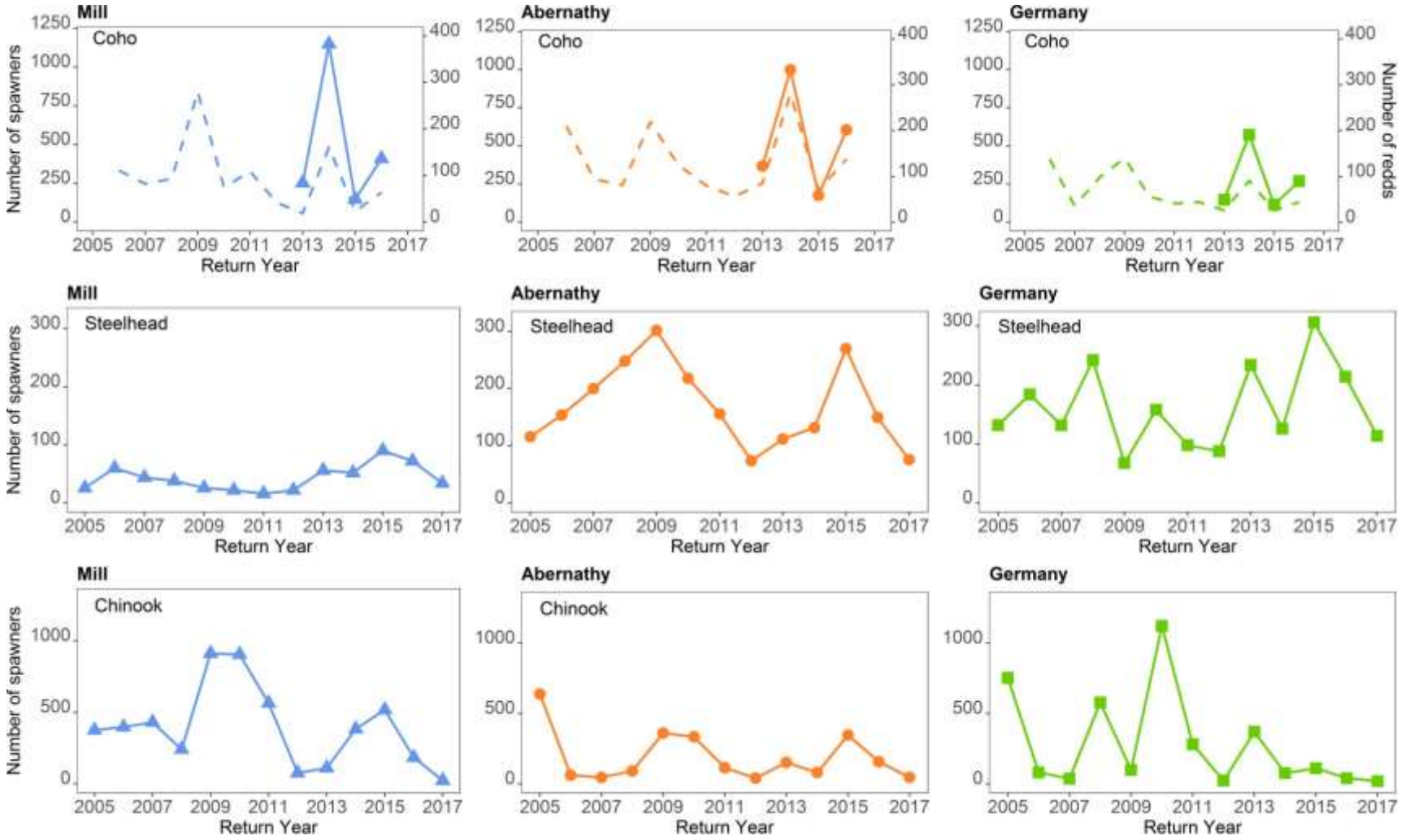
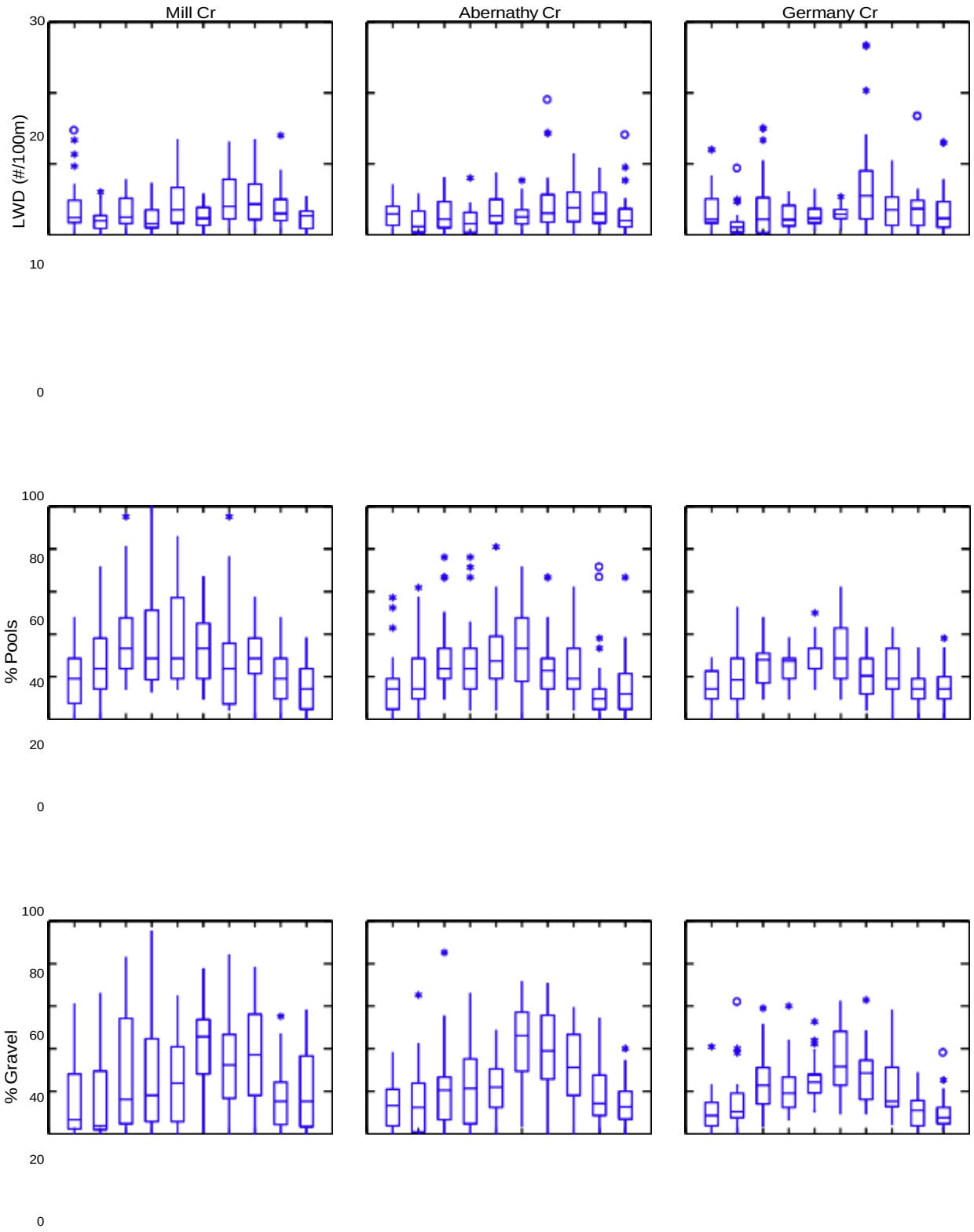


Figure 5. Time series of selected habitat metrics in Mill, Abernathy, and Germany creeks, 2007-2016. Metrics include large wood debris (LWD counts per 100 m), percent pool, percent gravel, and bankfull width to depth ratio. Box and whisker plots show the median, 25-75% values (box), range (whiskers), and outliers (points) among sites for each year.



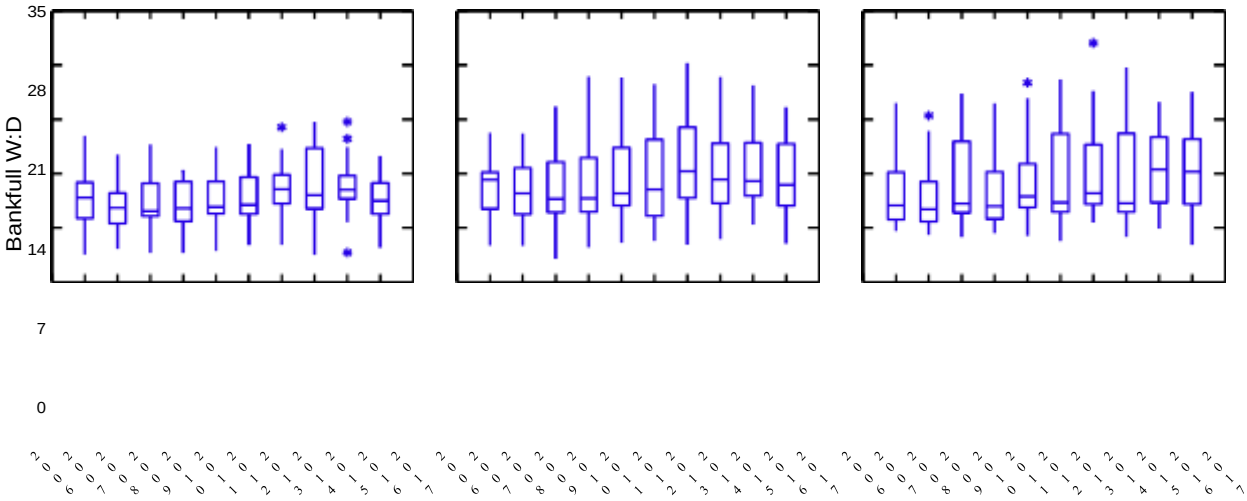
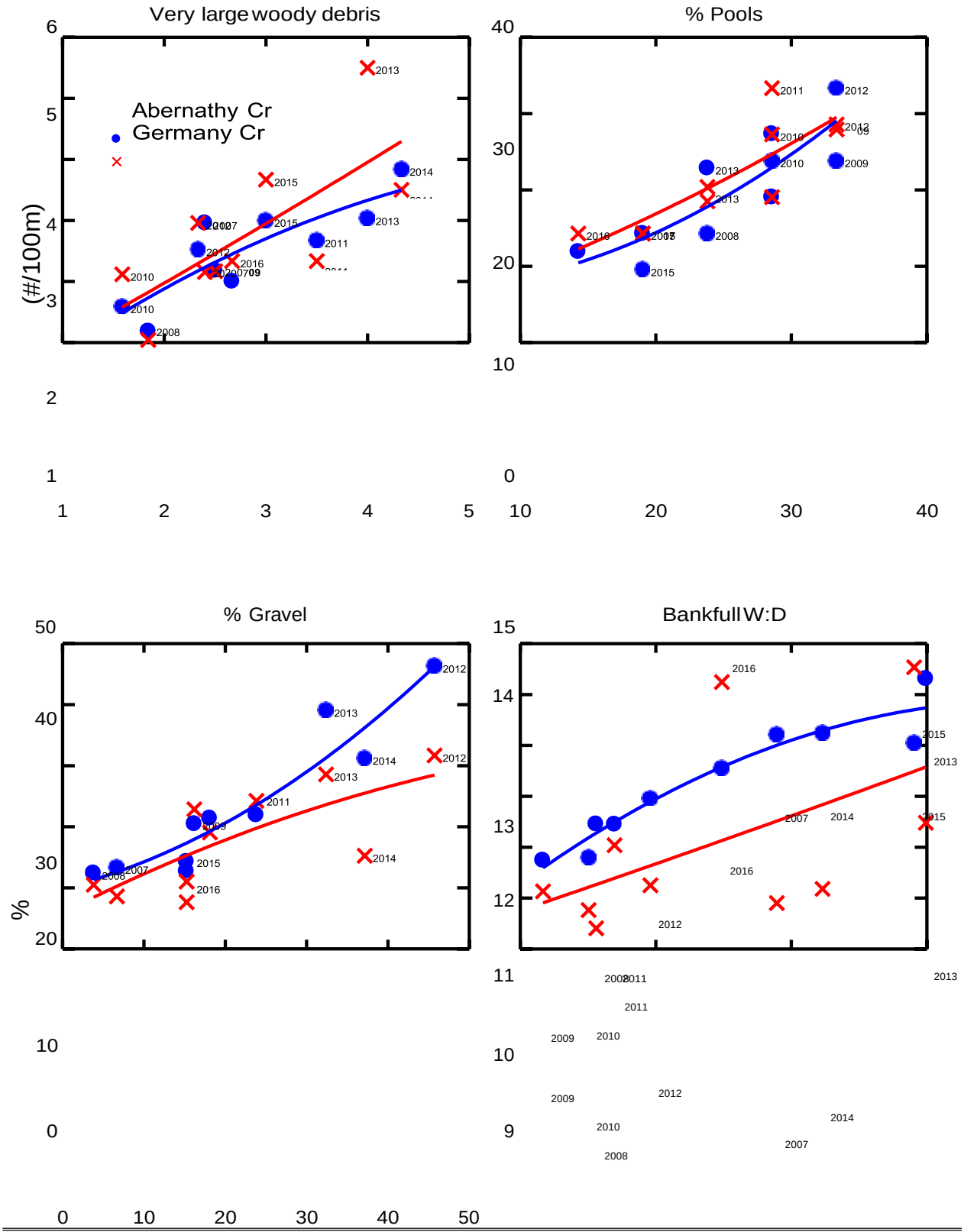

Bankfull W:D
35
28
21
14
7
0

Figure 6. Scatterplots of habitat metrics showing the positive correlation among lower Columbia River IMW streams, 2007 – 2016. Points are median values among sample sites for each year. Lines are quadratic function fit to the data.



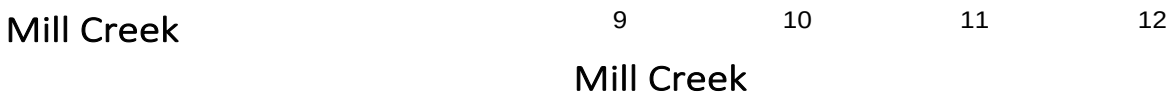

Mill Creek
9
10
11
12
Mill Creek

Figure 7. Monthly streamflow for lower Columbia River IMW streams. Data are mean monthly flows for water year 2017 (black) shown with long-term flow percentiles (WY 2005-2016) for comparison.

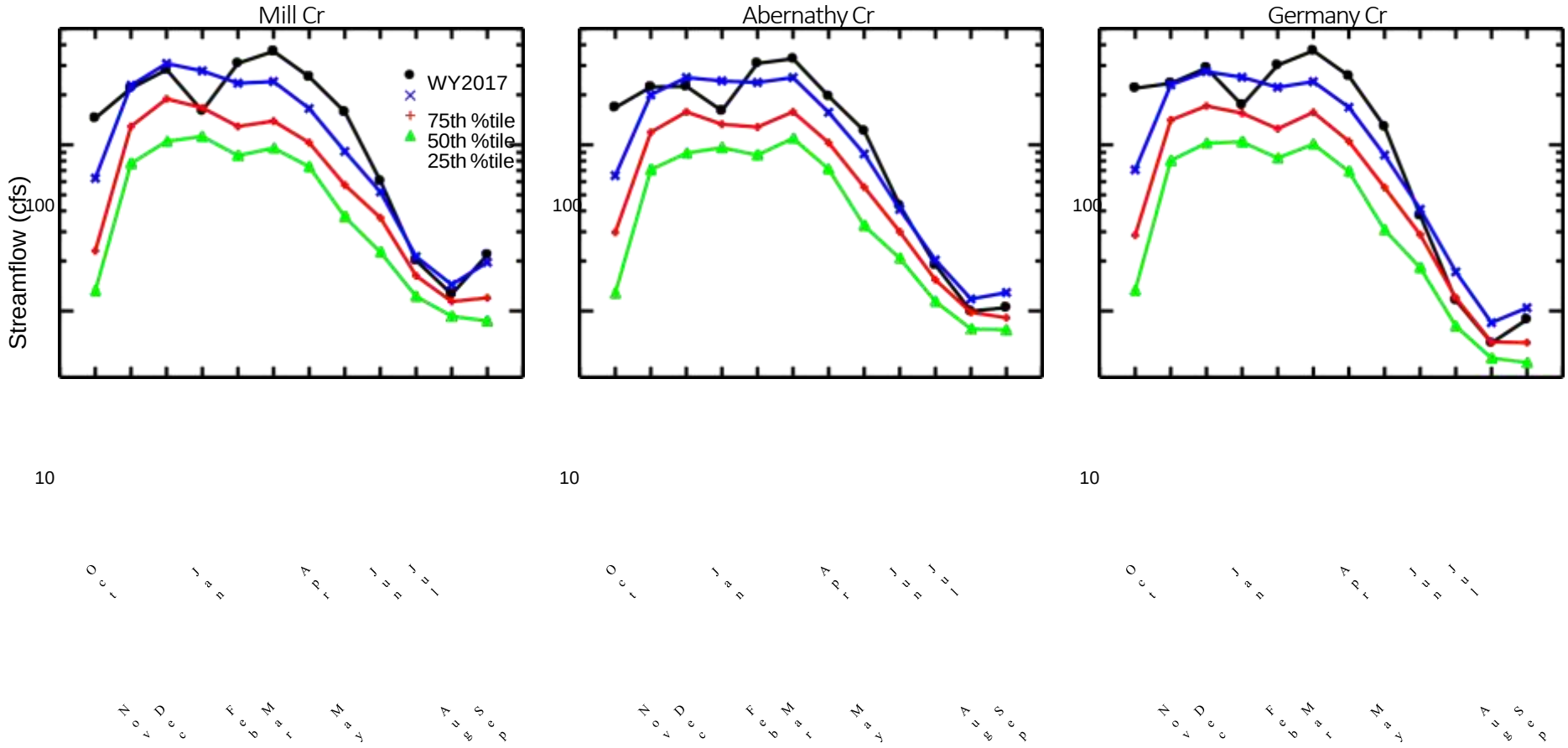
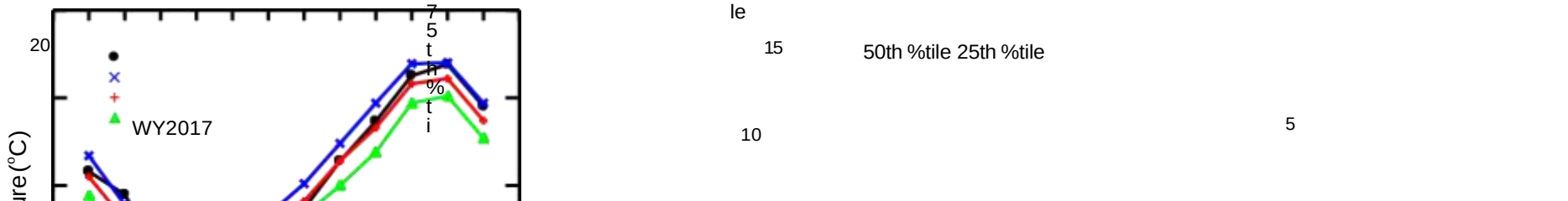
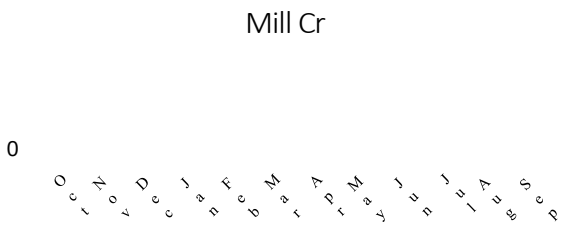


Figure 8. Monthly water temperature for lower Columbia River IMW streams. Data are average maximum daily temperatures for water year 2017 (black) shown with long-term percentiles (WY 2005-2016) for comparison.




Mill Cr
0
Oct
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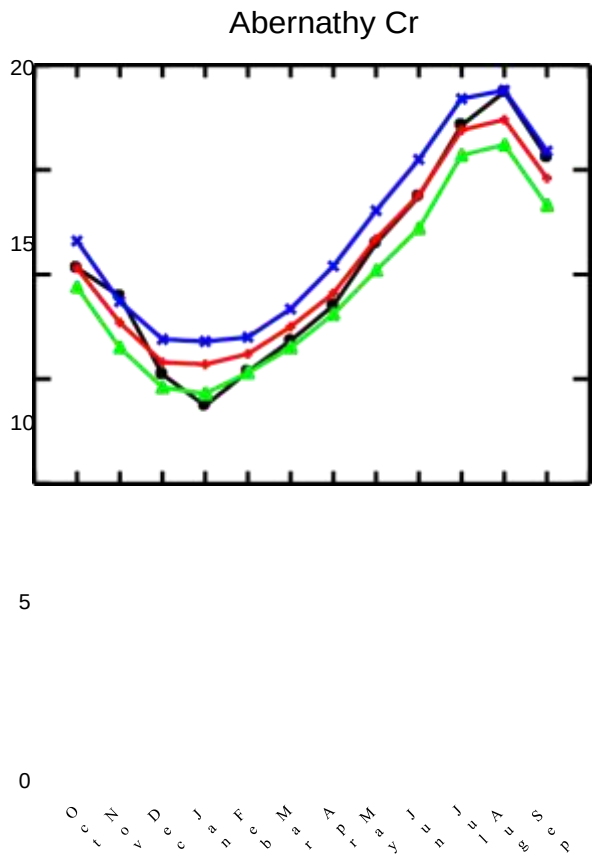
Abernathy Cr
20
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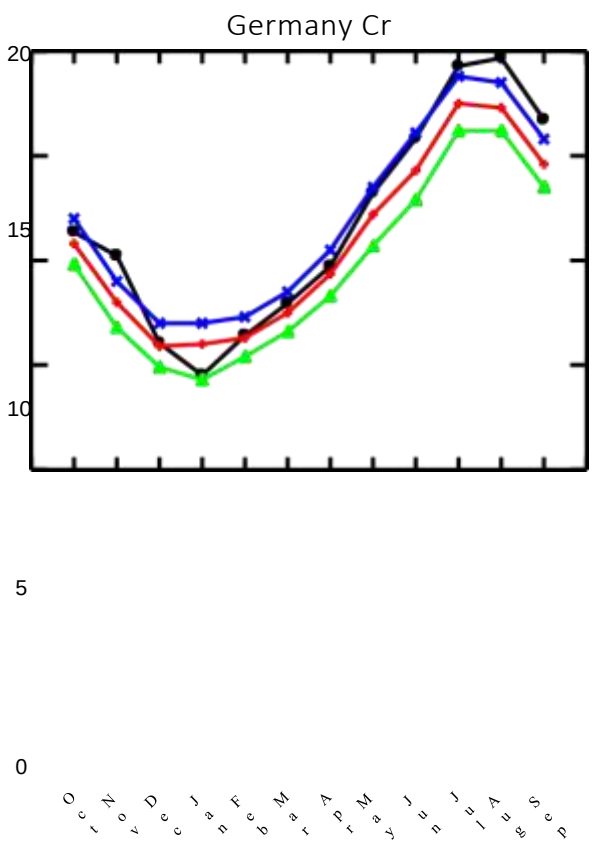
Germany Cr
20
15
10
5
0
Oct
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Jun
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Figure 9. Time series of summer flow metrics representing quantity of summer flows in Mill, Abernathy, and Germany creeks, summer 2005-2017. Points are annual values. Horizontal line is the geometric mean of annual averages across years.

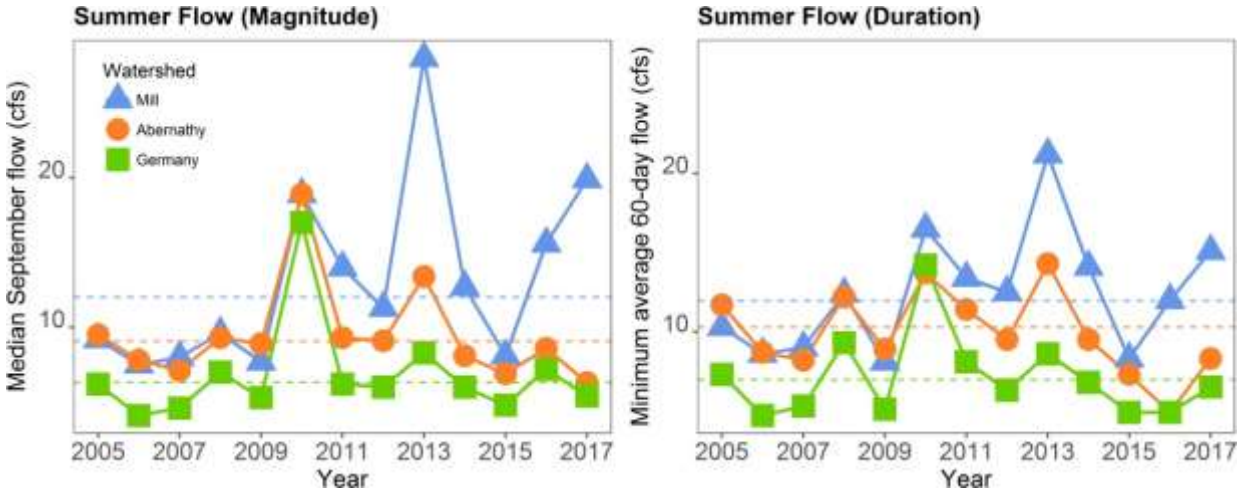


Figure 10. Habitat metrics associated with the Abernathy Creek Two Bridges (11-1386) and Abernathy Creek Bridge Removal Project (11-1329). Two Bridges restoration project (red dots) shown in context of all other monitoring sites (box and whisker plots) in Abernathy Creek. Vertical line represents the year that instream construction was completed at the project site. The absence of red dots prior to 2011 means that a new sampling site was specifically established to measure the Two Bridge restoration project.

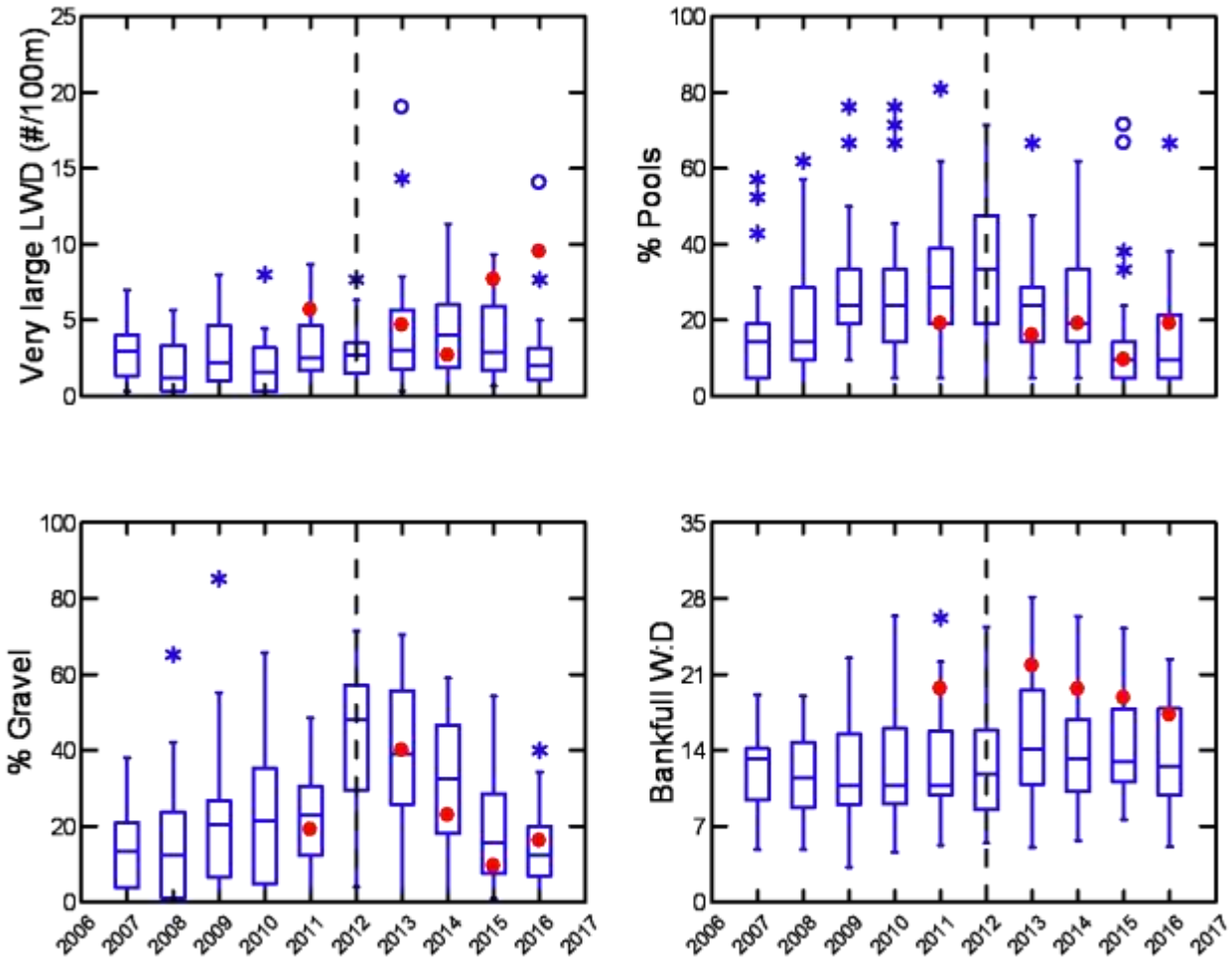
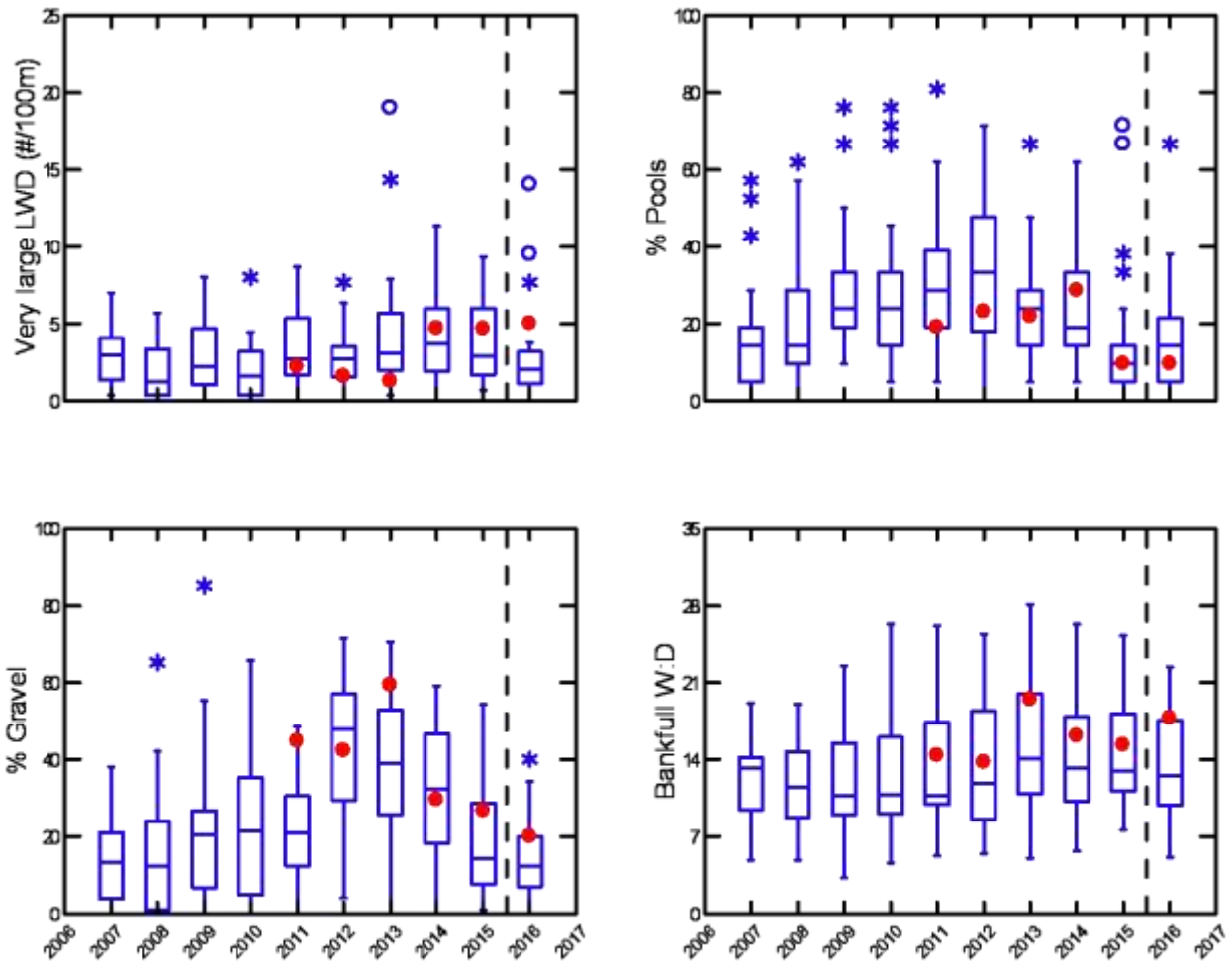


Figure 11. Habitat metrics associated with the Abernathy Sitka Spruce Project are shown before and after instream habitat treatment. The Sitka Spruce restoration project (red dots) is shown in context of all other monitoring sites (box and whisker plots) in Abernathy Creek. Vertical line represents the year that instream construction was completed at the project site.



DISCUSSION

This section describes accomplishments within the reporting period, identifies uncertainties and challenges identified for the study, defines the study timeline, and provides estimated monitoring costs.

Accomplishments in 2016-2017

- Restoration Projects: In 2017, two projects were funded for construction. Two projects are designed but not yet funded for construction.
- Fish Life Cycle Monitoring: Life cycle data (smolt, adult) were successfully obtained for each of

the three target species (Coho, Steelhead, Chinook) in 2016-2017. These data currently provide a 17-year time series for analysis. In addition, detectable levels of Chum Salmon spawners and

fry were observed in 2015-2016 and again in 2016-2017. The first estimate of chum fry production was obtained in 2017.

- Habitat Monitoring: Watershed scale estimates of habitat characteristics were successfully obtained in 2016-2017. These data currently provide 12-year time series for analysis.
- Water Quality and Quantity Monitoring: Stream flow and water quality data were successfully obtained in 2016-2017. These data currently provide a 13-year time series for analysis.
- Project Effectiveness Monitoring: Habitat data was successfully obtained at all project restoration sites in 2016-2017. Based on the implementation schedule of the restoration projects, these data currently provide pre- vs. post-treatment comparisons at three locations.
- Research Products: Results from the lower Columbia River IMW study were presented in written and oral format during this reporting period. A Master's thesis completed at Western Washington University evaluated the ecosystem response to fall and spring nutrient enhancement (SCA treatments). An organized session organized at the 2017 Salmon Recovery Conference provided comprehensive presentations on the strategy, implementation, and monitoring work associated with restoration of Abernathy Creek.

Uncertainties and Future Challenges

Much of the recent discussion within our research group has focused on analysis and interpretation of the habitat data. The relatively long time series of habitat data has shown very clearly that:

- Commonly-used habitat metrics are quite variable within each of the streams. This variability was expected given that both landuse and streams power vary along the stream gradient.

- The metrics are highly correlated between the streams and among years. This is the basis of the BACI design and will improve our ability to detect watershed level responses in habitat.

- The metrics varied greatly over time exhibiting long-term patterns across all three streams. This variability over time was unexpected, especially in the absence of any restoration actions.

The overall effect of the inter-annual variability in habitat is that detecting a response in habitat at any single restoration project is difficult. Over time, the watershed-wide variability will likely mask the changes seen at any specific restoration site. This may partially explain the lack of response seen in the data at the Two Bridges and Sitka Spruce restoration projects. We intend to further explore the project effectiveness monitoring by:

- Schedule field visits to each restoration project with the habitat monitoring staff to review the habitat measurement procedures and locate the boundaries of the habitat monitoring site relative to the restoration project.

- Identify additional habitat data that may be useful for evaluating project site responses to restoration actions. Based on our observations to date, additional information is needed to

evaluate wetted habitat during winter flows, especially channels that may not be evident or

monitored under current protocols and may not have been present prior to habitat restoration actions (e.g., Abernathy 5A Side Channel project).

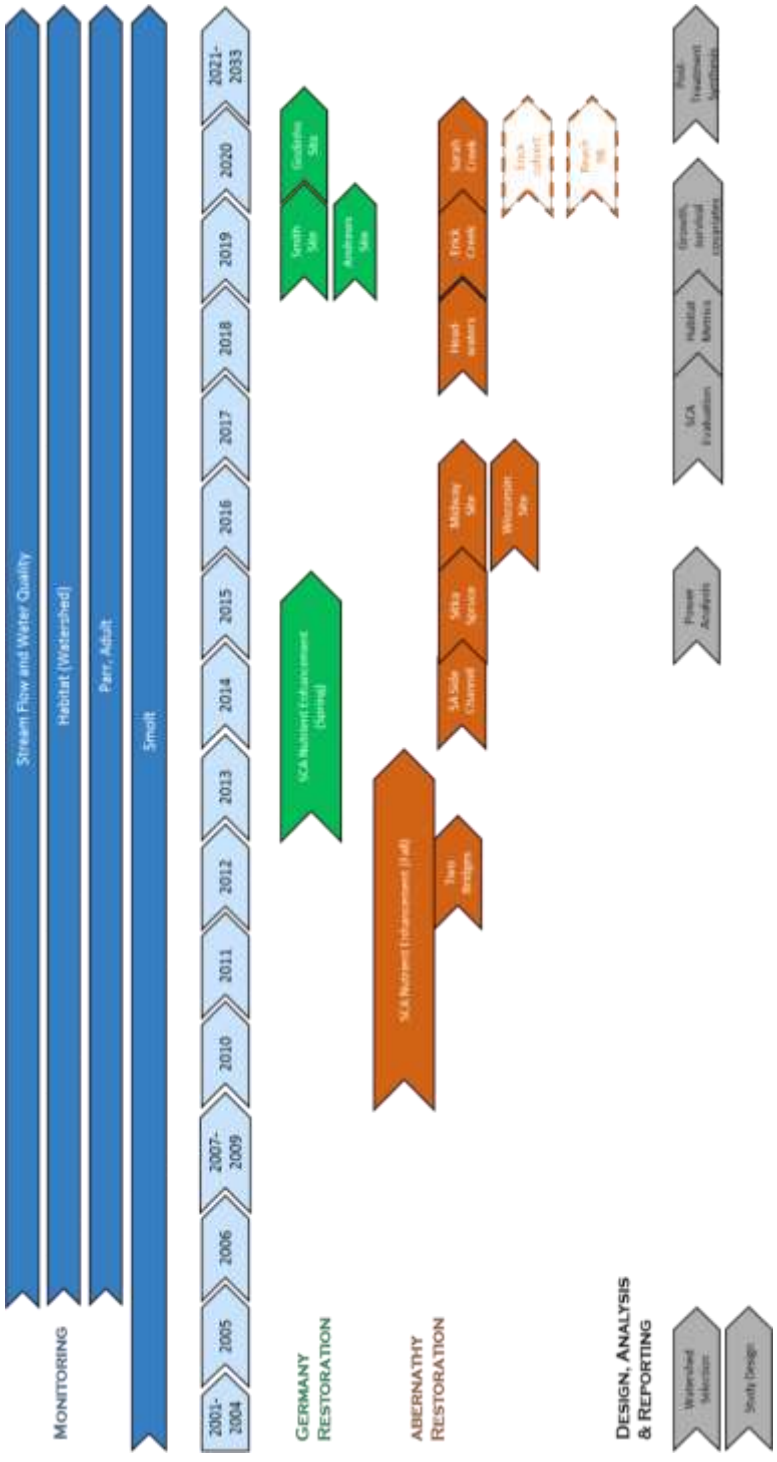
- Explore the use of other habitat metrics, using our existing measurements, which better describe the expected habitat changes for each project. This will be an exploratory effort and we will ground-truth this with additional field visits such that metrics may vary from among restoration projects.

- Explore the use of within stream reference sites in a BACI analysis of each restoration project. A habitat monitoring site will be selected within an unrestored reach of the same stream, based on physical characteristics, location in the watershed, and the strength of the correlation between sites. The analysis will include a comparison of the correlation between sites before and after the restoration project was completed. This analysis process will also be explored using selected habitat monitoring sites in Mill Creek, the reference stream.

- Conduct analyses to partition the sources of variability in the habitat data among Stream, Site, and Year using a mixed-effect model to better understand how to account for the variability in the project-scale and watershed-wide habitat analyses.

Timeline

Figure 12. Timeline for monitoring, restoration treatments, analysis and reporting in the Lower Columbia Intensively Monitored Watersheds stream complex.



Monitoring Costs

Annual costs of monitoring associated with the lower Columbia River IMW study were calculated and presented to the Salmon Recovery Funding Board in June 2017. The annual cost of fish, habitat, and water quality monitoring between October 1, 2016 and September 30, 2017 was $512,211. In subsequent years, a 3% inflation rate per year should be expected to support this monitoring program and keep pace with increased costs of staff salaries and equipment.

Monitoring efforts in the lower Columbia River IMW stream complex are expected to increase as the restoration projects are implemented. In Abernathy Creek alone, a total of 14 restoration projects have been or will be implemented. In order to conduct project effectiveness monitoring at each location (in addition to the randomly selected locations at the watershed scale), we estimate that one additional Scientific Technician can assist current staff to complete all expected field habitat monitoring needs.

This will cost approximately $32,000 per year in addition to the current annual monitoring costs.

- *Annual monitoring - $512,211 (FFY17) + 3% annual inflation*
- **Additional annual project effectiveness monitoring - $32,000**

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APPENDIX A: MONITORING PANEL QUESTIONS TO BE ADDRESSED IN ANNUAL REPORTS

1. *Species of concern*

a. What are your focal species and their associated listing status?
Coho Salmon (ESA threatened), Chinook Salmon (ESA threatened), Steelhead Trout (no listing status).

2. *Effectiveness*

a. What are the limiting factors believed to be in your watershed?
Please see report section 'Limiting Habitats and Life Stages'

b. How were specific restoration actions tied to limiting factors?
Limiting processes in these watersheds include processes that generate channel complexity and connectivity. Treatment types address (1) instream habitat complexity,

(2) off-channel/side channel connection, (3) floodplain reconnection, (4) fish passage, and (5) riparian enhancement. The connection between these treatment types and the expected functional response of stream habitat is provided in Table 1 of the Updated Treatment Plan.

c. Are the findings of this IMW applicable to other watersheds? Be specific about what findings are transferable and where? Specify criteria by which the findings translate to other watersheds (e.g. geomorphic conditions, climate regimes, land cover, ESUs, etc.).
The geographic landscape of the lower Columbia IMW stream complex is representative of southwestern Washington with respect to its geomorphology and history of landuse. From this perspective, the results of this work and lessons learned should be applicable to other watersheds in this region. Other information gained from the different IMW stream complexes will come from their contrast – most of the stream complexes have similar limitations in their steam-forming processes (i.e., lack of channel complexity and connectivity) and similar types of treatments (i.e., large wood debris, side channel reconnection). Similarities and differences in the responses among complexes will provide an understanding of which types of treatments have universal or more localized benefits in their application.

3. *Collaboration and Communication*

a. Cite examples of how your program has collaborated with monitoring partners (including project sponsors, lead entities, and local, state, tribal, and federal agencies). The purpose of this is to demonstrate the depth and breadth of collaboration that is occurring; a comprehensive list of every communication with your partners is not necessary.
Pparticipation in the lower Columbia IMW complex is necessarily collaborative and involves monitoring and research partners as well as land owners, engineers, grant administrators and restoration practitioners. The list of collaborators includes the WA

Department of Fish and Wildlife, WA Department of Ecology, WA Department of Natural Resources, Weyerhaueser Corporation, Sierra Pacific, Lower Columbia Fish Recovery

Board, Cowlitz Indian Tribe, Cowlitz County Conservation District, and USFWS Abernathy Fish Technology Center.

b. List reports and other technical products (e.g. presentations, maps, graphics, videos, etc.) that have been produced and where they can be obtained by the public. The purpose of this is to document public access to the results of your work; a comprehensive list of all materials is not necessary.
Please see Appendix F.

c. Provide examples of conferences/meetings in which your program presented or participated; a comprehensive list of every presentation is not necessary.
Please see Appendix G.

4. *Adaptive Management*

a. Please identify any specific changes made in your methodology over the reporting period.
None.

b. What challenges have you encountered in implementing your monitoring program?

Please see report section 'Discussion - Uncertainties and Future Challenges'

c. How will the findings of this IMW inform future salmon recovery (broad answers are appropriate)?
Salmon recovery efforts in Washington State rely heavily on the assumption that instream habitat restoration – especially the addition of large wood debris and opening of fish passage barriers – will cause a substantial increase in the numbers of salmon and steelhead returning to our rivers. This study tests that key assumption at a population scale and is designed to address the question 'why or why not'.

APPENDIX B: DETAILED SUMMARY OF RESTORATION PROJECTS

Table B- 1. Detailed summary of nutrient enhancement projects. Table includes goals, years completed, actions, and detailed description of the watershed-scale application of salmon carcass analogs Germany and Abernathy creeks. Analog and distance calculations are the total coverage summed over all treatments during a season. Density (kg/m^2) is calculated using a 6-m bankfull width based on annual habitat surveys in these watersheds.

			Action Detail				
Watershed	Goal	Year	Action	Analog (kg)	Distance (m)	Density (kg/m^2)	Comments
Germany	Increase marine-derived nutrients available to stream food web during fall months	2010	Fall	9,630	12.1	0.13	Disintegrated
		2010	Spring	5,987	12.2	0.08	Disintegrated
		2011	Fall	11,567	18.7	0.12	Two treatments (Sept, Oct)
		2012	Fall	10,206	18.7	0.11	Two treatments (Sept, Oct)
		2013	Fall	7,257	18.7	0.12	One treatment (Oct)
Abernathy	Increase marine-derived nutrients available to stream food web during spring months	2013	Spring	5,126	9.3	0.09	Two treatments (May, June)
		2014	Spring	6,532	11.5	0.10	Two treatments (May, June)

Table B- 2. Detailed summary of instream habitat projects completed in Abernathy Creek[a]. Table includes goals, years completed, actions, and detailed description of the action. Primary treatments (actions) are Off-Channel/Side Channel (OF/SC), Floodplain Reconnection (FR), Instream Habitat Complexity (IHC), Fish Passage (FP), and Riparian Planting/Management (RP).

Project	Goal	Year	Action	Action Detail
Abernathy Creek Bridge Removal	Increase connectivity	2012	FR, RP	Removed one bridge, placed rootwads over 100 feet of off-channel habitat, and planted 0.1 riparian acres.
Abernathy Creek Two Bridges	Increase complexity	2012	FR, IHC	Removed 1200 feet of abandoned roadbed from the floodplain, re-meandered and placed large wood, rootwad and boulder structures over 1500 feet of stream channel, and planted 1.5 riparian acres.
Abernathy 5A Side Channel	Increase connectivity	2015	OC/SC, IHC	Connected and placed rood wad and large wood structures over 600 feet of side-channel habitat, and planted 1.7 riparian acres.
Abernathy Sitka Spruce	Increase complexity	2015	IHC, FR	Placed large wood structures over 500 feet of stream channel and planted 0.1 riparian acres.
Abernathy Creek Wisconsin Site	Increase complexity	2016	IHC	Placed large wood structures over 1300 feet of stream channel, and connected 580 feet of off-channel habitat.
Abernathy Creek Cameron Site	Increase complexity	2016	IHC, FR, RC	Placed large wood structures through 6400 feet of stream channel and planted 1.8 riparian acres.
Abernathy Creek Midway	Increase complexity	2016	IHC, OC/SC	Removed one bridge, placed large wood structures over 1800 feet of stream channel, and planted 0.1 riparian acres
Abernathy Creek Davis Site	Increase complexity	2017	OC/SC, IHC	Placed large wood structures through 1800 feet of stream channel, reconnected 720 feet of off-channel/side-channel habitat, and planted 1.0 riparian acres.

[a]Projects listed in this table were located among the smolt trap location and are in 'Completed' status.

APPENDIX C: RECOMMENDED HABITAT TREATMENT IN GERMANY CREEK TO SUPPORT THE LOWER COLUMBIA INTENSIVELY MONITORED WATERSHED

Lower Columbia Fish Recovery Board

Memorandum

Date: December 7, 2017

To: Salmon Recovery Funding Board Monitoring Panel

From: Steve Manlow, Executive Director

Subject: Recommended Habitat Treatment in Germany Creek to support the Lower Columbia Intensively Monitored Watershed (IMW)

This memo is in response to the May 2017 Salmon Recovery Funding Board (SRFB) Monitoring Panel annual review recommendations. Specifically, this memo responds to the Monitoring Panel's condition requiring identification of remaining restoration projects in Abernathy and Germany creeks, along with associated cost estimates and priority for implementation[1].

The Lower Columbia Intensively Monitored Watershed (IMW) addresses the subbasin complex that includes Mill, Abernathy and Germany Creeks. The 2009 restoration treatment plan identified potential restoration projects in Abernathy and Germany Creeks. Mill Creek serves as the control stream. The treatment plan calls for three phases of restoration project implementation, with each phase composed of 20 projects. Given inadequate funding to fully implement all 60 of the identified restoration projects from the treatment plan, as well as statewide implementation challenges, the SRFB made a decision to allocate up to $2 million per year from 2014 through 2016 to accelerate implementation of IMW projects in the Lower Columbia, Hood Canal and Straits complexes[2]. To ensure sufficient restoration work occurs in a focused and timely manner, the SRFB and Lower Columbia Fish Recovery Board (LCFRB) also made the decision to focus habitat restoration work in the Lower Columbia IMW complex in Abernathy Creek, and focus efforts in Germany Creek on nutrient enhancement.

In 2017, dedicated IMW funding for restoration projects via a SRFB allocation was discontinued. The LCFRB is not advocating for reestablishing dedicated SRFB funds for restoration projects in IMW complexes. Remaining treatment plan projects in Abernathy Creek will therefore need to be funded through other competitive, region-wide grant round processes. To be competitive, project proposals must address regional restoration needs for high priority populations. However, the region also recognizes the broader importance of completing necessary treatments in Abernathy Creek, and will work to move remaining high priority projects forward. Currently, there are two remaining projects in Abernathy Creek that have completed designs, but need to be implemented to address detectable response estimates for coho salmon. These are the Erick Creek Culvert Replacement and Abernathy Creek Reach 9B projects.

The IMW treatment plan was updated in 2016. The plan update included recommendations for future treatment prioritization, with highest priority placed on implementing the remaining projects in

[1] See May 2017 SRFB Monitoring Panel Recommendations. Cost estimates for project implementation are found in the 2009 Abernathy and Germany Creeks Intensively Monitored Treatment Plan.

[2] See August 2012 SRFB Briefing Memo and March 2014 SRFB Meeting Minutes.

Abernathy Creek that target coho salmon life history bottlenecks. The plan update also includes the recommendation that habitat restoration work in Germany Creek be reconsidered, as long as it does not negatively impact the ability to measure responses in Abernathy Creek. It is important to note that as with future treatments in Abernathy Creek, any additional work in Germany Creek would need to occur through existing or new competitive grant processes. While efforts will be made to align any future work in Germany Creek with IMW study goals, the primary focus will be on ensuring high priority salmon and steelhead recovery needs and priorities are met. This is consistent with the SRFB and LCFRB's direction of focusing funding on completing the necessary restoration treatments for the IMW study in Abernathy Creek. The following is therefore presented within this context.

Implementing treatment actions in Germany Creek could address different habitat restoration questions than actions in Abernathy Creek. The Abernathy Creek watershed is lower gradient with numerous tributaries, and treatment is primarily focused on coho rearing needs. In contrast, the Germany Creek watershed is higher gradient with few tributaries and off-channel areas, and habitat conditions are more conducive to the rearing needs of winter steelhead. With these differences in mind, the LCFRB IMW Technical Oversight Group (TOG) brainstormed priorities for treatment options in Germany Creek during two meetings in 2017. Identified priorities include:

- Identifying and treating sediment point sources in the headwaters of Germany Creek;
- Increasing habitat complexity in the upper watershed mainstem and side-channels of Germany Creek; and
- Increasing habitat complexity in high priority stream reaches[3] that are situated on rural residential and agriculture parcels.

Sediment input from the mid to upper reaches of Germany Creek is high, and multiple slope failures have been identified during the duration of the IMW study. These inputs affect habitat conditions throughout the watershed. Addressing excessive headwater sediment sources is therefore essential to habitat treatments. Some sediment point sources in the headwaters of Germany Creek may already be identified through the Washington Department of Natural Resources (DNR) Road Maintenance and Abandonment Plan (RMAP) program, and it will be important to review available data to determine if sources are negatively impacting anadromous fish habitat both locally and downstream. It is also recommended that projects focus on adding complexity to simplified, mainstem and side channel habitat throughout watershed. The structural design of projects that increase mainstem habitat complexity may be difficult due to high stream power. However, increased habitat complexity could increase flow heterogeneity, leading to improved rearing and spawning conditions via the retention of sediment and conversion of plane-bed to forced pool-riffle channel type.

The majority of high priority (Tier 1 and Tier 2) stream reaches occur in the middle and lower portions of the Germany Creek watershed, where the creek flows adjacent to the primary access road and through small, privately owned parcels. Treatment actions through these stream reaches should address habitat complexity needs, but must also incorporate current and anticipated land uses. Given these constraints, the types and scale of treatments may differ from currently implemented IMW projects, especially those conducted on state-owned forest land in Abernathy Creek. For these reasons, projects implemented in Germany Creek can provide valuable information on how habitat treatment in transitional and constrained landscapes may benefit watersheds and focal populations.

[3] Stream reaches are identified in the regional Habitat Strategy: https://www.lowercolumbiasalmonrecovery.org/landingpage#b

SRFB funds can be used to design and implement habitat projects in Germany Creek, but as noted above, proposals must compete with others across the Lower Columbia region. To be competitive under the LCFRB and SRFB review process, projects must address restoration needs for high priority populations and stream reaches, which are typically Tier 1 and 2 reaches supporting multiple Primary populations (see the LCFRB Project Evaluation Criteria). The limited length and number of Tier 1 reaches, combined with the lack of multiple species in the middle to upper portions of the watershed, may reduce competitiveness of project proposals in Germany Creek. Absent a non-SRFB funding source, and given the above constraints and policy direction, restoration work in Germany Creek may occur on a protracted schedule with less spatial intensity than work already completed and planned for Abernathy Creek. Given this reality, the IMW monitoring plan for Germany Creek should be updated and adaptively managed to identify approaches that will evaluate this potentially protracted strategy of treatment in an effective and timely manner.

References

HDR Inc, and Cramer Fish Sciences. 2009. Abernathy and Germany Creeks Intensively Monitored Treatment Plan. Prepared for the Lower Columbia Fish Recovery Board, Longview, Washington.

Lower Columbia Fish Recovery Board. 2016. Lower Columbia IMW Treatment Plan Update: September 2016 Supplement.

APPENDIX D: EVALUATION OF SALMON CARCASS ANALOGS

Effectiveness of Salmon Carcass Analogs as a Form of Nutrient Enhancement for Juvenile Coho Salmon (Oncorhynchus kisutch) In Three Lower Columbia Watersheds

Matthew Sturza, Western Washington University
Masters of Science, 2017

ABSTRACT: Adult Pacific salmon exhibit a form of parental care after spawning and perishing by depositing a subsidy of marine derived nutrients (MDN) that may be incorporated into the stream food web and feed juvenile salmon. Adult salmon populations have significantly declined since the late 19th century, thereby reducing the amount of MDN within Pacific Northwest Streams. This loss in nutrients within stream food webs may be limiting the growth and survival of juvenile salmon and therefore reducing the population sizes of adult salmon. One strategy to mitigate for nutrient deficiencies within a stream is the use of salmon carcass analogs (SCA), pellets composed of pulverized and pasteurized marine forage fish. We investigated the effectiveness of SCA in enhancing the size and abundance of juvenile coho salmon within a complex of three watersheds (Abernathy, Germany, and Mill Creek) that empty into the lower Columbia River near Cathlamet, WA. SCA applications occurred in the fall (2010- 2013) on Germany Creek and in the spring (2013-2015) on Abernathy Creek, while Mill Creek served as a reference watershed and did not receive SCA applications. We periodically gathered samples of periphyton, macroinvertebrates, and juvenile coho (fin clips) before and after SCA application at approximately two month intervals. Juvenile coho were also sampled for fork length and weight.

Samples were taken at three sites at the lower, middle, and upper extent of adult coho spawning within each watershed. During the final sampling event of each year, while juvenile coho were outmigrating, fin clips were taken at smolt traps located near each river's confluence with the Columbia River. Data from smolt traps were used to estimate the average fork length and abundance of juvenile coho during each year of this project. To evaluate the timing and extent of nutrients from SCA being incorporated into the stream food web, samples were processed and analyzed for δ15N, a measure of the abundance of the heavier isotope of nitrogen that occurs more abundantly in the marine environment. Seasonal trends of δ15N in periphyton, macroinvertebrates, and juvenile coho, as well as seasonal trends of juvenile coho fork length and weight were compared between fertilized and unfertilized watersheds. We detected SCA effects on seasonal trends of macroinvertebrate and juvenile coho δ15N for the fall and spring treatments, indicating SCA nutrients were incorporated by these communities. We detected SCA effects on the seasonal trends of juvenile coho fork length and weight for the spring treatment, but not for the fall treatment. We could not detect SCA effects on seasonal trends of periphyton δ15N for either the fall or spring treatment, potentially due to smaller than needed sample sizes. Overall the effect of fall SCA application was to disrupt the seasonal trend of δ15N values among trophic levels by causing an

increase in δ15N during the late fall/early winter when values are normally decreasing. The effect of spring SCA application was to enhance the seasonal trend, causing increases in δ15N values greater than those seen in the absence of SCA applications. Comparing juvenile coho sizes and abundances between years with and without SCA application and between fertilized and unfertilized watersheds indicated that

neither the fall or spring treatment had a significant effect on coho growth and survival. Where SCA are to be used as a salmonid recovery tool, we recommend that careful watershed selection and subsequent monitoring be employed to ensure investments are worthwhile.

Full thesis available at: http://cedar.wwu.edu/wwuet/597/

APPENDIX E: DATA MANAGEMENT

The overall IMW program is comprised of one federal agency, two state agencies, two tribal organizations, and one private company. From the beginning we chose to use each entity's existing data management system(s) rather than construct a single system unique to the IMW program. As a result the data quality control elements identified by the ISP are in varying formats, distributed among participating entities, and are specific to a particular data stream (i.e. there is no single document that contains all this information). As described below, data for the Lower Columbia IMW Study are maintained by the Washington Department of Ecology (ECY), Washington Department of Fish and Wildlife (WDFW), Weyerhaeuser (WEYCO). The Pacific States Marine Fisheries Commission maintains the PTAGIS database which stores all tag data from this study.

WATER QUALITY

Finalized water quality and quantity data are publically available:

- https://fortress.wa.gov/ecy/wrx/wrx/flows/regions/state.asp

ANNUAL ADULT SPAWNERS

Reach-scale and georeferenced spawner data are housed in the WDFW Traps-Weirs-Survey (TWS) database. Final adult spawner estimates are publically available through the Salmon Conservation Reporting Engine:

- https://fortress.wa.gov/dfw/score/score/species/species.jsp

ANNUAL SUMMER PARR

Reach-scale parr and habitat data are maintained by WEYCO in a project database.

PIT tag data are publically available through the PTAGIS database:

- http://www.ptagis.org/

ANNUAL SMOLTS

Field data, final estimates, and protocols are archived by WDFW in the Juvenile Migrant Exchange (JMX) database. Final smolt estimates will be publically available through the WDFW Salmon Conservation Reporting Engine:

- https://fortress.wa.gov/dfw/score/score/species/species.jsp

ANNUAL HABITAT

Habitat data are maintained by WDFW in a project database.

PROJECT MONITORING

PROJECT monitoring data are maintained by WDFW in a project database.

APPENDIX F: REPORTS

Bennett, S., G. Pess, N. Bouwes, P. Roni, R. E. Bilby, S. Gallagher, J. Ruzycki, T. Buehrens, K. Krueger, W. Ehinger, J. Anderson, C. Jordan, B. Bowersox, and C. Greene. 2016. Progress and Challenges of Testing the Effectiveness of Stream Restoration in the Pacific Northwest Using Intensively Monitored Watersheds. Fisheries **41**:92-103.

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2005. Evaluating Watershed Response to Land Management and Restoration Actions: Intensively Monitored Watersheds (IMW) 2005 Progress Report. Washington Department of Fish and Wildlife, Olympia, Washington, Available online: http://wdfw.wa.gov/publications/00781/

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IMW Scientific Oversight Committee (IMWSOC). 2013. Intensively Monitored Watersheds Synthesis Report 2013.

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Kinsel, C., P. R. Hanratty, M. S. Zimmerman, B. Glaser, S. Gray, T. Hillson, D. Rawding, and S. Vanderploeg. 2009.

Intensively Monitored Watersheds: 2008 fish population studies in the Hood Canal and Lower Columbia stream complexes, FPA 09-12, Washington Department of Fish and Wildlife, Olympia, Washington. Available online: http://wdfw.wa.gov/publications/00783/

Krueger, K. L., K. Pierce, E. Pittman, K. Samson, R. Nauer, D. Price, and T. Quinn. 2010. Intensively monitored watersheds: habitat monitoring report 2010.

Krueger, K. L., K. Pierce, E. Pittman, K. Samson, R. Nauer, D. Price, and T. Quinn. 2012. Intensively monitored watersheds: habitat monitoring report 2012.

Zimmerman, M. S., K. Krueger, T. Johnson, W. Ehinger, and A. Johnson. 2016. Lower Columbia Intensively Monitored Watershed Study: 2016 Progress Report. Report to the Salmon Recovery Funding Board Monitoring Panel, Olympia, Washington.

Zimmerman, M. S., K. Krueger, and W. Ehinger. 2016. Lower Columbia Intensively Monitored Watershed Study: 2016 Annual Report. Report to the Salmon Recovery Funding Board Monitoring Panel, Olympia, Washington.

Zimmerman, M. S., K. Krueger, B. Ehinger, R. E. Bilby, J. Walter, and T. Quinn. 2015. Intensively Monitored Watersheds Program: Lower Columbia River Study Plan Update. Report to the Salmon Recovery Funding Board Monitoring Panel, Olympia, Washington.

Zimmerman, M. S., K. Krueger, B. Ehinger, P. Roni, R. E. Bilby, J. Walter, and T. Quinn. 2012. Intensively Monitored Watersheds program: an updated plan to monitor fish and habitat responses to restoration actions in the Lower Columbia watersheds, FPA 12-03, Washington Department of Fish and Wildlife, Olympia, Washington. Available online: http://wdfw.wa.gov/publications/01398/

APPENDIX G: CONFERENCES

2017

2017 Salmon Recovery Conference, Wenatchee, Washington, April 25-27, 2017

- Ehinger, W. 2017. Lower Columbia Intensively Monitored Watershed: Study Design and Challenges.
- Johnson, A. 2017. Developing and Updating the Lower Columbia IMW Treatment Strategy.
- Zimmerman, M.S. 2017. Restoration in Abernathy Creek: Have We Done Enough? 2016

2016

PNAMP Intensively Monitored Watersheds Workshop, Portland, OR, November 1-2, 2016

Workshop - RESEARCH IN THE MILL, ABERNATHY, GERMANY CREEK WATERSHEDS. Abernathy Fish Technology Center, Longview, Washington, July 21, 2016

- Zimmerman, M.S. 2016. Overview of adult and juvenile time series (Chinook, coho and steelhead).
- Johnson, T. 2016. Snorkel survey evaluation of steelhead passage at electric weir/Abernathy falls

2015

Workshop - RESEARCH IN THE MILL, ABERNATHY, GERMANY CREEK WATERSHEDS. Vancouver, Washington, July 22, 2015.

- Zimmerman, M.S. 2015. Overview of the Lower Col IMW Program.
- Ehinger, W. 2015. Water quality/quantity monitoring
- Johnson, T. 2015. Lessons from baseline monitoring
- Sturza, M. 2015. Response to Salmon Carcass Analog – preliminary results

2013

PNAMP Intensively Monitored Watersheds Workshop, Portland, OR, March 20-21, 2013

- Zimmerman, M.S. 2013. Lower Columbia Intensively Monitored Watershed Study.

Using Existing Data and Models to Understand Restoration Effectiveness Workshop, Ellensburg, WA, February 8, 2013