ASOTIN CREEK

INTENSIVELY MONITORED WATERSHED:

SUMMARY OF RESTORATION AND MONITORING

2014 PROGRESS REPORT

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EXECUTIVE SUMMARY

The Asotin Creek Intensively Monitored Watershed (IMW) was implemented in 2008 after an extensive selection process coordinated by the Snake River Salmon Recovery Board and consultation with the Regional Technical Team. Asotin Creek was chosen as an IMW location in southeast Washington because there was extensive fish and habitat data going back to the 1980's, ongoing fish-in fish-out monitoring, minimal hatchery influence, moderate seeding levels of steelhead, and agency and public support. 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 have implemented the IMW within an adaptive management framework and have revised the experimental design, restoration plan, and monitoring plan using the iterative evaluation process of adaptive management. The experimental design has been finalized and includes three study creeks in the upper part of the watershed: Charley Creek, North Fork Asotin Creek (North Fork) and South Fork Asotin Creek (South Fork). The first 12 km of each stream is divided into three 4 km long sections: one section of each stream has been restored (treatment sections) and two sections within each creek are used as control sections. We are monitoring juvenile steelhead abundance, growth, survival, and movement in each section using mark-recapture surveys in 300-600 m fish sites. All steelhead ≥70 mm are PIT tagged, weighed (nearest 0.1 g), and measured (fork length nearest mm) and a subsample of scales are collected to estimate the age distribution. Mark-recapture surveys are conducted in the summer (June-July) and fall (September-October) every year and mobile PIT tag surveys are conducted in the winter (December-January) and spring (March-April) each year to allow for estimation of seasonal population parameters. Stream and riparian habitat was measured using the Pacfish-Infish Biological Opinion protocol (PIBO) from 2008-2009 but we now use the Columbia Habitat Monitoring Protocol (CHaMP). LiDAR, aerial photography, temperature, and discharge monitoring are also used throughout the watershed.

The treatment section of South Fork was restored in 2012 (after summer mark-recapture and habitat surveys). A total of 196 LWD structures were built consisting of 585 pieces of LWD (≥ 0.1 m diameter and ≥ 1.0 m in length). The LWD structures were built mostly by hand using wooden fence posts driven into the stream bottom to secure LWD in place. These structures consisted of deflector, mid-channel, spanners/debris jams, and key piece structures. In 2013, the treatment section of Charley Creek was restored in a similar manner to the South Fork and a total of 207 LWD structures were built using 497 pieces of LWD. In 2014, the treatment section of North Fork was restored. A total of 135 LWD structures were built and 568 pieces of LWD were added to the North Fork.

Preliminary assessments of the treatment response in the combined treatment sections compared to the combined control sections suggest a significant increase in juvenile steelhead abundance in the treatment compared to the control sections. Survival estimates are being recalculated and will be available in future reports. Both hydraulic and geomorphic changes were observed due to the restoration structures and significant changes in erosion and deposition and habitat unit diversity were observed. A synthesis of the habitat and fish responses conducted using net rate of energy modeling suggested that the overall carrying capacity for juvenile steelhead was increased by the restoration structures from 2012 to 2013. An estimate of smolts per spawner will be presented in future reports for the study creeks and compared to smolts per spawner estimates from the WDFW fish-in fish-out monitoring of the Asotin Watershed. These data and continued monitoring the Asotin Creek IMW are expected to provide valuable information on the response of wild steelhead to LWD additions and how to improve the effectiveness of restoration actions in other watersheds.

ACKNOWLEDGEMENTS

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 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, WRIA 35/Asotin County Public Utilities District (PUD) 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 PUD provides us with office space and storage for field gear. Del Groat of the USFS has provided generous donations of time and large wood for the restoration treatments and Billy Bowels, also with USFS, has help with safety training for field crews. Bruce Heiner, WDFW Habitat Engineer and Barry Sutherland, USDA Natural Resources Conservation Service (NRCS) Fluvial Geomorphologist provided comments of 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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LIST OF ABBREVIATIONS

ACCD - Asotin County Conservation District

CHaMP - Columbia Habitat Monitoring Protocol

DEM - Digital elevation model

DoD - Geomorphic change detection using the difference between two DEMs

DOE - Washington State Department of Ecology

DWS - Dynamic woody structure (main restoration technique proposed)

ELR - Eco Logical Research Inc.

IMW - Intensively Monitored Watershed

ISEMP - Integrated Status and Effectiveness Monitoring Program

LWD - Large woody debris

NREI - Net rate of energy intact (model)

NOAA - National Oceanic and Atmospheric Administration's

NRCS - Natural Resources Conservation Service

PCSRF - Pacific Coastal Salmon Recovery Fund

PTAGIS - PIT Tag Information System

PUD - Public Utility District

RTT - Regional Technical Committee

RCO - Washington State Recreation and Conservation Office

SRSRB - Snake River Salmon Recovery Board

USDA - United States Department of Agriculture

USGS - United States Geological Survey

WDFW - Washington Department of Fish and Wildlife

WRIA - Washington Water Resource Inventory Area

1. INTRODUCTION

1.1 Background

In 2008, Asotin Creek was chosen as a location to implement an Intensively Monitored Watersheds (IMW) project in southeast Washington (Figure 1). A series of IMWs have been established in the Pacific Northwest to assess the effect of different restoration actions on populations of salmonids at the watershed scale (Bilby et al. 2005, Bennett et al. 2015). IMWs use an experimental framework to increase the probability of detecting a population level response to restoration actions. A detailed account of the process to select and design the Asotin Creek IMW can be found in Bennett and Bouwes (2009) and a summary of the IMW monitoring methods and data collection can be found in Bennett et al. (2012). A summary of the fish-in fish-out monitoring conducted by the Washington Department of Fish and Wildlife (WDFW) in Asotin Creek is summarized by Crawford et al. (2014).

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. A separate document on the adaptive management plan has been accepted for publication in the Fisheries and is currently being revised (Wheaton et al. 2015) . More details on the adaptive management plan can also be seen in Wheaton et al. (2012). 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"; Figure 2). The study creeks generally exhibit homogenized and degraded habitats, with exceptionally low availability of pool habitat for summer and overwintering refugia, which is thought to be limiting salmonid production (SRSRB 2011). The low amount of large woody debris (LWD) in the channel and low LWD recruitment has been identified as a significant limiting factor for the wild steelhead population that exists in Asotin Creek (ACCD 2004, Bennett and Bouwes 2009). 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 riparian enhancement treatments include a mix of short and longer term measures ranging from fencing, planting, and weed control. These treatments are intended to create a more diverse riparian corridor (in terms of age and species structure) that is sustained by fluvial processes and more regular interaction and exchange with the channel (Opperman and Merenlender 2004). The long-term benefits of such a riparian treatment are the reestablishment of sustainable levels of wood recruitment (of all sizes) to the channel. By contrast, the LWD additions focus on intensive additions of high densities of LWD designed to work in concert with one other to initiate and promote more dynamic creation, shaping and maintenance of active bar and pool habitat by fluvial processes.

The Asotin Creek IMW is funded from NOAA's Pacific Coastal Salmon Recovery Fund (PCSRF). The PCSRF funds are used to fund the ongoing fish and habitat monitoring and data collection and analysis. These funds are now 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. 2014). 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 form WDFW and SRSRB.

Eco Logical Research Inc. is the primary contractor that manages the Asotin Creek IMW and implements the restoration. This report is intended as a brief progress report on work completed to date (2008-2014). Ongoing analyses of the data, especially the response of habitat and fish to the recent restoration actions, will be provided as completed.

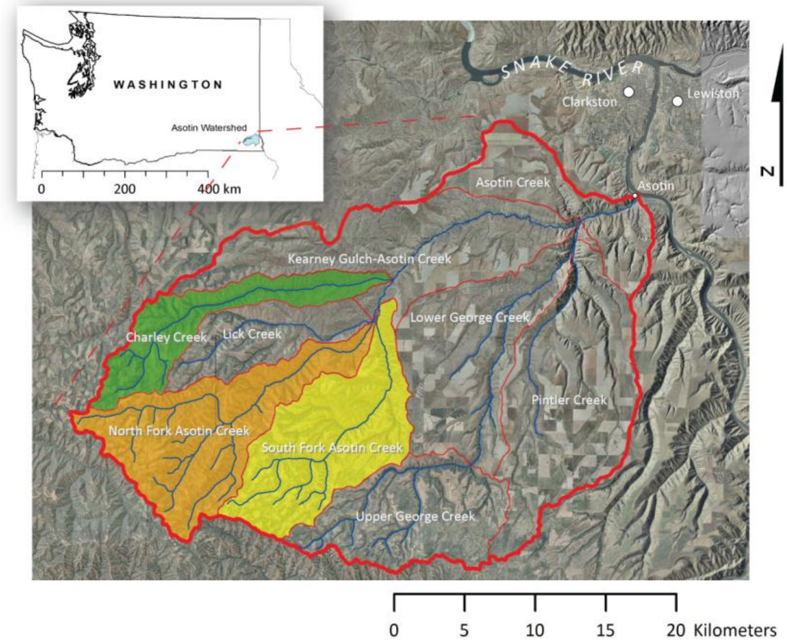


Figure 1. Location of Asotin Creek within Washington and the Asotin Creek Intensively Monitored Watershed study creek watersheds (i.e., three colored watersheds) within the Asotin Creek.

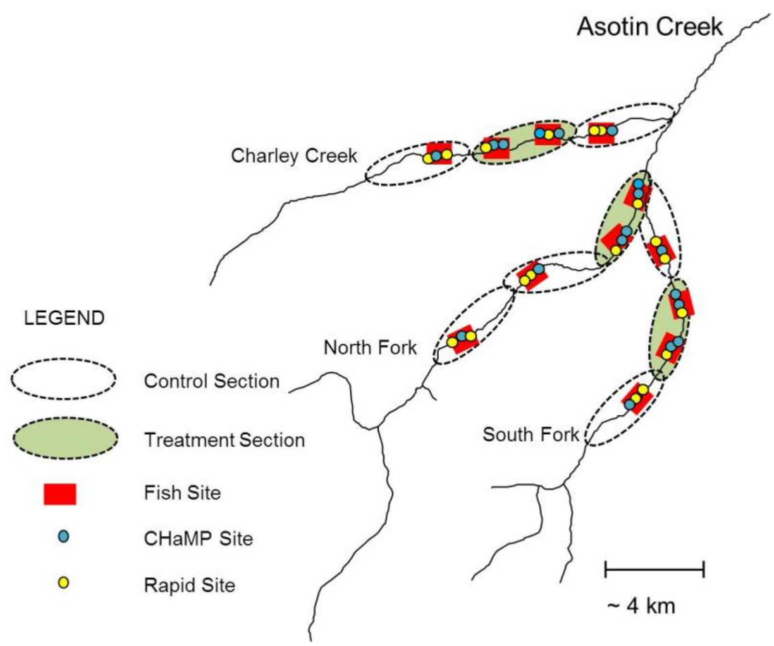


Figure 2. Experimental and monitoring design layout. The green sections are restoration treatments: South Fork was restored in 2012, Charley Creek in 2013, and North Fork in 2014. All sections not colored will be controls throughout the project. Fish sites and habitat survey sites (CHaMP and rapid) are nested within each section.

1.2 Restoration Schedule and Experimental Design Setting

A detailed review of our experimental design and rationale can be found in Bennett and Bouwes (2009) and Wheaton et al. (2012). Briefly, each study creek has three sections each 4 km long (Figure 2). One section in each stream is a treatment section where LWD has been added and the remaining sections are controls. The streams were treated in different years for logistical reasons and to prevent a year effect from biasing the results of the study (Walters et al. 1988, Loughin et al. 2007). South Fork was treated in 2012, Charley Creek was treated in 2013, and the North Fork was treated in 2014. The location of the treatments has been revised since the start of the IMW based on logistical limitations and a power analysis that suggested treating all the streams would give us a higher probability of detecting a fish response. The final design has the middle section of the South Fork and Charley Creek being treated and the lower section of North Fork. Out-of-basin controls are being evaluated in the John Day watershed, Oregon and the Potlatch watershed in Idaho.

1.3 Study Area

Asotin Creek is a tributary of the Snake River, flowing through the town of Asotin, in the southeast portion of Washington and the SRSRR (Figure 1). The Asotin Creek watershed is within the Columbia Plateau and Blue Mountains level III ecoregions. These ecoregions are dominated by deep narrow canyons cut into underlying basalt lithology and surrounded by semi-arid sagebrush steppe and grasslands at lower elevations and open conifer dominated forests at higher elevations (Omernik 1987, Clarke 1995, Omernik 1995). The Asotin watershed is approximately 842 km^2 and the average annual precipitation ranges from 96 cm at higher elevations in the Blue Mountains to less than 31 cm at lower elevations (240 m) along the Snake River. The study creeks occupy the western half of the watershed and drain the headwaters of the Asotin Watershed. Charley Creek is a left bank tributary to the mainstem Asotin Creek and its confluence is approximately 2 km downstream of the split between the South Fork and North Fork confluence.

The study creeks have a predominantly plane bed form with a relatively steep gradient, low sinuosity and large substrate (Table 1). The study creeks flow through steep V-shaped valleys with narrow (< 100 m wide) floodplain areas. Much of the riparian corridor is dominated by alder and scattered Douglas-fir and cottonwood which provide good shading. However, the trees are relatively young (20-40 years old) and so are not contributing much LWD to the stream.

Table 1. Summary of stream characteristics for Charley, North Fork, and South Fork Creeks*.

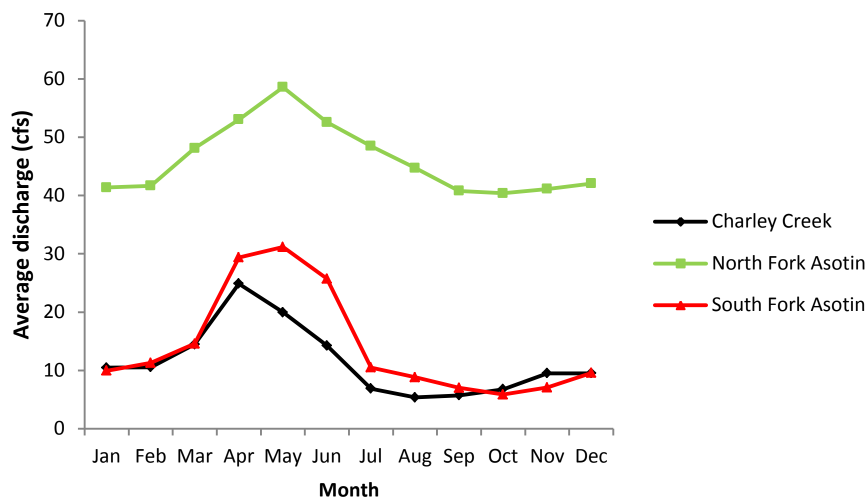
Stream	Sinuosity	Gradient (%)	D50 (mm)	% fines < 2 mm	% fines < 6 mm	BFW (m)	Pools/ 100 m	RPD (m)	LWD/ 100 m
Charley	1.20	3.01	53.2	11.1	19.1	4.8	2.1	0.26	15.3
North Fork	1.17	1.65	76.3	5.3	12.9	9.8	1.5	0.30	16.7
South Fork	1.15	2.63	72.2	6.3	12.8	6.4	2.3	0.20	10.6

* Data collected using the CHaMP habitat protocol at sites from 2011-2013 (CHaMP 2012). Grad = % slope; D50 based on Wolman pebble counts; % fines = pool tail fines; BFW = bankfull width; Pool/ 100 m = number of pools per 100 m; RPD= average residual pool depth; LWD/ 100 m = number of large woody debris pieces >= 1.0 m long and >= 0.1 m in diameter per 100 m.

1.4 Stream Flows, Water Temperature, and Climate

We have observed a unique discharge and temperature cycle and a relatively wide variety of peak flows and summer water temperatures in the study creeks (Figure 4). North Fork has the largest discharge of the three study creeks with approximately four times the flow during low flow periods and at least two times the discharge during flood flows (Figure 3a). South Fork has higher average flows than Charley Creek during spring runoff but from the fall through early spring the South Fork flows can be equal or less than Charley Creek (Figure 3a). We have noted that water temperatures have generally decreased since the start of the IMW compared to the previous few years and this appears to be correlated to higher peak flows (and average flows) observed since 2008 (Figure 3b).

a)



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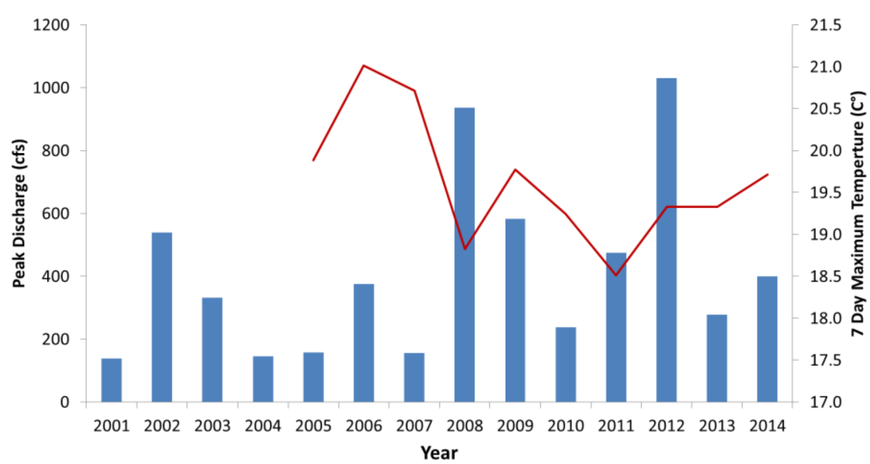


Figure 3. a) Average discharge by month for each of the study creeks (2009-2013) and b) Asotin Creek peak annual flow (blue bars) and the average summer water temperature (July and August – red line) by year. Peak flows measured at USGS gauge 13334450 and water temperature measured at DOE gauge 35D100.

The average 7-day moving average of maximum daily temperatures has been below 20 C° for all study creeks and years since the IMW started (month of August shown; Figure 4). South Fork has had consistently warmer maximum daily temperatures than the other study creeks.

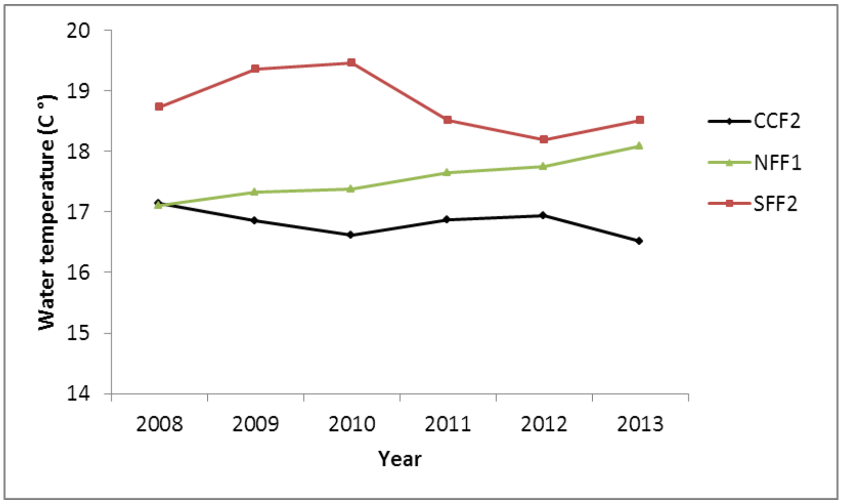


Figure 4. Average 7-day moving maximum water temperature for August by year and study creek as measured within 1 km of the mouth of each creek. Note that the highest average monthly maximum daily temperature happened in July (9) and August (10) almost equally since the start of the IMW.

Thirty year climate averages for the area near Asotin Creek are calculated by the National Climatic Data Center using a gauge located approximately five miles away at the Lewiston, ID airport. These measurements indicate that, on average, the most precipitation occurs in April and May, and the hottest months are in July and August (Figure 5Figure 5). Within the basin, temperatures range from -20° C in the winter to 40° C in the summer according to the Washington Department of Ecology gauge #35D100, located mid-basin. Total precipitation is much larger at higher elevations in the watershed, and mostly occurs as snow during the winter (Figure 6).

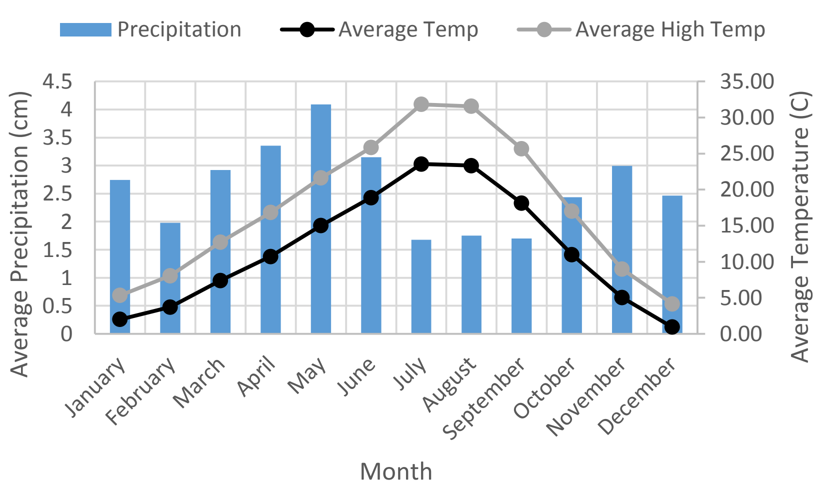


Figure 5. Mean monthly precipitation, air temperature, and max air temperature from 1981 to 2010 recorded at the Lewiston, ID airport by the National Climatic Data Center.

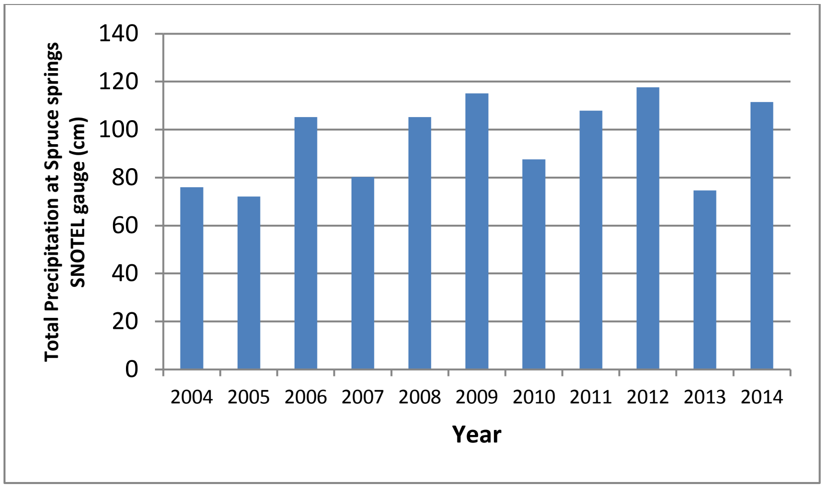


Figure 6. Total annual precipitation measured at the Spruce Springs SNOTEL gauge, located in the Blue Mountains at 1740 meters in elevation, near the headwaters of Asotin Creek.

Peak flows in the Asotin Creek watershed are largely driven by snowpack in the headwaters. Overall snowmelt runoff efficiency (the amount of water from snowmelt that reaches the stream network; SRE) for Asotin Creek was 40.9 % (*SD = 29.6)* for all months between 2007 and 2012 where snowmelt occurred at the Spruce Springs SNOTEL station, located near the headwaters of Asotin Creek (Figure 7). Mean SRE among years was variable, but there was no significant difference among years ($p=0.60$; Figure 7). Likewise, there is a strong positive correlation between monthly snow melt near the headwaters and mean monthly discharge (Pearson's $r(34) = 0.846$, $p<.001$). Although annual peak flows on the mainstem of Asotin Creek typically occur in the spring during snowmelt, 10 year or greater occurrence floods have happened due to winter or early spring rain on snow events. Likewise, high intensity and highly localized summer thunderstorms and rain on snow (or frozen ground) events can also cause sudden discharge peaks in the subbasins of the watershed (Figure 8). Investigating the interplay of these climatic factors, steelhead population dynamics, and restoration actions will be the focus of the remainder of the IMW.

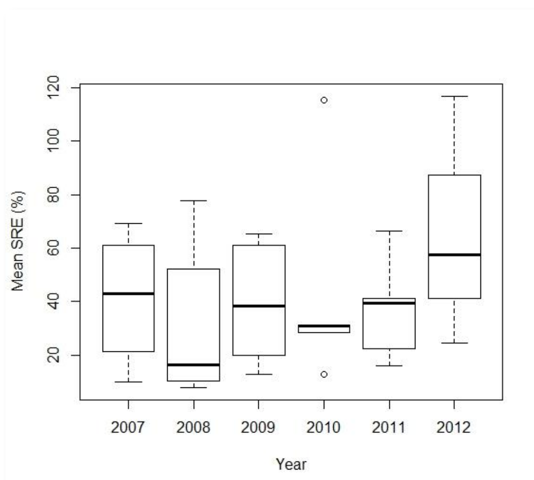
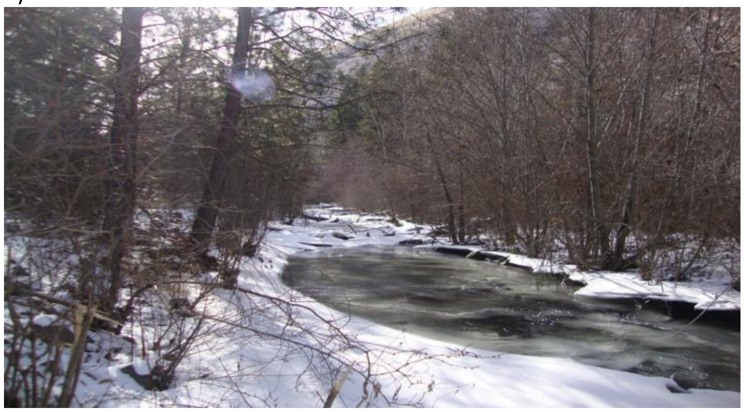


Figure 7. Boxplot of mean yearly snowmelt runoff efficiency (SRE) in Asotin Creek from 2007 - 2012. SRE was calculated using discharge estimates from the Washington State Department of Ecology stream gauge #35D1000 and daily snow melt depth from the Sourdough Gulch and Spruce Springs SNOTEL gauges.

a)



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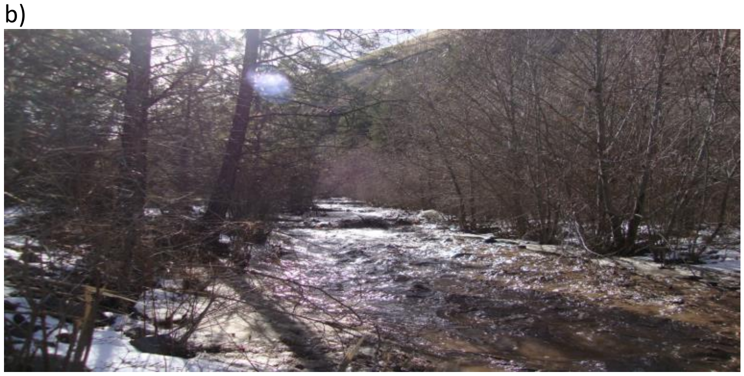


Figure 8. Photos of control section of South Fork just downstream from Warner Gulch taken with a trail cam on February 12th 2014 a) at 0800 hours and b) at 12:00 hours. Suspected cause of this high discharge that only lasted a few hours was rain on frozen ground.

2 MONITORING METHODS

The monitoring design is composed of four components: fish, instream habitat, stream channel/floodplain, and riparian habitat monitoring. We are using a set of monitoring protocols for these components that are either regionally recognized protocols or well supported monitoring methods from the literature. This will allow for efficient and precise data collection, data sharing between various agencies, and the detection of biological and geomorphological changes due to restoration actions. Most monitoring activities are focused on the three study creeks: Charley Creek, North Fork, and South Fork.

2.1 Watershed Context

Considerations of fish and habitat responses to restoration activities will be most informative if appraised within the appropriate spatio-temporal context (e.g., Wohl et al. 2005, Hemstad and Newman 2006). This requires the collection, analysis and presentation of geospatial data describing baseline and changed environmental conditions as well as some conceptual model within which biological and physical relationships are appraised. To support this end, we are in the process of developing the Biophysical Framework for Asotin Creek (Figure 9). Development of this framework and its application are based on the River Styles Framework (Brierley and Fryirs 2005) which provides a description of landscape units and reach types (e.g., river styles) as well as the geomorphic and fluvial processes that shape river channels and ultimately constrain the types of fish habitat that can be present. This procedure will provide us with the context in which to interpret and understand the habitat responses to restoration actions and enable better transfer of the lessons learned in the Asotin Creek IMW to other watersheds. Our preliminary assessment indicate there are four landscape units and nine distinct river styles in the Asotin Creek watershed (Camp 2015).

There are four landscape units in the Asotin Creek drainage (Figure 9). The landscape units are largely based off of 1:250,000 scale Level IV EPA ecoregions with some boundary refinement based off of geologic unit mapping at a finer 1:100,000 scale. The four units are mesic forest zone, canyons and dissected highlands, dissected loess uplands, and lower snake canyons. There are nine distinct River Styles in the Asotin Creek drainage based on landscape units and controls, river character, and river behavior (Figure 9). The majority of the river network with defined channels in the Asotin Creek drainage is either confined or partly confined. The long segments of confined valleys are common because the basin is dominated by multiple layers of ancient basalt flows, topped by Palouse loess soils on some ridge tops. The only instances of laterally unconfined streams are found in the very bottom of the catchment where the valley is uncharacteristically wide. We will develop this framework further in our next report.

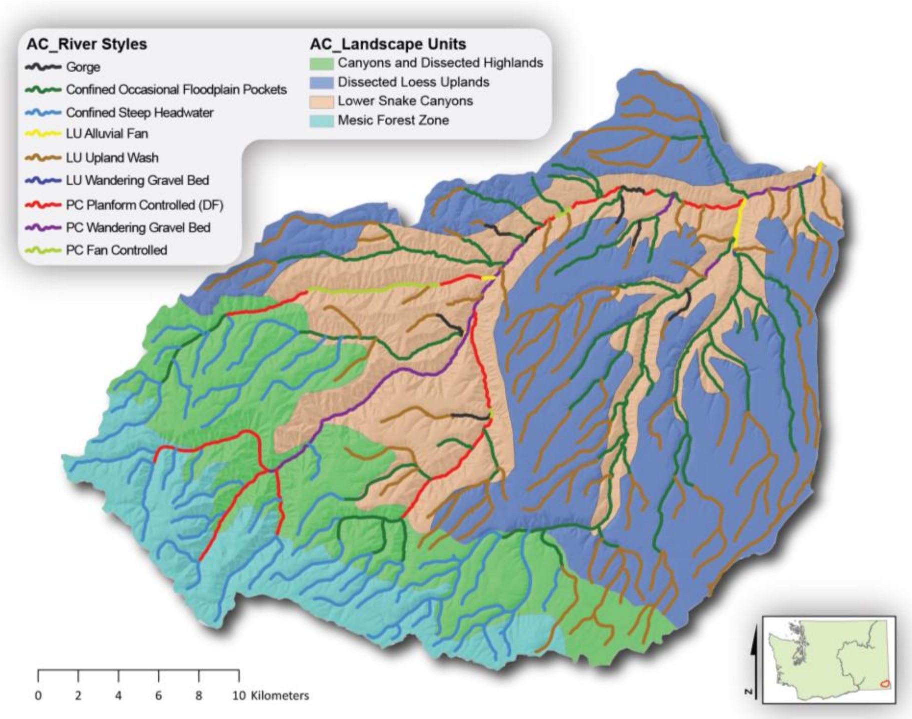


Figure 9. Draft landscape units and River Styles of 2nd order and higher streams in the Asotin Creek watershed.

2.2 Condition Assessment

The capacity for adjustment of a River Style can be defined as "morphological adjustments brought about by the changing nature of biophysical fluxes that do not record a wholesale change in river type." This interpretation is based on three degrees of freedom: the capacity of a river's channel attributes, planform, and bed character to change. Thus, it wholly represents the river's sensitivity to disturbances that inform the river's evolution. The detailed assessments of each River Style provide the basis for these interpretations. River Styles with a *low* capacity for adjustment are more resistant to disturbance than those with a *high* adjustment potential. For example, River Styles within a confined valley setting are resistant to disturbances due to the impervious physical controls that typically define their valley. Whereas River Styles in wider valleys (partly or unconfined) typically have a greater capacity for adjustment, simply because they have more space to move and develop dynamic features. Likewise, the position in the watershed plays a defining role, with flows typically increasing downstream.

Based on an assessment of relevant geo-indicators for each river style, and an in-depth review of the watershed's history, we developed a set of evolutionary sequence diagrams to explain each reach's geomorphic progression since Euro-American settlement in the drainage. The result of this assessment is represented in Figure 10, depicting the geomorphic condition of stream reaches as one of four categories. A reach can be in *good, moderate, poor,* or *intact* geomorphic condition. We did not identify an *intact* reaches based on the effects of historic land use that has occurred throughout the watershed. However, we designated the majority of the North Fork of Asotin Creek and the headwaters of the South Fork of Asotin Creek as *good* condition variants of the associated River Styles. The rest of the South Fork of Asotin Creek is in *moderate* geomorphic condition with a short reach of *poor* condition near the mouth of Warner Gulch. Nearly the entire length of Charley Creek is in *moderate* or *poor* geomorphic condition. Similarly, most of George Creek and its tributaries are in *moderate* or *poor* condition. We recognize, however, that much of the IMW study streams are currently in recovery, and there is no indication that geomorphic condition is deteriorating at most of the reaches.

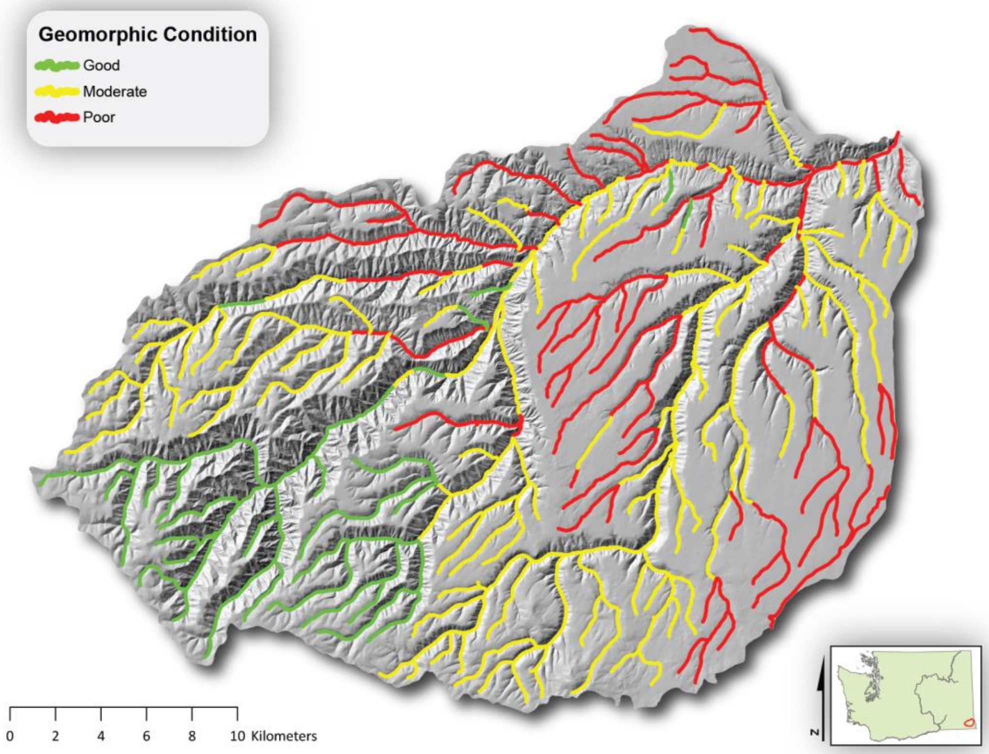


Figure 10. River Styles geomorphic condition assessment of 2nd order and higher streams in the Asotin Creek watershed.

2.3 Monitoring Infrastructure

We have developed a monitoring infrastructure based on the experimental design and project objectives. Most of our sampling effort is directed to the lower 12 km of the study creeks. The monitoring infrastructure has been developed from preexisting monitoring programs (e.g., WDFW Asotin Program, USGS gauges) and new installations, such as new juvenile steelhead and habitat sampling sites, PIT tag arrays, temperature probes, and water levels gauges (Figure 11). This base infrastructure will allow us to relate responses of fish populations to hydrologic attributes (i.e., discharge and water temperature) and specific stream habitat attributes at the site/reach, stream, subbasin, and watershed scale. See Crawford et al. (2014) for more details on the fish-in fish-out monitoring.

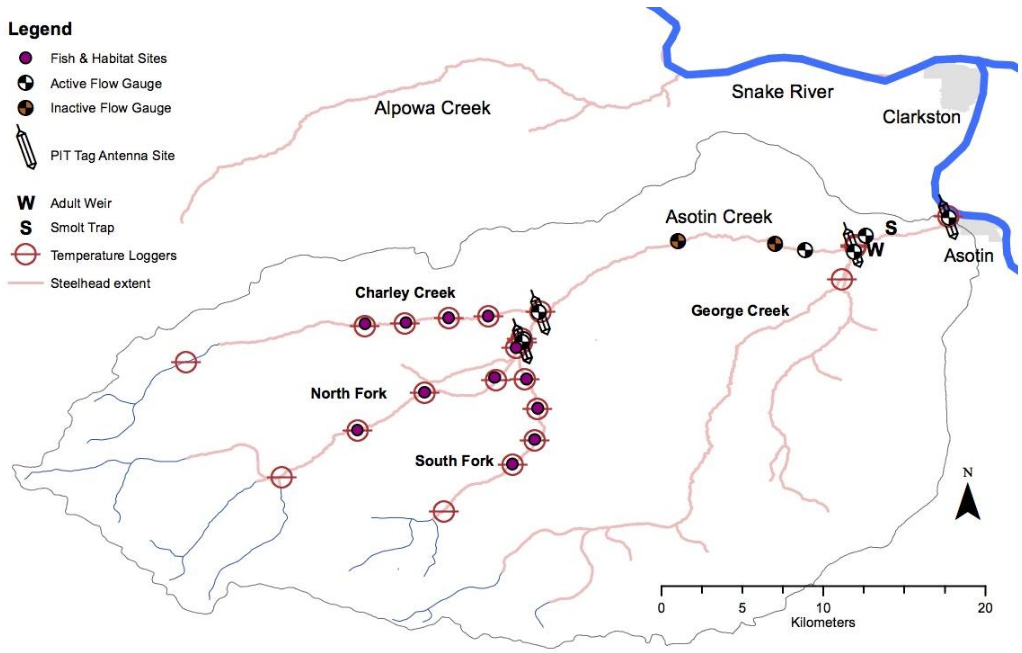


Figure 11. Monitoring infrastructure including fish and habitat sites in Charley Creek, North Fork, and South Fork Creek, temperature and discharge gauges, PIT tag antenna arrays, and the WDFW adult weir and smolt trap for fish-in fish-out monitoring.

2.4 Fish Monitoring

Our fish monitoring program is primarily focused on juvenile steelhead capture, PIT tagging, and recapturing or resighting of fish within the study creeks. We are focusing on this proportion of the population because it will provide the best measure of freshwater production that is most directly influenced by stream habitat conditions and restoration actions. These fish monitoring efforts will be enhanced by WDFW monitoring of outmigrating smolts and returning adults with the mainstem smolt trap and adult weir respectively (Crawford et al. 2014). Spawning surveys are also conducted by WDFW and IMW staff as stream conditions permit. Below we report on the monitoring to date and any changes in the monitoring protocols. For detailed methods see Bennett et al. (2012).

To assess the direct effects of stream restoration we are capturing and PIT tagging juvenile steelhead within the treatment and control sections of the study creeks. Juvenile tagging in the study creeks will allow us to determine juvenile abundance, growth, movement, and survival pre and post restoration. We started tagging juvenile steelhead in 2008 (a pilot year) where we captured and PIT tagged juveniles at three fish sites in each study creek. The current tagging program calls for 12 sites to be sampled but the arrangement of the sites has changed to four fish sites in each study creek to ensure replication of sample sites within the treatment sections. Each fish site is visited twice a year during a summer tagging session (late June to July) and a fall tagging session (late September to October). The two tagging sessions allow us to calculate the population parameters over shorter time periods (i.e., summer to fall and fall to the following summer; Appendix 1). We also conduct mobile PIT tag surveys in the winter and spring to detect PIT tagged juvenile steelhead overwintering in the study area. These detections, along with the summer and fall capture sessions, are used to calculate seasonal survival rates.

2.5 Habitat Monitoring

2.5.1 CHaMP Surveys

We began using the Columbia Basin Habitat Monitoring Protocol (CHaMP) to survey habitat sites in 2011(Appendix 2). CHaMP collects data on instream, channel, and riparian characteristic and provides a topographic survey of the site. We now monitor 18 CHaMP sites a year; four sites are allocated to each treatment section (12 sites) and one site is allocated to each control section (6 sites). This level of effort will result in approximately 30-40 restoration structures being “captured” by the topographic surveys in each treatment section. From these surveys, we are able to monitor changes to geomorphic channel units and differences in erosion and deposition pre and post restoration within predictable levels of uncertainty (Camp 2015). We used similar methods to Wyrick and Pasternack (2014) to delineate geomorphic channel units using lines of evidence derived from the topographic surveys of each CHaMP reach. In addition, we estimated the volumetric change in erosion and deposition using geomorphic change detection analysis (Wheaton et al. 2013). Because restoration on the North Fork was completed in 2014 and no post restoration surveys are yet available, we are only including geomorphic change results for Charley Creek and the South Fork of Asotin Creek in this report.

The remainder of each fish site will be surveyed with a rapid protocol that focuses on large wood, pools, and sediment sources (18 sites). LiDAR and aerial photography were collected in 2010 and will be collected again between 2015-2019 to determine changes to floodplain. See Bennett et al. (2012) for more detail.

2.5.2 Rapid Habitat Surveys

Because the CHaMP surveys cover about 25% of the IMW restoration structures, we implemented a rapid survey approach to increase our monitoring coverage to 100% of the structures. To facilitate the rapid collection of restoration effectiveness data, we developed a mobile database application (app) deployable on iOS devices called the $_{HD}$LWD Effectiveness App. Using the app, we make annual visits to each structure after high flows to identify specific hydraulic and geomorphic responses relevant to the IMW restoration hypotheses (Camp, 2015; Camp and Wheaton, 2014; Wheaton et al., 2012). In addition, by inputting the size, location, and other relevant information into the app, we build spatially representative diagrams of the channel units around every structure. In doing so, we are able to monitor geomorphic changes, such as an increase in pool density or water depth, around every structure in the IMW restoration design (e.g., Figure 12).

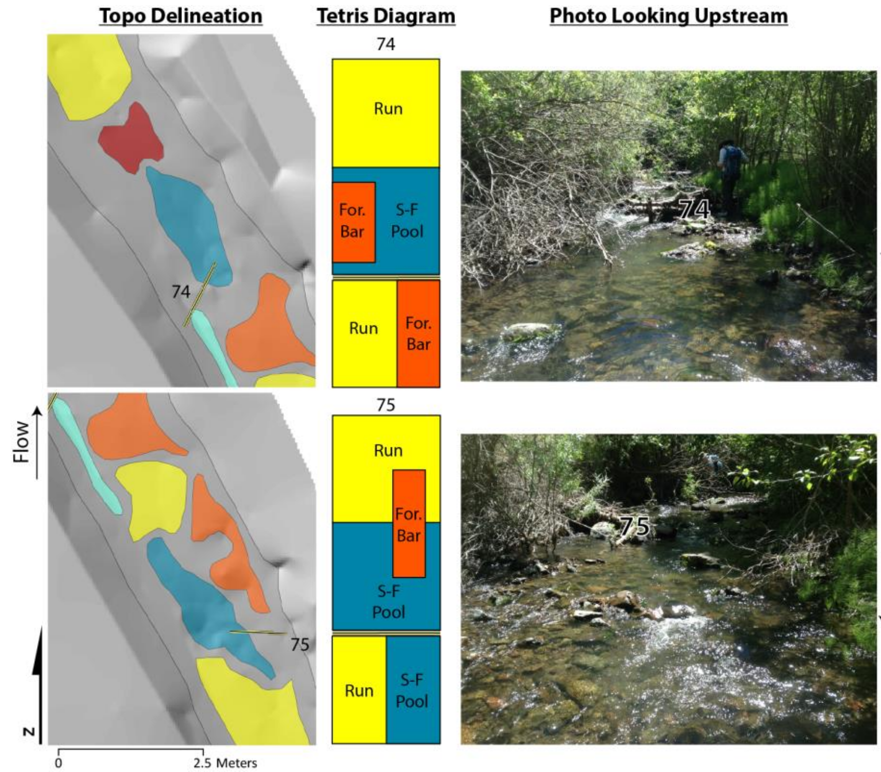


Figure 12. An example of geomorphic channel units delineated from topographic surveys (left) compared to the tetris diagrams which are created in the field (middle). The tetris diagrams are spatially representative assemblages of the geomorphic channel units surrounding a structure.

In addition, we developed an app to facilitate a rapid census of pools, bars, and LWD in the IMW study streams. Every year we visit 18 habitat sites that are not covered by CHaMP surveys to monitor physical trends in habitat within the same sites where we monitor fish. Every pool, bar, and piece of large wood is marked with a GPS location, and we record relevant measurements of size and/or depth of each feature.

					Year/Protocol											
					PIBO		DRAFT CHaMP		FULL CHaMP							
Stream	Section	Type	Fish Site	IMW Habitat Site	2008	2009	2010	CHaMP Site#	2011	2012	2013	2014	2015	2016	2017	2018
Charley	1	Control	CC-F1	Detailed (H1)		X	X									
				Detailed (H2)		X	X	ASW00001-CC-F1 P2BR	C	Dropped from sample design						
				Rapid (H3)			X									
			CC-F2	Detailed (H1)	X	X	X	ASW00001-CC-F2 P1BR	C	C	C	C	C	C	C	C
				Rapid (H2)		X	X			R	R	R	R	R	R	R
				Rapid (H3)			X			R	R	R	R	R	R	R
	2	Treatment	CC-F3	Detailed (H1)		X	X	ASW00001-CC-F3 P1BR		R	C	C	C	C	C	C
				Detailed (H2)	X	X	X	ASW00001-CC-F3 P2BR		C	C	C	C	C	C	C
				Rapid (H3)			X			R	R	R	R	R	R	R
			CC-F4	Rapid (H1)	R		X				R	R	R	R	R	R
				Detailed (H2)	R	X	X	ASW00001-CC-F4 P2BR			C	C	C	C	C	C
				Detailed (H3)	R	X	X	ASW00001-CC-F4 P3BR			C	C	C	C	C	C
	3	Control	CC-F5	Detailed (H1)	X	X	X	ASW00001-CC-F5 P1BR	C	C	C	C	C	C	C	C
				Rapid (H2)		X	X	ASW00001-CC-F5 P2BR		C	R	R	R	R	R	R
				Rapid (H3)			X			R	R	R	R	R	R	R
			CC-F6	Detailed (H1)		X	X	ASW00001-CC-F6 P1BR	C	C						
				Detailed (H2)		X	X	ASW00001-CC-F6 P2BR		C	Dropped from sample design					
				Rapid (H3)			X			R						
North Fork	1	Treatment	NF-F1	Detailed (H1)		X	X	ASW00001-NF-F1 P1BR		C	C	C	C	C	C	C
				Detailed (H2)	X	X	X	ASW00001-NF-F1 P2BR	C	C	C	C	C	C	C	C
				Rapid (H3)			X			R	R	R	R	R	R	R
			NF-F2	Detailed (H1)				ASW00001-NF-F2 P1		C	C	C	C	C	C	C
				Detailed (H2)				ASW00001-NF-F2 P2		C	C	C	C	C	C	C
				Rapid (H3)						R	R	R	R	R	R	R
	2	Control	NF-F3	Not sampled												
			NF-F4	Detailed (H1)	X	X	X	ASW00001-NF-F4 P1BR	C	C	C	C	C	C	C	C
				Rapid (H2)		X	X			R	R	R	R	R	R	R
				Rapid (H3)			X			R	R	R	R	R	R	R
	3	Control	NF-F5	Not sampled												
			NF-F6	Rapid (H1)		X	X			R	R	R	R	R	R	R
				Detailed (H2)	X	X	X	ASW00001-NF-F6 P2BR	C	C	C	C	C	C	C	C
				Rapid (H3)			X			R	R	R	R	R	R	R
South Fork	1	Control	SF-F1	Not sampled												
			SF-F2	Rapid (H1)		X	X			R	R	R	R	R	R	R
				Detailed (H2)	X	X	X	ASW00001-SF-F2 P2BR	C	C	C	C	C	C	C	C
				Rapid (H3)			X			R	R	R	R	R	R	R
	2	Treatment	SF-F3	Rapid (H1)		X	X			R	R	R	R	R	R	R
				Detailed (H2)	X	X	X	ASW00001-SF-F3 P2BR	C	C	C	C	C	C	C	C
				Detailed (H3)			X	ASW00001-SF-F3 P3BR		C	C	C	C	C	C	C
			SF-F4	Detailed (H1)				ASW00001-SF-F4 P1		C	C	C	C	C	C	C
				Detailed (H2)				ASW00001-SF-F4 P2		C	C	C	C	C	C	C
				Rapid (H3)						R	R	R	R	R	R	R
	3	Control	SF-F5	Rapid (H1)			X			R	R	R	R	R	R	R
				Rapid (H2)		X	X			R	R	R	R	R	R	R
				Detailed (H3)	X	X	X	ASW00001-SF-F5 P3BR	C	C	C	C	C	C	C	C
			SF-F6	Not sampled												
Total FULL CHaMP Sites/Year					**9**	**24**	**36**		**10**	**18**	**18**	**18**	**18**	**18**	**18**	**18**
Total Rapid Survey Sites/Year					**-**	**-**	**-**		**-**	**18**	**18**	**18**	**18**	**18**	**18**	**18**

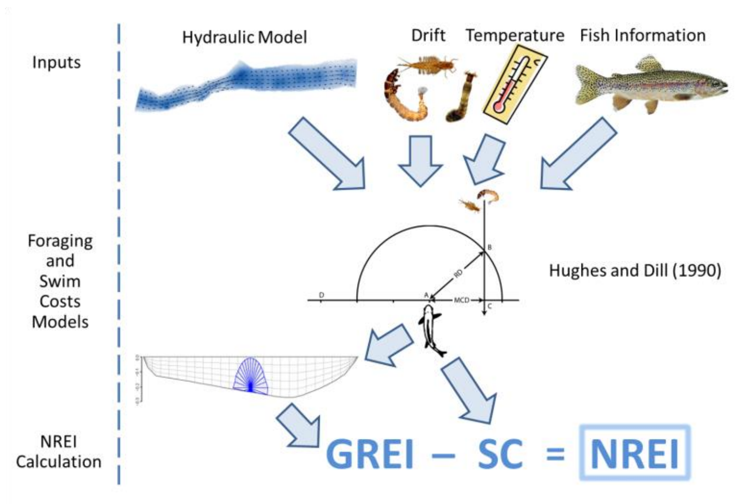
X - pre CHaMP surveys (i.e., PIBO and CHaMP stick and tape)
C - full CHaMP survey (topo and auxiliary data)
R - rapid survey (i.e., fluvial audit georeferencing all LWD, pools, and sediment sources/sinks)

2.6 Synthesis of Fish and Habitat Data

We have been developing different methods for synthesizing the information from habitat and fish monitoring to assess the response of fish to restoration treatments and to better understand the system as a whole. One method we are using is the net rate of energy intake model (NREI; Hayes et al. 2007). We have expanded the application of the NREI model from single habitat unit applications to entire stream reaches to predict carrying capacity for juvenile steelhead in our treatment versus control sections. The model uses data from CHaMP surveys (topographic data, hydraulic model), drift samples (collected annually at all fish sites), water temperature, and fish abundance information as inputs into the Hughes and Dill (1990) foraging and swim cost models (Figure 13). The foraging model estimates the area a fish might use to feed (i.e., capture area) and uses the capture area to estimate GREI (gross rate of energy intake). A swim costs model (SC) predicts the energetic costs of swimming in the current and the NREI is calculated by subtracting swimming costs from GREI (Figure 13a). The carrying capacity of a site is calculated with an iterative process whereby the highest NREI value in the raster is assigned a fish

(Figure 13b). A territory rule is then used to exclude another fish from occupying a location within the territory. The next highest NREI value outside the first fish's territory is identified and assigned as a fish location. This process is repeated until all the suitable locations in a site are occupied by fish. The carrying capacity is calculated as the total of all fish capable of being supported. See Wall (2014) for more details on the NREI modeling process we used.

a)



b)

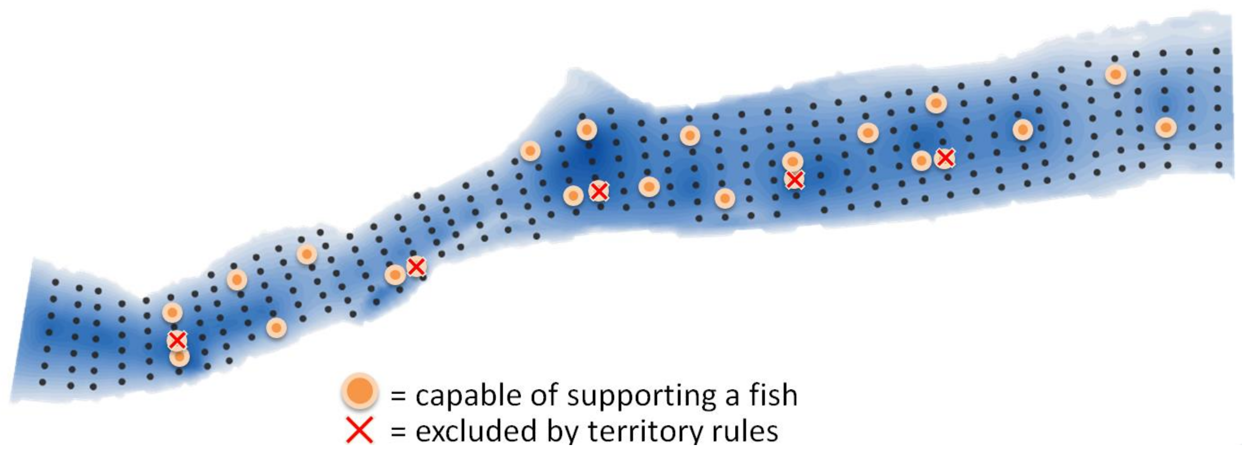


Figure 13. a) Net rate of energy intake (NREI) modeling process used to synthesize fish and habitat data and b) converting NREI raster values into carrying capacity based on territory rules for juvenile steelhead (Wall 2014). Site carrying capacity equals the summation of all sites capable of supporting a fish.

3 RESTORATION METHODS

3.1 Restoration Goals and Objectives

The restoration goals can be split into long-term and short-term objectives. In the long-term, we hope to restore riparian function by promoting the development and maintenance of a healthy riparian zone that more resembles historic conditions. This forest will be dominated by native species, have a diversity of seral stages appropriate to the natural disturbance regime of the vegetation and ecosystem type types they represent, and provide a suite of attributes that will benefit the streams they border. A separate riparian restoration proposal is being developed by the Asotin County Conservation District to achieve these objectives.

In the short-term, we are adding LWD to the study creeks at densities similar to or exceeding the mean reference conditions. The goals of the treatments are to learn how LWD additions change the hydrologic and geomorphic conditions in the study creeks. Ultimately, we want to cause a positive population response in wild steelhead as a result of the LWD additions and understand what the mechanisms are that lead to the response. A secondary goal is to develop an inexpensive, low impact, and widely applicable LWD restoration method that can be used in many small to medium sized tributaries to increase habitat complexity.

The specific objectives of the LWD treatments are to:

1. Increase channel width variability,
2. Increase instream habitat diversity (e.g., fish cover, pool frequency and depth), and
3. Promote mobilization and sorting of sediment by encouraging bar development, bed scour, bank erosion, and substrate sorting.

3.2 Treatment and Structure Design

We are adding pieces of LWD that were small enough to carry by hand instead of using heavy machinery to minimize potential damage to the existing riparian vegetation. The pieces of LWD were installed at each site and usually secured in place with wooden fence posts driven into the stream bed with a hydraulic driver (Figure 14 and Figure 15). Three structure types are secured in place with posts: deflectors, mid channel, and debris jams (Figure 16). Some LWD was installed with no posts to act as seeding (allowed to move) and some very large pieces (often with rood wads) were installed using an excavator to act as “key pieces” more resistant to high flows. See Wheaton et al. (2012) and Camp (2015) to see how the treatments were designed and the specific hypotheses developed for each structure type.

Figure 14. Example of the hydraulic post driver that is used to install large woody debris structures in Asotin Creek.

Figure 15. Example of the hydraulic power unit used to power the post driver for installing DWS in the Asotin Creek Watershed.

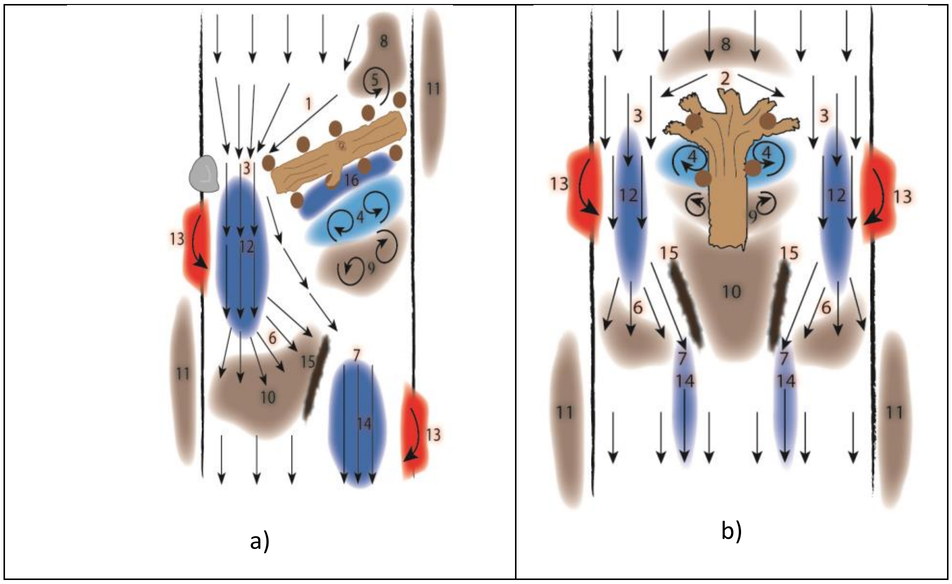


Figure 16. Design and expected responses of a) deflector structure and b) mid-channel structure. Red indicates bank erosion, blue indicates scour, brown indicates deposition, and arrows indicate flow direction. See Wheaton et al. (2012) for a description of the geomorphic and hydraulic responses which are represented by the numbers.

4 PRELIMINARY RESULTS

4.1 Fish Tagging and Abundance

Since 2008 we have tagged 23,795 juvenile steelhead $\geq$ 70 mm in the three study creeks of the IMW (Table 2). We capture relatively few bull trout and Chinook and have only tagged 25 bull trout and 131 Chinook since the start of IMW. This report will focus on the results of steelhead tagging.

Table 2. Summary of the number of juvenile steelhead (> 70 mm) PIT tagged in Asotin Creek from 2005 to 2014 at the smolt trap on the Asotin mainstem by WDFW and in the IMW study creeks by Eco Logical Research Inc. WDFW counts are provisional for 2013 & 2014.

Stream	2005	2006	2007	2008	2009	2010	2011	2012	2013*	2014*	Total
Asotin	2,462	1,552	1,895	1,862	946	2,605	4,002	4,680	3,944	4,880	28,828
Charley	-	-	-	424	1297	1955	1283	1136	1246	1180	8,521
North Fork	-	-	-	372	470	1397	906	931	1796	1545	7,417
South Fork	-	-	-	549	737	1862	1275	1495	1939	1846	7,857
IMW subtotal	-	-	-	1,345	2,504	5,214	3,464	3,562	4,981	4,571	23,795
Total	**2,462**	**1,552**	**1,895**	**3,207**	**3,450**	**7,819**	**7,466**	**8,242**	**8,925**	**9,451**	**52,623**

** includes 620 and 362 juveniles PIT tagged on mainstem and captured with hook and line in 2013 and 2014*

The density of juvenile steelhead is very similar across all three study creeks and generally tracks across years (Figure 17). South Fork tends to have the highest densities of juvenile steelhead and the North Fork tends to have the lowest. The average density of juvenile steelhead in the treatment sections appears to be increasing from 2013 onwards compared to the density in control sections. A preliminary assessment of this trend was analyzed using an intervention analyses where we calculated the average density of juvenile steelhead in all treatments sections and all control section combined pre and post restoration (Figure 18). We then subtracted the average density of juvenile steelhead in treatment sections from the density in control sections and compared these differences pre and post restoration (Figure 18). The average difference between the density of juvenile steelhead in treatment compared to control sections increased from 1.78/ 100 m^2 to 6.24/ 100 m^2 from pre to post restoration indicating the density of steelhead increased in the treatment section compared to the control section after restoration. This trend was significant when compared using a t-test with α = 0.1 (P = 0.052).

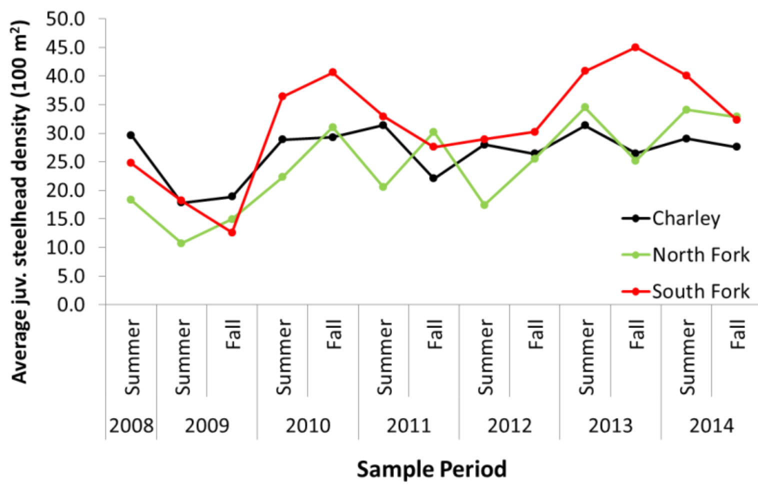


Figure 17. Average density of juvenile steelhead > 70 mm by study creek, season, and year: 2008-2014.

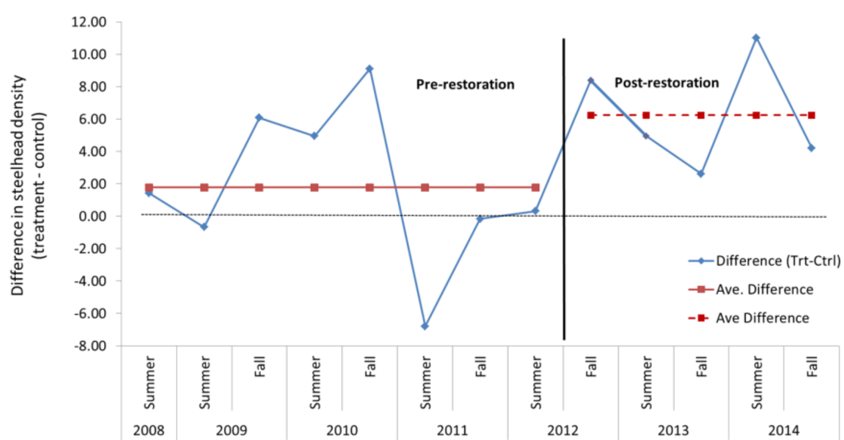


Figure 18. Difference of juvenile steelhead density between all treatment sections combined and all controls combined (blue line). Red lines represent the average of differences in density (treatment minus control) pre and post restoration. Differences between pre and post restoration are significant (α = 0.10, P =0.052).

4.2 Fish Growth

Growth rates were gererally correlated across study streams and were lower in Charley Creek compared to the North Fork and South Fork (Figure 19). Three distinct periods of very low average growth were observed (summer to fall 2009, 2010, and 2014). Low growth happened during periods with high abundance but not consistently which suggests other factors (e.g., flow and temperature) may also be infuencing growth. We conducted the same analysis for growth, comparing the average growth in the all treatment sections combined to the average growth in all other control sections combined (Figure 20). The average growth in the treatment sections appeared to decrease slightly after the restroation was implemented compared to growth in the control sections.

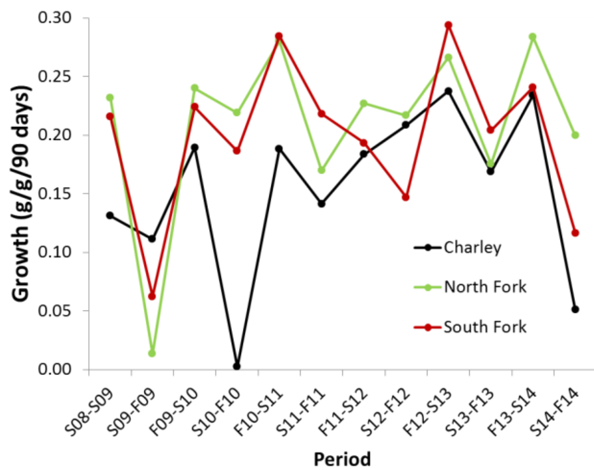


Figure 19. Average growth rate (g/g/90 days by study creek and growth period. Growth periods are summer (s) to fall (f) and fall to the following summer from 2008-2014.

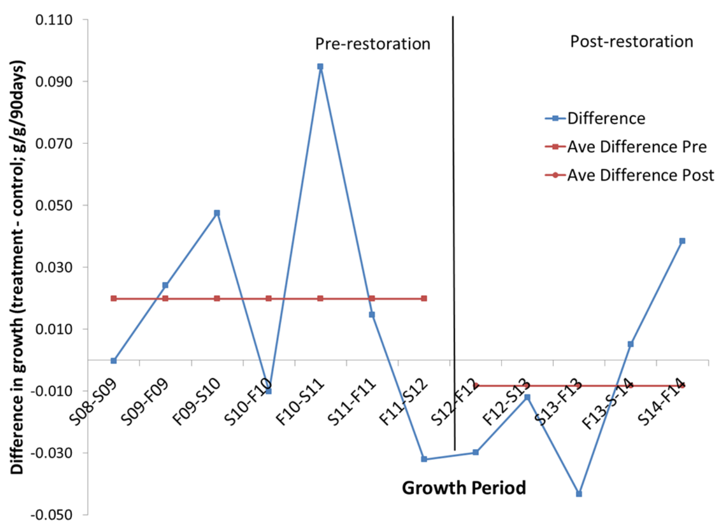


Figure 20. Difference of juvenile steelhead growth (g/g/90 days) between all treatment sections combined and all control sections combined (blue line). Red lines represent the average of differences in growth (treatment minus control) pre and post restoration. Difference between pre and post treatment is not significant (α = 0.10, P =0.12).

4.3 Fish Movement

A preliminary assessment of juvenile and adult steelhead movement was presented in previous reports (Bennett et al. 2012). It appears that there is limited movement of juvenile steelhead between fish sites within a stream (i.e., most fish captured at site X are recaptured at site X). There is also little juvenile movement between streams (i.e., fish tagged in stream Y are recaptured in stream Y). We have documented a significant proportion of juvenile steelhead that migrate from the study creeks and spend up to one year in the mainstem Asotin Creek before they smolt and leave the watershed. Approximately 40-50% of the adult steelhead migrating past the WDFW adult weir on the mainstem of Asotin Creek above George Creek enter one of the IMW study creeks ((Bennett et al. 2012, Wheaton et al. 2015). Future work will focus on quantifying smolt production/spawner in each tributary.

4.4 Fish Survival

We have been developing a method to improve survival estimates using a Barker model instead of the commonly used Cormack-Jolly Seber (CJS) method. We have recently published a paper demonstrating that the Barker method can provide more precise and less bias estimates of true survival (i.e., survival accounting for emigration) compared to the apparent survival estimates of the CJS method (Conner et al. 2014). We will be calculating new survival estimates in 2015 to reflect this improved method.

4.5 Habitat Monitoring

The number of pieces of wood ($\geq$ 0.1 m diameter and $\geq$ 1.0 m long) has remained relatively low in the study creeks throughout the monitoring period. The average number of pieces of LWD in the treatment sections was consistently lower than the LWD in all the other control sections combined throughout the study until 2012 after the restoration in South Fork (Figure 21). We estimate that there is almost three times more LWD in the treatment sections compared to the control section as of the completion of the North Fork restoration in 2014. The addition of LWD appears to have caused an upward trend in the average number of pools in the treatment sections as predicted (Figure 22**Error! Reference source not found.**).

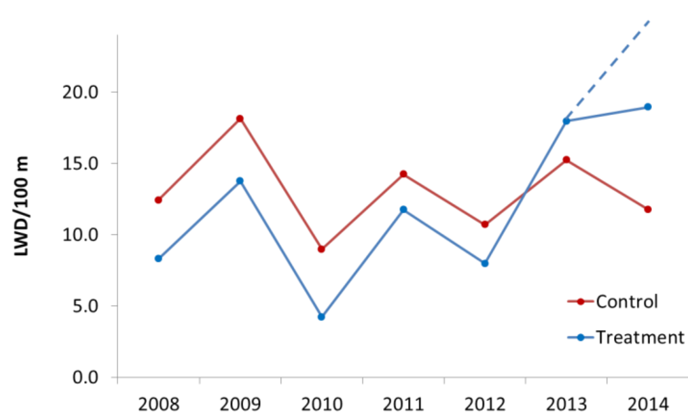


Figure 21. Average frequency of large woody debris (LDW) per 100 m in treatment and control sites: 2008-2014. Dashed line represents approximate LWD frequency post restoration in 2014 (data not completely summarized).

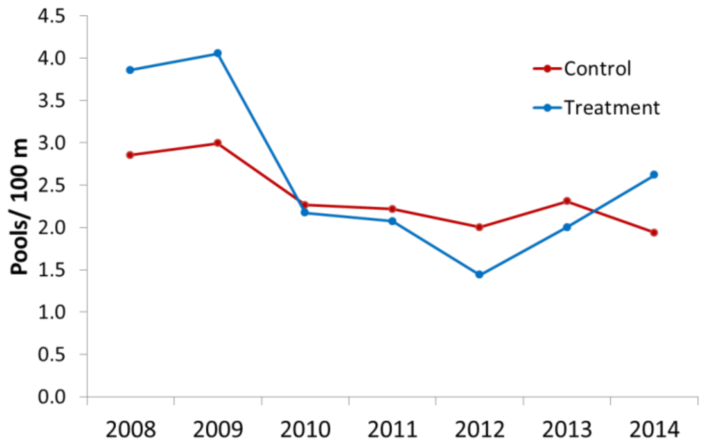


Figure 22. Average frequency of pools per 100 m in treatment and control sites across all study creeks: 2008-2014.

4.6 Habitat Complexity

Since restoration on Charley Creek and the South Fork, structures have imposed several changes to typically uniform flow patterns in the channel. As of 2014, the majority of structures have created upstream and downstream eddys, and convergent jets off the end of the structures (Figure 23). While these hydraulic responses may have implications for juvenile steelhead habitat, they also lead to specific and predictable geomorphic responses, in the forms of erosion and deposition, during high flows. We identified the results of these geomorphic responses as distinct channel units.

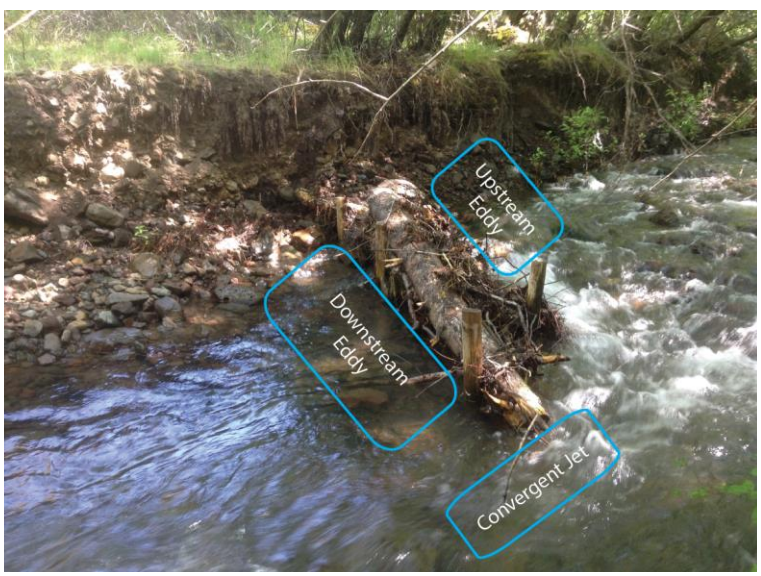


Figure 23. An example of hydraulic responses that significantly increased at restoration structures on the South Fork of Asotin Creek and Charley Creek since restoration (note flow direction is from right to left).

At all of the combined treatment sections, the proportional area of all tier two units significantly changed after restoration. Pool and bar area increased by 3.6% and 3.1% and planar feature area decreased by 8.0% ($p < 0.0001$ for all changes). However, control sites did not remain the same after restoration implementation either. At control sites, pool area increased by 3.1% and bar area increased by 1.5% ($p < 0.0001$ for both changes). Planar features at control sites did not significantly change. In contrast, the number of bars, pools, and planar feature units per 100 m all significantly increased at treatment sites, but did not change at control sites (Figure 24). At treatment sites, the number of pools and bars per 100 m increased by 2.0 ($p = 0.006$) and 2.8 ($p = 0.006$). Planar features per 100 m also significantly increased by 2.0 ($p = 0.01$) at treatment sites. More specifically at treatment sites, the most common increases were in structurally forced pools and forced bars, while runs were the most common unit to decrease (Figure 25).

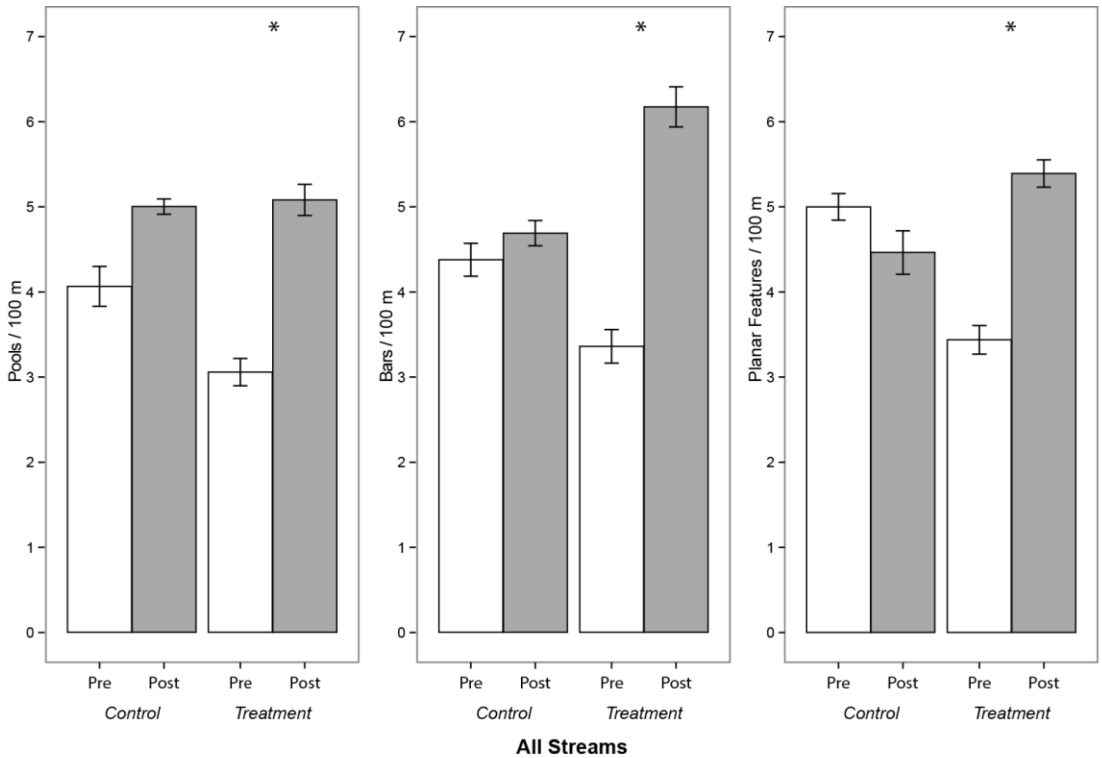


Figure 24. Comparison of the number of pools, bars, and planar features per 100 meters at treatment and control sections, pre and post restoration. This comparison includes data from Charley Creek and the South Fork of Asotin Creek. Asterisks (*) above a bar pair represent and significant difference between pre and post restoration.

Figure 25. Example of the increased number of pools and bars after restoration within a CHaMP site on the South Fork of Asotin Creek. The left image shows the topography and delineated units pre restoration, and the right image shows the changes post restoration.

4.7 Geomorphic Change Detection

We estimated the mean thickness of erosion and deposition at all CHaMP sites from 2011 to 2014. The mean thickness is a standardized representation of change and is equal to volumetric change divided by bankfull area. These changes are separated by epochs (the span of time between two subsequent CHaMP surveys). The mean thickness of erosion and deposition has decreased in the last four years. Prior to restoration, there was substantially more erosion at the treatment reaches at 0.30 ± 0.14 m, leading to a net thickness of -0.26 ± 0.13 m. Since restoration, erosion thickness has decreased to 0.14 ± 0.09 m in the 2014-2012 epoch, resulting in a net thickness of -0.02 ± 0.08. Likewise, the depth of deposition was lower in the final epoch than prior to restoration. However, there was an increase in deposition in the 2013-2012 epoch resulting in a net positive thickness of 0.10 ± 0.08. The control sites were arguably more stable through each epoch. However, the mean depth of erosion in the

2012-2011 epoch was very similar to the treatment reaches at 0.31 ± 0.14 m. In contrast to the treatment reaches, deposition that year was large enough at control sites to keep the net thickness near equilibrium at 0.05 ± 0.09 m.

For example, Figure 26 shows the DoDs for each epoch at one reach on the South Fork of Asotin Creek. Prior to restoration, there were substantial high flows in the spring of 2012, resulting in a large amount of erosion. The far left DoD for the 2012-2011 epoch shows the result of the 2012 spring flows where 94% of the change was erosional and the amount of volumetric change was much greater than any year since.

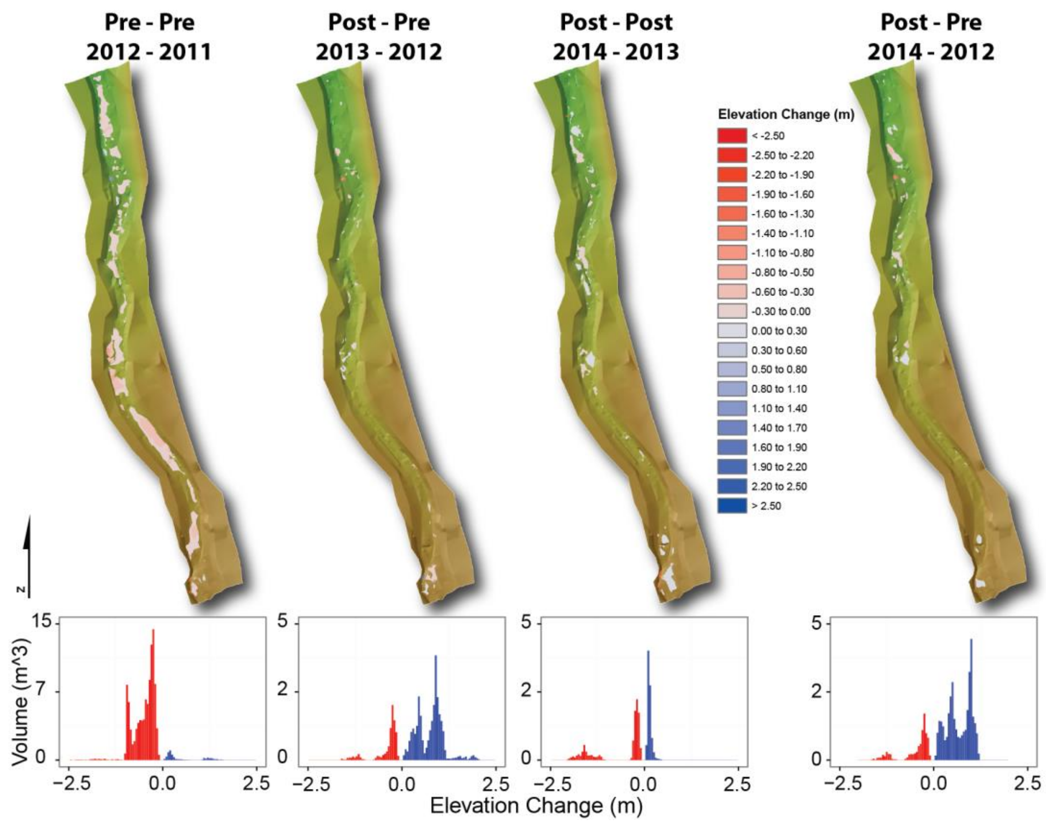


Figure 26. Example of geomorphic change detection for South Fork, CHaMP site ASW00001-SF-F3P2BR. Image is the digital elevation model of difference (DoD) resulting from the differences in elevation values between years. Only changes (erosion = red, deposition = blue) within 80% confidence interval limits are shown.

4.8 Synthesis of Fish and Habitat Responses to Restoration

To date we have helped to improve the process for generating the necessary data streams from CHaMP data to more rapidly calculate net rate of energy intake (NREI) at multiple reaches (champmonitoring.org). We have also assessed if the predictions of fish density and carrying capacity predicted from NREI are correlated to fish densities we observed both in Asotin Creek IMW and Bridge Creek IMW in the John Day Watershed (**Error! Reference source not found.**). Our findings suggest that there is a relatively strong and significant correlation between observed juvenile steelhead density and predicted fish density (i.e., carrying capacity) from NREI in both IMWs ($r^2 > 0.61$, $p < 0.001$; Figure 27a). When we assumed spatially uniform drift densities and small fish territories, carrying capacity predictions were related to the number of foraging locations simulated, suggesting the model is highly sensitive to territory size assumptions (Wall 2014).

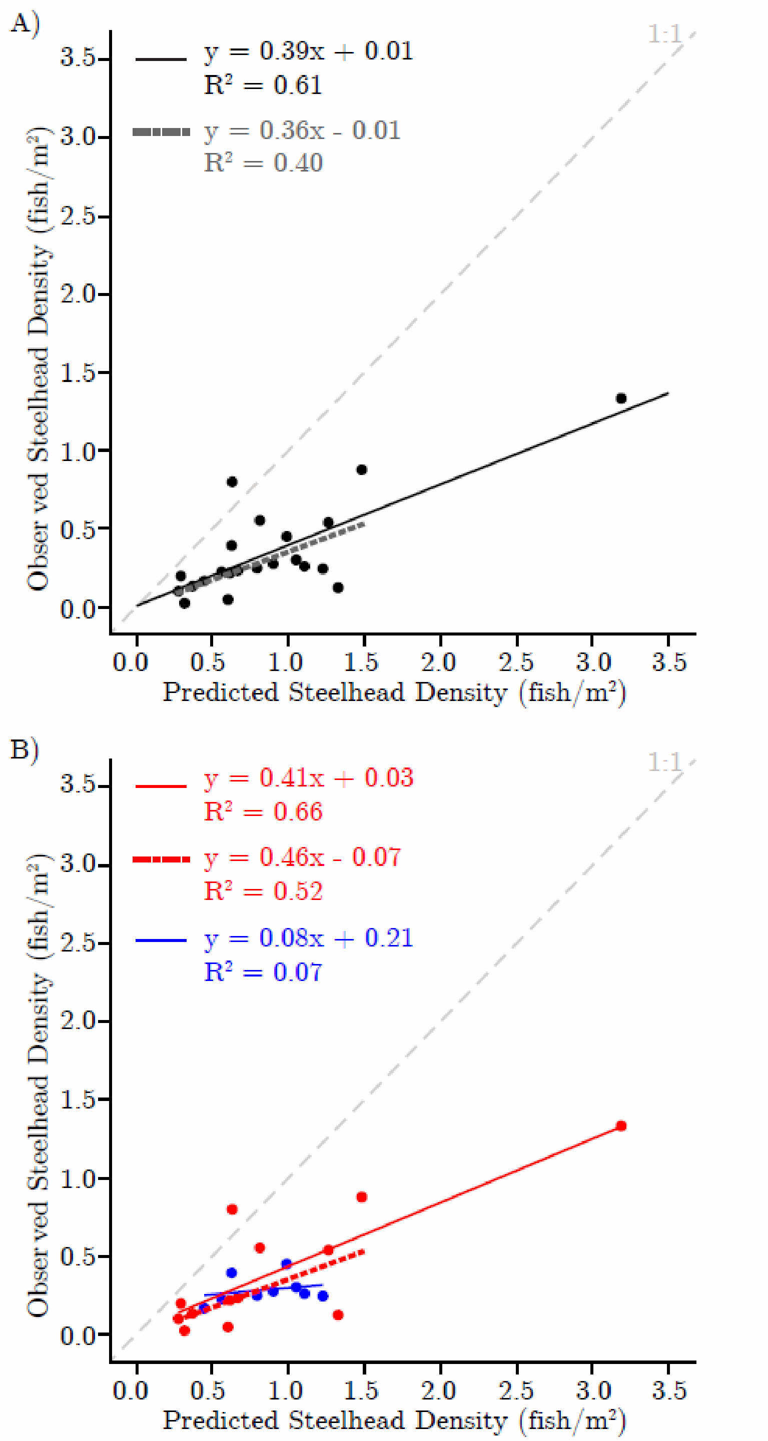
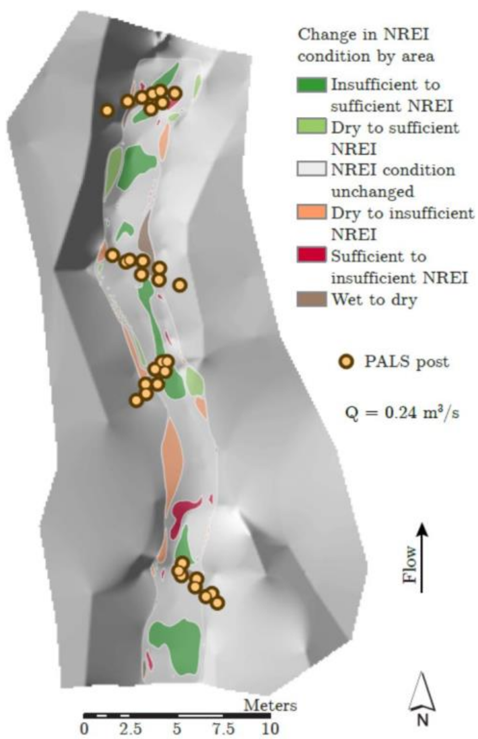


Figure 27. Observed and predicted juvenile steelhead densities for all sites in 2013 (A; black line), sites with mean fish length at least 70mm (A; dashed gray line), all John Day sites (B; red line), John Day sites with mean fish length at least 70mm (B; dashed red line), and Asotin sites (B; blue line).

We compared foraging before restoration and again following restoration implementation to assess the effect of restoration on fish habitat and carrying capacity (Figure 28). We used raster differencing to compare the `NREI before' to the `NREI after' restoration. The mean NREI before (2012) was -0.05 J/s (standard deviation = 0.12), while the mean NREI after (2013) was 0.015 J/s (standard deviation = 0.12). These calculations were only done on a 50 m segment of the restoration segment in South Fork. The change in carrying capacity in this segment went from ## before to ## after restoration. These results suggest the mean net energy intake increased and that more areas shifted from having an acceptable energy balance than to an unacceptable energy balance following restoration.

a)



b)

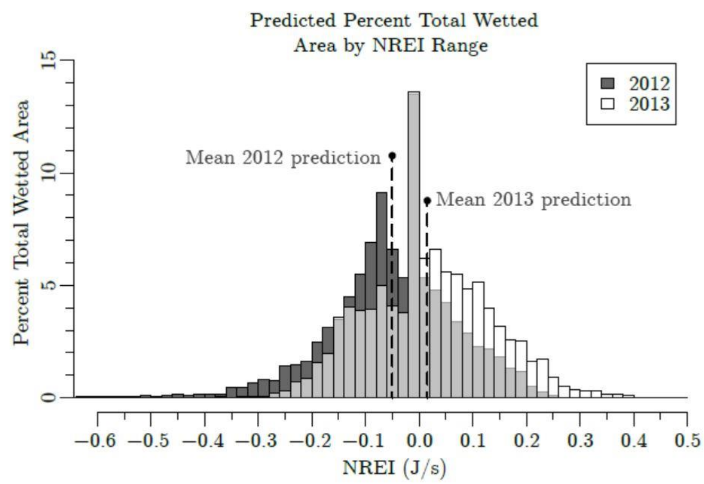


Figure 28. An example from a 50 m segment of South Fork treatment section showing a) changes in net rate of energy intake (NREI) condition from 2012 to 2013 after restoration with post assisted log structures (PALS), and b) the distribution of NREI values in the segment in 2012 (dark gray) and 2013 (white). Light gray bars indicate overlap between two years. Mean NREI value increased from -0.05 J/s (SD = 0.12) in 2012 to 0.015 J/s (SD = 0.12) in 2013.

5 RESTORATION IMPLEMENTATION

5.1 Extent of Restoration and Structure Types

We built 197 structures in the South Fork, 208 in the Charley Creek, and 135 in North Fork treatment sections from 2012-2014 (Figure 29). The total number of pieces of LWD added to each treatment section was 585 pieces in the South Fork, 497 pieces in Charley Creek, and 568 pieces in North Fork (Figure 30). The majority of structures built were deflector_PALS in all streams (Figure 29). On average the structures were approximately 20 m apart and the average length and diameter of LWD added to structures was larger in the North Fork and South Fork compared to Charley Creek. Photos examples of deflector, mid-channel, debris jams, and key pieces are presented in Appendix III.

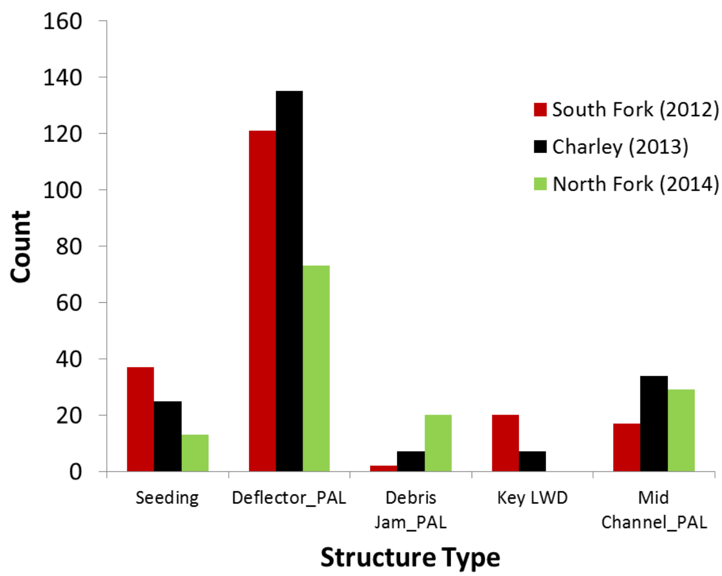


Figure 29. Count of each large woody debris structure type built in treatment sections in South Fork in 2012, Charley Creek in 2013, and North Fork in 2014. No wooden posts were used to secure seeding and Key LWD. All other PALS (post assisted log structures) were not built using non-treated wooden fence posts driven into the stream bottom (see section 3 for more details).

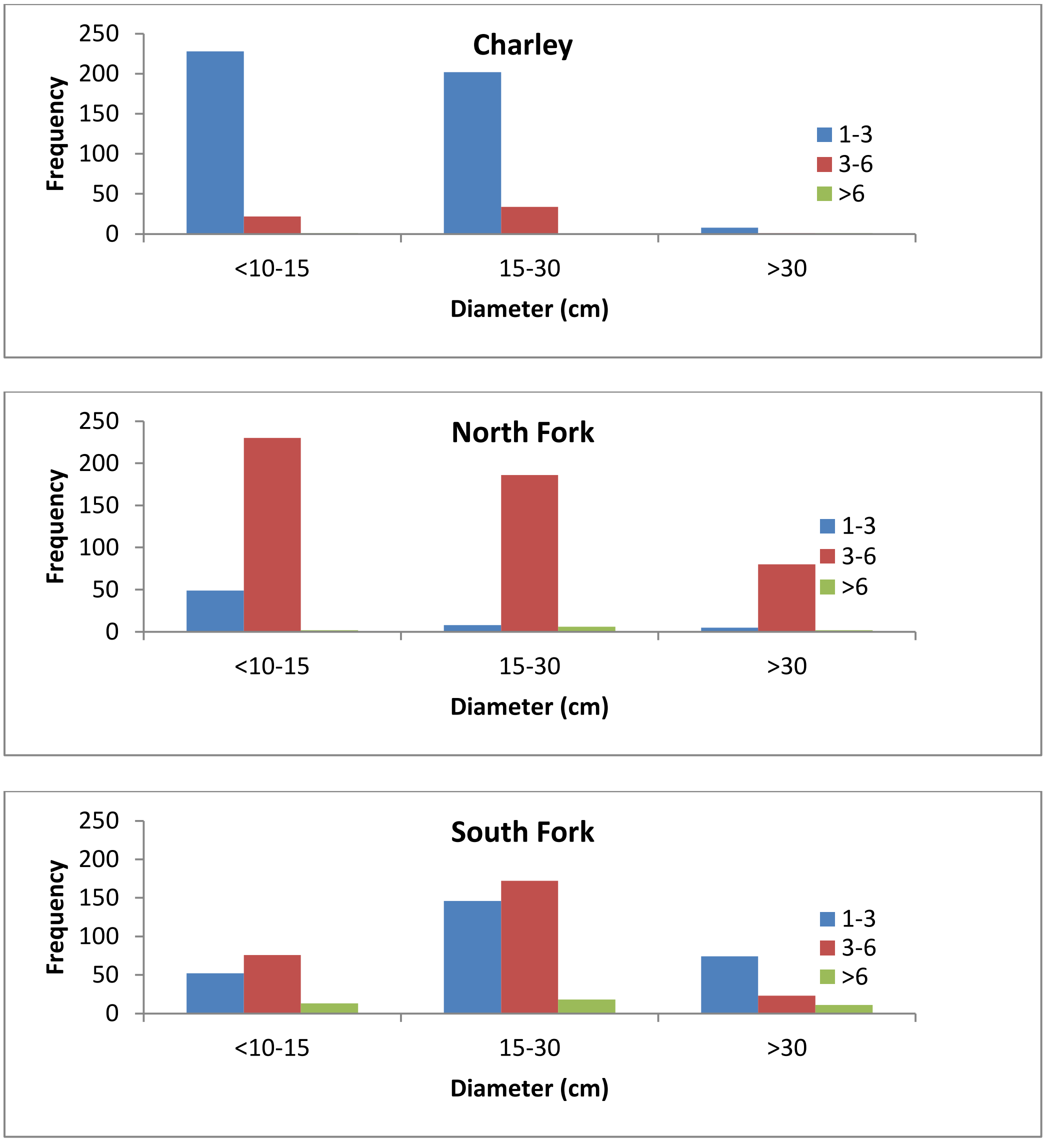


Figure 30. Frequency of large woody debris (LWD) added to the treatment section of each study creek by diameter class (x-axis; cm) and length class (color of bars).

6 DISCUSSION

6.1 Fish and Habitat Responses to Restoration

Despite relatively small spring high flows in 2013 and 2014 we have noted significant changes in fish habitat in treatment sections compared to control sections. Preliminary assessments of the treatment response suggest a significant increase in the abundance of juvenile steelhead in the treatment sections and a non-significant decrease in growth compared to the control sections. Geomorphic change analysis using the CHaMP topographic data and rapid assessment of habitat units suggest there has been significant change in the amount of erosion and deposition and that in general pool habitat has increased and run habitat has decreased in the treatment compared to the control sections. The changes we are observing are consistent with the hypothesized responses we predicted. An estimate of smolts per spawner will be presented in the upcoming report for the study creeks and compared to smolts per spawner estimates from the WDFW fish-in fish-out monitoring of the Asotin Watershed. These data and continued monitoring of Asotin Creek IMW are expected to provide valuable information on the response of wild steelhead to LWD additions and how to improve the effectiveness of restoration actions in other watersheds.

6.2 Synthesis of Responses

It is apparent based on NREI modeling that the restoration actions have increased the carrying capacity for juvenile steelhead in the treatment sections. The results of the NREI modeling are also correlated to observed fish density in both Asotin Creek and Bridge Creek (in the John Day watershed) suggesting that the NREI approach may have broad application for assessing fish and habitat responses to restoration actions. However, we have much more work to do to fully assess the responses of juvenile steelhead to restoration and to gain better understanding on the mechanisms responsible for observed changes. Our focus will now be on refining the NREI approach and our estimates of survival and smolts per spawner in the study creeks.

7 FUTURE WORK

Below is a summary of the tasks for 2015 and beyond:

- Assign fish ages based on sub-sample of scale samples and Bayesian model
- Estimate abundance of juvenile steelhead in study creeks and smolts/spawner
- Recalculate survival using refined Barker model approach
- Refine NREI approach
- Analyze 2014 CHaMP data and incorporate into analyses
- Assist Asotin County Conservation District in riparian restoration design and planning
- Continue fish and habitat monitoring
- Publish experimental design using hierarchical-staircase approach
- Publish life history of juvenile steelhead in Asotin Creek

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APPENDIX 1. FISH SAMPLE SITE MATRIX WITH COMPLETED AND PROPOSED SAMPLE SCHEDULE THROUGH TO THE END OF THE IMW PROJECT. GREY SHADING REPRESENTS THE LENGTH OF TIME EACH SECTION WILL BE IN A "POST-RESTORATION" STATE. ALL "X'S" WITHOUT SHADING REPRESENT CONTROL SAMPLES.

		Fish	Year										
Stream	**Section**	**Site**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Charley	1	CC-F1		X	X	X							
		CC-F2	X	X	X	X	X	X	X	X	X	X	X
	2	CC-F3	X	X	X		X	X	X	X	X	X	X
		CC-F4		X	X			X	X	X	X	X	X
	3	CC-F5	X	X	X	X	X	X	X	X	X	X	X
		CC-F6		X	X	X	X						
North Fork	1	NF-F1	X	X	X	X	X	X	X	X	X	X	X
		NF-F2					X	X	X	X	X	X	X
	2	NF-F3											
		NF-F4	X	X	X	X	X	X	X	X	X	X	X
	3	NF-F5											
		NF-F6	X	X	X	X	X	X	X	X	X	X	X
South Fork	1	SF-F1											
		SF-F2	X	X	X	X	X	X	X	X	X	X	X
	2	SF-F3	X	X	X	X	X	X	X	X	X	X	X
		SF-F4					X	X	X	X	X	X	X
	3	SF-F5	X	X	X	X	X	X	X	X	X	X	X
		SF-F6											
Total Sites/Year			**9**	**12**	**12**	**10**	**12**	**12**	**12**	**12**	**12**	**12**	**12**

APPENDIX 2. LOCATION OF COMPLETED (2008-2013) AND PROPOSED (2014-2018) HABITAT SURVEYS WITHIN CHARLEY, NORTH FORK, AND SOUTH FORK CREEKS. GREY SHADING REPRESENTS THE LENGTH OF TIME EACH TREATMENT SECTION WILL BE IN A "POST-RESTORATION" STATE. WE ARE USING TWO METHODS TO SURVEY HABITAT: CHAMP TO COLLECT TOPOGRAPHIC DATA ("C") AND RAPID SURVEYS TO MEASURE ATTRIBUTES THAT ARE A FOCUS OF THE IMW (I.E., LWD, POOLS, AND SEDIMENT SOURCES; "R").

					Year/Protocol												
					PIBO		DRAFT CHaMP	FULL CHaMP									
Stream	**Section**	**Type**	**Fish Site**	**IMW Habitat Site**	**2008**	**2009**	**2010**	**CHaMP Site#**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**
Charley	1	Control	CC-F1	Detailed (H1)		X	X									
				Detailed (H2)		X	X	ASW00001-CC-F1 P2BR	C	Dropped from sample design						
				Rapid (H3)			X									
			CC-F2	Detailed (H1)	X	X	X	ASW00001-CC-F2 P1BR	C	C	C	C	C	C	C	C
				Rapid (H2)		X	X			R	R	R	R	R	R	R
				Rapid (H3)			X			R	R	R	R	R	R	R
	2	Treatment	CC-F3	Detailed (H1)		X	X	ASW00001-CC-F3 P1BR		R	C	C	C	C	C	C
				Detailed (H2)	X	X	X	ASW00001-CC-F3 P2BR		C	C	C	C	C	C	C
				Rapid (H3)			X			R	R	R	R	R	R	R
			CC-F4	Rapid (H1)	R		X				R	R	R	R	R	R
				Detailed (H2)	R	X	X	ASW00001-CC-F4 P2BR			C	C	C	C	C	C
				Detailed (H3)	R	X	X	ASW00001-CC-F4 P3BR			C	C	C	C	C	C
	3	Control	CC-F5	Detailed (H1)	X	X	X	ASW00001-CC-F5 P1BR	C	C	C	C	C	C	C	C
				Rapid (H2)		X	X	ASW00001-CC-F5 P2BR		C	R	R	R	R	R	R
				Rapid (H3)			X			R	R	R	R	R	R	R
			CC-F6	Detailed (H1)		X	X	ASW00001-CC-F6 P1BR	C	C						
				Detailed (H2)		X	X	ASW00001-CC-F6 P2BR		C	Dropped from sample design					
				Rapid (H3)			X			R						
North Fork	1	Treatment	NF-F1	Detailed (H1)		X	X	ASW00001-NF-F1 P1BR		C	C	C	C	C	C	C
				Detailed (H2)	X	X	X	ASW00001-NF-F1 P2BR	C	C	C	C	C	C	C	C
				Rapid (H3)			X			R	R	R	R	R	R	R
			NF-F2	Detailed (H1)				ASW00001-NF-F2 P1		C	C	C	C	C	C	C
				Detailed (H2)				ASW00001-NF-F2 P2		C	C	C	C	C	C	C
				Rapid (H3)						R	R	R	R	R	R	R
	2	Control	NF-F3	Not sampled												
			NF-F4	Detailed (H1)	X	X	X	ASW00001-NF-F4 P1BR	C	C	C	C	C	C	C	C
				Rapid (H2)		X	X			R	R	R	R	R	R	R
				Rapid (H3)			X			R	R	R	R	R	R	R
	3	Control	NF-F5	Not sampled												
			NF-F6	Rapid (H1)		X	X			R	R	R	R	R	R	R
				Detailed (H2)	X	X	X	ASW00001-NF-F6 P2BR	C	C	C	C	C	C	C	C
				Rapid (H3)			X			R	R	R	R	R	R	R
South Fork	1	Control	SF-F1	Not sampled												
			SF-F2	Rapid (H1)		X	X			R	R	R	R	R	R	R
				Detailed (H2)	X	X	X	ASW00001-SF-F2 P2BR	C	C	C	C	C	C	C	C
				Rapid (H3)			X			R	R	R	R	R	R	R
	2	Treatment	SF-F3	Rapid (H1)		X	X			R	R	R	R	R	R	R
				Detailed (H2)	X	X	X	ASW00001-SF-F3 P2BR	C	C	C	C	C	C	C	C
				Detailed (H3)			X	ASW00001-SF-F3 P3BR		C	C	C	C	C	C	C
			SF-F4	Detailed (H1)				ASW00001-SF-F4 P1		C	C	C	C	C	C	C
				Detailed (H2)				ASW00001-SF-F4 P2		C	C	C	C	C	C	C
				Rapid (H3)						R	R	R	R	R	R	R
	3	Control	SF-F5	Rapid (H1)			X			R	R	R	R	R	R	R
				Rapid (H2)		X	X			R	R	R	R	R	R	R
				Detailed (H3)	X	X	X	ASW00001-SF-F5 P3BR	C	C	C	C	C	C	C	C
			SF-F6	Not sampled												
Total FULL CHaMP Sites/Year					**9**	**24**	**36**		**10**	**18**	**18**	**18**	**18**	**18**	**18**	**18**
Total Rapid Survey Sites/Year					**-**	**-**	**-**		**-**	**18**	**18**	**18**	**18**	**18**	**18**	**18**

X - pre CHaMP surveys (i.e., PIBO and CHaMP stick and tape)
C - full CHaMP survey (topo and auxiliary data)
R - rapid survey (i.e., fluvial audit georeferencing all LWD, pools, and sediment sources/sinks)

APPENDIX 3. EXAMPLES OF THE TYPES OF LWD STRUCTURES BUILT IN SOUTH FORK ASOTIN CREEK (2012), CHARLEY CREEK (2013), AND NORTH FORK ASOTIN CREEK (2014).


Mid-channel structures in Charley Creek.


Debris jam Charley Creek


Deflector structure Charley Creek


Deflector structure Charley Creek


Mid-channel structure South Fork Asotin Creek


Key piece South Fork Asotin Creek


Debris jam South Fork Asotin Creek


Deflector South Fork Asotin Creek

 Mid-channel structure North Fork Asotin Creek	 Seeding North Fork Asotin Creek
 Debris jam North Fork Asotin Creek	 Deflector North Fork Asotin Creek