SUBMITTED

DECEMBER 31, 2021


securing LWD with posts


placed tree with root


juvenile steelhead monitoring


grip-hoist in action

ASOTIN CREEK

INTENSIVELY MONITORED WATERSHED

ANNUAL PROGRESS REPORT

2008-2021 Data Summary and Adaptive Management

Submitted To: **Recreation and Conservation Office, Olympia, Washington**

Submitted By: Stephen Bennett[1,2,3], Eliza Keksi[1,2,3], Nick Bouwes[1,2,3]
[1]Eco Logical Research, Inc., Providence, Utah; [2]Utah State University, Logan, Utah; and [3]Anabranch Solutions, Newton, Utah

Scott Nicolai, reverse logging expert

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EXECUTIVE SUMMARY

Project Description

The Asotin Creek Intensively Monitored Watershed (IMW) project was established in 2008 in southeast Washington. Asotin Creek is managed as a wild steelhead refuge, and ***Snake River summer run steelhead are the focal species of the IMW***. The juvenile steelhead and sculpin are the most abundant fish species in the IMW study area, and there are small numbers of longnose dace, bull trout, Chinook, and Pacific Lamprey. The IMW is implemented in three Asotin Creek tributaries: 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 cover a range of sizes, gradients, and flow regimes, but all are structurally starved (i.e., low large wood and debris jam frequency). Structural starvation is a very common riverscape impairment caused by historic removal of instream and riparian wood and trees, trapping of beaver, successive large floods, and straightening of channels. Structural starvation is the key ***limiting factor*** the IMW is studying as it limits instream complexity, frequency of overbank flow, and extent and function of active floodplain and riparian area, which limits production and productivity of riverscapes generally, and specifically steelhead populations.

Goals

The goals of the IMW are to increase channel complexity with large wood additions and eventually ***promote and sustain natural rates and magnitudes*** of overbank flow, floodplain connection, riparian extent and function, and riverscape physical and biological processes (e.g., erosion, deposition, and sustained wood accumulation). The goal is also to fully develop and test an alternative restoration strategy for dealing with structural starvation using post-assisted log structures (PALS). We call the restoration approach low-tech process-based restoration of riverscapes, and the goal is to cost-effectively add wood, protect recovering riparian habitat, and provide an approach to expand the scale of restoration (i.e., extent treated) to address the immense scope of riverscape degradation (i.e., 10,000's of km of structurally starved streams).

Restoration Design and Actions

We implemented restoration (addition of LWD using PALS) in each study creek in different years using a staircase experimental design. Based on simulation models we demonstrated that staircase designs had more statistical power to detect changes compared to traditional before-after control impact (BACI) designs. Each study stream has at least one 4 km long treatment section and one or more control sections. We ***completed the initial restoration treatments in 2012, 2013, 2014, and 2016*** and have built 650 large woody debris (LWD) structures over 14 km (39% of study area at a frequency of 3-5 structures/100m). Total costs of restoration and maintenance costs to date is ~$523,200 total, or $37,400/km.

Adaptive Management

Generally, the Asotin IMW is an ideal situation for an experiment because there is only one landowner (WDFW), one focal species (steelhead) with very limited hatchery influence, and identifiable and specific type of habitat degradation (structural starvation). We are using an adaptive management framework to design, implement, monitor, evaluate, and adjust the IMW experiment. We articulated a series of predicted short and long-term structure and habitat that could lead to fish responses, and used these predicted responses to develop explicit restoration design hypotheses. We recognize that promotion of natural rates and magnitudes of self-sustaining processes (e.g., natural wood accumulation, erosion, deposition, floodplain connection) are unlikely to be achieved after one restoration treatment; therefore, we developed an adaptive management plan that included phased maintenance/enhancement of restoration treatments. Triggers in the adaptive management plan included risk to infrastructure, decreasing LWD frequency and effectiveness, and promotion of natural rates and magnitudes of self-sustaining processes (i.e., success). We are now in the maintenance and evaluation phase of the IMW and have added several thousand more pieces of LWD to the treatment sections to maintain and/or increase wood density. To date, most of the hypothesized geomorphic and fish responses have been small to modest due to most habitat changes occurring within the existing channel. In the final stage of the adaptive management plan, we are evaluating and adjusting the maintenance and enhancement of the restoration treatments to force greater geomorphic responses in the floodplain with the hypothesis that this will lead to greater connection of side-channels, inundation at low flow, and ultimately more volume of stream/km of valley length. This should lead to greater fish responses and provide managers and funders with a clear contrast between the benefits of increasing channel complexity versus floodplain connection, and help improve and prioritize restoration. Total costs of maintenance and enhancement are ~$100,000 with a proposed $50,000. Therefore, total costs of restoration by completion are expected to cost ~$675,000 or ~$48,200/km.

Monitoring and Analysis

We monitored habitat with PACFISH INFISH Biological Opinion (PIBO) protocol from 2008-2009 and the Columbia Habitat Monitoring Protocol (CHaMP) from 2010-2017. We currently use a rapid monitoring protocol that encompasses metrics from both PIBO and CHaMP along with geomorphic units including planar (runs, rapids, cascades), convexity (bars), and concavities (pools). With these protocols we can construct time series of basic channel characteristics (e.g., bankfull width, sinuosity, residual pool depth, substrate composition), LWD, debris jams, and pool frequency, and geomorphic unit area, volume, and frequency. We also have LiDAR flown pre-restoration and recently collected high resolution aerial imagery of the floodplain which we will use to assess changes in floodplain connection.

To assess fish populations, we partner with WDFW that operate an adult weir and smolt trap near the mouth of Asotin Creek. The fish-in fish-out operation provides a wealth of life-history data as well as estimates of adult escapement and juvenile migrants (smolts and juveniles emigrating from Asotin Creek or tributaries). In the three study creeks, we conduct two-day mark-recapture in the summer and fall and tag all unmarked juvenile steelhead ≥ 70 mm with 12 mm passive integrated transponder (PIT) tags. From the summer and fall PIT tagging data, we estimate site ***abundance*** (fish/km) and ***biomass*** (g/km). We then estimate annual ***growth, survival, and production rates*** across two seasons: summer to fall and fall to summer. We also estimate ***juvenile emigration and productivity*** (smolts/female) by estimating the age of PIT tagged juvenile steelhead from 10%~ subsample of scales, tag detections at PIT tag interrogation sites (of juveniles and adults), and the ratio of tagged/untagged juveniles in the study creeks. There are four PIT tag interrogation sites, two located at the mouth of each IMW study creek, and two located near the mouth of Asotin Creek. We also monitor stream temperature and discharge throughout Asotin Creek and the study creeks.

For most metrics presented, we use a linear mixed effects model specifically designed for the staircase experimental design to assess the effect of the restoration. The resulting test determines the ***% change in the treatment sections compared to the control sections*** (both in stream and other stream controls). Because each stream was restored in a different year, the statistical test compares responses in the different streams in the same year after treatment (YAT). We provide 90% confidence intervals on the % change estimate, and when the intervals do not cross zero on the y-axis, the response (either negative or positive) is significant at p<0.1. We then present the Least Square Mean estimate for each metric (e.g., fish/km, g/season, etc.) for YAT=0 (pre-restoration), YAT=≥ 1 (post-restoration, and the difference (treatment -control).

Results and Synthesis to Date

We implemented a large-scale treatment (14 km) of high density LWD structures across three study streams and maintained or increased wood frequency with simple and cost-effective hand-built wood additions. As hypothesized, some of the wood from PALS moved and reformed as new log jams within the treatment section due to the high density of structures. We found that a similar number of new "natural" debris jams (combination of LWD added and natural recruitment) formed compared to the number of PALS that moved, and we documented increased natural wood recruitment due to bank erosion forced by PALS. LWD and debris jams frequency has increased dramatically in treatment sections compared to controls because of the restoration (Table 1). The increase in wood is forcing significant increases in geomorphic diversity in treatment areas compared to control areas by increasing bar and pool frequency and area, and increasing planar frequency and decreasing planar area. Most of the geomorphic changes are happening within the existing channel; however, small increases in side-channel, back-water, and floodplain connection are occurring.

The positive changes in habitat are leading to relatively consistent and small-moderate increases in juvenile steelhead abundance (fish/km), biomass (g/km), production (g/km/season), and productivity (smolts/km) in treatment sections compared to control sections (Table 1). We have not observed any changes in growth (g/season/fish) or survival. An increase in juvenile production and productivity, with relatively little change in growth or survival in treatment sections, may be from benefits to fry which are too small to PIT tag during our surveys. It is possible that fry are surviving in greater numbers because of the flow refugia and/or increased off-channel and edge habitat that increased LWD is providing. It is also possible the egg-fry survival has increased due to improved spawning sites. The increase in bars in treatment sections demonstrate that substrate is being mobilized and sorted more regularly which provides clean, less compacted spawning sites and many bars are located downstream of PALS which provide more protection to redds from freshets. This report focuses on responses pooled across age classes, but the results also appear to hold within age class comparisons.

New Findings – Lamprey

The Nez Perce Tribe has been relocating adult Pacific Lamprey to Asotin Creek mainstem since 2007. Prior to 2016 most of the adult lamprey were relocated in the lower mainstem below Headgate dam which was considered a partial barrier. In 2016, Headgate dam was completely removed, and the Nez Perce started relocating lamprey higher up in the watershed. We began detecting PIT tags from lamprey at the IMW interrogation sites in 2019 and caught some juvenile lamprey in the fish sites we survey annually. In 2021, we conducted a test survey to target lamprey and found ~ 100 juvenile lamprey in a short-stretch of South section 1. We are proposing to test if juvenile lamprey are more abundant in IMW treatment sections compared to control sections. We hypothesize that the fine sediment that is sorted and trapped near PALS is creating ideal rearing areas for juvenile lamprey.

Collaboration and Communication

We have been successful in partnering with local stakeholders, seeking input from the Regional Technical Team, and selecting a good location for an IMW (i.e., meets criteria conducive to conducting an experiment; Bennett et al. 2016). This was the critical first step to implementing the IMW. We have since partnered with WDFW to monitor juvenile steelhead and share monitoring results. We meet regularly with the Snake River Salmon Recovery Technical Team, present our findings to a broad range of stakeholders including the SRFB monitoring panel, Salmon Recovery Conferences, American Fisheries Society meetings, Conservation Districts, private landowners, and the public. We have published several manuscripts based on the IMW findings, supported Masters and PhD theses, developed the Low-tech Process-based Restoration Manual, and conducted dozens of in-person and online workshops to teach the principles of LTPBR to restoration practitioners, managers, funding agencies, and private landowners. We provide links to IMW resources on a variety of public websites as well.

Table 1. Summary of restoration actions, and habitat and fish responses. Responses presented as range of % change in treatment compared to controls and least squares means difference (treatment – control) across the study creeks.

Action/Measurement	Unit	Action / %Change	LSM Difference (treatment - control)	Data Available	Treatment Response (Summer/Fall Season)
Structures Implemented	Post-assisted log structure (PALS)	750 PALS and natural jams formed	NA	NA	NA
Structures Effectiveness	Geomorphic Units/BFW	20-30%	NA	pre, post	*
LWD Frequency	LWD/100m	153-1,025%	19.7-55.6	pre, post, ctrl, trt	*
Debris Jam Frequency	Jams/100m	116-765%	2.3-5.5	pre, post, ctrl, trt	*
Pools Frequency	Pools/100m	22-58%	0.6-2.1	pre, post, ctrl, trt	*
Geomorphic Complexity	Geomorphic Units/100m	-13-104%	NA	pre, post	*
Bars Frequency	Bars/100m	57-202%	NA	ctrl,trt	*
Planar Frequency	Planar/100m	-7- -18%	NA	ctrl, trt	*
Abundance (fall)	fish/km	15-31%	133-527	pre, post, ctrl, trt	* *
Growth	g/season/fish	-72-113%	-0.16-0.72	pre, post, ctrl, trt	- 0/+
Survival	season	-1-18%	-0.06-0.09	pre, post, ctrl, trt	0 0
Biomass	g/km	19-40	3,250 -10,449	pre, post, ctrl, trt	* *
Production	g/km/season	4-40%	29-2,631	pre, post, ctrl, trt	0 *
Productivity	smolts/section/brood year	24-88%	297-1,275	pre, post, ctrl, trt	*
Productivity	smolts/section/year	30-77%	510-2,260	pre, post, ctrl, trt	*
Age at Migration	Migrant Age Distribution	SF<Age1,CC>Age2, NF>Age3	NA	pre, post, ctrl, trt	*

*LSM Difference = least square means difference between treatment mean and control mean; Treatment responses are 0 = no change, - = negative trend; + = positive trend; * = significant change (p-value ≤ 0.1); pre = before restoration, post = after restoration, ctrl = control, trt = treatment. Restoration and habitat responses are annual, fish responses are by summer to fall and fall to summer periods and standardized to 90 day seasons.*

Management Implications and Core Messages

Results from the Asotin IMW are particularly applicable to wadeable (order 1-5) streams which typically make up 90% or more of the perennial stream network. We see huge potential for this approach to help buffer the imminent threats of climate change. There are tens of thousands of miles of wadeable streams that are structurally starved in the Pacific Northwest and traditional engineering approaches cannot scale up to the scope of the problem due to their high cost and potential damage to recovering riparian areas. Applying low-tech process-based restoration could help slow water leaving watersheds, recharge groundwater, reconnect disconnected floodplains creating more storage opportunity, and perhaps provide higher base flows, and limit impacts of climate change. We provide a summary of key management implications and core messages in this report.

Schedule for completion of Phase 1 and Future Research Potential

We then plan to continue to monitor at the same level until 2024/25 to collect enough data to evaluate freshwater production and productivity. We also plan to further investigate the influence of creating more floodplain connection on the habitat and fish responses we have already observed. We will also develop an Asotin specific life cycle model to model the implications of the current response as well as assess different restoration scenarios. We then anticipate another year to complete all the analysis and reporting including submitting manuscripts for publication.

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1. INTRODUCTION

Restoration of the freshwater habitat of anadromous salmonids has been occurring for decades with little evidence that restored habitat has led to an increase in salmonid populations at the watershed scale (Bernhardt et al. 2005, Roni et al. 2008). The lack of demonstrating a fish response may in part be due to the limited size of many restoration actions and high natural spatial and temporal variability in environmental conditions and population abundance (Roni et al. 2002, Wagner et al. 2013). Recently a series of Intensively Monitored Watersheds (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. 2016). IMWs use large-scale restoration treatments and robust experimental designs to increase the probability of detecting a population level response to restoration actions, should one exist (Loughin et al. 2021). A population level response can be defined as any increase in fish freshwater production or productivity due directly or indirectly to a restoration action. Freshwater production can be measured by summation of salmonid abundance, growth, and survival over a defined area and period (Almodóvar et al. 2006, Horton et al. 2009, Bouwes et al. 2016a), whereas freshwater productivity can be measured by calculating the recruits from one life stage to another such as smolts/spawner (Crawford and Rumsey 2011, Petrosky et al. 2001, Ward and McCubbing 2007). For practical purposes, it is assumed a population level response will need to be large (i.e., > 20%) to be detected by most monitoring efforts (Hinrichsen 2010, Roni et al. 2010). The main goals of IMWs are to assess how restoration actions alter stream habitat conditions (e.g., increase habitat quantity and/or quality), and to understand the casual mechanisms between stream habitat restoration and changes in salmonid production at the watershed scale. ***Ideally, IMWs that are based on robust experimental designs, large-scale restoration actions, and detailed and lengthy monitoring programs (e.g., spanning several generations pre- and post-restoration), can identify causal mechanisms of changes in fish populations, and therefore extrapolate results across a wide range of stream types and regions where funding for such intensive monitoring is not available***.

1.1 BACKGROUND

Asotin Creek was chosen as the site of an IMW in southeast Washington through a process coordinated by the Snake River Salmon Recovery Board (SRSRB; Bennett and Bouwes 2009). The Washington Department of Fish and Wildlife (WDFW) designated Asotin Creek as a wild steelhead refuge in 1997 and steelhead are the focus of the Asotin IMW (Bennett and Bouwes 2009, Herr et al. 2020). 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 (Wheaton et al. 2012, Bouwes et al. 2016b). An experimental study design has been developed and refined for the Asotin Creek IMW that includes treatment and control sections within three tributaries of Asotin Creek: Charley Creek, North Fork Asotin Creek (North Fork), and South Fork Asotin Creek (South Fork; hereafter referred to together as "study creeks"; Loughin et al. 2021; Appendix A). The study creeks cover a range of sizes, gradients, and flow regimes (Table 2). The study creeks generally exhibit homogenized and degraded habitats, with poor riparian function and low frequencies of large woody debris (LWD) and pool habitat which is thought to be limiting salmonid production (SRSRB 2011). A detailed Restoration Plan was developed that proposed long-term riparian enhancement and short-term LWD additions as restoration treatments in the Asotin Creek IMW (Wheaton et al. 2012). The focus of the IMW is to test the effectiveness of LWD additions. Riparian enhancement is **not** being directly assessed by the IMW because benefits are expected to be realized over the coming decades. The study plan for the IMW was updated as part of our Adaptive Management Plan to reflect changes in the experimental and monitoring designs (Bennett et al. 2015).

The primary goal of the Asotin IMW is to test the effectiveness of LWD at increasing the production and productivity of juvenile steelhead. Other important goals of the Asotin Creek IMW are to assess the transferability of lessons learned by:

- identifying the causal mechanisms by which changes in habitat lead to changes in fish production and productivity to extrapolate results to other watersheds,
- assessing cost-effectiveness of LTPBR methods,
- improving the effectiveness of LWD additions to promote and sustain the process of wood accumulation and recruitment (i.e., low-tech process-based restoration [LTPBR]; Wheaton et al. 2019), and
- providing guidance for buffering climate change impacts on small streams, especially in snow dominated flow regimes.

Table 2. Watershed characteristics for the three Asotin Creek IMW study creeks. Area and 2-year return interval determined from StreamStats (USGS 2016), bankfull width and gradient determined from IMW habitat monitoring (Bouwes et al. 2011), and average annual discharge determined from IMW discharge monitoring.

Stream	Area (km^2)	Bankfull width (m)	Gradient (%)	Average annual discharge (cfs)	2 Year return interval (cfs)
Charley	58	4.8	3.0	9.5	292
North Fork	165	9.8	1.7	60.0	674
South Fork	104	6.3	2.6	11.5	448

1.2 FUNDING AND SUPPORT

The Asotin Creek IMW is funded from NOAA's Pacific Coastal Salmon Recovery Fund (PCSRF) and the Pacific States Marine Fisheries Commission (PSMFC). NOAA funds are used to support the ongoing fish and habitat monitoring and data collection and analysis and administered via the Governor's Salmon Recovery Office. 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, along with logistical support and equipment from WDFW and SRSRB. Asotin County Conservation District and WDFW have been sponsors of both restoration and monitoring grants for the IMW and provided oversight and assistance with budgets and contracting.

Eco Logical Research Inc. (ELR) is the primary contractor that manages the Asotin Creek IMW and coordinates and implements monitoring and restoration with assistance from WDFW. Stephen Bennett is the Asotin IMW coordinator and works for ELR, and as a researcher at Utah State University (USU). Through the affiliation with USU, several graduate students have studied aspects of the Asotin IMW including restoration effectiveness (Camp 2015), changes in juvenile steelhead carrying based on low-tech process-based restoration (Wall 2014), and wood movement (Sutherland 2020). Anabranch Solutions LLC (AS) also provides support via research and development of Low-Tech Process-based restoration methods and donates $15,000 annually to support project management and data analysis.

A separate project funded by the Bonneville Power Administration (BPA) and implemented by the Washington Department of Fish and Wildlife (WDFW) provides fish-in, fish-out monitoring for the Asotin watershed (Herr et al. 2020). The WDFW fish-in fish-out monitoring collects annual steelhead population abundance and life history data that is critical for the Asotin IMW to fully assess restoration effectiveness.

The goal of this progress report is to provide an update on the status of the Asotin IMW (what has been done to date), and what are the next steps based on our Adaptive Management Plan. Specifically, we describe:

- ongoing IMW and WDFW fish and habitat monitoring for project context,
- goals and objectives and link them to monitoring indicators,
- adaptive management monitoring, evaluation, and adjustments
- extent, timing, and costs of restoration actions,
- geomorphic responses to restoration actions,
- juvenile steelhead abundance, growth, survival, biomass, production, productivity, and life history responses to restoration,
- synthesis and interpretation,
- documentation of collaboration, communication, and outreach of IMW lessons learned, and
- schedule for completion

2. PROJECT CONTEXT

The Asotin Creek IMW began in 2008 and was implemented in Asotin Creek after an extensive selection process (Bennett and Bouwes 2009). Asotin Creek has a WDFW fish-in fish-out monitoring that began in 2004 which provides a wealth of juvenile and adult data, the watershed has limited hatchery influence, the experimental design is logistically feasible, and there is strong local support for the project. Below we provide a summary of some the WDFW ongoing monitoring efforts along with trends in IMW fish abundance and some basic habitat, flow, and water temperature as context for the project. For further information see Herr et al. (2020) for a detailed summary of the fish-in fish-out monitoring, Bennett et al. (2015) for study design and methods for the Asotin IMW, and Wheaton et al. (2012, 2019) for restoration planning and low-tech process-based restoration methods.

2.1 STEELHEAD MONITORING TRENDS

Steelhead are monitored with a combination of fixed trapping sites on the mainstem Asotin Creek and dispersed tagging sites in treatment and control sections in the study creeks. WDFW capture and PIT tag emigrating juvenile steelhead at a rotary screw trap near the mouth of Asotin Creek at rKM 3.0 in the spring and fall and estimate the total annual emigrants from Asotin Creek including the mainstem of Asotin Creek, Charley, North Fork, and South Fork Asotin Creek (Herr et al. 2020). WDFW also operates an adult weir at rKM 4.5 from late winter through spring runoff to estimate adult steelhead escapement (Herr et al. 2020). Each year the IMW monitoring program conducts a 2-day mark-recapture survey at 12 fish sites in the summer (July) and again in the fall (late September to mid-October). All unmarked juvenile steelhead > 70 mm are PIT tagged and the Chapman estimator is used to calculate a population estimate for the site (Seber 1992, Krebs 1999).

2.1.1 Tagging Summary

The WDFW and IMW tagging programs combined have tagged over 100,000 juvenile steelhead with passive integrated transponder (PIT) tags (Table 2). WDFW capture and tag juvenile steelhead at a smolt trap, and IMW tagging programs PIT tag an average of approximately 6,800 new PIT tags each year spread out across the mainstem Asotin Creek and at sample sites in Charley, North Fork, and South Fork Asotin Creek. WDFW also PIT tags adult steelhead captured at a weir on the mainstem of Asotin Creek. The location of the WDFW smolt trap, IMW fish capture sites, and other monitoring infrastructure are provided in Appendix A.

Table 3. Summary of total annual steelhead passive integrated transponder (PIT) tagging by WDFW at the smolt trap near the mouth of Asotin Creek and the Asotin IMW fist sites in Charley, North Fork, and South Fork Asotin Creeks.

Stream	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Total	Average
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	6,346	4,919	3,107	*NA*	**53,777**	**3,361**
Charley	-	-	-	424	1296	1,955	1,283	1,136	1,246	1,180	1,048	1,086	1,207	1,174	676	864	1,150	15,725	1,123
North Fork	-	-	-	372	470	1,397	906	931	1,797	1,549	2,035	2,244	1,794	2,376	1,587	1,101	1,379	19,938	1,424
South Fork	-	-	-	549	737	1,862	1,275	1,499	1,939	1,848	1,892	1,782	1,811	3,141	1,577	1,266	1,132	22,310	1,594
IMW subtotal	-	-	-	1,345	2,503	5,214	3,464	3,566	4,982	4,577	4,975	5,112	4,812	6,691	3,840	3,231	3,661	**57,973**	**3,410**
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**	**7,990**	**13,037**	**8,759**	**6,338**	**3,661**	**111,750**	**6,574**

** WDFW totals include 620, 362, 222, and 217 juveniles PIT tagged on mainstem and captured with hook and line in 2013, 2014, 2015, and 2016 respectively.*

2.1.2 Asotin Steelhead Adult Returns and Juvenile Emigration

WDFW continues to limit the contribution of hatchery steelhead to the spawning population by operating the adult weir for most of the spawning season and removing all hatchery adults captured at the weir (Herr et al. 2020). It is estimated that over the last 15 years, hatchery steelhead have made up 6.1% of spawners. Adult returns have dropped from a high in 2010 and 2017-2020 have the lowest adult returns to Asotin Creek since 2005 (Figure 1). Returning natural origin adults exhibit many life history pathways spending 1-4 years in freshwater and 1-4 years in the ocean based on scales collected by WDFW as of 2019 (Herr et al. 2020). The dominant life history of steelhead in Asotin Creek since 2005 has been fish that spend two years in freshwater and one or two years in the ocean (Herr et al. 2020).

Since 2010, returning adults have been captured at the adult weir and PIT tagged. PIT tagged adults can be detected if they enter study creeks. On average, 60% of the returning adults appear to spawn in the mainstem Asotin Creek, 17% in North Fork Asotin Creek, 7% in South Fork Asotin Creek, and 7% in Charley Creek based on PIT tag detections. As the adult escapement has declined it appears that the proportion of adults spawning in the mainstem Asotin Creek has increased and the proportion of spawning in the IMW study creeks has decreased.

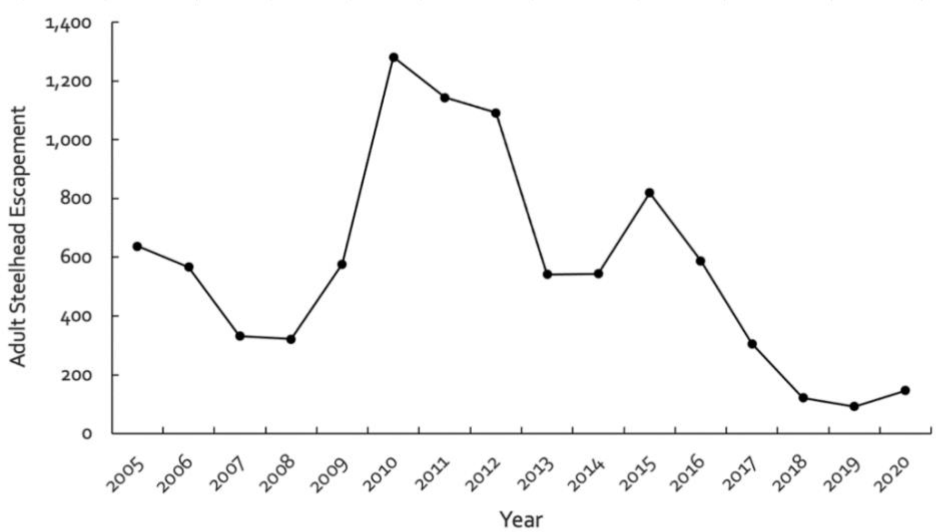


Figure 1. Adult steelhead escapement in Asotin Creek mainstem as determined by WDFW fish-in fish-out adult weir captures and PIT tagging: 2008-2020 (Herr et al. 2020).

Most juvenile steelhead emigration occurs in the spring with a second smaller pulse in fall (Figure 2). Age 2 juveniles dominate the spring emigration and age 1 juveniles dominate the fall emigration. Emigration in 2018 and 2019 were two of the three highest observed since 2004 and are generally attributed to density dependent effects related to low adult abundance and possibly more spawning and survival of resident steelhead offspring, many of which appear to produce anadromous offspring (Kendall et al. 2015).

Figure 2. Juvenile (≥ 70 mm steelhead emigrants from Asotin Creek as determined by WDFW rotary screw trap captures, PIT tagging, and population estimates (Herr et al. 2020). Estimates include emigration from Asotin Creek above George Creek confluence from 2004-2010 and estimates of Asotin Creek below George Creek confluence from 2011 onward (see Appendix A - maps of the watershed).

2.2 DISCHARGE AND TEMPERATURE SUMMARY

As reported previously, the average peak flows in the mainstem Asotin Creek pre-restoration were larger (652 cfs) than the average peak flows post-restoration (429 cfs; Figure 3). The peak 7-day maximum stream temperatures tend to be higher when peak flows are lower; however, we have observed complex relationships between flows (prior years and current years), air temperature, and stream temperature that may in part be due to significant contributions of springs to summer base flows. We have also observed that the timing and form of peak flows range widely from year to year. Peak flows have occurred from December through June and peak stream temperatures have occurred from June through August. The 2017 flow was the largest since restoration began and we observed significant geomorphic change and overbank flow as a result.

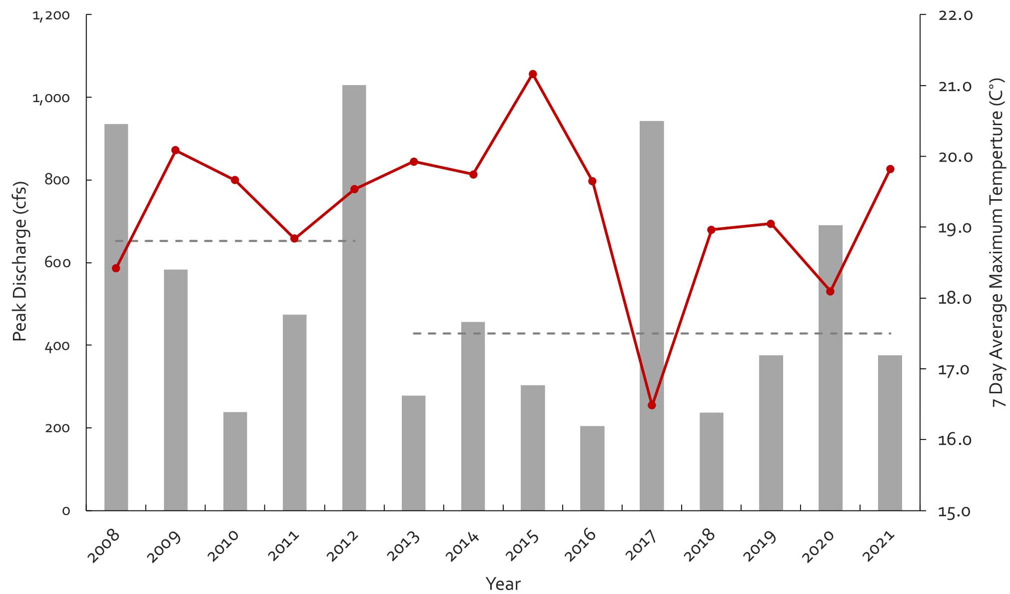


Figure 3. Asotin Creek mainstem peak discharge (bars) and peak 7-day maximum temperature by year (red line). Discharge data from USGS gauge #13334550 on Asotin Creek below confluence of North Fork and South Fork Asotin Creek. Temperature data from Asotin temperature monitoring on the mainstem Asotin Creek downstream of confluence between North Fork and South Fork Asotin creeks. Grey dashed line indicates the average peak flow prior to restoration (2008-2012) and post-restoration (2013-2021).

3. GOALS AND OBJECTIVES

The over-arching goal of the Asotin Creek IMW restoration is to mimic natural wood accumulations, promote the process of natural wood accumulation, and ultimately attain self-sustaining processes of wood recruitment, wood accumulation, dynamic and complex channel and floodplain conditions. We use the term "wood accumulation" deliberately here because it is a process that we are trying to restore. Large woody debris is important, but ultimately it is the movement of LWD and its accumulation in log jams that produce most of the ecological benefits (Wheaton et al. 2019). In our original restoration plan (Wheaton et al. 2012), we described the steps to accomplish these goals: namely addition of high densities of post-assisted log structures (PALS; called dynamic woody structures or DWS in Wheaton et al. 2012), seeding and trees (non-secured), implementation of an Adaptive Management Plan to determine when and how more LWD should be added, and riparian planting as a future source of LWD. Table 4 outlines the goals, objectives, and monitoring indicators we are using to track progress and restoration responses.

Table 4. Asotin Intensively Monitored Watershed project goals, objectives, and monitoring indicators.

Goals	Objectives	Monitoring Indicators
Increase channel hydraulic and geomorphic complexity	1. Install 654 post-assisted log structures (PALS)	1a. Wood accumulations (log jams and LWD frequency) 1b. Hydraulic diversity (visual estimates; constriction jets, shunting or splitting flows, etc.) 1c. Geomorphic unit frequency and area (bars, pools, planar features; Wheaton et al. 2015) 1d. Fish habitat complexity (cover, undercut banks, off-channel, riffles) 1e. Thalweg depth and channel variability
Maintain/Increase channel hydraulic and geomorphic complexity, promote LWD recruitment	2. Add more woody debris in form of PALS, brush, unsecured LWD, and whole trees to maintain or increase wood accumulations and force more hydraulic and geomorphic complexity as per the Adaptive Management Plan	2a. Wood accumulations (log jams and LWD frequency) 2b. Hydraulic diversity (visual estimates) 2c. Geomorphic unit frequency and area (bars, pools, planar features) 2d. Fish habitat complexity (cover, undercut banks, off-channel, riffles) 2e. Thalweg depth and channel width variability 2g. Tree recruitment/LWD frequency

Table 3 continued

Specific Goals	Objectives	Monitoring Indicators
Increase overbank flow, floodplain connectivity, and riparian extent	3. Wood additions as needed, and natural recruitment to force more frequent overbank flows	3a. Area of inundation at low flow and high flow 3b. Number of off-channel, side-channels, beaver dams 3c. Riparian extent/stage of treatment sections (i.e., Stage 0; Cluer and Thorne 2014) 3d. Normalized difference vegetation index (NDVI) to assess riparian productivity pre- and post-restoration in treatment and control sections (Silverman et al. 2018)
Increase the quality and eventually the amount of juvenile rearing and adult spawning habitat leading to increased freshwater capacity, production, and productivity of juvenile steelhead	4. Increase juvenile abundance, growth/feeding efficiency (i.e., more shear zones), survival, life history diversity, production, or productivity by creating flow, predation, and/or temperature refugia, and sediment sorting (i.e., improved spawning sites and egg survival), more habitat per km of valley, and ultimately self-sustaining Stage 8 (some inaccessible floodplain still exists) or Stage 0 (full floodplain connection)	4a. Juvenile abundance estimates 4b. Juvenile growth estimates 4c. Juvenile survival estimates (within treatment section and during outmigration) 4d. Age at migration (length of time in treatment stream and mainstem) 4e. Biomass (g/km), Production (g/km/period), Productivity (total smolts/section, smolts/spawner), Capacity (fish capacity/km; Net Rate of Energy Intake [NREI]; Wall et al. 2016, 2017)

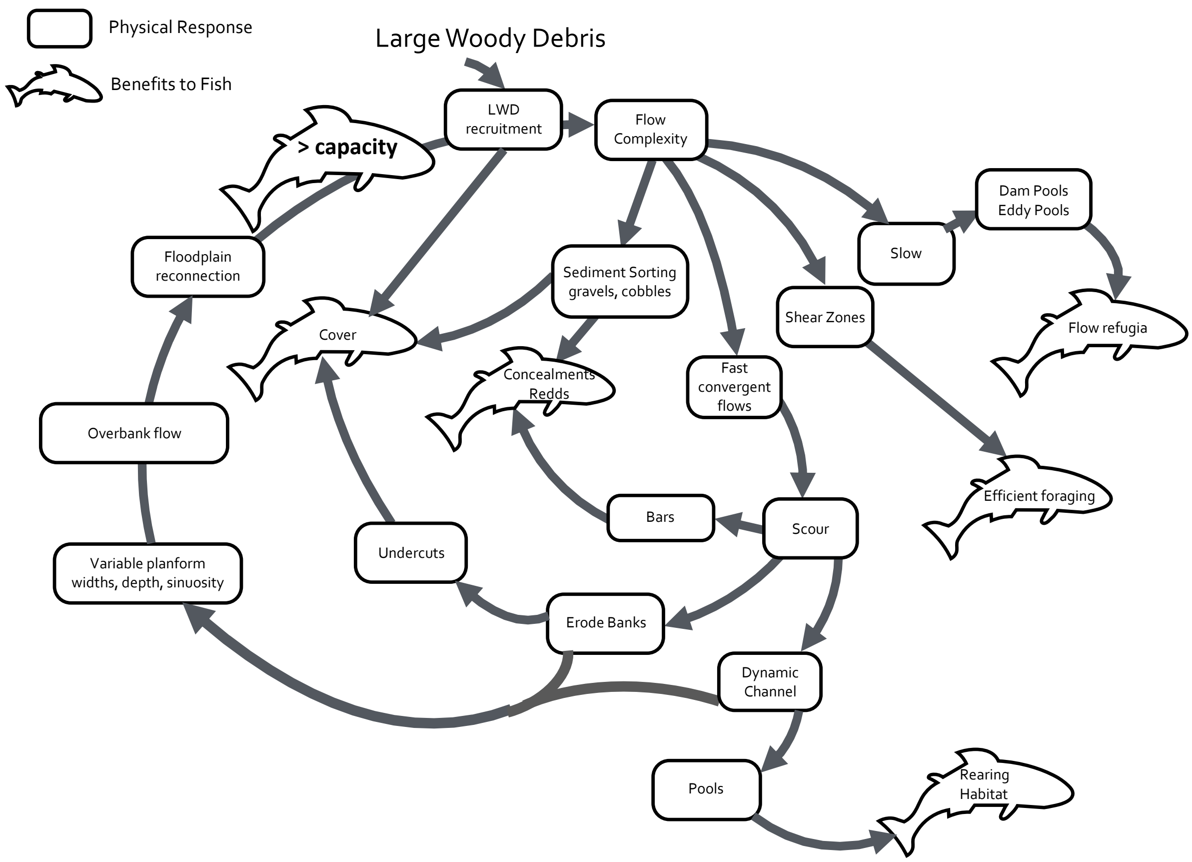


Figure 4. Conceptual diagram of hypothesized physical and fish responses to the addition of large wood. The right side of the diagram captures increases in channel complexity and the left-hand side captures increase in floodplain connection which ultimately increases the available habitat for fish per km of valley bottom and can lead to greatest increases in fish production.

4. RESTORATION ACTIONS

It is important to stress that the Asotin Creek IMW has borrowed from the experience and conclusions of the Bridge Creek IMW that was managed by Integrated Status and Effectiveness Monitoring Program and implemented by Eco Logical Research, Inc., NOAA Fisheries, and Oregon Department of Fish and Wildlife (Bouwes et al. 2016a, ISEMP 2018). We use a similar experimental design, survey methods, analyses, and most importantly, the same philosophy and approach to restoration referred to as ***low-tech process-based restoration of riverscapes***. We developed and refined the low-tech approach from the combined lessons of historic low-tech approaches (Kraebel and Pilsbury 1934), experience form Bridge Creek and Asotin IMWs, dozens of smaller low-tech restoration projects across the west (https://bda-explorer.herokuapp.com), and workshops (http://lowtechpbr.restoration.usu.edu/workshops/). Low-tech process-based restoration actions are not new, but we integrated the actions into the process-based approach to restoration, and developed a set of riverscape and restoration principles to help guide practitioners in designing, implementing, and assessing low-tech restoration (Wheaton et al. 2019). We briefly describe the restoration actions we have implemented and the low-tech approach we have used in the Asotin IMW, and encourage readers to review the manual for more details.

4.1 RESTORATION DESIGN AND APPROACH

The Asotin Creek IMW has a hierarchical-staircase experimental design which includes the lower 12 km of three tributaries: Charley Creek, North Fork Asotin Creek, and South Fork Asotin Creek (hereafter the study creeks; Appendix A). Each study creek is divided into three 4 km long sections and one section of each creek was treated (i.e., restoration applied) consecutively from 2012-2014 (Figure 5). Part of another section of South Fork Asotin Creek was treated in 2016 to increase the total restoration area to 14km of the 36 km study area (i.e., ~ 39% of study area is treated). Large wood restoration treatments were chosen as the main restoration action. Riparian areas are generally recovering throughout Asotin Creek (Bennett et al. 2018), but where riparian recovery is limited in the IMW study area (mainly lower parts of Charley Creek), riparian planting is being implemented to provide LWD recruitment in the future (see ACCD project in PRISM 13-1405). Only the effectiveness of the addition of LWD is being explicitly tested in the IMW.

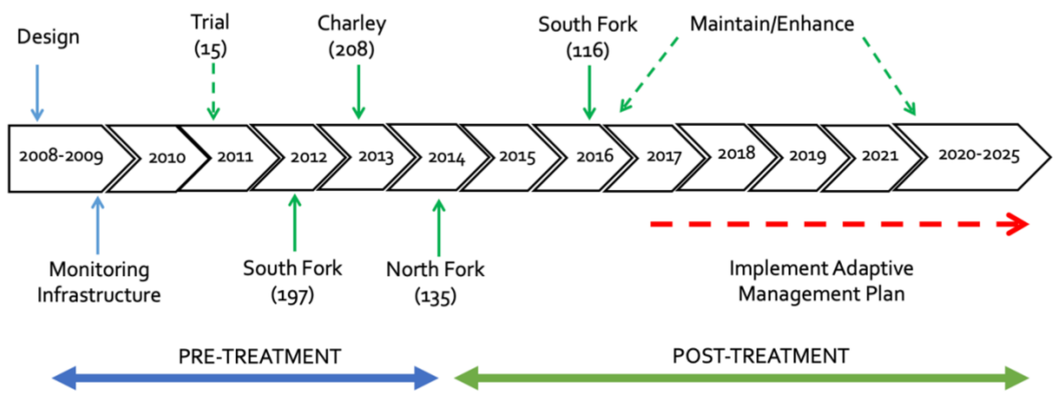


Figure 5. Timeline of design, implementation of monitoring infrastructure, and restoration actions by year and stream, pre- and post-treatment in the Asotin Creek Intensively Monitored Watershed.

The addition of LWD to streams to improve habitat complexity and quality is not a new restoration strategy (Kraebel and Pillsbury 1934, Thompson 2005). However, we argue that most projects place undue focus on the size and stability of LWD with frequent attempts to anchor LWD in place. From a stream or watershed perspective, we think that the low density of LWD is a much bigger problem than wood size, and streams with healthy rates of LWD recruitment see much more dynamic behavior in their LWD (i.e., it moves regularly). Therefore, in the Asotin IMW we are attempting to produce a population-level response in steelhead by treating 14 km of stream in three study creeks with almost 700 hand-built LWD structures. We expect this to fundamentally alter the complexity of habitat of four treatment sections inducing an increase in steelhead production and productivity at the stream scale.

Achieving the desired LWD densities with traditional treatment methods would be extremely expensive, highly disruptive to the existing riparian vegetation, and logistically and financially infeasible over the broad range of steelhead habitat in the Columbia Basin. Therefore, we are testing the effectiveness of a simple, cost-effective method of installing LWD using post-assisted log structures (PALS; low-tech process-based restoration; Wheaton et al. 2019). Post-assisted log structures that mimic wood accumulations (i.e., log jams) and are constructed using LWD that can be moved by hand and pinned in place by driving untreated wooden posts into the streambed using a hydraulic driver. The structures are designed to produce an immediate hydraulic response by constricting the flow width (Camp 2015). Like natural wood accumulations, alteration of the flow creates more hydraulic heterogeneity and increases the number of shear zones (i.e., areas with swift flow that abut areas of slow flow providing fish places with low swimming cost next to places with high rates of invertebrate drift). Moreover, the increase in hydraulic diversity produced by PALS is likely to promote aggradation, scour, sediment sorting, and the creation a diversity of bars and fish habitat (cover, spawning areas, etc.).

The fate of an individual structure is not as critical as the overall density of structures. A high density of PALS (e.g., 3-5 structures/100m) will increase the large-scale roughness of the stream creating much more variability in flow width and opportunities to build, alter, and maintain complex assemblages of active bar and pool habitat. Ideally, the high density of PALS will eventually initiate a more regular exchange of materials (sediment, water, LWD, etc.) with the adjacent riparian area and floodplain as PALS promote overbank flow, side-channel reconnection, aggradation, and slowing and attenuation of high flows. We have articulated these predicted responses into a series of explicit design hypotheses, which are guiding our monitoring efforts (Figure 4, Appendix B; Wheaton et al. 2012).

4.2 RESTORATION IMPLEMENTATION AND COST

We built 196 structures in South Fork section 1, 207 in Charley Creek section 2, 135 in North Fork section 1, and 116 in South Fork section 1 in 2012-2014, and 2016 (Figure 5, Table 5). The approximate number of pieces of LWD added to each treatment section was 2,000 pieces in the South Fork (section 1 and 2), 1,000 pieces in Charley Creek, and 750 pieces in North Fork. Approximately 5-10 times more small woody debris (<0.1 cm dbh) was added to the structures. Most structures we built were deflector PALS in all streams. On average the LWD structures are approximately 21 m apart or 4.7 LWD structures/ 100 m. In 2021, we focused maintenance on the North Fork and Charley Creek. In North Fork, we rebuilt 17 PALS that washed out of the treatment in 2019 and enhanced 22 existing structures by adding LWD and/or posts and wood (see PRISM Project 17-1304). In Charley Creek, we built 25 beaver dam analogs to promote more overbank flow and try increase the area of active floodplain. We also added five mainstem and 20 side-channel BDAs to Charley Creek in 2021 (Figure 8). We built BDAs to force overbank flow and floodplain connection at low flow with the intent of creating greater inundation and more volume of stream/km of valley bottom. We hypothesize that this will increase the production and productivity of Charley Creek from responses mainly to increases in channel complexity to responses to greater volume of stream/km of valley bottom. The trial of BDAs connected over 550 m of side-channels and inundated several hundred m2 of floodplain (Figure 8). We may expand the use of BDAs and large channel spanning PALS to further reconnect side-channels on Charley, North Fork, and South Fork if the existing treatments do not force more floodplain connection.

Figure 6 shows an example of a stream reach pre- treatment and post-restoration and Figure 7 shows examples of the type of PALS we built. The restoration actions we have implemented were relatively low cost compared to average stream restoration projects that add wood to streams. The initial restoration treatment of 14 km cost ~ $580,000 or ~$41,400/km which includes planning, design, permitting, wood material and transportation, equipment and construction costs (i.e., labor).

4.3 RESTORATION MAINTENANCE

We are implementing our adaptive management plan (Wheaton et al. 2012. Bouwes et al. 2016b) and maintaining or enhancing the exiting restoration treatments. We conducted maintenance and enhancement of the 14 km treatment area between 2016-2021 at a cost of ~ $100,000. The cost of maintenance in 2021 was $44,000. The initial treatments and ongoing maintenance were done using donated wood from the USFS and WDFW and we are combining forest thinning with wood collection to increase the efficiency of the treatments by providing a thinning service and reducing local fire risks. We anticipate one more $25-50,000 maintenance/enhancement round could push portions of the treatment area to Stage 8 or Stage 0 (i.e., near to complete floodplain connection, Cluer and Thorne 2104) for a total restoration cost of ~ $523,200 for the initial treatment and ~$150,00 for maintenance and enhancement (implemented and proposed) = $675,000 or $48,200/km total restoration costs.

Table 5. Summary of the type and count of large woody debris (LWD) structures 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	115	129	75	67	386
Mid-channel	17	38	31	17	103
Debris Jam	2	10	15	18	45
Seeding	50	30	14	14	108
Key LWD	12	0	0	0	12
Total	**196**	**207**	**135**	**116**	**654**

In 2021, we focused maintenance on the North Fork and Charley Creek. In North Fork, we rebuilt 17 PALS that washed out of the treatment in 2019 and enhanced 22 existing structures by adding LWD and/or posts and wood (see PRISM Project 17-1304). In Charley Creek, we built 25 beaver dam analogs to promote more overbank flow and try increase the area of active floodplain. We also added five mainstem and 20 side-channel BDAs to Charley Creek in 2021 (Figure 8). We built BDAs to force overbank flow and floodplain connection at low flow with the intent of creating greater inundation and more volume of stream/km of valley bottom. We hypothesize that this will increase the production and productivity of Charley Creek from responses mainly to increases in channel complexity to responses to greater volume of stream/km of valley bottom. The trial of BDAs connected over 550 m of side-channels and inundated several hundred m^2 of floodplain (Figure 8). We may expand the use of BDAs and large channel spanning PALS to further reconnect side-channels on Charley, North Fork, and South Fork if the existing treatments do not force more floodplain connection.

Figure 6. Example of treatment section pre- restoration (left) and as-built restoration (right) in South Fork Section 1.

Figure 7. Example of the three post-assisted log structure types (PALS) built in the Asotin Creek IMW. Top left = series of Bank-attached, top right = Mid-channel, and bottom picture = Debris Jam PALS.

Figure 8. Example of a beaver dam analogues built on the mainstem of Charley Creek (top left- view from downstream; and top right – view from upstream) that forced a side-channel connection of over 250 m (bottom photo). Multiple smaller BDAs were built in side-channel to inundate more floodplain and connect other side-channels. Stream is flowing left to right, mainstem is mostly obscured by riparian trees, and the side-channel is in the open.

5. ADAPTIVE MANAGEMENT

Generally, the Asotin IMW is an ideal situation for an experiment because there is only one landowner (WDFW), one focal species (steelhead) with very limited hatchery influence, and identifiable and specific type of habitat degradation (structural starvation). We are using an adaptive management framework to design, implement, monitor, and adjust the IMW experiment. We articulated a series of predicted short and long-term structure and habitat that could lead to fish responses, and used these predicted responses to develop explicit restoration design hypotheses (Bennett and Bouwes 2009, Wheaton et al. 2012, Camp 2015). These hypotheses are captured in conceptual diagrams we have developed for the addition of PALS in the short-term (1-5 years - Appendix B), and riverscapes and fish responses in longer term (5-10 years -Figure 4).

5.1 EVALUATION AND ADJUSTMENT

We annually evaluate, and if necessary, adjust our actions (monitoring or restoration) based on the responses (restoration, habitat, or fish) that we observe compared to our original hypotheses (Bouwes et al. 2016b). We started with a trial of the post-assisted log structures, then moved to a full implementation, and have since maintained or enhanced the restoration treatments (Figure 9). The initial treatments have resulted in increased channel complexity, overbank flow during high flow, and small to modest increases in fish abundance (Bennett et al. 2020). However, after several years of maintenance it was clear that floodplain connection during low flow is limited, and most of the channels are still single thread with limited sinuosity. We feel the results to-date provide an opportunity to test the effectiveness of expanding low flow floodplain connection by forcing more overbank flow at low water using beaver dam analogs (BDAs) or increasing wood loading to force side-channel connection. The goal of the maintenance is to evaluate if we can force an increase in active floodplain that results in increased inundation area and active channels (i.e., greater area/volume of water), that leads to greater increases in production.

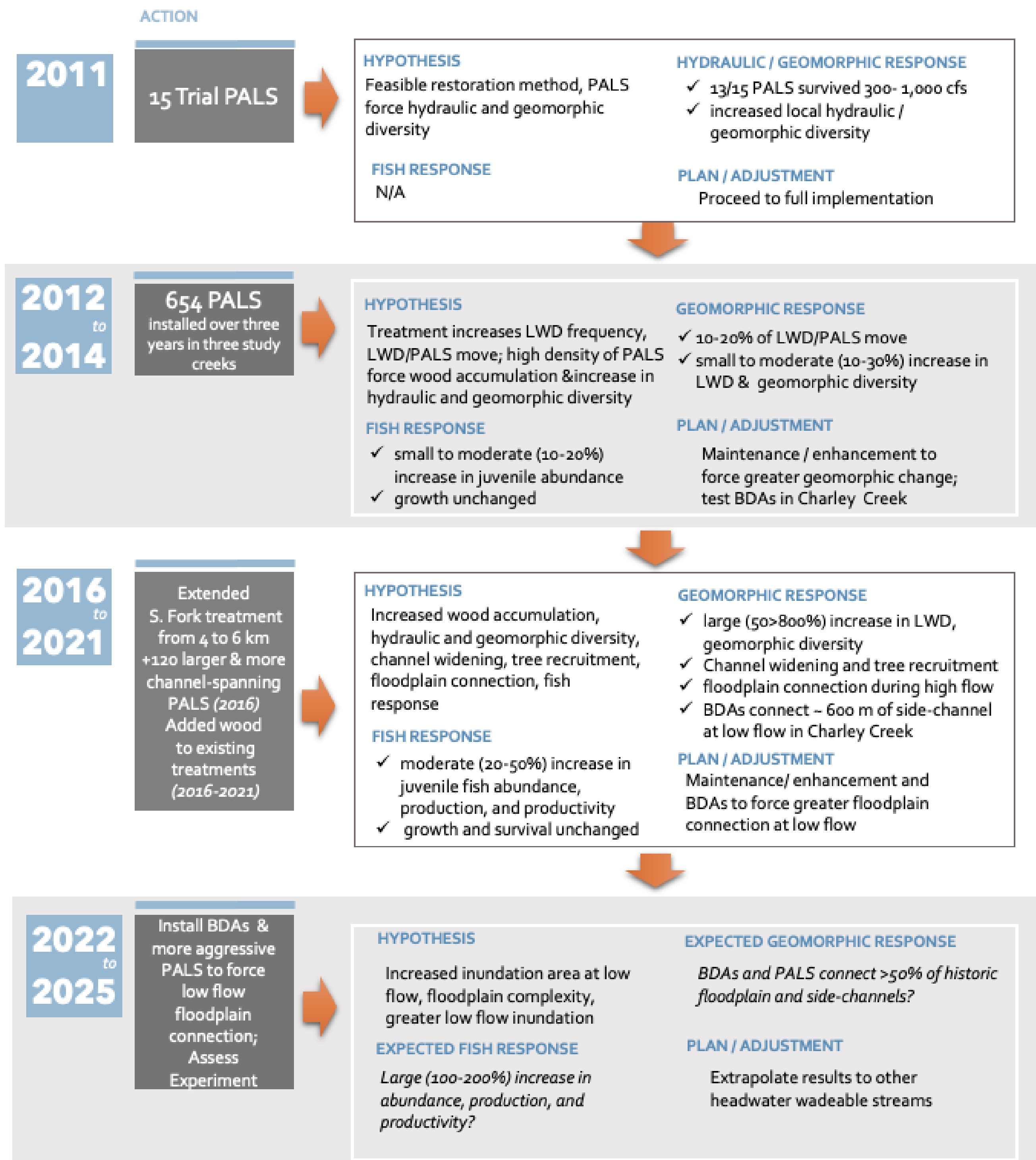


Figure 9. Adaptive management process for the Asotin IMW highlighting actions, hypotheses, habitat and fish responses, and adjustments from 2011-2025.

5.2 CHALLENGES

A large wildfire burnt over a large portion of the Asotin Creek IMW study area starting in July. The fire effectively closed the IMW study area for most of the summer preventing staff from completing normal habitat and fish surveys for most of July, August, and September. As such, we only collected fish abundance data for Charley Creek during our regular summer survey period. We were able to resume regular surveys at the end of September and completed a full set of fall juvenile fish tagging and rapid habitat surveys. The limited tagging in the summer may limit growth, survival, and production estimates next year as there will be less tagged fish to recapture or detect at PIT tag interrogation sites.

Both PIT interrogation sites at the mouths of the study creeks (AFC and CC; Appendix A) were damaged by the fire and were not operational from July 7th through December 20th, 2021. All equipment has been replaced by WDFW staff and is currently working. Luckily there is typically limited emigration of juvenile steelhead during the period when the sites were not working and we have two other interrogation sites on Asotin mainstem (ACB, ACM), so fire damage will have limited impact on our ability to enumerate migrants.

The fire severity was much less in most of the IMW study area compared to the upper watershed (Figure 10). Generally, in the IMW study area the hillsides were composed of grasses, herbs, and small shrubs and completely burnt. However, the riparian areas were dominated by deciduous trees (mainly alder and birch), and they mostly survived the fire with some isolated hotspots throughout. The upper watersheds, which were more dominated by dense stands of conifers, burnt on both the uplands and across the riparian areas. There is already evidence of bank failure, tree recruitment, and increased sediment delivery in the upper watershed. The fire could lead to significant sediment and wood delivery to the IMW which could lead to rapid aggradation and floodplain connection in treatment areas.

Figure 10. Example of fire impact on IMW study area in Charley Creek (left) and outside the IMW study are in the upper North Fork (right).

6. METHODS AND MONITORING INFRASTRUCTURE

We briefly describe the habitat and fish monitoring and analysis methods and any changes here. See Bennett et al. (2012, 2015) for more details. There are four PIT tag interrogations sites to detect tagged fish entering and leaving Asotin Creek and the IMW study creeks (Appendix A). WDFW operate an adult weir and smolt trap in the mainstem Asotin Creek near the mouth and they enumerate adult escapement and juvenile emigration. We also monitor temperature and discharge in the study creeks and there are USGS and DOE gauge stations on the mainstem (Appendix A).

6.1 HABITAT SURVEYS

6.1.1 Channel and Geomorphic Unit Surveys

From 2008-2009 we used the PACFISH IINFISH Habitat Monitoring protocol to monitor stream habitat (PIBO; Heitke et al. 2010). We switched to using the Columbia Basin Habitat Monitoring Protocol (CHaMP) to monitor instream, channel, and riparian characteristics at 18 permanent sites/year from 2011-2017 (Bouwes et al. 2011). The survey reaches are 160 m long in Charley and the South Fork and 200 m long in the North Fork. PIBO and CHaMP have similar definitions for key habitat metrics we are evaluating including: frequency of LWD and pools, residual pool depth, and variability in channel characteristics (thalweg, channel width and depth). We surveyed six CHaMP sites in each study creek – four in each treatment section and one in each control section (Appendix A). CHaMP were nested within the fish survey sites. The CHaMP protocol also included conducting a topographic survey of each habitat site. We created digital elevation models from the topographic survey data and used these data to assess changes erosion and deposition pre- and post-restoration (Wheaton et al. 2013). We also used the Geomorphic Unit Toolkit (GUT) to generate GIS reach maps of geomorphic units based on the topographic signature of geomorphic units (Figure 11) and quantify the number, area, and volume of geomorphic units (Wheaton et al. 2015, Williams et al. 2020, https://riverscapes.github.io/pyGUT/). A PhD student also assessed the influence of wood on geomorphic units using the CHaMP data (Sutherland 2020).

Since 2018, we have been using a rapid habitat survey to survey LWD, log jams, and geomorphic units because CHaMP is no longer supported by the Bonneville Power Authority. We increased the number of habitat sites we surveyed to 36 sites (three rapid habitat reaches in each fish site). These sites are the same lengths as the CHaMP sites and incorporate the 18 CHaMP sites we surveyed. We use the same definitions of LWD, debris jams, and pools from previous PIBO and CHaMP surveys. We visually identify geomorphic units using Wheaton et al. (2015) and estimate the length and width of geomorphic units and the volume of LWD jams and PALS.

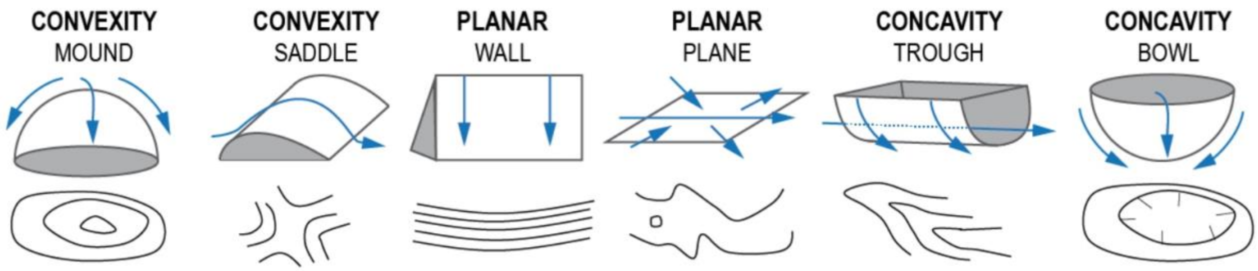


Figure 11. Shape, form, and topographic signature of Tier 2 geomorphic units identified using the Geomorphic Unit Delineation Tool (GUT) to analyze digital elevation models from Columbia Habitat Monitoring Protocol (CHaMP) topographic surveys (Wheaton et al. 2015, Williams et al. 2020). The same units are identified using rapid habitat surveys.

6.1.2 Floodplain Surveys

We are mapping out the pre- and post-restoration active floodplain to assess how well the restoration actions reconnect the floodplain. First, we identify the **Valley Bottom** – a low-lying area in a valley containing the stream channel and contemporary floodplain. The valley bottom represents the current maximum possible extent of channel movement and riparian areas. We then map the **Active Channel,** which is the area that is geomorphically activated by typical (i.e., 1-2 year) flows, and is characterized by sediment entrainment, deposition, and transport. It is identified by open water and the presence of bare surfaces that are the result of either scour or deposition, that have not been colonized by vegetation. We then map the **Active Floodplain** -which is the area within the valley bottom that is inundated by 5–10-year recurrence interval flows, and is generally capable of recruiting and supporting riparian vegetation. The remaining valley bottom is considered the **Inactive Floodplain,** which is the area which could flood under the current flow regime, but is disconnected, due to channel degradation. We used LiDAR collected pre-restoration, field surveys, and aerial imagery to map out these zones pre- and post-restoration to evaluate the increase in active channel and floodplain.

We also took advantage of the recent fire in the IMW study area and collected drone imagery of almost the entire study area in December (~ 36 km of flights). The lack of leaves reduced understory and canopy due to the fire, higher fall flows, and snow cover provided a greater view of the valley bottom than we have had since the start of the IMW. We will be mapping the active channel with this new imagery and comparing it to existing LiDAR to better understand how the restoration has influenced floodplain connection.

6.2 STRUCTURE EFFECTIVENESS SURVEYS AND WOOD MOVEMENT

We use a custom IOS App to map out hydraulic responses and geomorphic units upstream and downstream of each structure pre- and post-restoration. We standardized the survey by mapping the width and length of 1 bankfull channel width upstream and 1-6 bankfull channel widths downstream depending on spacing of structures and geomorphic responses. We used R packages to extract and quantify the number and area of geomorphic units around each structure. We also use these surveys to track wood movement. We tagged most of the wood we have added to structures with a numbered tags that corresponds to the structure the wood was added to. We recorded the number of tagged wood on or near structures during surveys. We used the georeferenced location of structures to determine how far wood had traveled using GIS. A PhD student also tagged wood in treatment and control areas that was added as part of the IMW and naturally occurring and used georeferencing to track the wood movement (Sutherland 2020).

6.3 FISH SURVEYS

6.3.1 PIT tagging, Abundance, Growth, and Age

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 are enhanced by WDFW monitoring of smolts and returning adults with the mainstem smolt trap and adult weir respectively (Herr et al. 2020).

To assess the direct effects of stream restoration we use a two-day mark-recapture survey to capture 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 tag juvenile steelhead at four sites in each study creek (12 total sites) and within each creek we sample two fish sites in control sections and two sites in treatment sections (Appendix A). Each fish site is visited twice a year during the summer (late June to July) and fall (late September to October). The two tagging sessions allow us to calculate the population parameters over shorter periods (i.e., summer to fall and fall to the following summer). We have also conducted 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, were used to calculate seasonal survival rates (Conner et al. 2014).

We calculate the length and weight growth (g or mm/day) of all fish captured at the beginning and end of the two capture seasons: summer to fall, and fall to the following summer.

We collect scales from a subsample of 10% of the fish captured during summer and fall surveys and use a Bayesian modeling approach to estimate the age of all fish based on the known age and length distribution at age of the subsample (Nahorniak 2012). We group fish into three age classes, 0, 1, and ≥2, because there are too few fish captured of age ≥ 3 to calculate most metrics.

6.3.2 Survival

We used Program Mark (Cooch and White 2010) to run the Barker model (Barker 1997) and data from our mark recapture PIT tagging surveys (summer and fall), mobile PIT tag surveys (winter and spring), and detections from the PIT tag arrays throughout Asotin Creek and the Columbia River Basin to estimate true survival. We estimated survival for fish remaining in the tributaries (i.e., tributary survival). We recently compared the results of the more parsimonious Cormack-Jolly Seber model (CJS; Seber 1992) to the Barker model and found the results to be very similar, so we have updated all our survival estimates using the CJS model. The Barker model estimates true survival (i.e., accounts for emigration) and we partially account for emigration in the CJS model by coding detections of emigrating fish detected at the PIT tag interrogation sites into the capture history. This essentially removes fish from further estimates of survival thus not biasing estimates low because the fish can no longer be recaptured at the site.

6.3.3 Biomass and Production

We are calculating biomass (g/km) and production (g/km/season) to integrate abundance, growth, and survival estimates as measures of freshwater productivity (Almodóvar et al. 2006). We calculate biomass at the beginning of each capture season by multiplying the abundance of fish (fish/km) in each age class, estimated by the mark-recapture surveys, by the average total growth (g/season) by a fish in each age class. We calculate the rate of production for each season (summer to fall and fall to summer) by multiplying the abundance at the beginning of the season for each age class by the average growth total growth (g/season) and the age specific survival estimate for the season. If restoration is increasing freshwater capacity and production, we should detect increases in biomass (i.e., standing crop) and production (rate of net growth per season).

6.3.4 Productivity

Juvenile/Smolt Emigration

We estimated the total number of steelhead smolts leaving the IMW tributaries as a measure of freshwater tributary productivity. We refer to these fish as smolts but recognize they can be a mixture of juveniles (i.e., pre-smolts) and smolts (i.e., migrants heading to the ocean). Previous IMW reports and analysis in this report demonstrate that many migrants leaving the tributaries may spend several months to more than a year in the mainstem Asotin Creek before migrating to the Snake River. Therefore, the best assessment of the effectiveness of LWD treatments may be the productivity as measured by fish leaving the tributaries because the fish that spend time rearing in the mainstem may be influenced by different conditions in the mainstem. However, we will calculate productivity by estimating the number of smolts leaving the Asotin Creek (that were produced in IMW tributaries) in future reports. The following steps were used to estimate productivity from the tributaries (see Appendix A for references to streams, sections, and sample sites, and ptagis.org for locations and configurations of PIT tag interrogation sites):

- estimate the total number of IMW tags detected leaving the tributaries (Charley, North Fork, South Fork)
- calculate the efficiency of each instream PIT tag array allowing us to expand the number of tag detections to an estimate of all tagged fish leaving each tributary
- calculate the abundance of juvenile steelhead in each IMW tributary using our summer and fall PIT tagging mark/recapture surveys at fish sites (completed 2008-2021) and expand these estimates up to the section and stream scale
- estimate the tagged to untagged ratio at each section (4 km long experimental unit), each year using the formula (New Tags)/(Abundance)

  - estimate the total number of smolts that left the IMW tributaries (Charley, North Fork, and South Fork) using the tagged/untagged ratio and the array efficiency (Array Detections/Detection Efficiency)/(New Tags/Abundance) assuming:
  - the survival rate for tagged and untagged fish is equal and tagged and untagged fish migrate at same rate
  - New Tagged Fish/Abundance is calculated at each site each year (and season)
- Above analysis is done for each year and age class and smolts are attributed to a brood year (migration year – age at migration) and year left (year they migrated)
- To date we have estimated total smolts from brood years 2009-2017 and smolts leaving from 2010-2020

Adult Escapement

We used the detection of adults entering the IMW tributaries as an index of adult abundance. Adults were PIT tagged either as juveniles, during ascending the Columbia or Snake River as they pass the dams, or at the WDFW adult weir as they enter Asotin Creek. We did not calculate smolts/spawner because there were years when no PIT tagged adults were detected entering some of the IMW study creeks.

6.3.5 Life History Expressions

We are also monitoring movement of PIT tag fish by documenting tag, recapture, and resight location. All tagging takes place at either the WDFW adult weir or smolt trap, or the 12 IMW fish sites located in the study streams (four fish sites per stream). Recaptures can occur at the original tagging site or other tagging sites and resights can occur at PIT tag interrogation sites within Asotin Creek (four sites) or within the Columbia River Basin hydrosystem. We use these different detections of PIT tagged steelhead to determine the time it takes for fish to migrate from tagging sites to the mainstem Asotin, travel down the mainstem Asotin to the Snake River, and migrate through the hydro system. We can also use tag detections to infer if some juvenile steelhead are resident if they are captured over multiple years and are not detected leaving the stream they were tagged in.

6.3.6 Analysis for Detecting a Treatment Response

For habitat and fish metrics where we have several years of pre- and post-restoration data in treatment and control sites, we use an ANOVA mixed effects model specifically designed for the staircase experimental design to assess the effect of the restoration (Loughin et al. 2021 *online*). The key part of this analysis is the *year after treatment* (YAT) factor. Because each stream was restored in a different year the statistical test compares responses in the different streams in the same YAT. The resulting test determines the % change in the treatment compared to the controls (both in stream and other stream controls). We provide 90% confidence intervals on the % change estimate, and when the intervals do not cross zero on the y-axis, the response (either negative or positive) is significant at $p<0.1$. The test also provides least squares means (LSM) estimates for each YAT by stream. Least squares means are a better measure of the population mean when there are missing values or unbalanced designs because they are computed using the staircase ANOVA model. We present the least squared means of each habitat and fish metric for YAT=0 (pre-restoration), YAT=≥ 1 (post-restoration, and the difference (treatment -control) to convert the % change into the increase or decrease in the original frequency (e.g., LWD/100 m) or rate (e.g., g/km/season). We then calculate the difference (treatment - control) to estimate the change in the metric (e.g., number of fish increase or decrease due to restoration).

7. RESULTS TO DATE

In 2020, we completed a high-level summary of the IMW results/outcomes and summarized available habitat and fish data collected over the project period (2008-2020; Bennett et al.2020). We cannot fully update the 2020 fish summaries due to the fire limiting our fish sampling effort in 2021 and lag time of getting scales read to estimate fish ages. Therefore, the 2021 high-level summary of fish data will be partial update to the summary presented in 2020 annual report. We will note where the results are reproduced from 2020 and where they are updated. We present new results on the effect of restoration on the number of migrants (i.e., smolts) leaving the study creeks and insights into the life history diversity of the IMW steelhead populations. The following section is divided into three parts: i) high-level results, ii) supporting habitat analyses, and iii) supporting fish analyses.

7.1 HIGH-LEVEL RESULTS SUMMARY

We have been successful in partnering with local stakeholders, seeking input from the Regional Technical Team, and selecting a good location for an IMW – this was the critical first step to implementing the IMW. We have since been able to develop a robust experimental design, implement a large and cost-effective series of restoration actions, conduct inexpensive maintenance and enhancement of the original restoration actions, consistently monitor fish and habitat attributes directly related to the goals and objectives of the project, develop analysis methods and tools to analyze the data, and are beginning to observe significant responses in habitat and fish metrics to restoration in treatment areas. We have done this all within a well-articulated Adaptive Management Plan where we detailed hypothesized responses and are now systematically testing these hypotheses. Table 6 summarizes the high-level results and interpretations as of December 31, 2021 related to the original goals and objectives, and the data available to make such conclusions as requested by the Monitoring Panel.

Table 6. Goals, results/outcomes, which variables have measures pre- and post-restoration actions, responses, and interpretation. Reponses are reported as a range in the three study streams by the percent change in treatment versus control and ranked from largest to smallest response by stream. As example, metric X had a positive response (i.e., increased in the treatment compared to the control) from 150-300% with SF>CC>NF (South Fork treatment had largest response, Charley intermediate, and North Fork the smallest response.

Specific Goals	**Result/Outcome**	**Data Available***	**Responses (% change in treatment compared to control)/Interpretation****
Increase channel hydraulic and geomorphic complexity	1a. Installation of 654 post-assisted log structures (PALS) resulted in increased wood accumulations and LWD frequency in all treatment sections 1b-c. Hydraulic and geomorphic diversity is higher in all treatment sections (more pools and bars, less planar habitat) 1d-e. Thalweg and width variability had minimal change in 2017	1a. CHaMP and rapid wood surveys pre and post restoration 1b-c. CHaMP, CHaMP Lite, rapid surveys 1d-e. CHaMP topographic data; future rapid surveys of control and treatment sections to collect depth and width profile (post–treatment only)	1a. Wood additions (PALS, brush, trees, and natural tree recruitment) have increased overall LWD frequency 153-1,025% (SF>NF>CC). LWD debris jams have increased 116-765% (SF>CC>NF) 1b-c. Geomorphic unit frequency is 13-104% higher in treatment versus control sites (SF>CC), but decreased in NF -13%. Pools frequency has increased 22-58% and bars increased (SF>CC>NF) 1d-e. Thalweg depth variability likely increasing marginally in treatment sections but needs further assessment; channel width increasing in NF and SF (~15-25%) but unchanged in CC
Maintain/Increase channel hydraulic and geomorphic complexity, promote LWD recruitment	2. Added approximately 2,000 pieces of LWD, over 100 trees, and thousands of SWD (brush) since 2016. Wood additions have helped maintain high wood density and continue to restore natural processes (e.g., sediment sorting, overbank flow, aggradation, scour, and lateral erosion)	2a-e. Same data as above	2a-e. Because the wood additions are strategic (replace wood where densities are low, force more change where change is already trending positive), the maintenance/ phased restoration approach is successfully increasing the overall treatment responses; however, the responses are variable and greater in areas of greater floodplain access

Table 6 continued

Specific Goals	Result/Outcome	Data Available*	Responses (% change in treatment compared to control)/Interpretation**
Increase overbank flow, side-channel and floodplain connectivity, and riparian extent	3. Have observed significant overbank flow in South Fork Section 1 during high flows in 2017 (video), and to a lesser extent in the other treatment sections in Charley and North Fork. Overbank flow is almost always confined to high spring flow periods (i.e., no sustained flows outside the main channel during low flow periods).	3a-c. Aerial imagery (drone, google earth, NAIP), LiDAR, field surveys, CHaMP (topographic data, auxiliary data, site maps) ** We are developing a simple monitoring protocol to better assess changes in overbank flow, floodplain connectivity, and riparian extent	3a. Area of inundation at low flow and high flow appear to be increasing but difficult to observe due to dense vegetation and short duration of overbank flows. Estimate 5-15% increase in low flow inundation area and more regular (1-5 year return interval) overbank flows. 3b. We have seen several new side-channels develop in treatment sections, especially South Fork Section 1; beaver activity has remained low but there are some signs (feeding and sightings) in the treatment reaches that suggest beaver activity may be increasing 3c. We plan to classify each section based on stream evolution stage pre- and post-restoration to see if there has been significant changes at the reach scale in riverscape condition (i.e., Stage 0 as per Cluer and Thorne 2014)

Table 6 continued

Specific Goals	Result/Outcome	Data Available*	Responses (% change in treatment compared to control)
Increase the quality and eventually the amount of juvenile rearing and adult spawning habitat leading to increased freshwater capacity, production, and productivity of juvenile steelhead	4. Increase juvenile feeding efficiency (i.e., more shear zones), flow, predation, and/or temperature refugia, and sediment sorting (i.e., improved spawning sites and egg survival), more habitat per km of valley, and ultimately self-sustaining Stage 8 (some inaccessible floodplain still exists) or Stage 0 (full floodplain connection)	4a-e. Summer and fall mark-recapture surveys (4 sites/stream, 2 treatment, 2 control), winter and spring mobile PIT tag surveys (same sites as mark-recapture), four PIT tag interrogation sites (at mouth of each study creek, and two on mainstem Asotin Creek), PTAGIS database, scale samples (~10% of all PIT tagged fish), age determination using Bayesian model based on known length/age relationship), adult redd counts and PIT tag detections, Net Rate of Energy Intake (NREI; Wall et al. 2016, 2017)	4a. Juvenile steelhead abundance increased 15-31% in summer and fall (NF>SF>CC). 4b. Growth rate across all streams and seasons decreased -43-72 % except CC growth in fall to summer which increased 113%. 4c. Survival from summer to fall and from fall to the following summer was unchanged (-1-18.4%). 4d. Age at migration was variable the proportion of Age 1 migrants decreasing in SF, Age 2 migrants increasing in CC, and Age 3 migrants increasing in NF 4e. Biomass increased in both summer and fall from 57-202% equally in all streams. 4e. Production was unchanged in all streams from summer to fall but increased in all streams 24-40% from fall to summer (SF & CC>NF) 4e. Productivity (smolts/brood year, total smolts/year) increased in all streams from 24-88%;

** numbers refer to goals and objectives from Table 4*
*** all results are based on pre and post surveys in treatment and control sections unless otherwise stated*

7.2 STRUCTURE EFFECTIVENESS AND INTEGRITY

7.2.1 Hydraulic Complexity

To create more geomorphic complexity in planar dominated systems, it is necessary to first force hydraulic diversity. We conducted detailed assessments of our predictions that additions of wood would force hydraulic complexity (Appendix B) by documenting the hydraulic conditions around each structure the year the structure was constructed and multiple times after high flows is subsequent years (Camp 2015). In general, we observed many of the hydraulic and geomorphic responses we predicted including creation of constriction jets that increase scour and lateral migration, eddies and shear zones that provide resting areas near areas of high food delivery for juvenile fish, and flow divergence.

7.2.2 Structure Effectiveness

The hydraulic changes we have observed around PALS is leading to changes in geomorphic unit composition around the structures and many of the hypothesized geomorphic responses are happening (Camp 2015, Sutherland 2020, Appendix B, C). Bank-attached PALS generally build bank-attached bars upstream of the structure on the bank the structure is attached to, scour pools downstream on the opposite bank, create plunge or eddy pools downstream, bank attached bars downstream on the bank the structure is attached to, and can develop riffles at the downstream end of the pools. Mid-channel PALS often split the flow and create mid-channel bars downstream of the structure. Channel-spanning PALS either fail at one end and become bank-attached PALS, develop large dam pools upstream, deep plunge pools downstream, and can aggrade the channel upstream if they become plugged with fine material and act like a BDA. Regardless of the structure type, bar and pool area tended to increase around structures and planar features tended to decrease.

7.2.3 Structure Integrity/Wood Movement

A concern of the PALS restoration actions was that the structures would only last 1-2 years and then wash downstream. However, we predicted that using wooden posts to secure the LWD would create a relatively stable log jam and installing high densities of structures would ensure that any structures that moved or LWD that washed off a structure would get caught on structures downstream (Wheaton et al. 2012). We tested these predictions by conducting annual surveys of structure integrity. In general, most PALS are intact or mostly intact, and many structures have grown as they accumulate natural LWD and wood from other structures (Figure 12). Approximately the same proportion of new log jams are forming as are structures that wash downstream (~10-20% depending on stream). We are also seeing that much of the wood that does move only moves 3-5 structures downstream (Sutherland 2020). We have also not observed or heard of any large wood accumulations downstream of the treatment sections in either the IMW control sites or outside the study area. We attribute this partly to the density of structures in the treatments and to the relatively small pieces of LWD we are using which are less likely to cause damage if they move outside of the IMW.

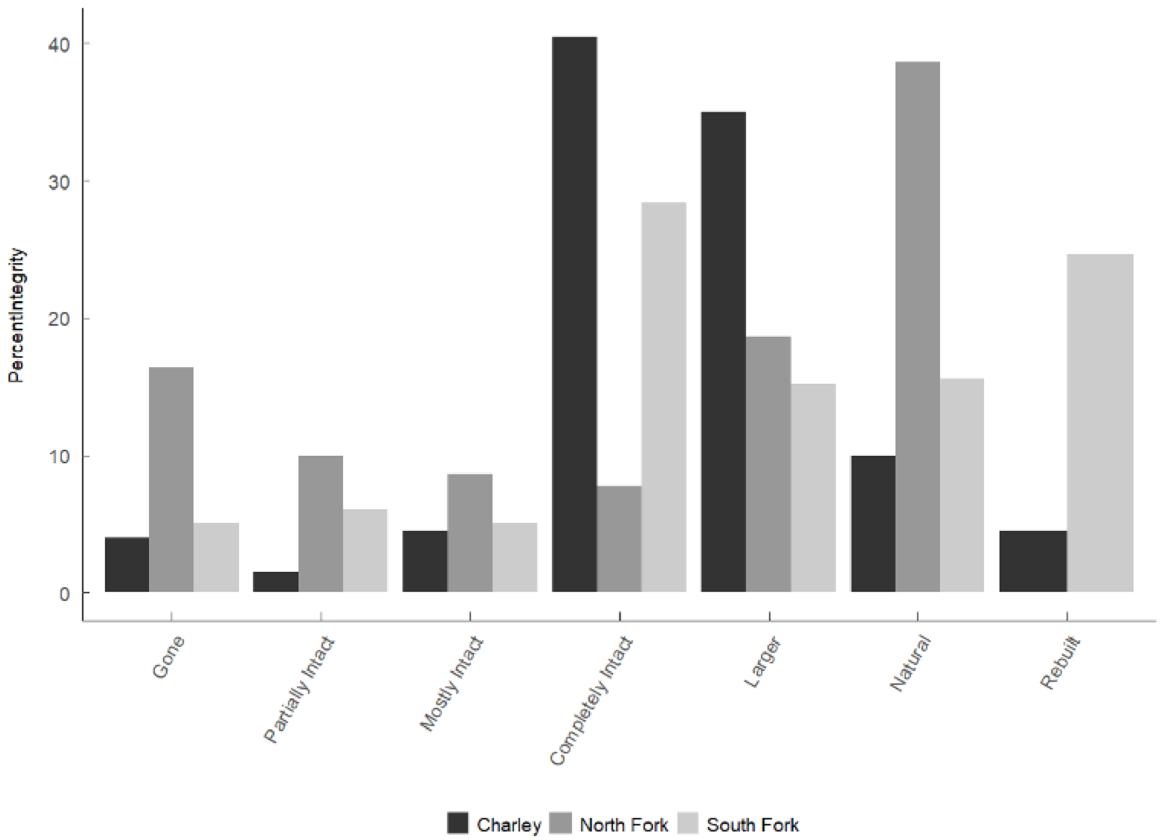


Figure 12. Percent of structures by category describing their integrity. "Larger" refers to structures that have increased 25% in volume due to wood accumulation and "New" refers to wood accumulations that have developed since the original restoration treatment from IMW wood, natural recruitment, or both (N = 750 in 14 km treatment area).

7.3 HABITAT

In the following section we provide a summary of the trends of key habitat metrics by treatment and control for each stream separately and all streams combined. Because of high annual variation within and between streams and the staircase design, it is difficult to see trends in the data summaries. We also provide a statistical analysis of the data using a linear mixed effects model which incorporates the complexity of the design into the analysis. These results are presented as the percent change of the treatment compared to the control. We provide 90% confidence intervals on the % change estimate, and when the intervals do not cross zero on the y-axis, the response (either negative or positive) is significant at p=0.1. We then present the least squared means of each metric for YAT=0 (pre-restoration), YAT=$\geq$ 1 (post-restoration, and the difference (treatment -control) to convert the % change into the increase or decrease in the original frequency (e.g., LWD/100 m).

7.3.1 Large Woody Debris and Debris Jams

Annual trends

LWD frequency was generally lower or similar in treatment sections compared to control sections pre-restoration and shows a steady increase after the initial restoration treatment and various levels of maintenance and enhancement (Figure 13). We also saw an increase in the frequency of LWD jams since restoration (Figure 14). The jams include the post-assisted log structures (PALS) we installed and jams that developed from PALS moving and reforming with naturally recruited wood to form new jams. We continue to observe variability at the individual fish and habitat site level with some sites in treatment sections having low LWD frequency and some control sites having large LWD frequency (Appendix D). This is likely due to wood movement, natural wood recruitment, variable effectiveness of structures, site specific conditions (i.e., site is in a narrower valley setting and may naturally short residence times for LWD), and a trend in all study creeks where the furthest upstream section (i.e., Section 3 which is a control in all three creeks) started in better condition and is trending towards recovery more than the downstream control sections.

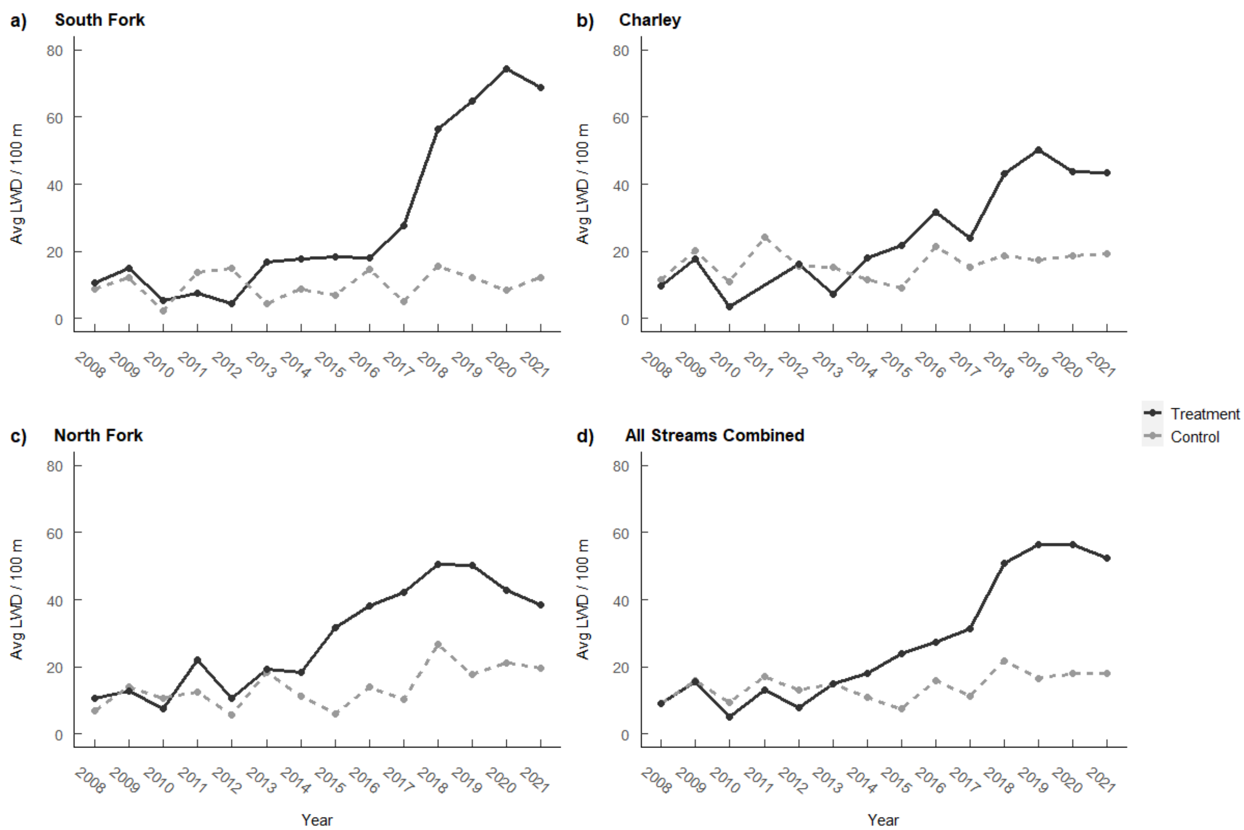


Figure 13. LWD frequency in treatment and control sections from in a) South Fork, b) Charley Creek, c) North Fork Creek and d) all streams combined: 2008-2021.

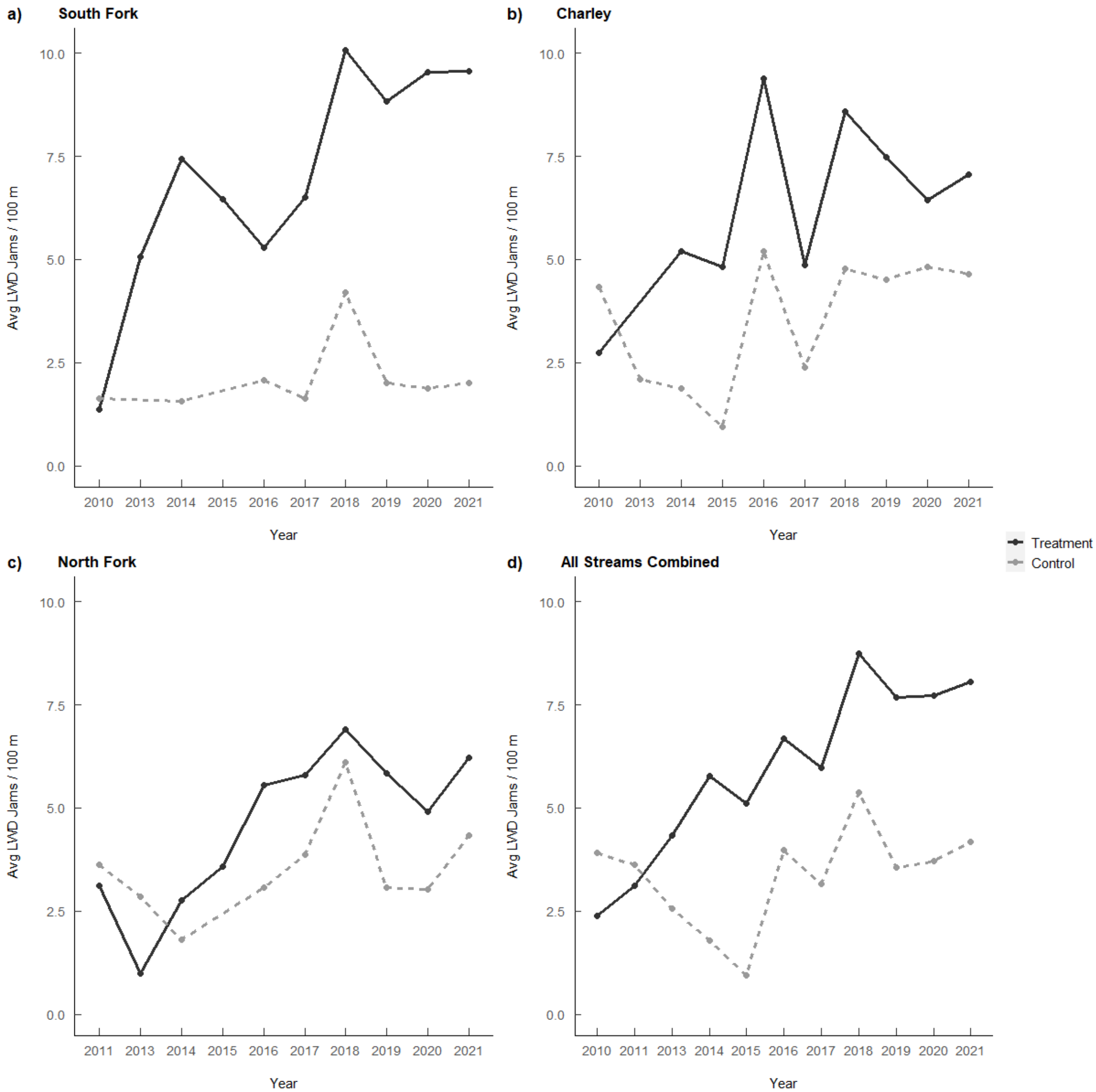


Figure 14. LWD debris jam frequency (jams/100 m) in control and treatment sections from in a) South Fork, b) Charley Creek, c) North Fork Creek and d) all streams combined: 2008-2021.

Treatment versus Control Comparison – LWD

There were large significant changes in LWD and LWD jam frequency in treatment sections compared to control sections in all streams (Figure 15). LWD frequency increased 153-1,025% ($p < 0.0001$) and jam frequency increased 116 to over 765% ($p < 0.02$). The average LWD frequency increased in treatment sections by 19.7-55.6/100m and the average jams in treatment sections increased by 2.3-5.5/100 m.

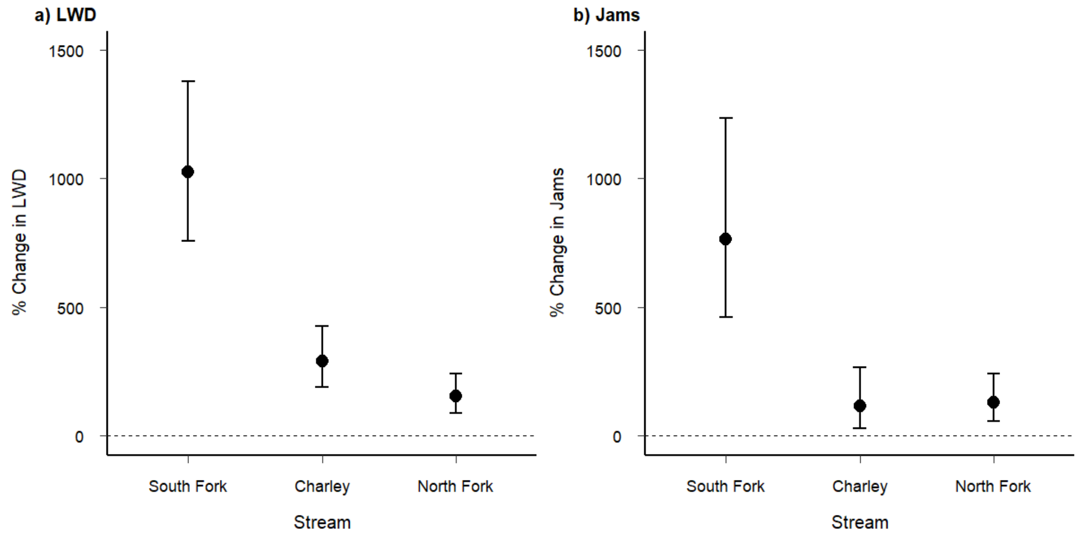


Figure 15. Percent change in a) large woody debris frequency (LWD/100 m) and b) LWD jam frequency (jams/100 m) in treatments compared to the controls pre- and post-restoration. LWD data collected from 2008-2021 and debris jam data collected from 2001-2020. Confidence intervals are 90% (α = 0.1).

Table 7. Least squares means of a) large wood frequency (LWD/100 m) and b) debris jams (jams/100 m) pre-restoration, post-restoration, and difference (treatment – control): 2008-2021.

a) LWD/100 m

Stream	Mean pre	Mean post	Difference
Charley	10.8	42.3	31.5
North Fork	12.9	32.6	19.7
South Fork	5.4	61.0	55.6

b) Jams/100 m

Stream	Mean pre	Mean post	Difference
Charley	2.0	4.3	2.3
North Fork	1.7	3.9	2.2
South Fork	0.7	6.2	5.5

7.3.2 Pools

Annual trends

In general pool frequency was lower or similar in treatment sections compared to control sections pre-restoration and shows a less consistent trend than LWD frequency (Figure 16). South Fork has a steep increase in pool frequency after the final treatment and maintenance in 2016 with little change in the control section. In Charley there is an increase in pool frequency in the treatment section post-restoration, but the pool frequency is increasing at a similar rate in control section. In the North Fork there is a general increase in pools in both treatment and control. We continue to observe high variability at the individual habitat site level with some treatment sites having low pool frequency and some control sites having large pool frequency (Appendix E). This is likely due to wood movement, natural wood recruitment, variable effectiveness of structures, site specific conditions (i.e., site is prone to creation of scour pools based on bed conditions or stream power), and a trend in all study creeks where the furthest upstream section (Section 3 which is a control in all three creeks) started in better condition and is trending towards recovery more than the downstream control sections.

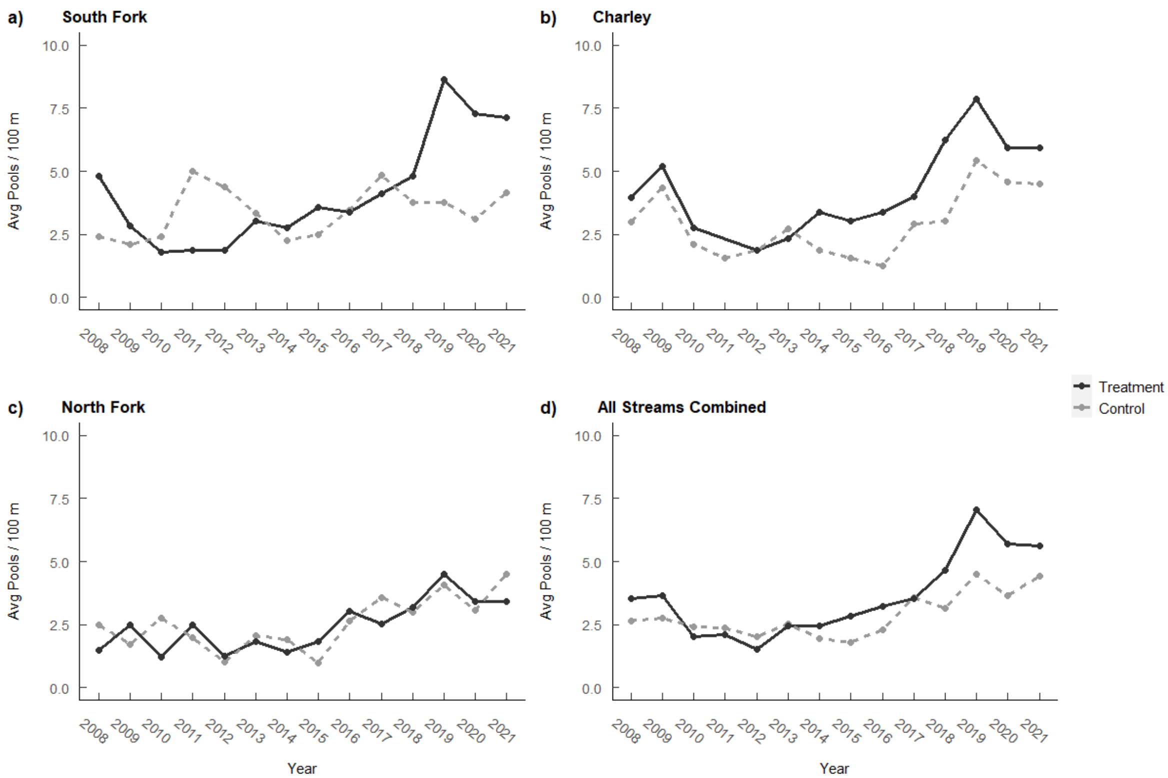


Figure 16. Trend in pool frequency in treatment and control sections in a) South Fork, b) Charley Creek, c) North Fork Creek and d) all streams combined: 2008-2021. Streams are ordered from first to last restoration implementation.

Treatment versus Control Comparison – Pools

There was a modest increase in the frequency of pools in treatment areas compared to control area in all streams (Figure 17). Pool frequency have increased from 22-58% (p 0.001-0.16). The average frequency of pools increased in treatment sections by 0.6-2.1/100 m.

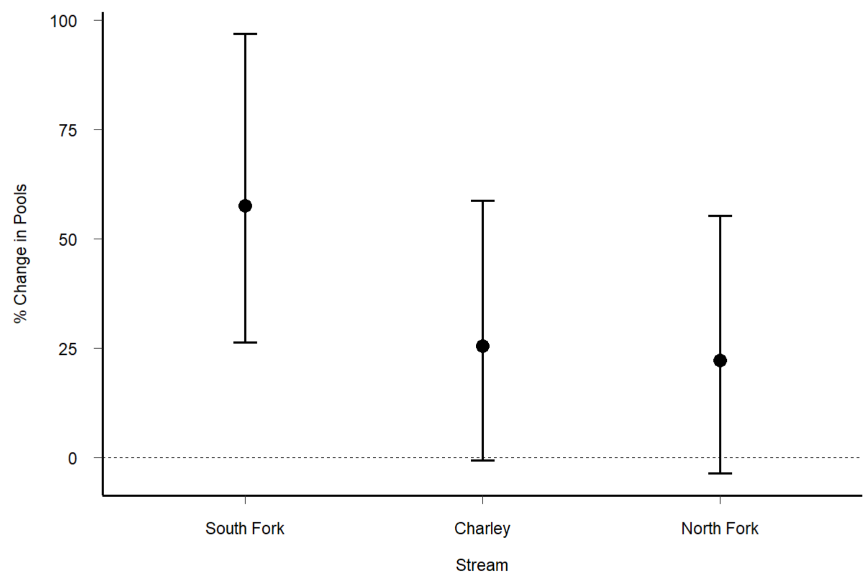


Figure 17. Percent change in pool frequency (pools/100 m) in treatments compared to the controls pre- and post-restoration based by stream: 2008-2021. Confidence intervals are 90% (α = 0.1).

Table 8. Least squares means of pools (pools/100 m) pre-restoration, post-restoration, and difference (treatment - control): 2008-2020.

Pools/100 m

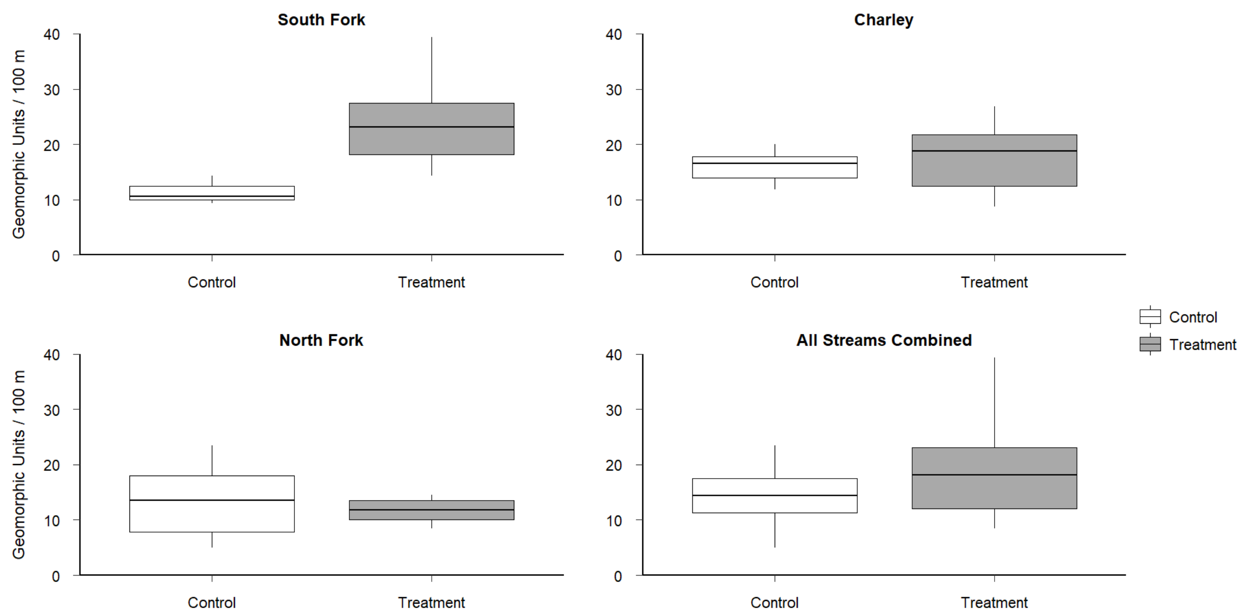
Stream	Mean pre	Mean post	Difference
Charley	3.7	4.6	0.9
North Fork	2.8	3.4	0.6
South Fork	3.6	5.7	2.1

7.3.3 Geomorphic Complexity

Unlike LWD and pools, we have not been surveying bars since the beginning of the IMW. However, we can derive geomorphic units from topography of the stream channel surveyed during 2011-2017 CHaMP surveys using the Geomorphic Unit Tool (GUT; http://gut.riverscapes.xyz; Appendix F). We still need to review and revise model outputs of GUT to determine the geomorphic composition pre-restoration in both controls and treatments (GUT mis-classified areas near banks as bars). In the meantime, we can infer geomorphic change by looking at the rapid habitat surveys in treatment and control sites (below), and the structure effectiveness surveys we conducted pre- and post-restoration around each structure (see Section 7.2). In the future, we will use GUT derived geomorphic units and rapid surveys of geomorphic units to develop a time series of geomorphic unit composition in control and treatment sections pre- and post-restoration.

Rapid Habitat Surveys

The frequency of all geomorphic units (pools, planar, and bars) decreased overall in 2021 although South Fork and Charley Creek geomorphic unit frequency in treatment areas compared to control areas indicating there is more geomorphic complexity due to the addition of wood to treatment sections (Figure 18, Appendix G – geomorphic unit frequency). The higher number of units is the result of large planar units being broken up into bars and pools, and as a result planar unit frequency has also increased, but planar area has decreased in treatment sections (Appendix G). The area of bars and pools is higher and the area of planar is lower in all treatment areas compared to control areas (Appendix G – geomorphic unit area).



Summary Statistics

Stream	Description	mean	median	min	q1	q3	max	sd	CV	n
South Fork	Control	11.5	10.6	9.4	10.0	12.5	14.4	2.6	0.2	3
South Fork	Treatment	23.5	23.1	14.4	18.1	27.5	39.4	7.7	0.3	9
Charley	Control	16.0	16.6	11.9	13.9	17.8	20.0	3.1	0.2	6
Charley	Treatment	17.7	18.8	8.8	12.5	21.7	26.9	6.9	0.4	6
North Fork	Control	13.5	13.5	5.0	7.9	18.0	23.5	7.2	0.5	6
North Fork	Treatment	11.7	11.8	8.5	10.0	13.5	14.5	2.4	0.2	6
All Combined	Control	14.1	14.4	5.0	11.2	17.5	23.5	5.1	0.4	15
All Combined	Treatment	18.5	18.1	8.5	12.0	23.1	39.4	7.9	0.4	21

Figure 18. Frequency of geomorphic units (units/100 m) in control and treatment sections, pre- and post-restoration by stream and all streams combined based on rapid habitat surveys of 36 habitat sites in 2021 over 3.2 km.

7.3.4 Floodplain Connection

We have completed a preliminary assessment of floodplain connection by mapping out valley bottom features (active channel, active floodplain, and active side-channels) pre-restoration (Wheaton et al.

2019; https://riverscapes.xyz/Data_Warehouses/). In 2021, we collected drone imagery over most of the IMW study area (~ 36 km) after the fire and plan to map out these same features and compare floodplain connection pre- and post-restoration. This analysis will mostly focus on the areas of floodplain that are active during low flow conditions because it is difficult to assess high flow floodplain connection because it generally last only a few days to weeks and is hard to delineate once the water has receded.

7.4 JUVENILE STEELHEAD RESPONSE

In the following section, we provide a summary of the trends of key juvenile steelhead metrics by treatment and control for each stream. Because of high annual variation within and between streams it is difficult to see trends in the data summaries. The results are not separated by age to reduce the number of figures and tables, and to first look at the overall response off all ages combined. All measurements can be separated by the three age classes (Age 0, 1, ≥2) and we looked at growth and survival by age in 2020 and did not see any differences, so unless otherwise stated the following analyses are grouped by all ages. Estimates that are not rates (e.g., abundance, biomass, smolts) are collected either during the summer and fall (abundance, biomass) or annually (smolts). Estimates that are rates (e.g., growth, survival, production) are estimated in two periods: summer to fall (mean 106 days), and fall to the following summer (mean 310 days). We standardize the time in these two periods by dividing by 90 days and present results by season (summer or fall). We also provide a statistical analysis of the data using a linear mixed effects model which incorporates the complexity of the staircase design into the analysis. These results are presented as the percent change of the treatment compared to the control. We also present the least squared means (LSM) of each metric for Year After Treatment or YAT=0 (pre-restoration) and YAT=≥ 1 (post-restoration), and the difference (treatment -control) to convert the % change into the increase or decrease in the original frequency (e.g., fish/km) or rate (e.g., g/season).

7.4.1 Summer and Fall Abundance

We have conducted mark-recapture estimates in the summer and fall at fish sites in each study creek and have an almost uninterrupted data series from 2008-2021 (Figure 19). However, in 2021 a large fire (>80,000 acres) swept across the IMW study area in July and prevented summer mark-recapture surveys on North Fork and South Fork creeks. We were able to conduct regular fall mark-recapture surveys on all three streams. Fall abundance estimates are typically larger than summer because young-of-year are generally too small to tag (< 70 mm) in the summer, but often attain tagging size (> 70 mm) by fall. There is limited annual variability in juvenile abundance in each stream despite large differences in the number of returning adults (Figure 1, Figure 19). More variability is evident within streams (Appendix H). Generally, there is an increase in abundance in treatment sections post-restoration in both seasons whereas the control sections decrease or stay the same.

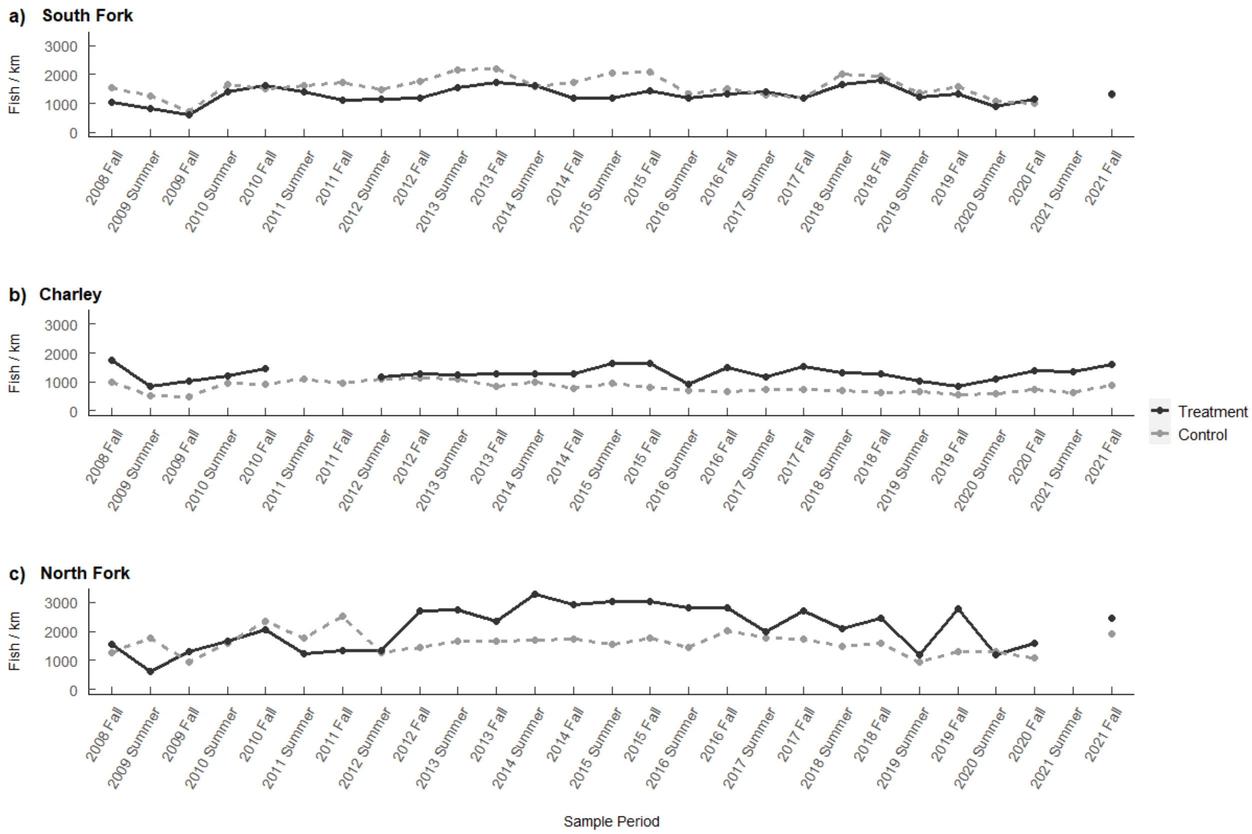


Figure 19. Average fish abundance (fish/km) by stream in treatment control sections: 2008-2021. Sample periods include one 2-day mark-recapture survey per fish site in the summer (July) and fall (late September to mid-October) every year except 2008 when only a fall survey was conducted.

Treatment versus Control Comparison – Juvenile Abundance

All streams have a positive increase in juvenile steelhead abundance in both the summer and fall (Figure 20). Abundance increased from 14.7-30.6% in the fall (p 0.01-0.22). Average abundance increased by 133-527 fish/km in the treatment sections post-restoration (Table 9).

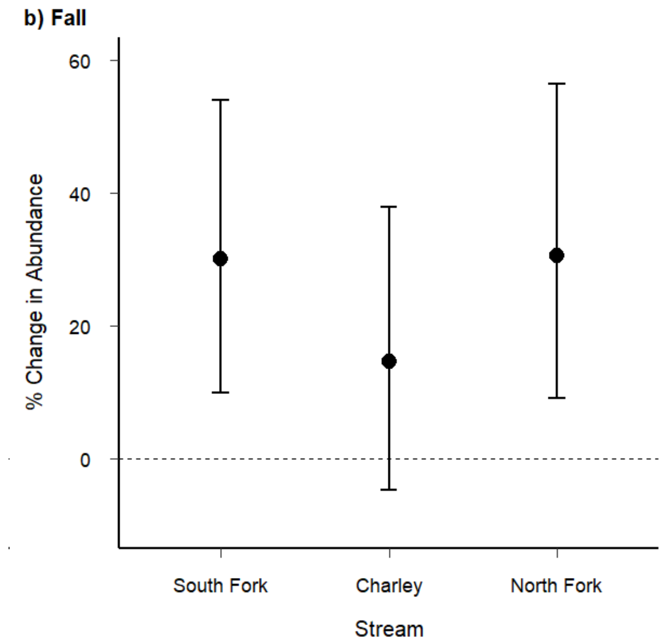


Figure 20. Percent change in juvenile steelhead abundance (fish/km) in the treatments compared to the controls pre- and post-restoration for b) fall mark-recapture surveys: 2008-2021. No estimates were available for South Fork and North Fork in the summer because mark-recapture surveys could not be conducted because of a fire in the study area.

Table 9. Least squares means of juvenile steelhead abundance (fish/km) pre-restoration, post-restoration, and difference (treatment - control) for fall mark-recapture abundance estimates: 2008-2021.

	Steelhead/km		
Stream	Mean pre	Mean post	Difference
Charley	907	1,039	133
North Fork	1,725	2,252	527
South Fork	1,192	1,510	318

7.4.2 Growth

We calculated average absolute growth (g/Season) of PIT tagged juvenile steelhead from summer to fall and fall to summer. We collected 27,590 measures of individual growth between 2008-2020 We are not presenting growth rates for 2021 because no summer surveys were completed for North Fork and South Fork due to fire restrictions). The summer to fall growth season was marked by very low growth rates in all streams in both treatment and control sections (Figure 21). Growth rate tended to be higher in the lower reaches in each stream (i.e., low fish site numbers F1 and F2; Appendix I). Treatment sections in all streams had lower growth rates post-restoration in the summer and mixed responses in the fall (Appendix I).

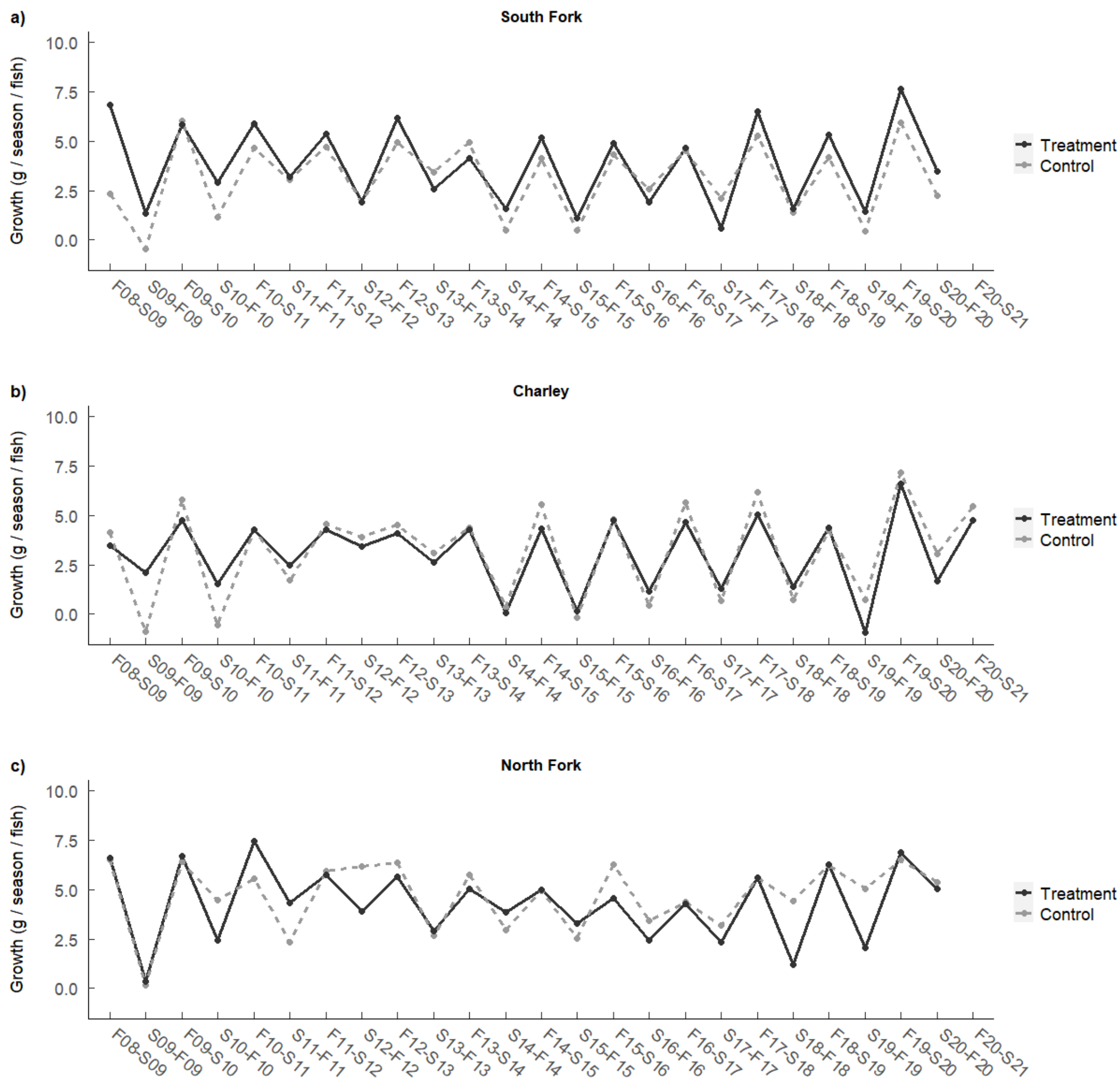


Figure 21. Average juvenile steelhead growth rate (g/season/fish) by stream in treatment control sections: 2008-2021. Sample seasons are Summer to Fall (e.g., S09-F09) and Fall to Summer (e.g., F08-S09).

Treatment versus Control Comparison – Juvenile Growth

There was a trend for treatment sections in all streams to have lower growth rates than control sections in the summer season (Figure 22). In the fall to summer season there were mixed effects in the treatment sections. In summer to fall season, the treatment section growth rate decreased from -43.4 to -72.3% (p 0.3-0.4). In the fall to summer season, the treatment section growth rate increased in Charley 113.1% and decreased in North Fork -15.8%, and South Fork by -23.7% (p 0.1-0.8). Average summer to fall growth rate decreased 0.43-0.72 g/season in the treatment sections post-restoration. Average fall to summer growth rate decreased -0.16-0.24 g/season in the North Fork and South Fork treatment sections and increased 1.1 g/season in Charley Creek post-restoration (Table 10).

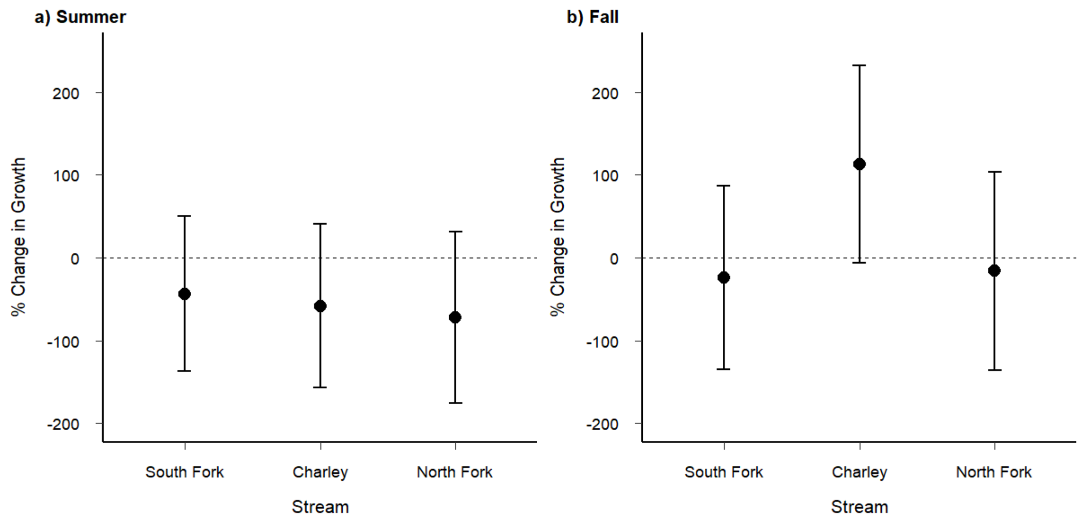


Figure 22. Percent change in juvenile steelhead growth rate (g/season) in the treatments compared to the controls pre- and post-restoration from a) summer to fall and b) fall to summer: 2008-2020.

Table 10. Least squares means of juvenile steelhead growth rate (g/season) pre-restoration, post-restoration, and difference (treatment – control) from a) summer to fall and b) fall to summer: 2008-2020.

a) Summer to Fall		**g/Season**	
Stream	Mean pre	Mean post	Difference
Charley	1.15	0.57	-0.58
North Fork	3.39	2.67	-0.72
South Fork	1.95	1.52	-0.43
b) Fall to Summer			
Stream	Mean pre	Mean post	Difference
Charley	4.4	5.5	1.13
North Fork	5.3	5.2	-0.16
South Fork	5.1	4.9	-0.24

7.4.3 Survival

We calculated survival rate by season using the CJS survival model and captures histories including PIT tag interrogation sites detection of fish leaving the study streams. We reran the analysis this year without including age (i.e., survival calculated for all age classes lumped) because we found no differences in survival across age classes in previous analyses (Bennett et al. 2020). Survival rates were generally high (~0.75) in the summer to fall season and low (~0.30) in the fall to summer season, but relatively consistent from year to year in both seasons (Figure 23Figure 23). Survival rates tended to be similar across all sites within each stream (Appendix J).

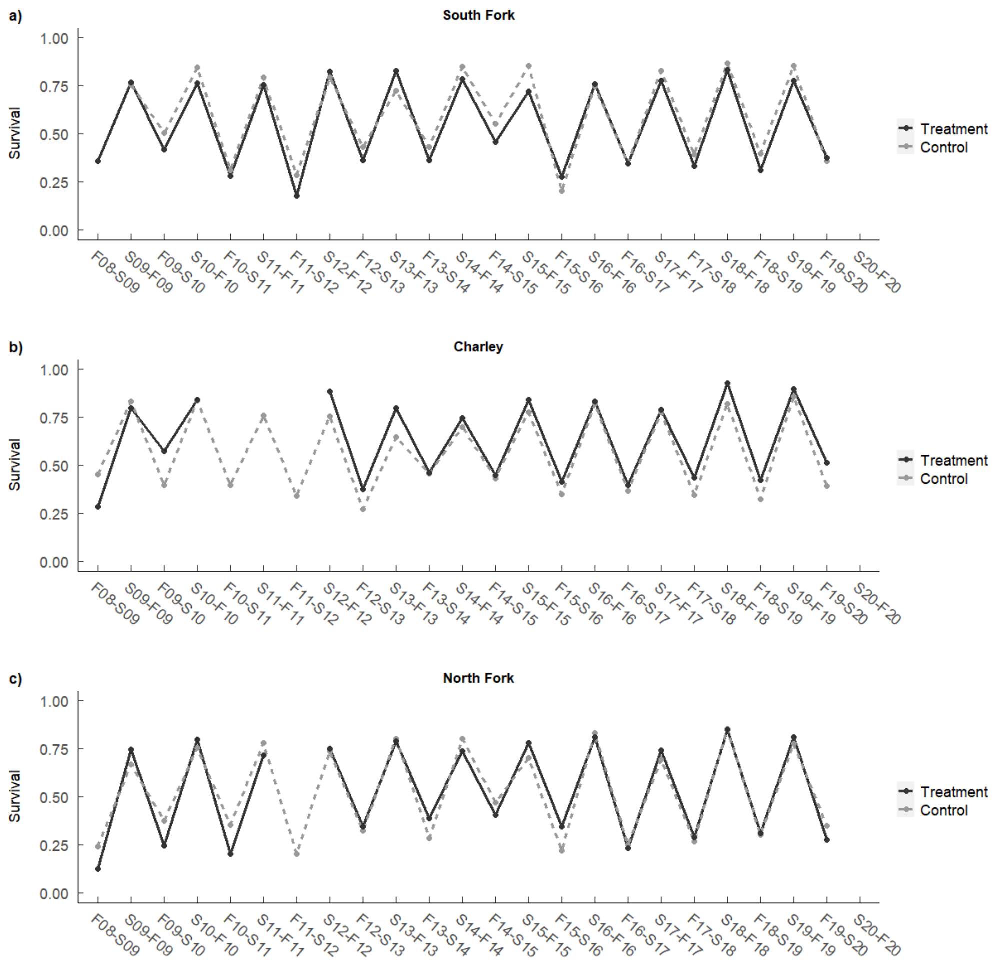


Figure 23. Average juvenile steelhead survival rate/period by stream in treatment control sections: 2008-2020. Survival seasons are Summer to Fall (e.g., S09-F09) and Fall to Summer (e.g., F08-S09).

Treatment versus Control Comparison – Juvenile Survival

There did not appear to be any change in survival in any of the streams in either the summer to fall or fall-summer seasons (Figure 24). The percent change in survival in treatment sections ranged from -2.9-4.2%

(p 0.14-0.7) in the summer-fall season and from 1.2-2.6% in the fall to summer season. The percent change in survival in treatment sections ranged from -0.06-0.09% in the summer-fall season and from 0.02-0.05% in the fall to summer season (Table 11).

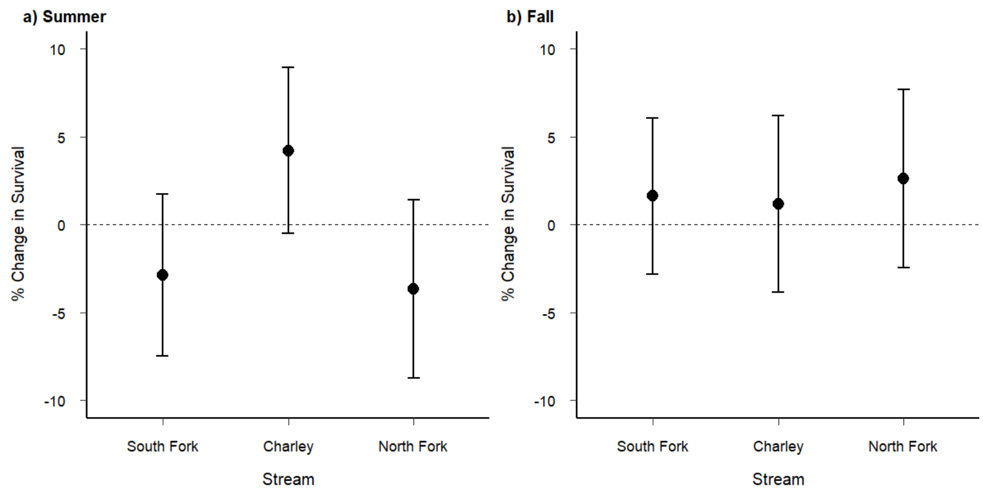


Figure 24. Percent change in juvenile steelhead survival rate/season in the treatments compared to the controls pre- and post-restoration from a) summer to fall and b) fall to summer: 2008-2018.

Table 11. Least squares means of juvenile steelhead survival rate (g/season) pre-restoration, post-restoration, and difference (treatment – control) from a) summer to fall and b) fall to summer: 2008-2018.

a) Summer to Fall		**season**	
Stream	Mean pre	Mean post	Difference
Charley	2.18	2.28	0.09
North Fork	2.11	2.03	-0.08
South Fork	2.17	2.11	-0.06
b) Fall to Summer			
Stream	Mean pre	Mean post	Difference
Charley	2.07	2.09	0.02
North Fork	1.97	2.02	0.05
South Fork	2.02	2.05	0.03

7.4.4 Biomass

We calculated the biomass of juvenile steelhead (g/km) in the summer and the fall. Biomass in treatment sections generally increased over time in all streams (Figure 25). Biomass tended to be more variable between sites, season, and year within each stream than other metrics (Appendix K). Biomass tended to go up in treatment sections across all streams relative post-restoration and stay the same or decrease in control sections.

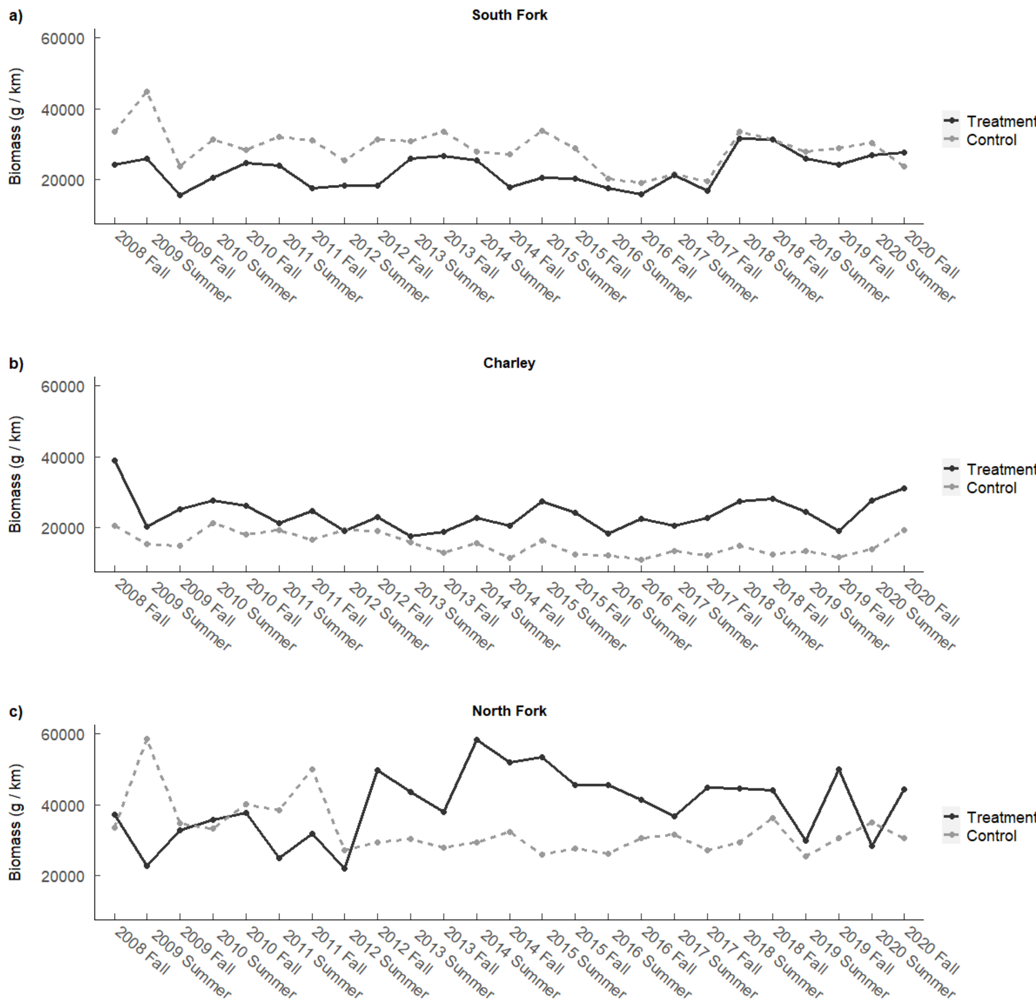


Figure 25. Average biomass of juvenile steelhead (g/km) by stream in treatment control sections: 2008-2020. Biomass measured each year in the summer (e.g., S09) and Fall (e.g., F08).

Treatment versus Control Comparison – Juvenile Biomass

All streams have a positive increase in biomass in both the summer and fall (Figure 20). The percent increase range from 32.7-36.2% (p 0.02-0.14) in the summer and 18.6-40.1% in the fall (p 0.002-0.13). The average biomass increased by 6,358-10,449 g/km in the treatment sections post-restoration in the summer season and 3,250 -9,601 g/km in the fall season (Table 12).

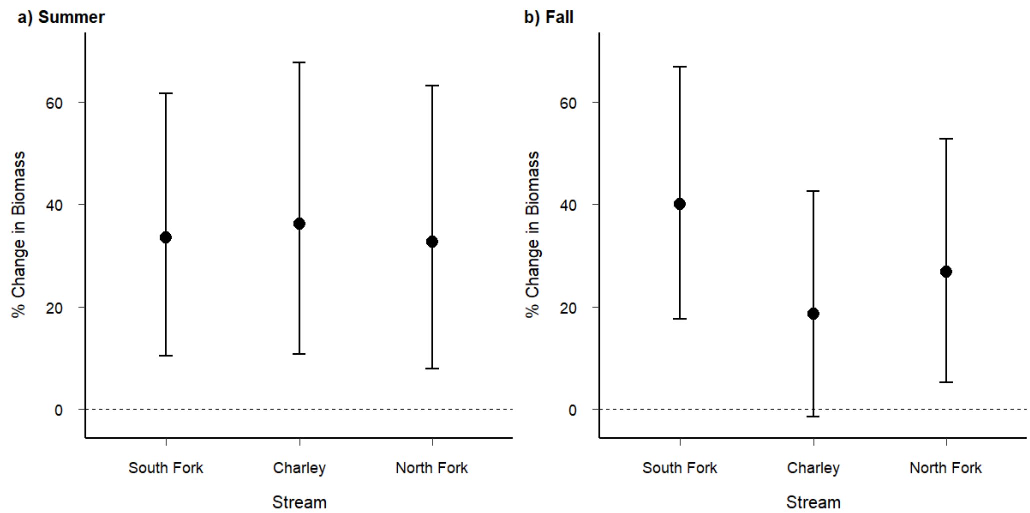


Figure 26. Percent change in juvenile steelhead biomass(g/km) in the treatments compared to the controls pre- and post-restoration for a) summer and b) fall: 2008-2020.

Table 12. Least squares means of juvenile steelhead biomass (g/km) pre-restoration, post-restoration, and difference (treatment - control) for a) summer and b) fall: 2008-2020.

a) Summer		**g/km**	
Stream	Mean pre	Mean post	Difference
Charley	17,546	23,904	6,358
North Fork	32,912	43,691	10,449
South Fork	23,163	30,937	7,774
b) Fall			
Stream	Mean pre	Mean post	Difference
Charley	17,515	20,764	3,250
North Fork	35,897	45,498	9,601
South Fork	21,024	29,459	8,435

7.4.5 Production

We calculated average production (g/km/season) juvenile steelhead over summer to fall and fall to summer seasons. Production was consistently lower in the summer to fall season. The summer to fall production season was marked by low production in all streams in both treatment and control sections (Figure 27). Treatment sections in all Charley and North Fork creeks had higher production rates post-restoration in both seasons. Production rate tended to be relatively consistent within streams and fish sites, but North Fork production varied the most (Appendix L).

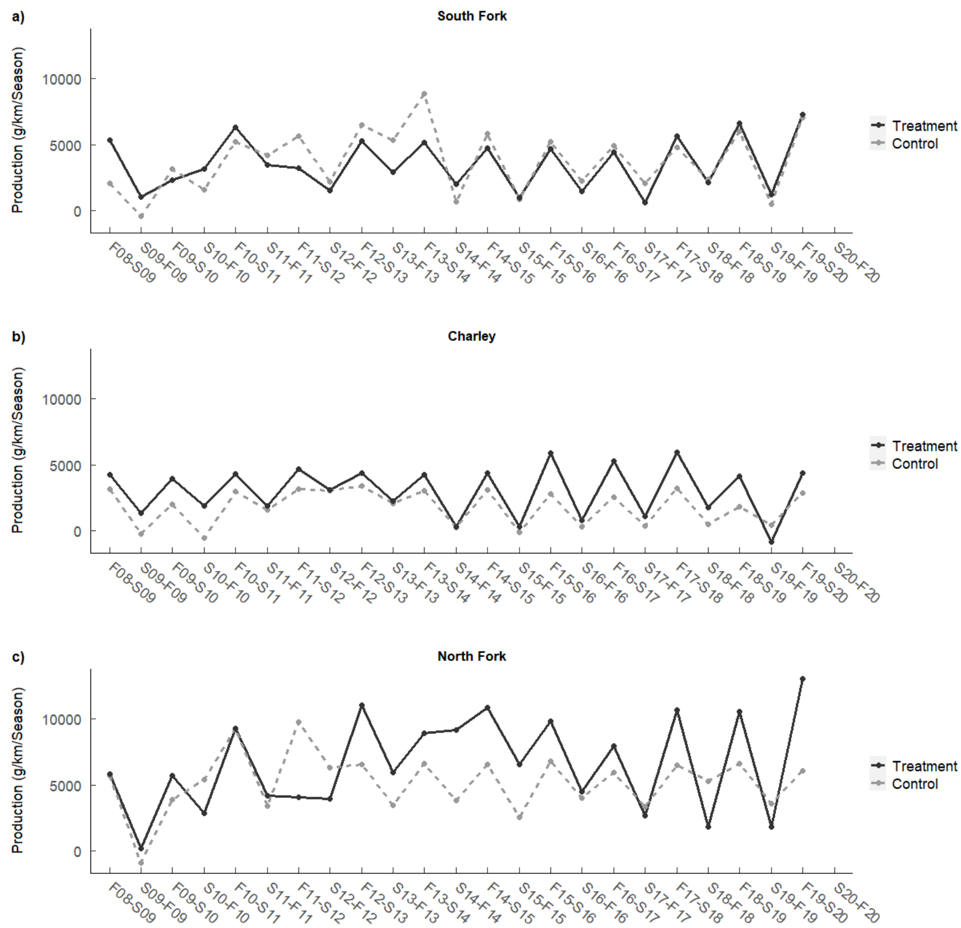


Figure 27. Average production juvenile steelhead (g/km/season) by stream in treatment control sections: 2008-2020. Sample seasons are Summer to Fall (e.g., S09-F09) and Fall to Summer (e.g., F08-S09).

Treatment versus Control Comparison – Juvenile Production

Treatment sections in all streams had little change in production in the summer to fall season and a positive trend in production in fall to summer season (Figure 28). The percent increase in production ranged from 3.7-20.0% (p >0.5) in the summer to fall and from 23.7-39.6% (p 0.009-0.12) in the fall to summer season. Average production increased by 29-382 g/km/season in the treatment sections post-restoration in the summer season and 745-2,631 g/km/season in the fall season (Table 13).

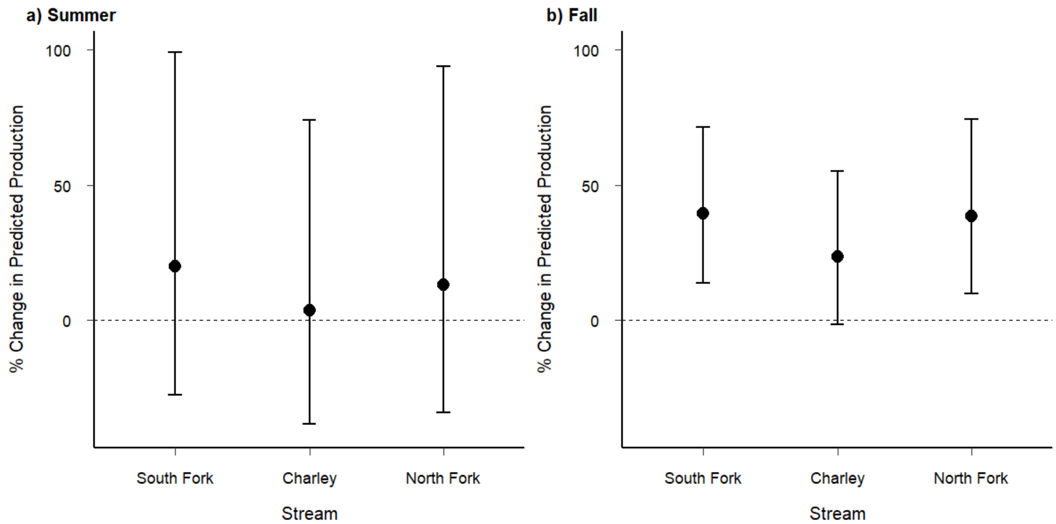


Figure 28. Percent change in juvenile steelhead production rate (g/km/season) in the treatments compared to the controls pre- and post-restoration from a) summer to fall and b) fall to summer: 2008-2019.

Table 13. Least squares means of juvenile steelhead production rate (g/km/season) pre-restoration, post-restoration, and difference (treatment - control) from a) summer to fall and b) fall to summer: 2008-2019.

a) Summer to Fall		**g/km/season**	
Stream	Mean pre	Mean post	Difference
Charley	781	810	29
North Fork	2,918	3,299	382
South Fork	1,296	1,556	260
b) Fall to Summer			
Stream	Mean pre	Mean post	Difference
Charley	3,146	3,891	7,45
North Fork	6,854	9,485	2,631
South Fork	4,455	6,218	1,763

7.4.6 Productivity

Annual Abundance

We use mark-recapture estimates of juvenile steelhead abundance in fish sites (Figure 19) to extrapolate to the total abundance in each stream and section which we then use to calculate tagged to untagged ratios and estimate total smolts by brood year and year left. The abundance is remarkably consistent from year to year for all streams (Figure 29).

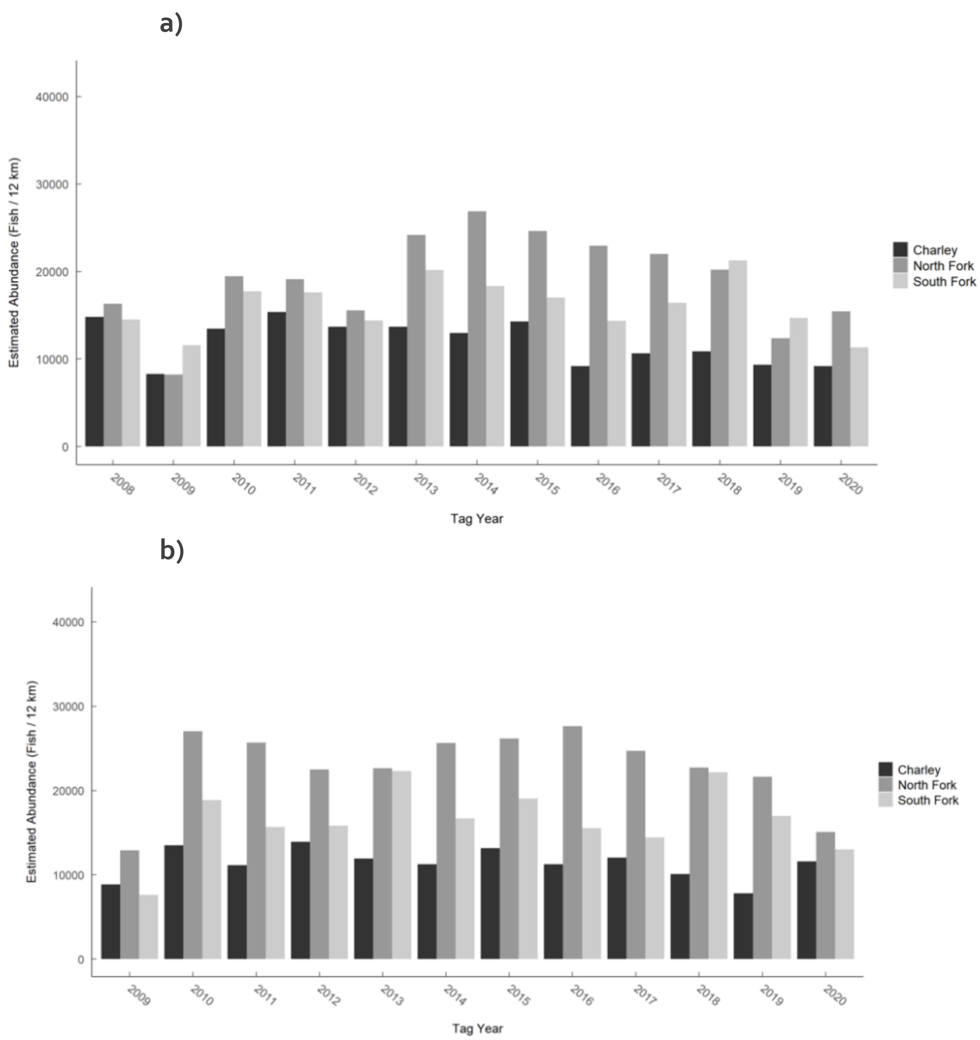


Figure 29. Abundance of juvenile steelhead (fish/12 km) by year and stream for a) summer and b) fall estimates for the entire 12 km study area of each stream.

Smolts by Brood Year

We estimated the total number of juvenile steelhead (tagged and untagged) migrating from each tributary by brood year from 2006-2020 (Figure 30). We refer to these as smolts but recognize that some are juveniles migrating to the mainstem. The North Fork consistently produces the most smolts followed by the South Fork and Charley Creek. Within each stream there appears to be a trend where the treatment section(s) tend to produce more smolts post-restoration relative to control sections.

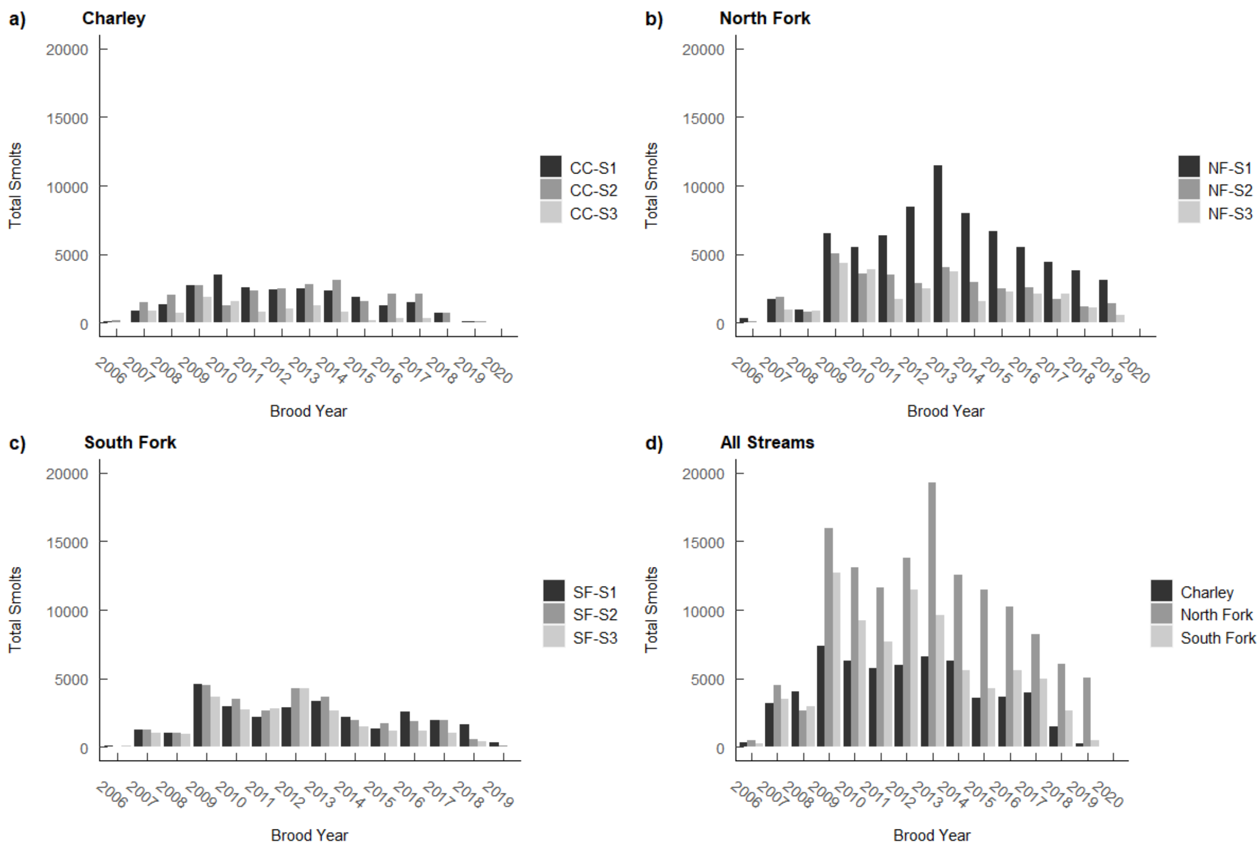


Figure 30. Estimates of number of juvenile steelhead migrating (smolts/ 4 km) by stream and section within stream by brood year from 2006-2020 (2008, 2009, 2019 are incomplete).

Treatment versus Control Comparison – Smolts by Brood Year

All three streams have a positive increase in brood year smolt productivity in treatment sections compared to control sections (Figure 31). Brood year does not correspond uniquely to year-after-treatment (YAT) in the staircase model. Therefore, these results encompass brood years where some experienced no treatment. For example, in South Fork Section 2 in brood year 2012, age 0 and 1 fish could migrate and experience no treatment, whereas age $\geq$ 2 fish that migrate would have at least one year where they experienced the treatment (i.e., Section 2 restoration effective 2013). The percent increase in smolts by brood year ranged from 24-88% (p 0.01-0.3; Figure 31). Average smolt productivity by brood year increased by 297-1,275 smolts/4km/brood year in the treatment sections post-restoration (Table 14).

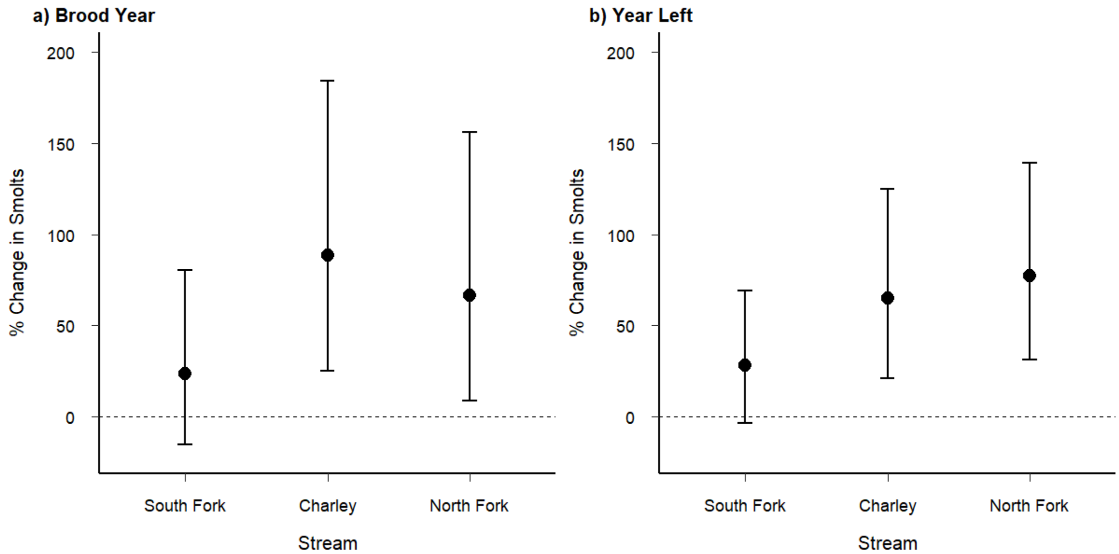


Figure 31. Percent change in juvenile steelhead migrating (smolts/section) by a) brood year and b) year left from treatments compared to the controls pre- and post-restoration for: brood year 2008-2018, year left 2010-2020. Sections are 4 km long.

Table 14. Least squares means of juvenile steelhead productivity (smolts/section) pre-restoration, post-restoration, and difference (treatment - control): 2008-2018.

	smolts/season		
Stream	Mean pre	Mean post	Difference
Charley	770	1,449	670
North Fork	1,911	3,186	1,275
South Fork	1,253	1,550	297

Smolts by Year Left

We estimated the total number of smolts (tagged and untagged) migrating from each tributary by the year they left from 2006-2020 (Figure 32). We refer to these as smolts but recognize that some are juveniles migrating to the mainstem. The North Fork consistently produces the most smolts each year followed by the South Fork and Charley Creek. Within each stream there appears to be a trend where the treatment section(s) tend to produce more smolts post-restoration relative to control sections.

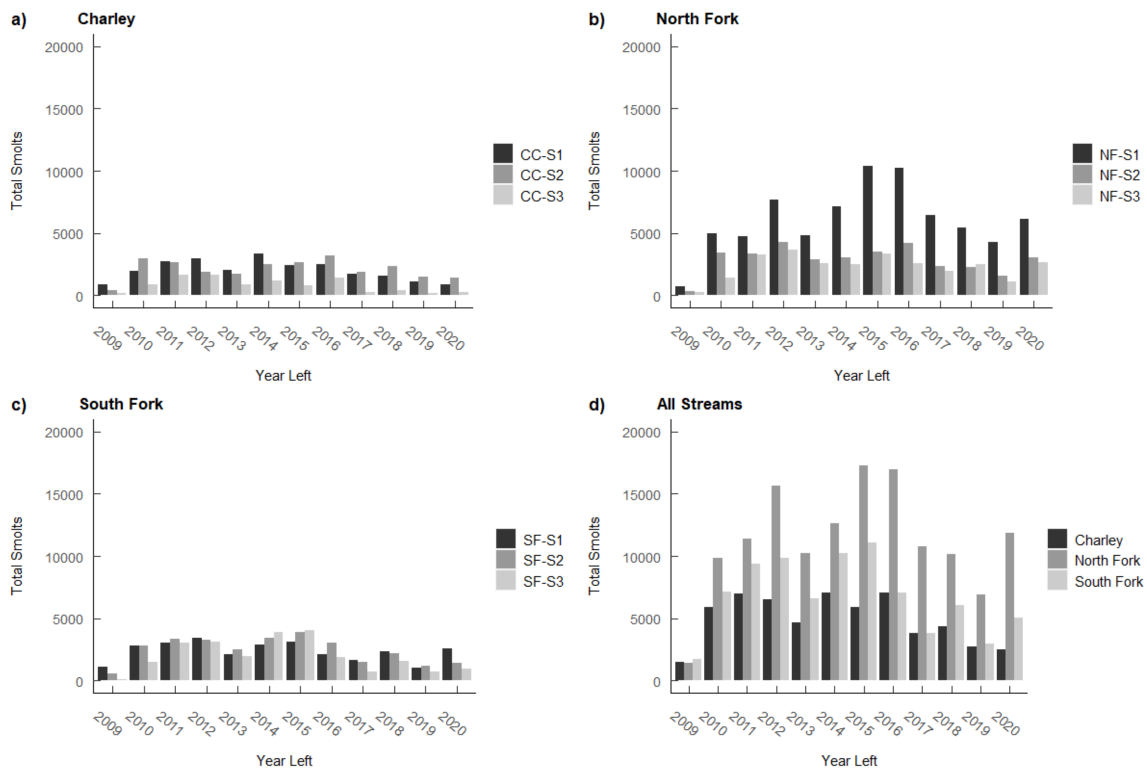


Figure 32. Estimates of number of juvenile steelhead migrating (smolts/ 4 km) by stream and section within stream by year left from 2009-2020 (2009 is incomplete).

Treatment versus Control Comparison – Smolts by Year Left

We analyzed the response of smolts to restoration using a linear mixed effects model for the years fish left 2010-2020. All three streams have a positive increase in smolt productivity by year left in treatment sections compared to control sections (Figure 31). This analysis is assessing the total number of migrants leaving each year regardless of what brood year they were produced from. The percent increase in smolts by year ranged from 30-77% (p 0.002-0.14). Average smolt productivity by year left increased by 510-2,260 smolts/4km/ year in the treatment sections post-restoration (Table 15).

Table 15. Least squares means of juvenile steelhead production rate (g/km/season) pre-restoration, post-restoration, and difference (treatment - control) from a) summer to fall and b) fall to summer: 2008-2018.

	smolts/season		
Stream	Mean pre	Mean post	Difference
Charley	1,170	1,930	760
North Fork	2,931	5,191	2,260
South Fork	1,828	2,339	511

Smolts/Spawner

We used the number of tagged adults detected entering each creek as an index of adult escapement (Figure 33). We calculated smolts/spawner by year by dividing the total smolts per brood year by the adult escapement index. North Fork consistently had the most spawners and Charley had the least spawners. Adult escapement in the IMW study creeks was very low (7-11 adults total) from 2018-2020. Charley Creek produces the most smolts/spawner in most brood years from 2010-2017 (Figure 34). We cannot break down the smolts/spawner by stream section because we are unable to determine which sections adults spawn in due to poor visibility and difficulties conducting spring red surveys. However, it appears that spawning by resident steelhead are both maintaining consistent juvenile abundance and producing smolts in years with low or no anadromous adults returning.

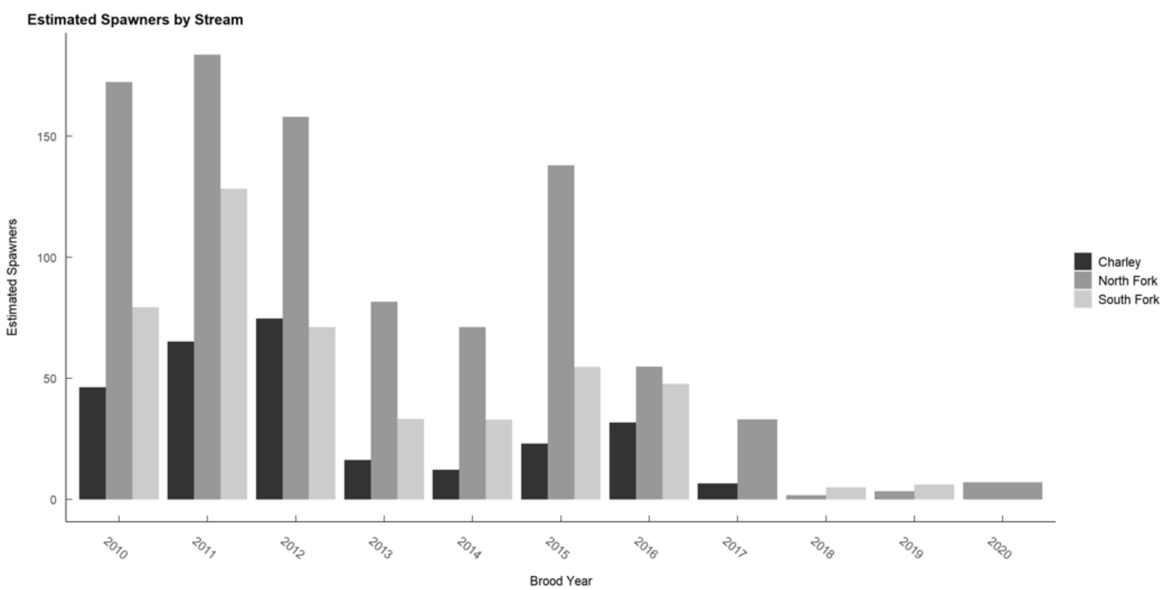


Figure 33. Estimated spawners (adult escapement index) based on the number of PIT tagged adults detected entering the IMW study creeks. Note no adults were detected entering Charley from 2018-2020 or South Fork 2020.

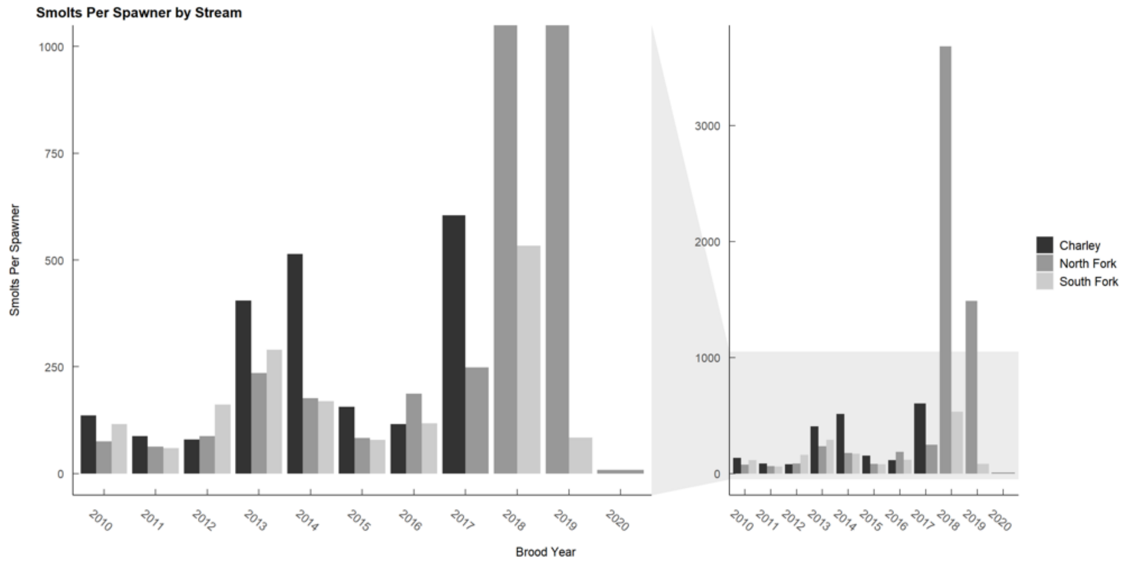


Figure 34. Smolts/spawner by stream and brood year from 2010-2020. Graph on the right is showing how the smolts/spawner exceed 1,000-3,000 in years with low adult escapement and where smolts/spawner cannot be calculated.

7.4.7 Life History Diversity

We have conducted some preliminary analysis of various aspects of life history expression and WDFW has compiled a list of life history types based on analysis of scales collected from adults at the weir (Herr et al. 2020). We present the summaries of these analyses

Life History Strategies

WDFW has identified at least 25 life history types expressed by adult steelhead caught at the Asotin weir (Figure 35). We have caught 24 juvenile steelhead that are at least 5 years old and 1 that was 7 years old which could add at least two more life history types. We observed that a large proportion of age 0 (50-70%) and age 1 (10-15%) spend 6-12 months or more rearing in the mainstem after leaving the IMW tributaries (Figure 37). This highlights other life history types that may benefit from the treatments. And we have also observed that a lower proportion of tagged juvenile steelhead from fish sites further up the tributaries are detected leaving the IMW tributaries (Figure 38). We feel that this pattern suggests that the proportion of resident juvenile steelhead increases by distance from the mouth of each tributary. We don't think this pattern is due the decreased survival the further migrants travel because survival rates are high and consistent across years, streams, and sites, and because migration mostly takes place during high flow and is rapid (often < week from tributaries to the mouth of Asotin Creek which is over 20 km). We will work with WDFW to further update life history types in Asotin Creek.

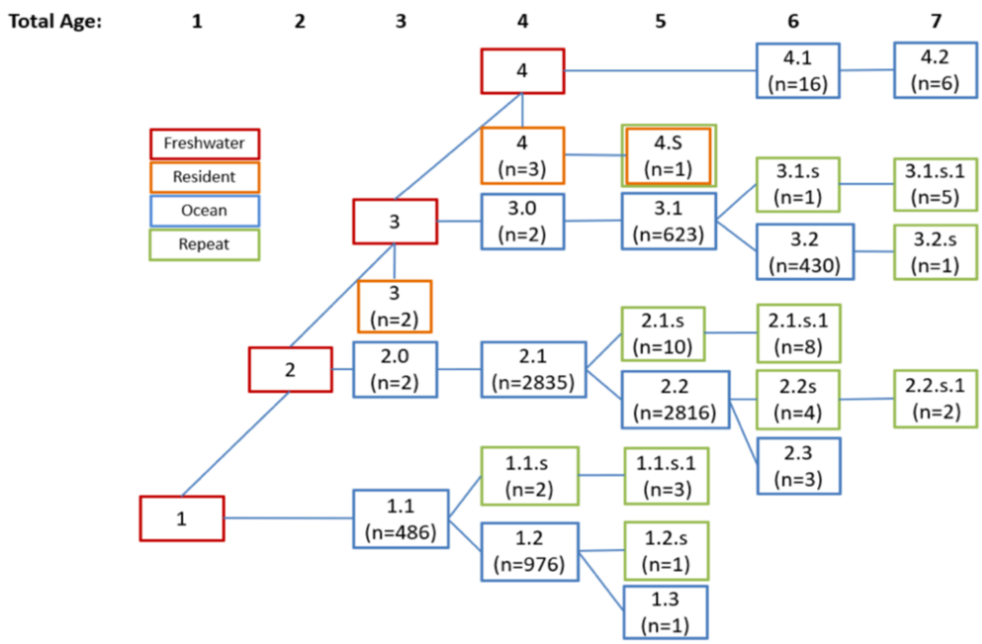


Figure 35. Life history pathways observed in natural origin steelhead scale samples from project weirs with corresponding number observed (2005-2020). Reproduced from Herr et al. 2020 based on 8,239 scales.

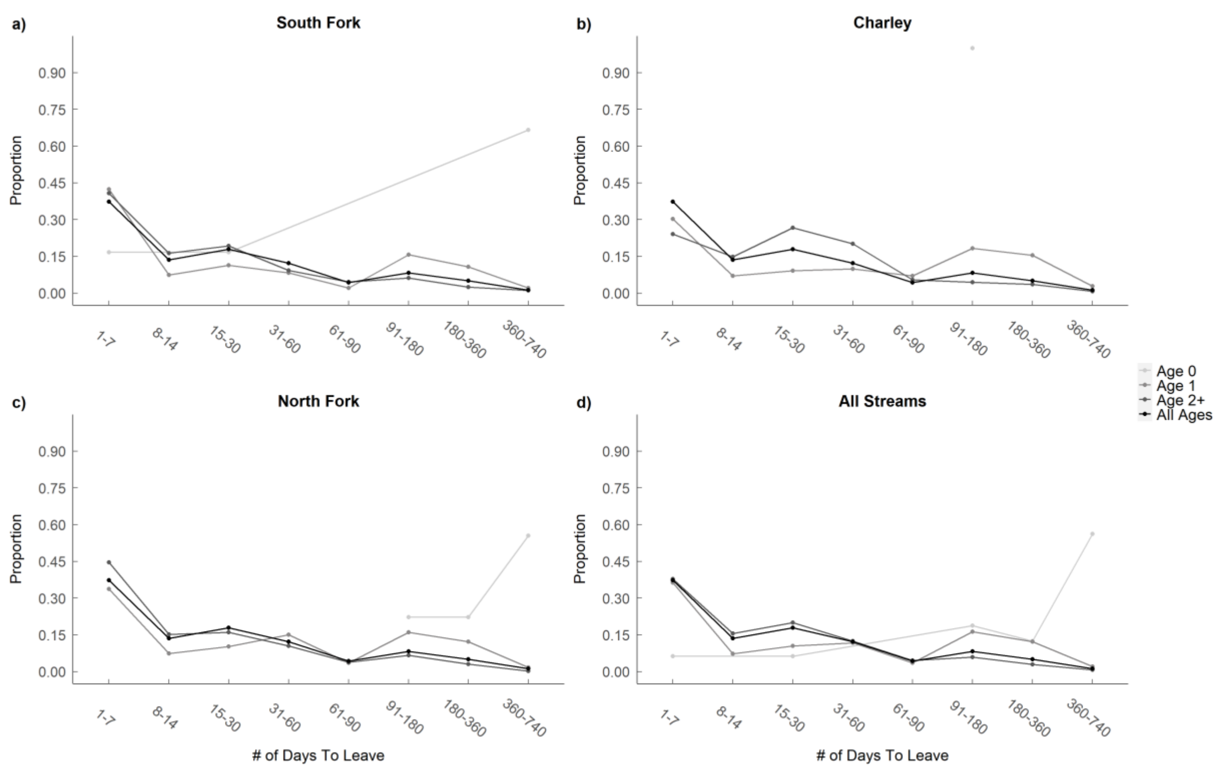


Figure 36. Proportion of PIT tagged juvenile migrants (detected leaving/total tags) by the number of days it takes for them to leave Asotin Creek after leaving the IMW study tributaries by age group.

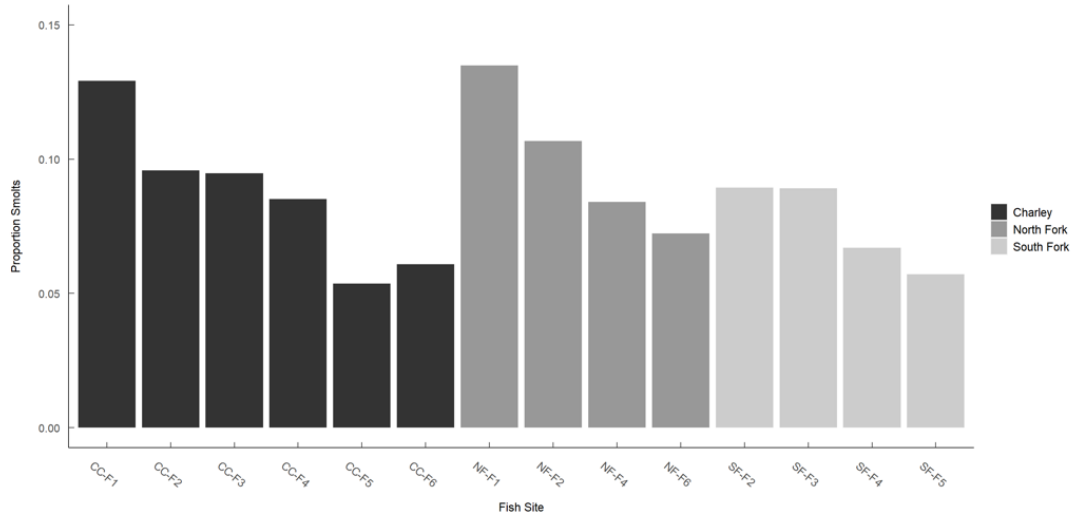


Figure 37. Proportion of juvenile migrants (detections/total new tag at a site) that were detected leaving the stream and fish site they were tagged in.

Proportions

We conducted a preliminary analysis of the proportion of different age classes pre- and post-restoration to assess whether fish are leaving earlier or later due to the restoration (Figure 39.) We found mixed results with proportion of Age 1 fish decreasing in the South Fork, Age 2 fish increasing in Charley Creek, and Age 3 fish increasing in both South Fork and North Fork. It is not clear what these patterns mean but could suggest fish are rearing for longer before migrating.

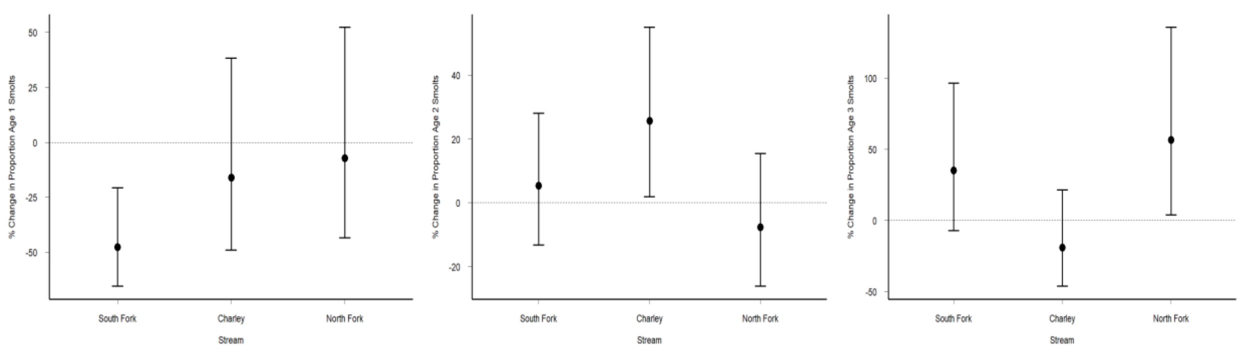


Figure 38. Percent change in the proportion of juvenile steelhead by age and stream from treatments compared to the controls pre- and post-restoration for: brood year 2008-2020.

7.5 PACIFIC LAMPREY

The Nez Perce Tribe has been relocating adult Pacific Lamprey to Asotin Creek mainstem since 2007. Prior to 2016 most of the adult lamprey were relocated in the lower mainstem below Headgate dam which was considered a partial barrier. In 2016, Headgate dam was completely removed, and the Nez

Perce started relocating lamprey higher up in the watershed (Figure 40). We began detecting PIT tags from lamprey at the IMW interrogation sites in 2019 and caught some juvenile lamprey in the fish sites we survey annually. In 2021, we conducted a test survey to target lamprey and found ~ 100 juvenile lamprey in a short stretch of South Fork section 1 (Figure 41). WDFW has also been catching increasing numbers of juvenile lamprey since 2019 (Table 15). We are proposing to test if juvenile lamprey are more abundant in IMW treatment sections compared to control sections. We hypothesize that the fine sediment that is sorted and trapped near PALS is creating ideal rearing areas for juvenile lamprey.

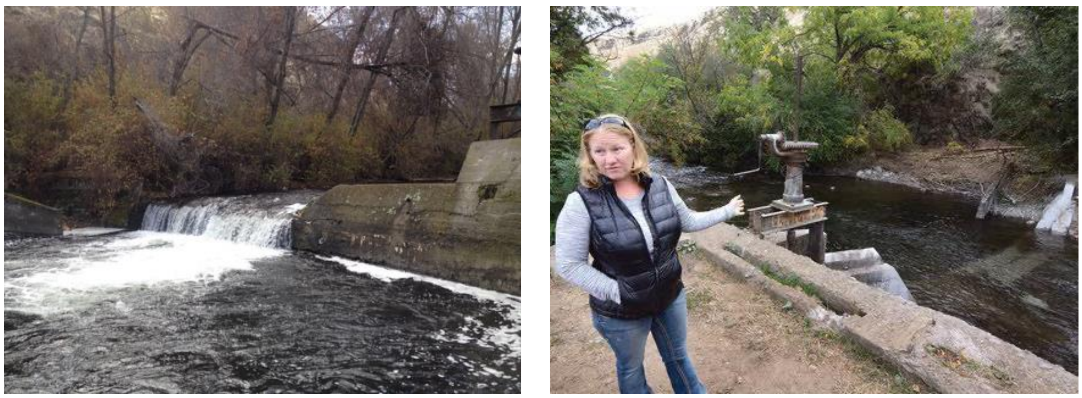


Figure 39. Headgate dam pre- and post-removal in 2016.

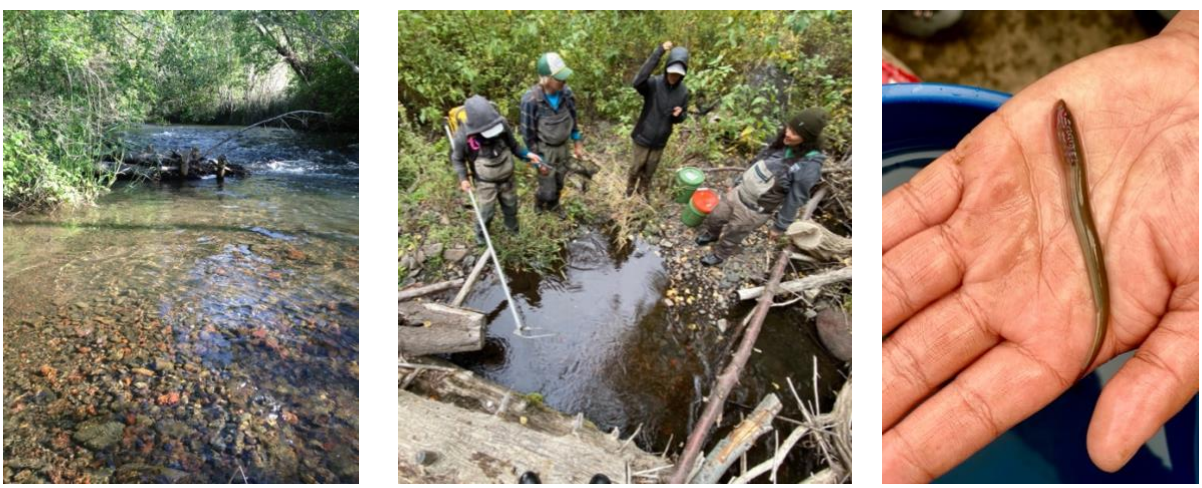


Figure 40. Fine sediment sorted behind a PALS, monitoring crew electroshocking off-channel habitat for lamprey, and a juvenile lamprey caught in South Fork Asotin Creek at an IMW fish site.

Table 16. Captures of juvenile Pacific Lamprey by WDFW at Asotin trap sites (E. Crawford, Pers. Comm.).

Year	Ammocoete	Macropthalmia	Adult	Total
2004	-	-	-	-
2005	-	-	-	-
2006	-	-	-	-
2007	3	1	-	4
2008	1	-	-	1
2009	2	1	-	3
2010	656	51	-	707
2011	27	7	-	34
2012	291	33	-	324
2013	590	62	-	652
2014	76	13	-	89
2015	138	83	-	221
2016	16	25	-	41
2017	120	9	1	130
2018	162	14	-	176
2019	564	88	-	652
2020	3,161	80	-	3,241
2021	3,778	41	1	3,820
Total	9,585	508	2	10,095

8. SYNTHESIS AND INTERPRETATION

In this report covering data from 2008-2021, we document positive habitat responses to restoration actions based on an increase in the frequency of large woody debris, debris jams, geomorphic units, pools, and bars in treatment sections compared to control sections. The positive changes in habitat are leading to relatively consistent and small-moderate increases in juvenile steelhead abundance (fish/km), biomass (g/km), production (g/km/season), and productivity (smolts/km) in treatment sections compared to control sections (Table 1). We have not observed any changes in growth (g/season/fish) or survival. An increase in juvenile production and productivity, with relatively little change in growth or survival in treatment sections, may be from benefits to fry which are too small to PIT tag during our surveys. It is possible that fry are surviving in greater numbers because of the flow refugia and/or increased off-channel and edge habitat that increased LWD is providing. It is also possible the egg-fry survival has increased due to improved spawning sites. The increase in bars in treatment sections demonstrate that substrate is being mobilized and sorted more regularly which provides clean, less compacted spawning sites, and many bars are located downstream of PALS, which provides more protection to redds from floods. This report focuses on responses pooled across age classes but the results also appear to hold within age class comparisons.

The percent increase in smolts per treatment section (by brood year or year left) ranges from 291-1,275 smolts/4km or roughly 75-320 smolts/km. This is a relatively modest increase in productivity, but it does suggest that the carrying capacity of treatment sections was increased by the restoration actions and this occurred without a significant increase in floodplain connection- in other words, increased habitat complexity and not increased area are likely contributing to the productivity increases.

9. COLLABORATION AND COMMUNICATION

9.1 COLLABORATION

The Snake River Salmon Recovery Board has coordinated the Asotin IMW from its inception in 2007. The selection of the location for the IMW was a collaborative effort that took over 6 months to complete. Meetings were held with the Regional Technical Team (RTT) and selection criteria for choosing a location for the IMW were established. The RTT is made up of project sponsors, lead entities, local, state, tribal, and federal agencies. The RTT provided data and input into the scoring and ranking of different watersheds which led to Asotin Creek being selected as the location for the IMW. Since then, we have presented experimental designs, monitoring approaches, and preliminary data to RTT and local stakeholders for review and input at 2-6 meetings annually. We have also hosted several tours of the IMW study area for project sponsors and stakeholders throughout the Snake River Salmon Recovery region. We continue to work with WDFW via maintenance of the PIT tag interrogation sites, monitoring and tagging juvenile steelhead, and general project management.

9.2 COMMUNICATION OF IMW LESSONS LEARNED

We have published several papers related to the Asotin IMW including an adaptive management plan, our restoration actions, survey methods, modeling approaches, and supported graduate theses on the IMW (Appendix H). We have also developed numerous newsletters and landowner/stakeholder tours and presentations of the IMW as well as presented aspects of the IMW at Salmon Recovery symposiums, American Fisheries Society meetings, and other science gatherings. We share our presentations with RCO, and SRSRB posts our reports on their website (https://snakeriverboard.org/reports/asotin-creek-documents/). We have also worked with RCO to develop a story map for the IMW. Our reports and research are posted on personal ResearchGate sites (Stephen Bennett), University website (Fluvial Habitat Center; https://restoration.usu.edu), company websites (Anabranch Solutions; Eco Logical Research), restoration manual (https://lowtechpbr.restoration.usu.edu/#), and data hub for all the models we develop and use (https://riverscapes.xyz).

See Appendix M for a list of publications, presentations, and outreach.

10. INFORMING FUTURE SALMON RECOVERY

The Asotin Creek IMW is testing and documenting a process-based and cost-effective restoration approach that can expand the restoration community (it is relatively easy to train people to do low-tech) and lead to more miles of stream being restored. This work is particularly applicable to wadeable and headwater streams that make up over 90% of a watershed. Applying low-tech process-based restoration could help slow water leaving watersheds, recharge groundwater, reconnect disconnected floodplains creating more storage opportunity, and perhaps provide higher base flows, and limit impacts of climate change.

Lessons learned from Asotin Creek IMW have already led to the publication of a low-tech process-based restoration manual that has been downloaded thousands of times (Wheaton et al. 2019). The manual provides a more appropriate restoration philosophy and approach to restoring wadeable streams that focuses less on stability of structures and creating form, and more on mimicking, promoting, and sustaining physical and biological processes. Low-tech restoration is also more flexible and cost-effective during project and structure design and implementation because it does not require flow and sediment models.

We are also redefining expectations for restoration by explicitly developing an adaptive management plan based on phased implementation and maintenance (it will be rare that we can fix 200 years of degradation with one treatment). This project could provide an example and guidance on how to set more realistic expectations and implement cost-effective phased restoration using a simple adaptive management approach.

The project is quantifying the physical and biological responses to low-tech process-based restoration which can aid in prioritization of future restoration actions. It appears that increasing habitat complexity can increase steelhead production, but the gains may be relatively small. We hope to complete the project by demonstrating that transforming a structurally starved single **thread** channel with limited hydraulic and geomorphic diversity to a riverscape with a fully connected floodplain can significantly increase the available fish habitat/km of valley bottom by increasing sinuosity and sustaining multiple channels (i.e.**,** an anastomosing stream evolution stage); it is becoming more evident based on results from the Bridge Creek IMW, the Asotin IMW, and other research, **that providing more stream miles/valley length will provide the greatest benefits to freshwater fish production.**

10.1 MANAGEMENT IMPLICATIONS OF ASOTIN IMW (TO DATE)

We provide some concise management implications we have developed from the IMW results to date.

1. Developed and implemented a cost effective, low impact and effective approach to adding large woody debris to streams to improve riverscape health

2. Demonstrated that high densities of large wood are effective at retaining wood in the system, promoting natural log jams, increasing geomorphic complexity, and improving fish habitat

3. Changes in habitat occurred mainly within the channel and led to modest increases in fish production and productivity; however, ongoing maintenance or enhancement of restoration could lead to greater floodplain connection and likely greater increases in juvenile steelhead and riverscape productivity

4. We are developing a greater understanding of the mechanisms by which the habitat and fish are responding to restoration which will allow us to transfer lessons learned from the Asotin IMW to 10,000's miles of wadable streams and scale restoration to scope of degradation across Pacific Northwest

5. Findings from low-tech process-based restoration (BDAs and PALS) suggest they could help to mitigate effects of climate change on stream flow and temperature

10.2 CORE MESSAGES FROM ASOTIN IMW (TO DATE)

We provide some concise core messages we have developed from the IMW results to date.

1. The benefits of beaver & wood on sustaining healthy riverscapes are indisputable
2. Floodplain connection maximizes production and productivity of riverscapes and fish populations
3. Commitment to maintenance & enhancement (or monitoring at the very least) is essential for stream restoration to be successful

11. SCHEDULE FOR COMPLETION, FUTURE WORK, AND NEEDS

11.1 SCHEDULE FOR COMPLETION

We plan to continue to monitor at the same level until 2024/25 to collect enough data to fully evaluate freshwater production and productivity. We then anticipate another year to complete all the analysis and reporting including submitting manuscripts for publication.

11.2 FUTURE WORK

We plan to maintain current monitoring levels, compile data sets on geomorphic conditions, fish abundance, growth, movement, survival, capacity, production, and productivity. We also plan to map floodplain connection pre- and post-restoration to document the effect on fish. In the spring of 2022, we will use aerial imagery, LiDAR, and site maps developed during PIBO and CHaMP surveys to assess pre-restoration floodplain conditions, and conduct field surveys and use newly acquired drone imagery to assess post-restoration floodplain conditions in treatment and control areas. We also plan to develop manuscripts on short (< 5 years) and long-term (> 5 years) geomorphic responses to LWD additions, a life history paper for Asotin steelhead, and begin to develop models to help us understand factors controlling juvenile steelhead abundance, growth, movement (i.e., age at migration), production, and productivity. We also plan to revise an existing life cycle model we developed for Chinook and develop a steelhead life cycle model for Asotin Creek so we can further investigate the implications for the restoration responses we are documenting, and for understanding other restoration scenarios (Weber et al. 2018, Wheaton et al. 2018).

11.3 FUTURE NEEDS

We can maintain a minimum level of habitat and fish monitoring to assess restoration effectiveness annually with an annual budget of ~$290,000 (includes ELR, WDFW, and RCO costs). However, we do not have funds to replace damaged equipment or for additional monitoring costs. At a minimum we would like to get funds for array replacements due to the fire, a post-restoration LiDAR flight, and topographic survey of habitat sites so we can run models developed by CHaMP and USU ETAL lab (e.g., GUT, NREI, GCD; Table 16).

Table 17. Estimated costs to replace damaged monitoring equipment and acquire topographic data to complete post-restoration monitoring of geomorphic change.

Infrastructure Type/Items	Description	Unit Cost	Units Requred	Total
PIT Tag Interrogation Sites				
Parts (Antennas, cables/nodes, master controller, etc.)	4 replacement PIT tag antennas of various size	21,270	1	21,270
Power Lines and Electrical Repairs	Power to AFC and CCA were damaged; repair bill from Inland Metals & Electric	2,617	1	2,617
subtotal				23,887
LiDAR and Topography				
LiDAR flight	Collect ~1 cm accurqacy digital elevation model	25,000	1	25,000
CHaMP topographic surveys	Labor for data collection and processing	80	320	25,600
subtotal				50,600
TOTAL				**$ 74,487**

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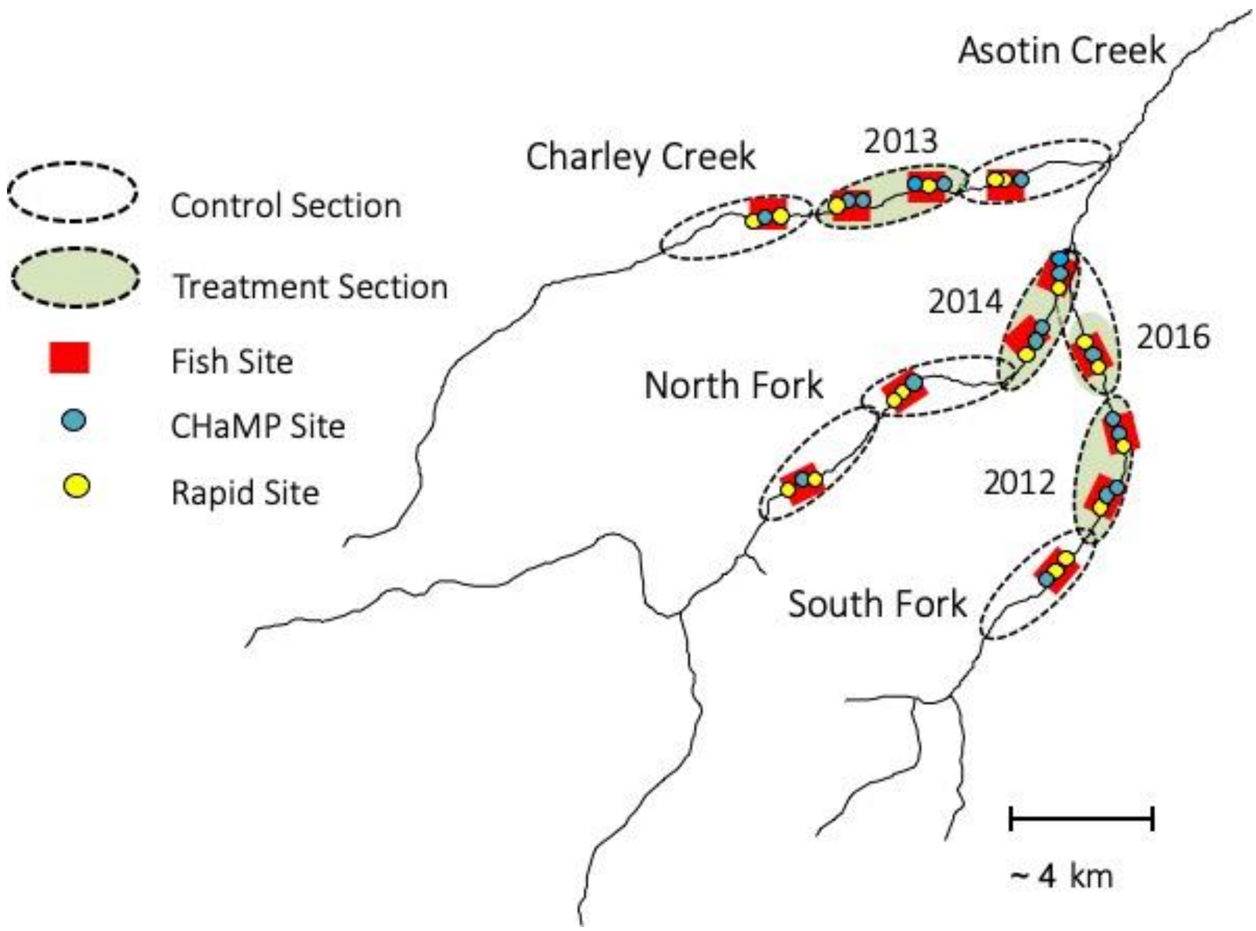
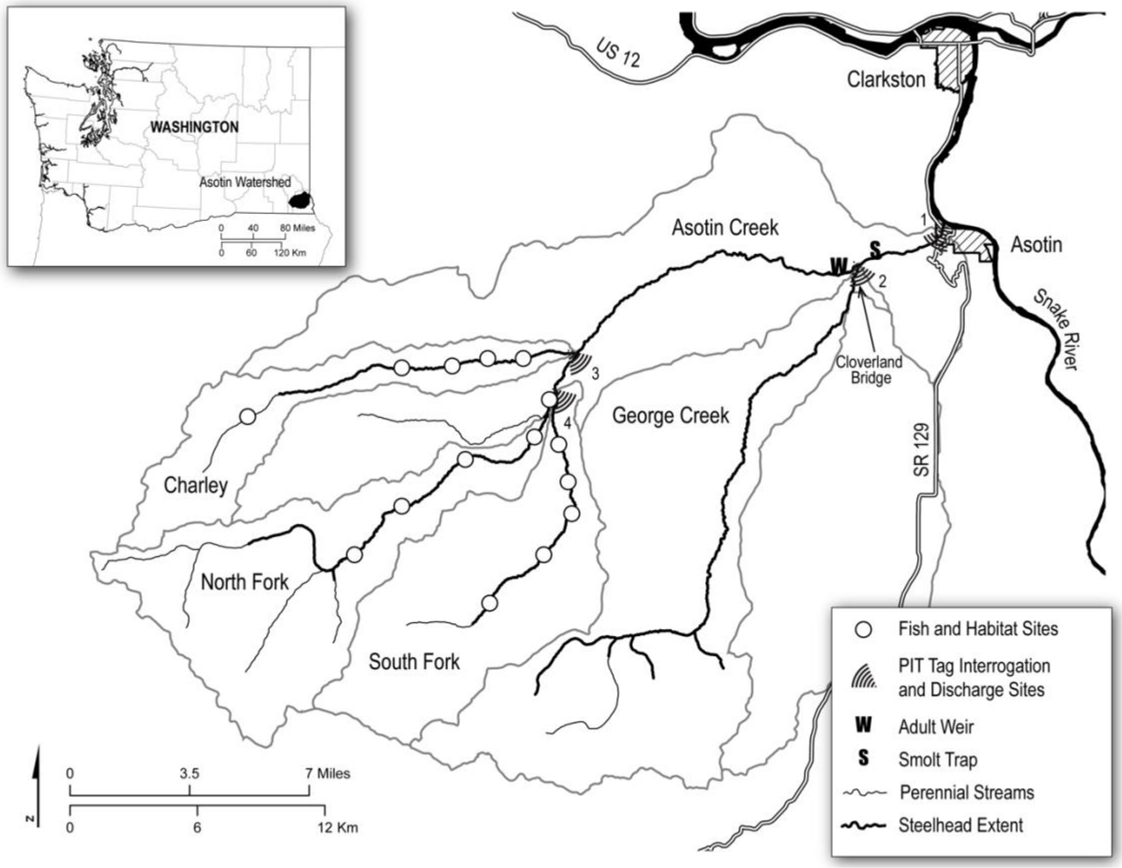
Appendix A – Experimental and Monitoring Designs and Infrastructure

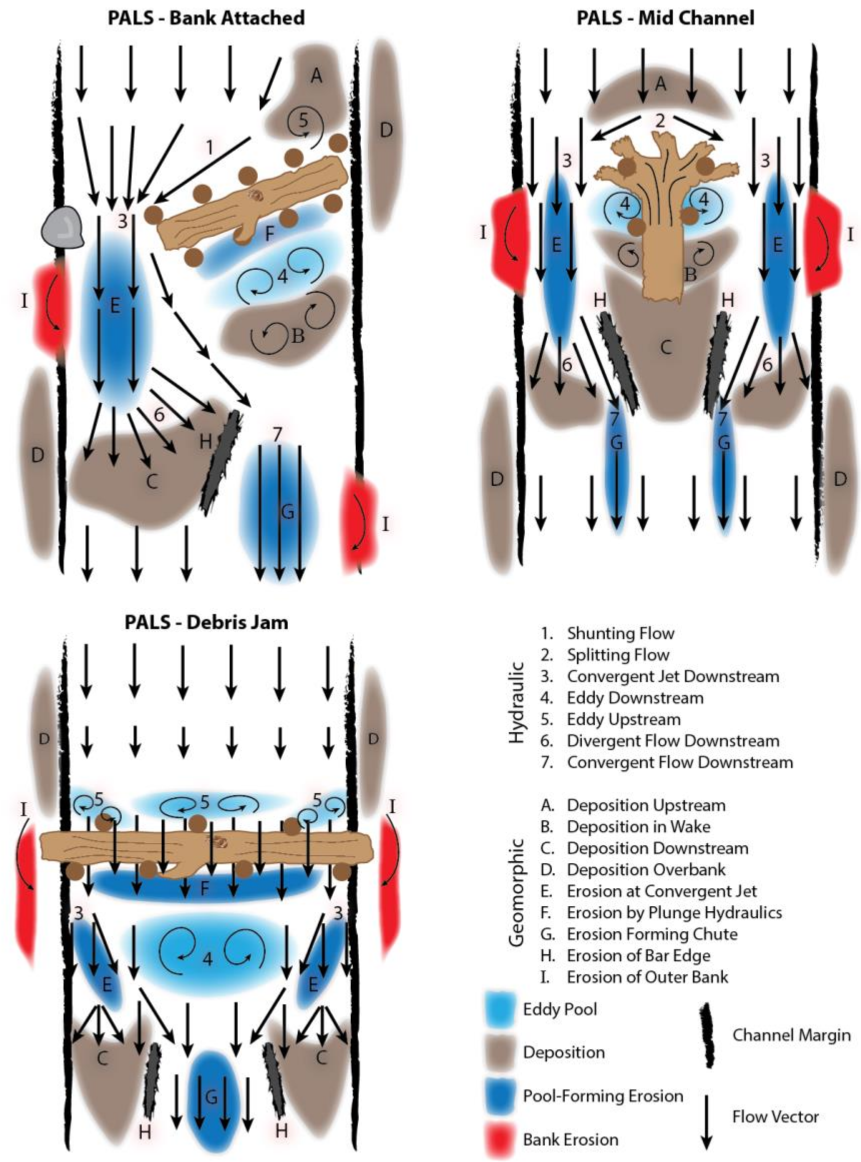


Appendix A- 1. Experimental design and sample sites for juvenile PIT tagging and habitat surveys for the Asotin Creek Intensively Monitored Watershed project. Each study creek has three 4 km long sections. One section in each stream was restored each year (staircase design) using post-assisted log structures (shaded green): South Fork (2012), Charley Creek (2013), and North Fork (2014). An additional section was restored in South Fork (lower section) in 2016 at part of the Adaptive Management plan. All other sections not colored are controls. Fish sites and habitat survey sites are nested within each section. CHaMP = Columbia Habitat Monitoring Protocol, Rapid = custom rapid habitat survey.



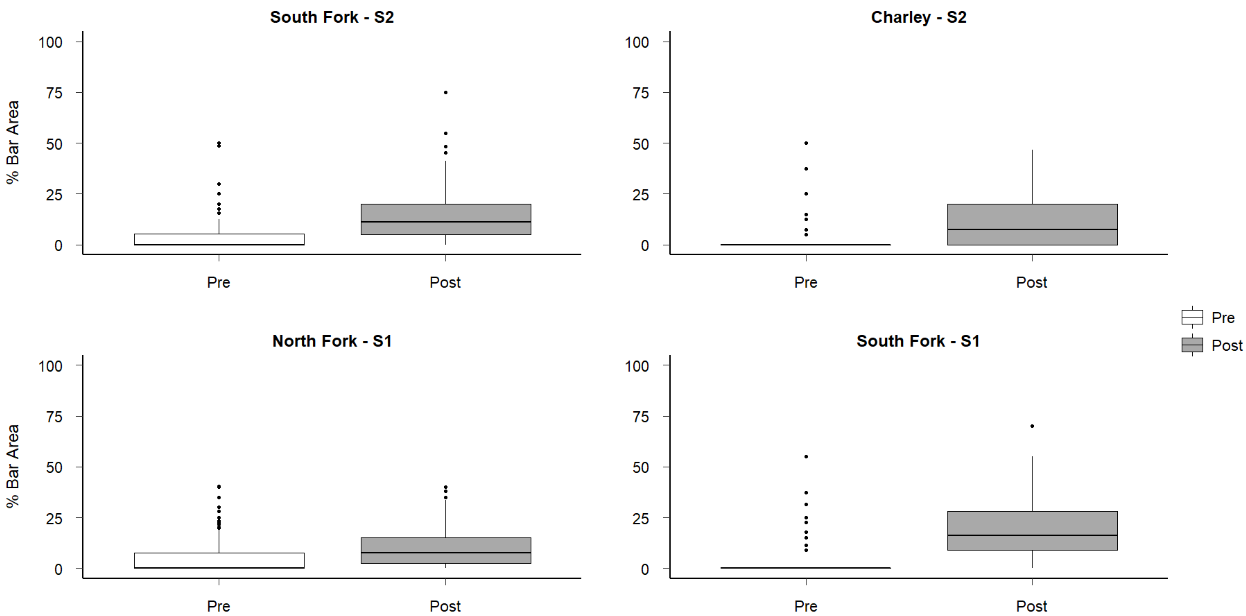
Appendix A- 2. Monitoring infrastructure including fish and habitat sites in Charley Creek, North Fork, and South Fork Creek, discharge gauges, passive integrated transponder (PIT) tag interrogation sites, and the WDFW adult weir and smolt trap for fish-in fish-out monitoring. Water temperature is monitored at each fish site and entering and leaving treatment and control sections. Discharge is measured at the mouth of Charley, North Fork, South Fork, and Asotin Creeks. The Columbia Basin PIT Tag Information System (PTAGIS) PIT tag interrogation sites are: 1) ACM – mouth of Asotin Creek, 2) ACB – Asotin Creek mainstem at Cloverland Bridge, 3) CCA – near mouth of Charley Creek, and 4) AFC – confluence of North Fork and South Fork Asotin Creek.

Appendix B – Hypothesized Short-term Hydraulic and Geomorphic Responses for Post-Assisted Log Structure by Type



Appendix B- 1. Design and expected responses of the three post-assisted log structure types: Red indicates bank erosion, blue indicates scour, brown indicates deposition, and arrows indicate flow direction and velocity (Wheaton et al. 2012, Camp 2015).

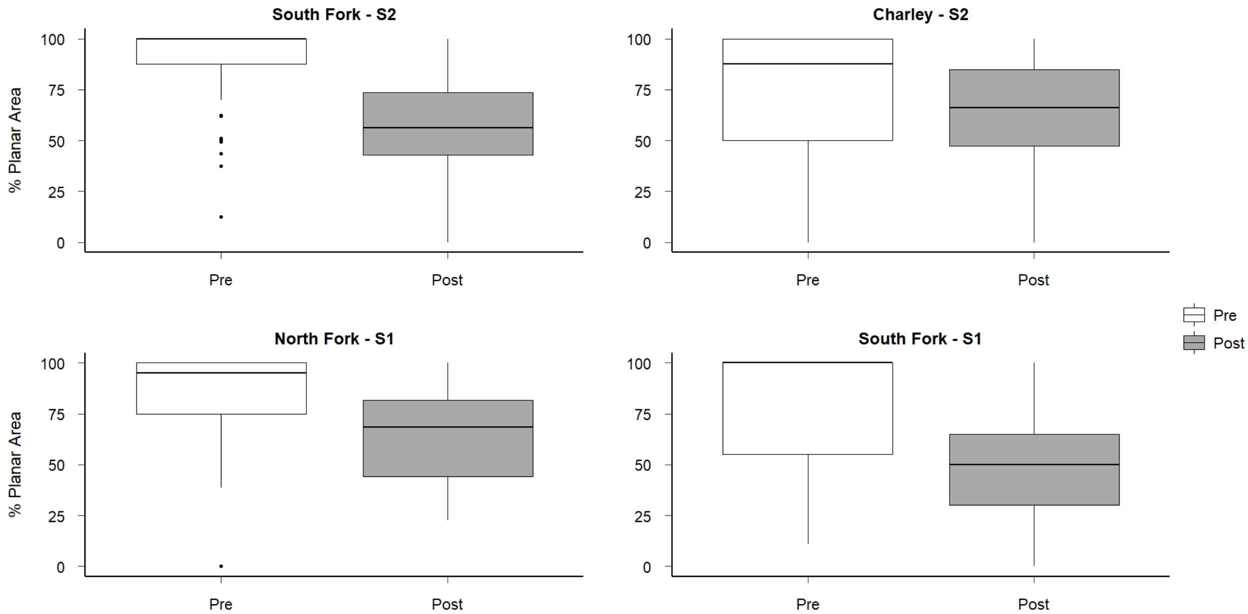
Appendix C – Structure Effectiveness Data Summary



Summary Statistics

Section	Status	mean	median	min	q1	q3	max	sd	CV	n
SF-S2	Pre	4.9	0.0	0	0.0	5.3	50.0	9.1	1.9	132
SF-S2	Post	14.7	11.2	0	5.0	20.0	75.0	13.3	0.9	106
CC-S2	Pre	4.7	0.0	0	0.0	0.0	50.0	9.5	2.0	173
CC-S2	Post	11.3	7.5	0	0.0	20.0	46.5	11.8	1.0	105
NF-S1	Pre	5.2	0.0	0	0.0	7.5	40.5	9.1	1.7	116
NF-S1	Post	10.0	7.5	0	2.5	15.0	40.0	9.6	1.0	77
SF-S1	Pre	2.5	0.0	0	0.0	0.0	55.0	8.4	3.4	101
SF-S1	Post	19.0	16.2	0	9.0	28.1	70.0	13.9	0.7	101

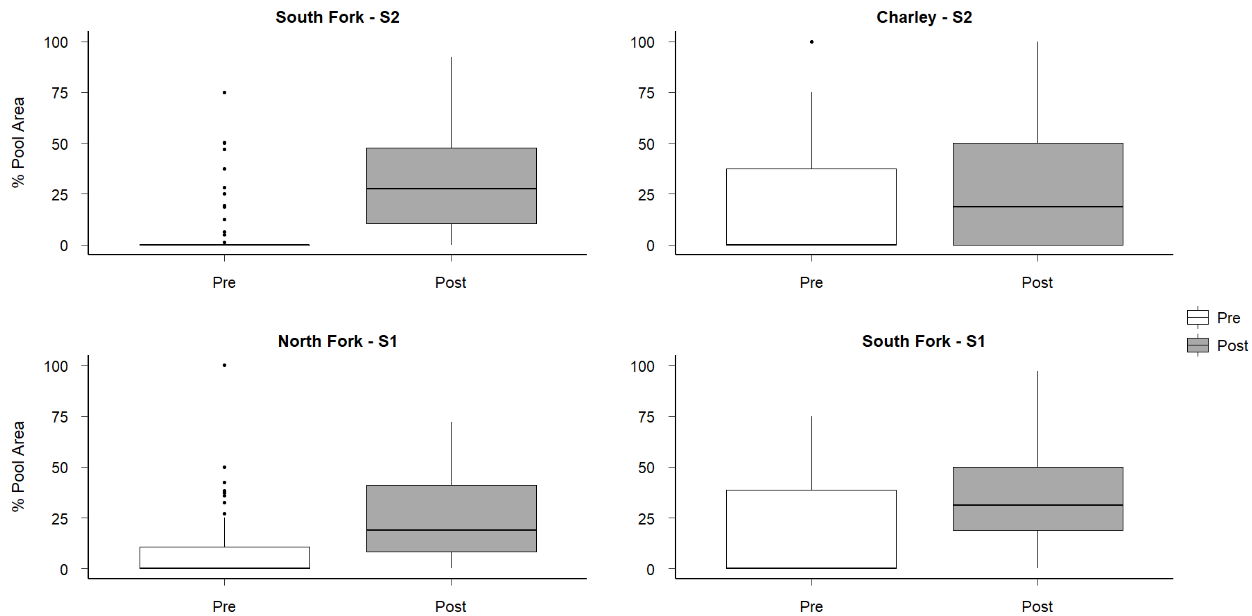
Appendix C- 1. Percent area bar geomorphic unit and summary statistics for one bankfull width upstream and downstream of each post-assisted log structure, pre- and post-restoration, by stream and treatment section. Surveys conducted at the time of construction (pre) and 2-3 years after construction (post).



Summary Statistics

Section	Status	mean	median	min	q1	q3	max	sd	CV	n
SF-S2	Pre	90.4	100.0	12.5	87.5	100.0	100	16.2	0.2	132
SF-S2	Post	55.4	56.2	0.0	42.8	73.4	100	24.0	0.4	106
CC-S2	Pre	77.9	87.5	0.0	50.0	100.0	100	25.9	0.3	173
CC-S2	Post	62.8	66.2	0.0	47.5	85.0	100	28.8	0.5	105
NF-S1	Pre	85.8	95.0	0.0	75.0	100.0	100	19.2	0.2	116
NF-S1	Post	65.2	68.5	22.5	44.0	81.5	100	22.7	0.3	77
SF-S1	Pre	82.6	100.0	11.0	55.0	100.0	100	23.9	0.3	101
SF-S1	Post	46.2	50.0	0.0	30.0	65.0	100	28.1	0.6	101

Appendix C- 2. Percent area planar geomorphic unit and summary statistics for one bankfull width upstream and downstream of each post-assisted log structure, pre- and post-restoration, by stream and treatment section. Surveys conducted at the time of construction (pre) and 2-3 years after construction (post).

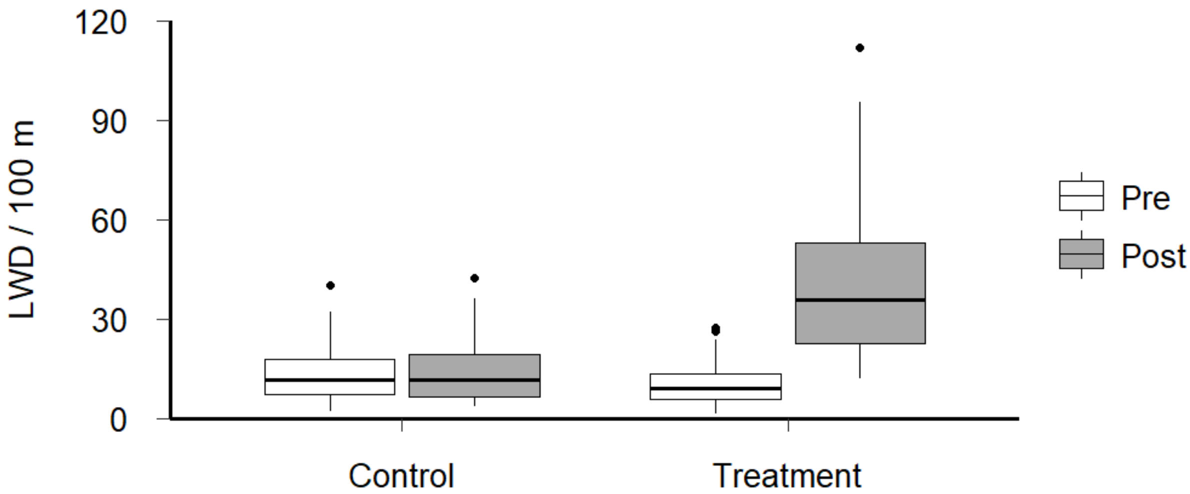


Summary Statistics

Section	Status	mean	median	min	q1	q3	max	sd	CV	n
SF-S2	Pre	4.7	0.0	0	0.0	0.0	75.0	12.7	2.7	132
SF-S2	Post	29.8	27.5	0	10.6	47.6	92.5	22.8	0.8	106
CC-S2	Pre	17.4	0.0	0	0.0	37.5	100.0	24.1	1.4	173
CC-S2	Post	25.9	18.8	0	0.0	50.0	100.0	28.4	1.1	105
NF-S1	Pre	9.1	0.0	0	0.0	10.6	100.0	17.1	1.9	116
NF-S1	Post	24.9	18.8	0	8.5	41.2	72.0	20.9	0.8	77
SF-S1	Pre	14.9	0.0	0	0.0	38.7	75.0	22.6	1.5	101
SF-S1	Post	34.8	31.2	0	18.8	50.0	96.9	26.5	0.8	101

Appendix C- 3. Percent area pool geomorphic unit and summary statistics for one bankfull width upstream and downstream of each post-assisted log structure, pre- and post-restoration, by stream and treatment section. Surveys conducted at the time of construction (pre) and 2-3 years after construction (post).

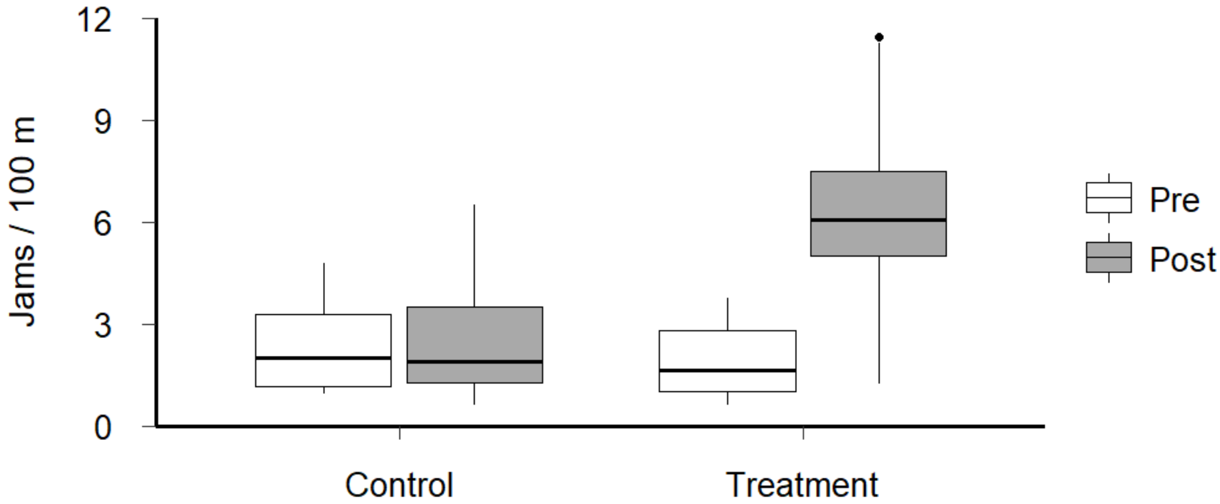
Appendix D – Large Woody Debris Data Summary



Summary Statistics

Description	Status	mean	median	min	q1	q3	max	sd	CV	n
Control	Pre	13.5	11.7	2.2	7.0	17.6	40.0	9.0	0.7	39
Control	Post	15.0	11.6	3.6	6.6	19.2	42.5	10.4	0.7	36
Treatment	Pre	10.7	9.2	1.2	5.6	13.5	27.4	7.4	0.7	34
Treatment	Post	40.1	35.8	11.9	22.7	53.0	111.9	21.7	0.5	46

Appendix D- 1. Frequency of large woody debris (LWD/100 m) in control and treatment sections, pre- and post-restoration by stream for all streams combined based on habitat surveys: 2008-2020.

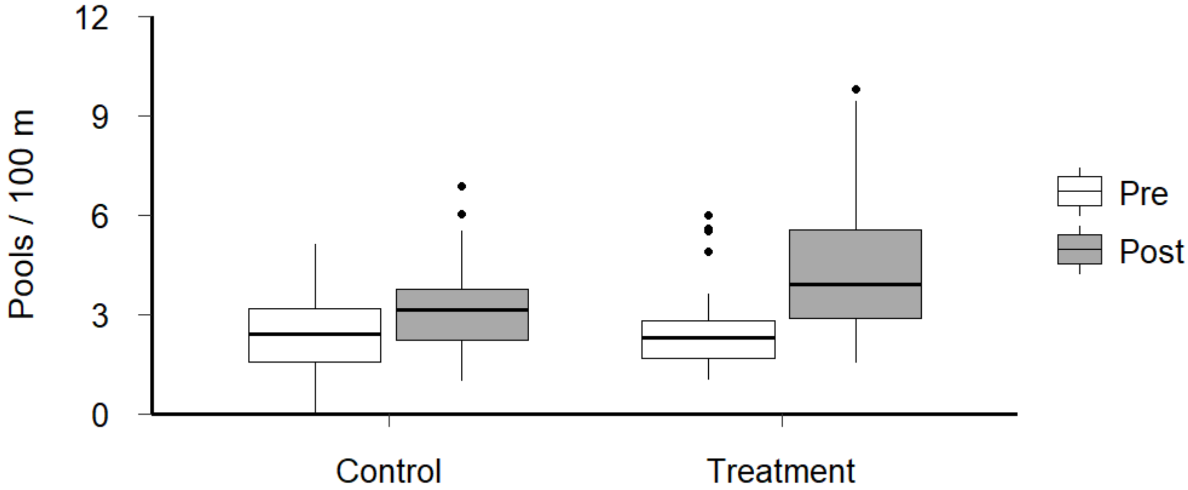


Summary Statistics

Description	Status	mean	median	min	q1	q3	max	sd	CV	n
Control	Pre	2.3	2.0	0.9	1.1	3.3	4.8	1.3	0.6	11
Control	Post	2.5	1.9	0.6	1.3	3.5	6.5	1.7	0.7	30
Treatment	Pre	1.9	1.6	0.6	1.0	2.8	3.8	1.1	0.6	14
Treatment	Post	6.1	6.1	1.2	5.0	7.5	11.5	2.3	0.4	46

Appendix D- 2. Frequency of large woody debris jams (Jams/100 m) in control and treatment sections, pre- and post-restoration by stream for all streams combined based on habitat surveys: 2008-2020.

Appendix E – Pools Data Summary

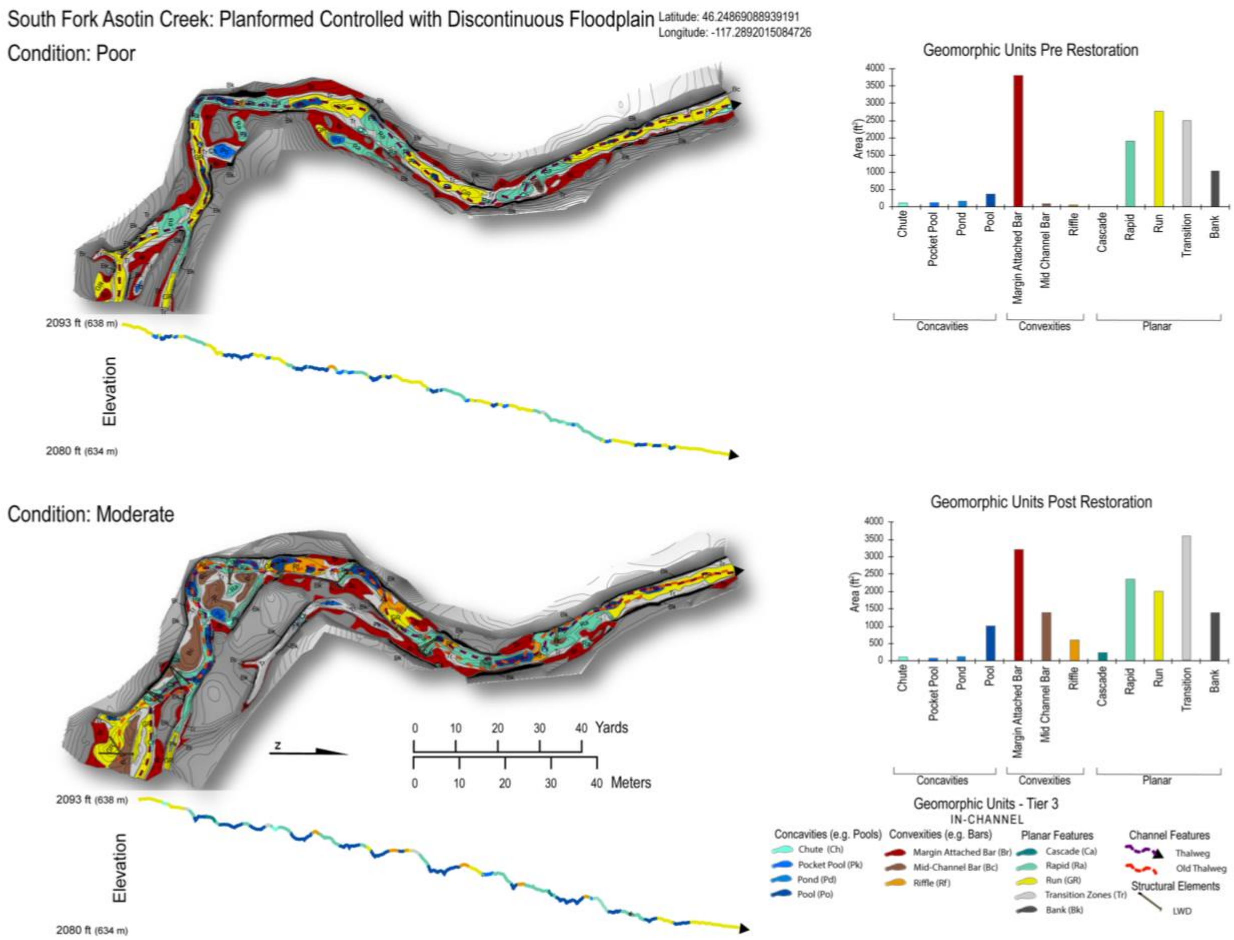


Summary Statistics

Description	Status	mean	median	min	q1	q3	max	sd	CV	n
Control	Pre	2.5	2.4	0.0	1.6	3.2	5.1	1.2	0.5	39
Control	Post	3.2	3.1	1.0	2.2	3.8	6.9	1.4	0.4	36
Treatment	Pre	2.5	2.3	1.0	1.7	2.8	6.0	1.3	0.5	34
Treatment	Post	4.5	3.9	1.5	2.9	5.6	9.8	2.1	0.5	46

Appendix E- 1. Frequency of pools (pools/100 m) in control and treatment sections, pre- and post-restoration by stream for all streams combined based on habitat surveys: 2008-2020.

Appendix F – Example output form the Geomorphic Unit Delineation (GUT) tool.



Appendix F- 1. Example of geomorphic unit delineation pre-restoration (top - 2012) and post-restoration (bottom - 2017) in South Fork Asotin Creek. Geomorphic units were delineated and quantified (area, count, type) using the Geomorphic Unit Tool (http://gut.riverscapes.xyz).

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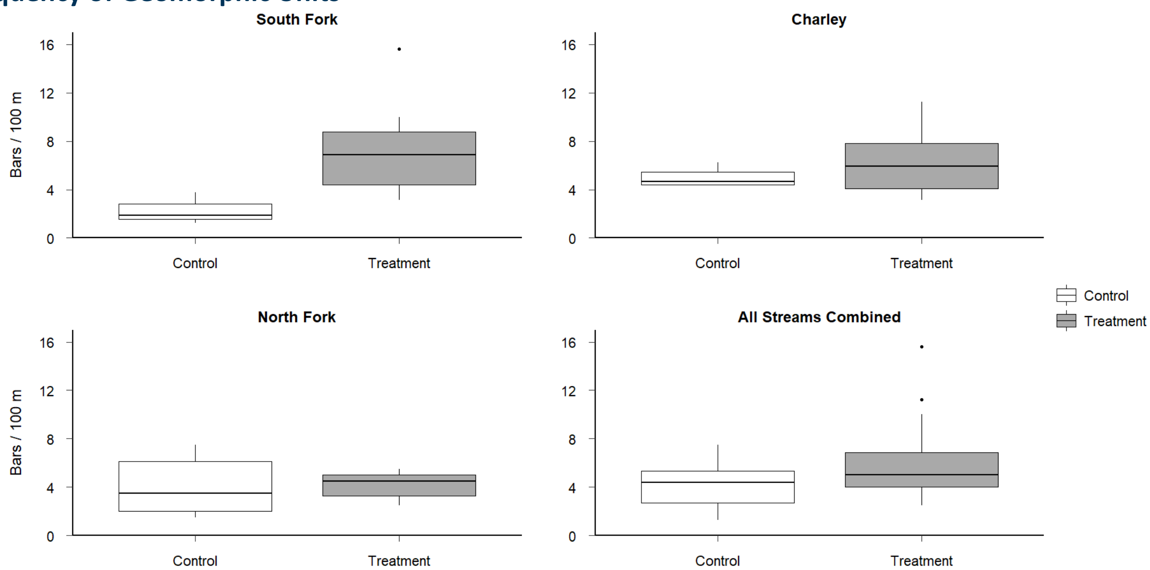
Appendix G – Rapid Habitat Data Summary

Data is a summary of the rapid habitat surveys where we counted and estimated the area of geomorphic units in each habitat site in 2021.

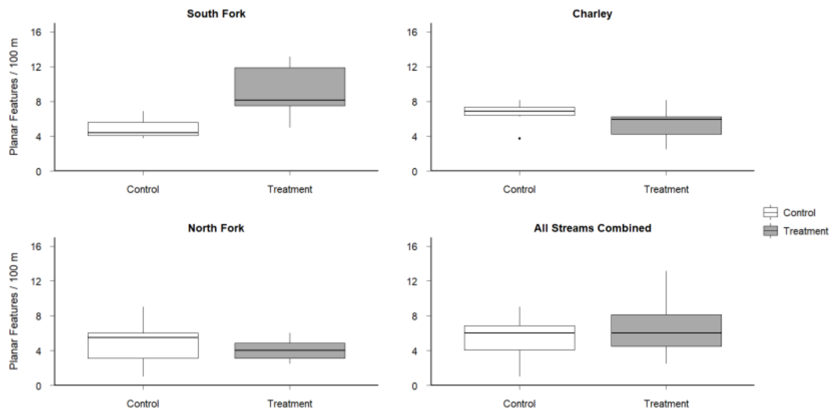
Frequency of Geomorphic Units



Summary Statistics

Stream	Description	mean	median	min	q1	q3	max	sd	CV	n
South Fork	Control	2.3	1.9	1.2	1.6	2.8	3.8	1.3	0.6	3
South Fork	Treatment	7.4	6.9	3.1	4.4	8.8	15.6	3.8	0.5	9
Charley	Control	5.0	4.7	4.4	4.4	5.5	6.2	0.8	0.2	6
Charley	Treatment	6.4	5.9	3.1	4.1	7.8	11.2	3.0	0.5	6
North Fork	Control	4.1	3.5	1.5	2.0	6.1	7.5	2.6	0.6	6
North Fork	Treatment	4.2	4.5	2.5	3.2	5.0	5.5	1.2	0.3	6
All Combined	Control	4.1	4.4	1.2	2.7	5.3	7.5	2.0	0.5	15
All Combined	Treatment	6.2	5.0	2.5	4.0	6.9	15.6	3.2	0.5	21

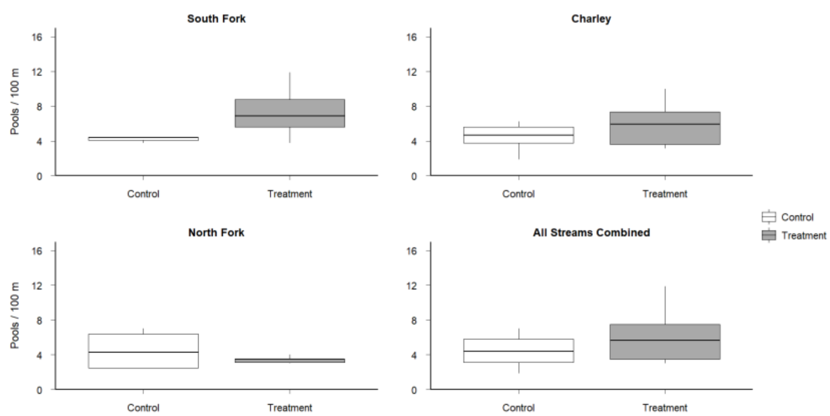
Appendix G- 1. Frequency of bar geomorphic units (units/100 m) in control and treatment sections, pre- and post-restoration by stream and all streams combined based on rapid habitat surveys of 36 habitat sites in 2021 over 3.2 km.



Summary Statistics

Stream	Description	mean	median	min	q1	q3	max	sd	CV	n
South Fork	Control	5.0	4.4	3.8	4.1	5.6	6.9	1.7	0.3	3
South Fork	Treatment	8.8	8.1	5.0	7.5	11.9	13.1	3.0	0.3	9
Charley	Control	6.6	6.9	3.8	6.4	7.3	8.1	1.5	0.2	6
Charley	Treatment	5.4	5.9	2.5	4.2	6.2	8.1	2.0	0.4	6
North Fork	Control	4.9	5.5	1.0	3.1	6.0	9.0	2.8	0.6	6
North Fork	Treatment	4.1	4.0	2.5	3.1	4.9	6.0	1.3	0.3	6
All Combined	Control	5.6	6.0	1.0	4.1	6.9	9.0	2.2	0.4	15
All Combined	Treatment	6.5	6.0	2.5	4.5	8.1	13.1	3.1	0.5	21

Appendix G- 2. Frequency of planar geomorphic units (units/100 m) in control and treatment sections, pre- and post-restoration by stream and all streams combined based on rapid habitat surveys of 36 habitat sites in 2021 over 3.2 km.

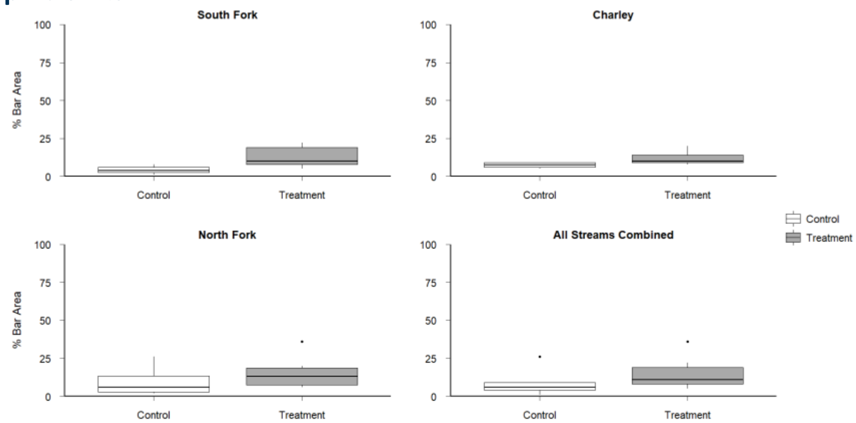


Summary Statistics

Stream	Description	mean	median	min	q1	q3	max	sd	CV	n
South Fork	Control	4.2	4.4	3.8	4.1	4.4	4.4	0.4	0.1	3
South Fork	Treatment	7.4	6.9	3.8	5.6	8.8	11.9	2.6	0.4	9
Charley	Control	4.5	4.7	1.9	3.8	5.6	6.2	1.6	0.4	6
Charley	Treatment	5.9	5.9	3.1	3.6	7.3	10.0	2.7	0.5	6
North Fork	Control	4.5	4.2	2.5	2.5	6.4	7.0	2.2	0.5	6
North Fork	Treatment	3.4	3.5	3.0	3.1	3.5	4.0	0.4	0.1	6
All Combined	Control	4.4	4.4	1.9	3.1	5.8	7.0	1.7	0.4	15
All Combined	Treatment	5.8	5.6	3.0	3.5	7.5	11.9	2.7	0.5	21

Appendix G- 3. Frequency of pool geomorphic units (units/100 m) in control and treatment sections, pre- and post-restoration by stream and all streams combined based on rapid habitat surveys of 36 habitat sites in 2021 over 3.2 km.

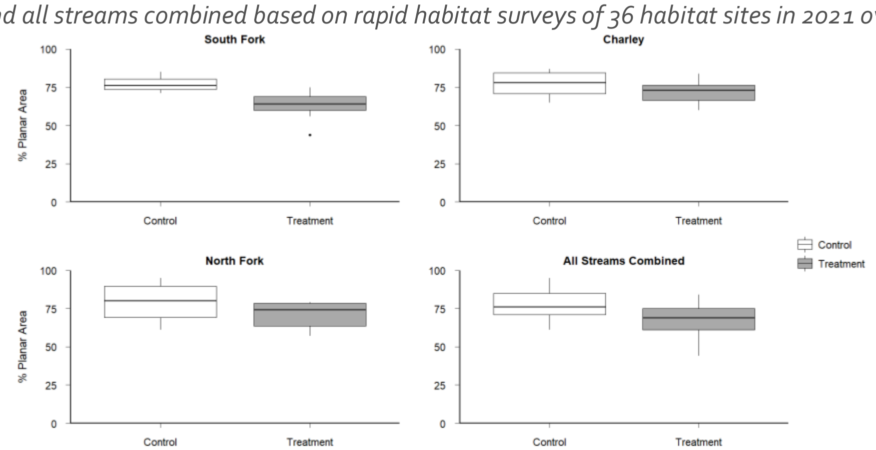
Area of Geomorphic Units



Summary Statistics

Stream	Description	mean	median	min	q1	q3	max	sd	CV	n
South Fork	Control	4.3	4.0	1	2.5	6.0	8	3.5	0.8	3
South Fork	Treatment	13.0	10.0	5	8.0	19.0	22	6.7	0.5	9
Charley	Control	7.3	7.5	5	6.0	9.0	9	1.9	0.3	6
Charley	Treatment	12.0	10.0	8	9.0	14.0	20	4.6	0.4	6
North Fork	Control	10.0	6.0	2	2.8	13.2	26	11.1	1.1	6
North Fork	Treatment	15.7	13.0	6	7.5	18.5	36	11.3	0.7	6
All Combined	Control	7.5	6.0	1	4.0	9.0	26	6.2	0.8	15
All Combined	Treatment	13.5	11.0	5	8.0	19.0	36	7.6	0.6	21

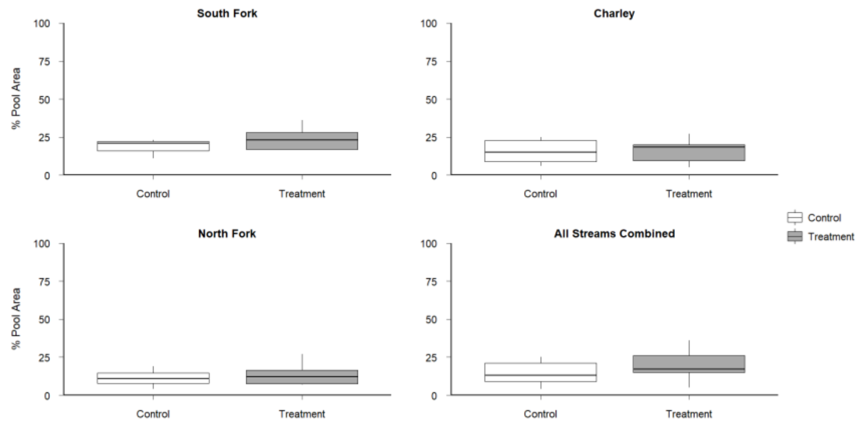
Appendix G- 4. Percent of bar geomorphic unit area in control and treatment sections, pre- and post-restoration by stream and all streams combined based on rapid habitat surveys of 36 habitat sites in 2021 over 3.2 km.



Summary Statistics

Stream	Description	mean	median	min	q1	q3	max	sd	CV	n
South Fork	Control	77.3	76	71	73.5	80.5	85	7.1	0.1	3
South Fork	Treatment	63.1	64	44	60.0	69.0	75	9.5	0.2	9
Charley	Control	77.2	78	65	70.8	84.5	87	9.0	0.1	6
Charley	Treatment	72.0	73	60	66.5	76.5	84	8.6	0.1	6
North Fork	Control	79.0	80	61	69.2	89.8	95	15.4	0.2	6
North Fork	Treatment	70.7	74	57	63.5	78.5	79	9.6	0.1	6
All Combined	Control	77.8	76	61	71.0	85.0	95	10.1	0.1	15
All Combined	Treatment	67.8	69	44	61.0	75.0	84	9.8	0.1	21

Appendix G- 5. Percent of planar geomorphic unit area in control and treatment sections, pre- and post-restoration by stream and all streams combined based on rapid habitat surveys of 36 habitat sites in 2021 over 3.2 km.

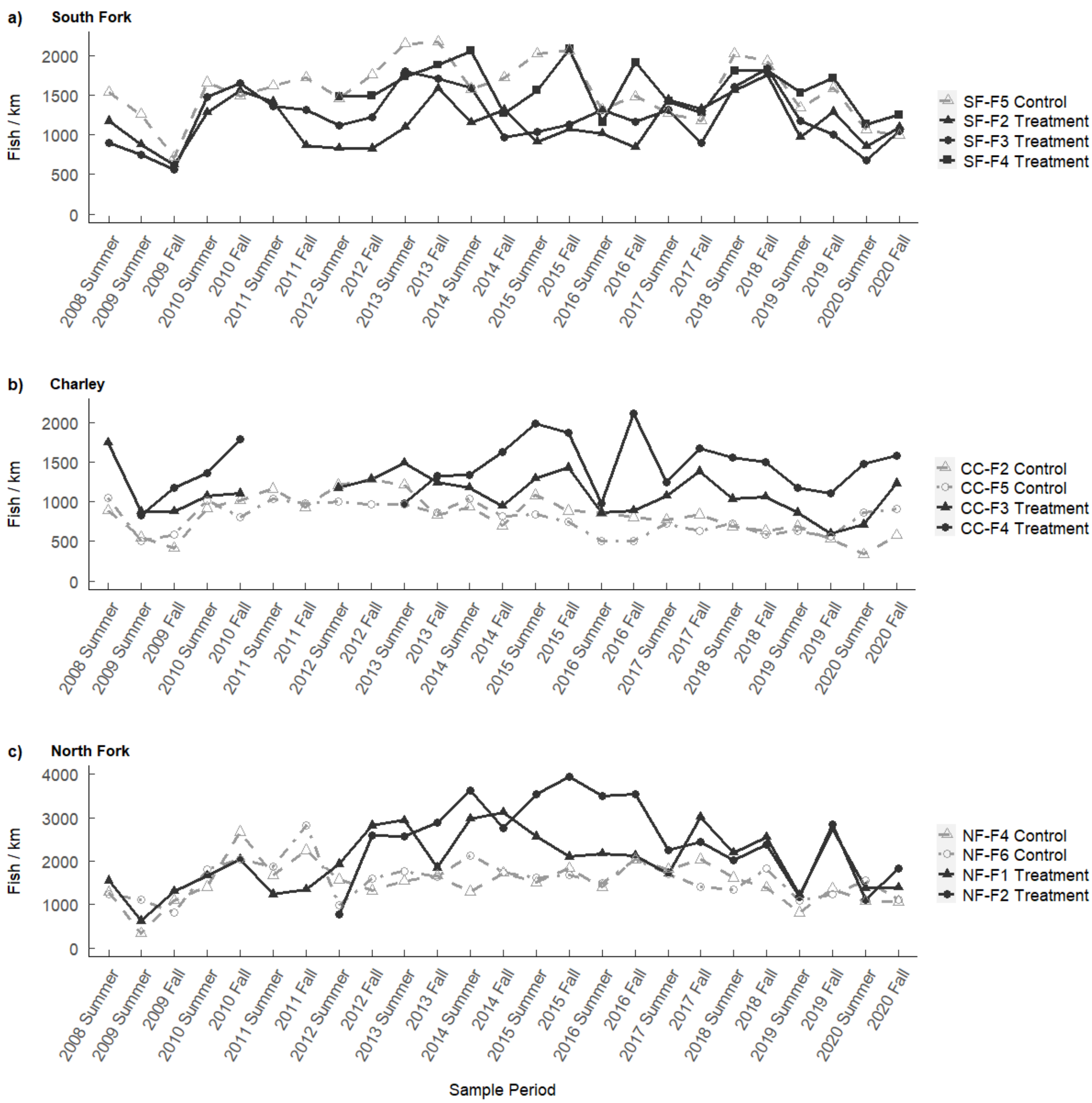


Summary Statistics

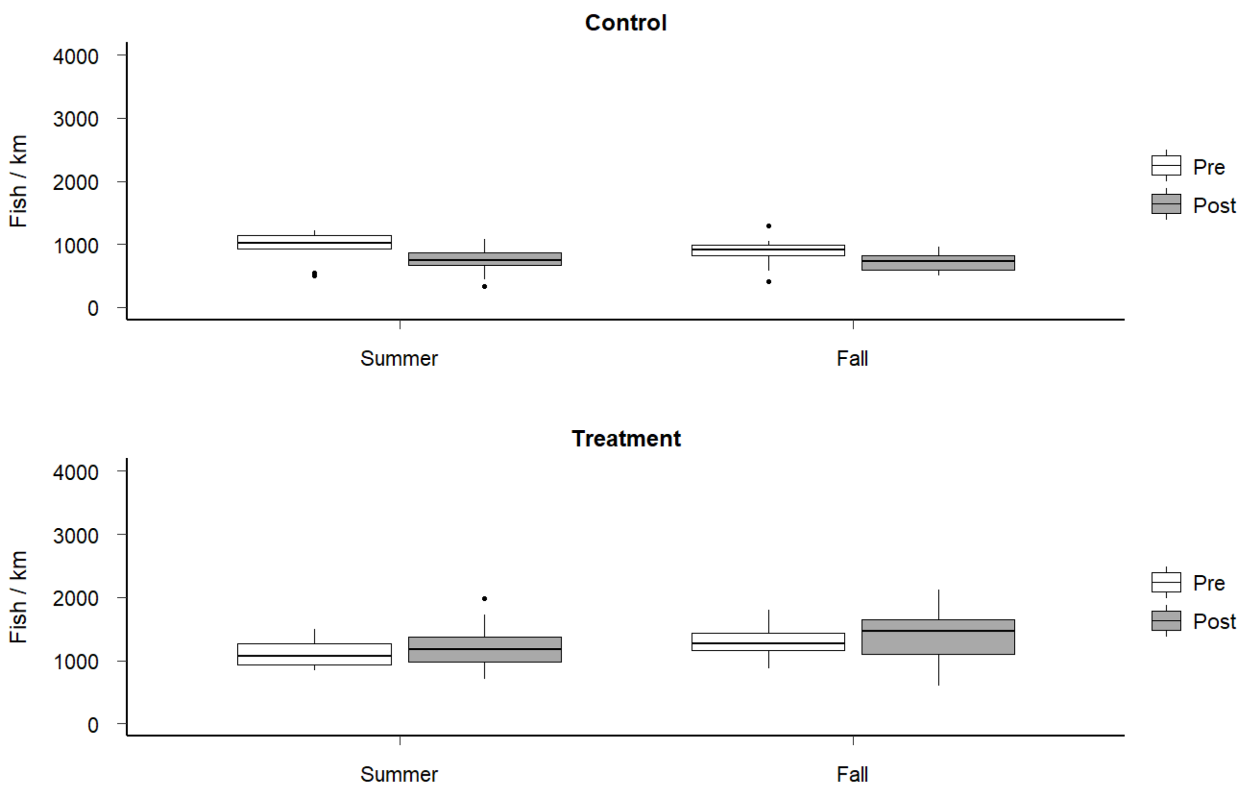
Stream	Description	mean	median	min	q1	q3	max	sd	CV	n
South Fork	Control	18.3	21.0	11	16.0	22.0	23	6.4	0.3	3
South Fork	Treatment	24.1	23.0	17	17.0	28.0	36	7.4	0.3	9
Charley	Control	15.5	15.0	6	8.8	22.8	25	8.3	0.5	6
Charley	Treatment	16.0	18.5	5	9.5	20.0	27	8.4	0.5	6
North Fork	Control	11.2	11.0	4	7.8	14.5	19	6.3	0.6	6
North Fork	Treatment	13.7	12.0	7	7.5	16.5	27	7.8	0.6	6
All Combined	Control	14.8	13.0	4	9.0	21.0	25	7.3	0.5	15
All Combined	Treatment	18.8	17.0	5	15.0	26.0	36	8.8	0.5	21

Appendix G- 6. Percent of pool geomorphic unit area in control and treatment sections, pre- and post-restoration by stream and all streams combined based on rapid habitat surveys of 36 habitat sites in 2021 over 3.2 km.

Appendix H – Abundance of Juvenile Steelhead Data Summary



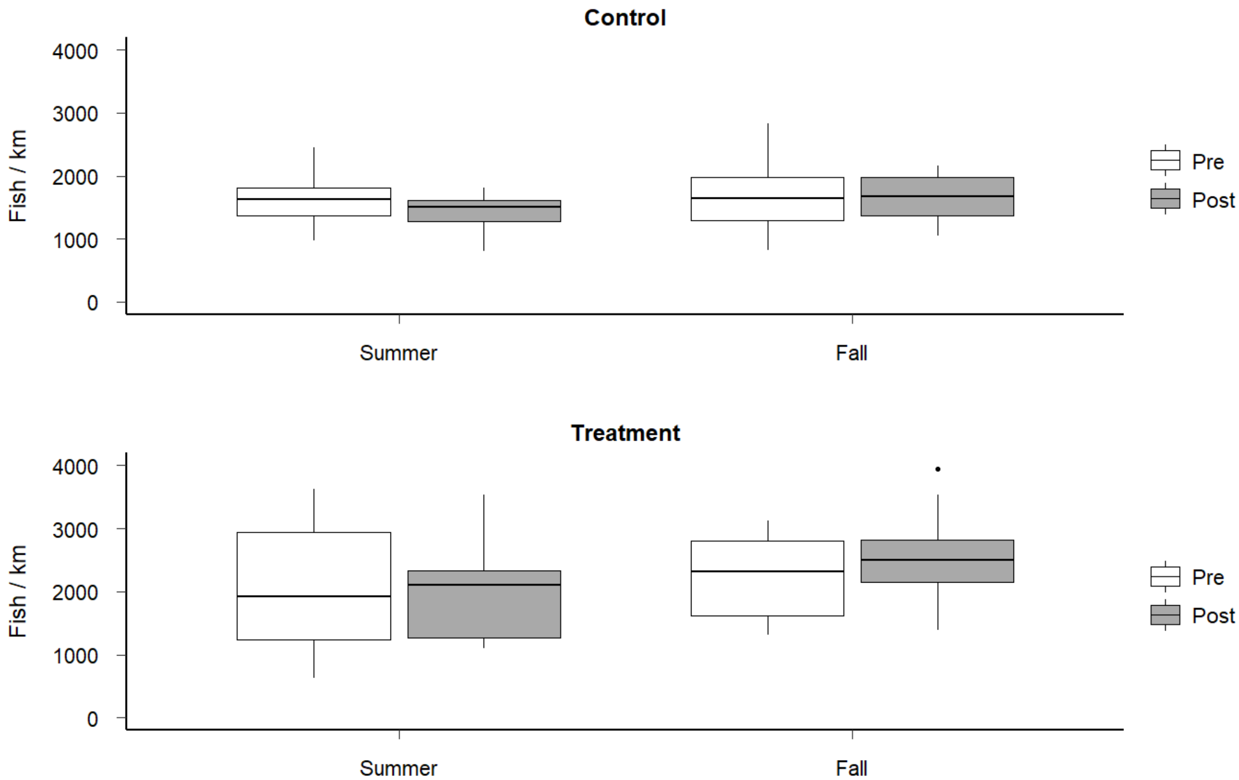
Appendix H- 1. Average fish abundance (fish/km) by fish site in treatment and control sections: 2008-2020. Sample seasons include one 2-day mark-recapture survey per fish site in the summer (July) and fall (late September to mid-October) every year except 2008 when only a summer survey was conducted.



Summary Statistics

Season	Description	Status	mean	median	min	q1	q3	max	sd	CV	n
Summer	Control	Pre	961	1014	509	934	1134	1215	248	0.258	10
Summer	Control	Post	750	752	337	672	864	1084	203	0.271	16
Summer	Treatment	Pre	1117	1075	835	932	1274	1496	247	0.221	7
Summer	Treatment	Post	1220	1181	712	982	1379	1989	340	0.279	16
Fall	Control	Pre	887	914	413	828	994	1288	224	0.253	12
Fall	Control	Post	719	727	506	589	829	952	145	0.202	16
Fall	Treatment	Pre	1323	1268	878	1162	1439	1797	312	0.236	8
Fall	Treatment	Post	1391	1470	599	1102	1648	2121	398	0.286	16

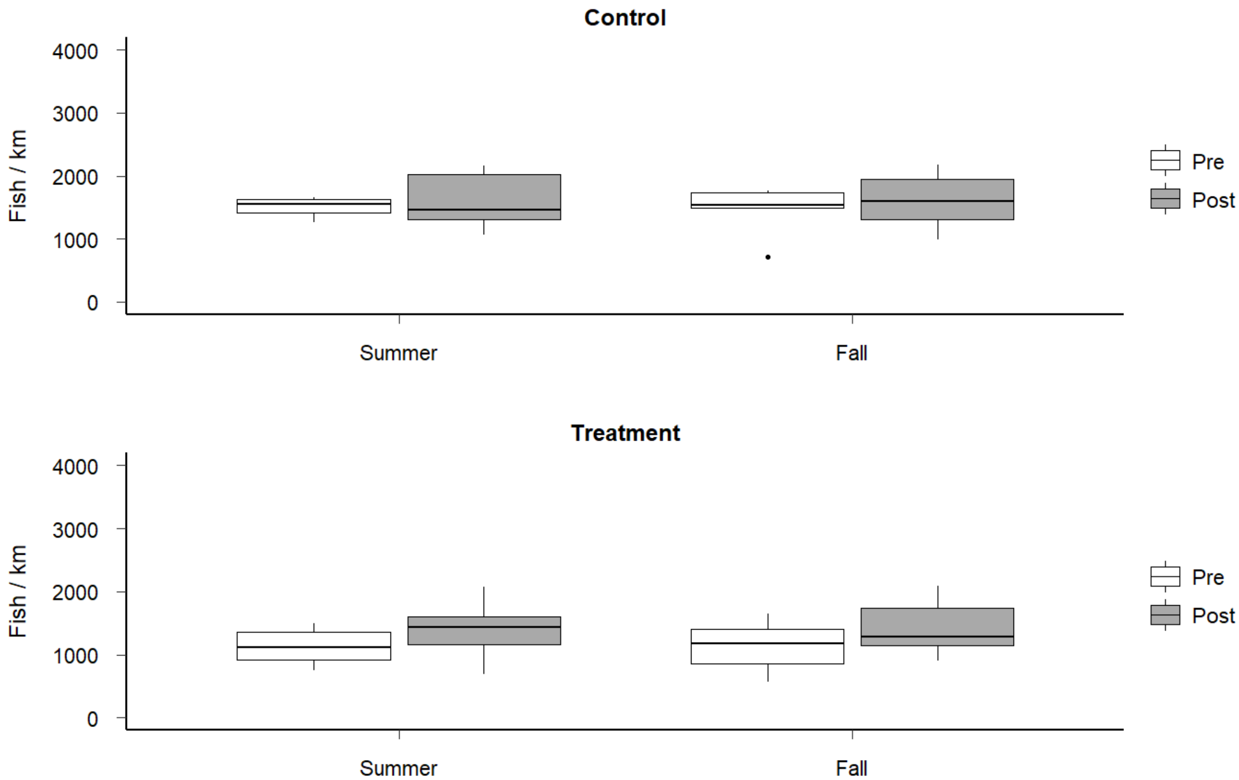
Appendix H- 2. Abundance of juvenile steelhead (fish/km) in Charley Creek averaged by control and treatment sections, pre- and post-restoration, for each season: 2008-2021.



Summary Statistics

Season	Description	Status	mean	median	min	q1	q3	max	sd	CV	n
Summer	Control	Pre	1629	1624	974	1375	1814	2445	416	0.255	12
Summer	Control	Post	1416	1500	809	1277	1609	1812	294	0.208	12
Summer	Treatment	Pre	2034	1929	621	1233	2939	3620	1054	0.518	9
Summer	Treatment	Post	2059	2097	1102	1264	2330	3536	836	0.406	12
Fall	Control	Pre	1708	1649	820	1295	1970	2825	575	0.337	14
Fall	Control	Post	1631	1666	1057	1376	1983	2161	371	0.227	14
Fall	Treatment	Pre	2226	2317	1307	1622	2805	3117	687	0.309	10
Fall	Treatment	Post	2557	2499	1388	2151	2820	3945	661	0.259	14

Appendix H- 3. Frequency of juvenile steelhead (fish/km) in North Fork Asotin Creek averaged by control and treatment sections, pre- and post-restoration, for each season.

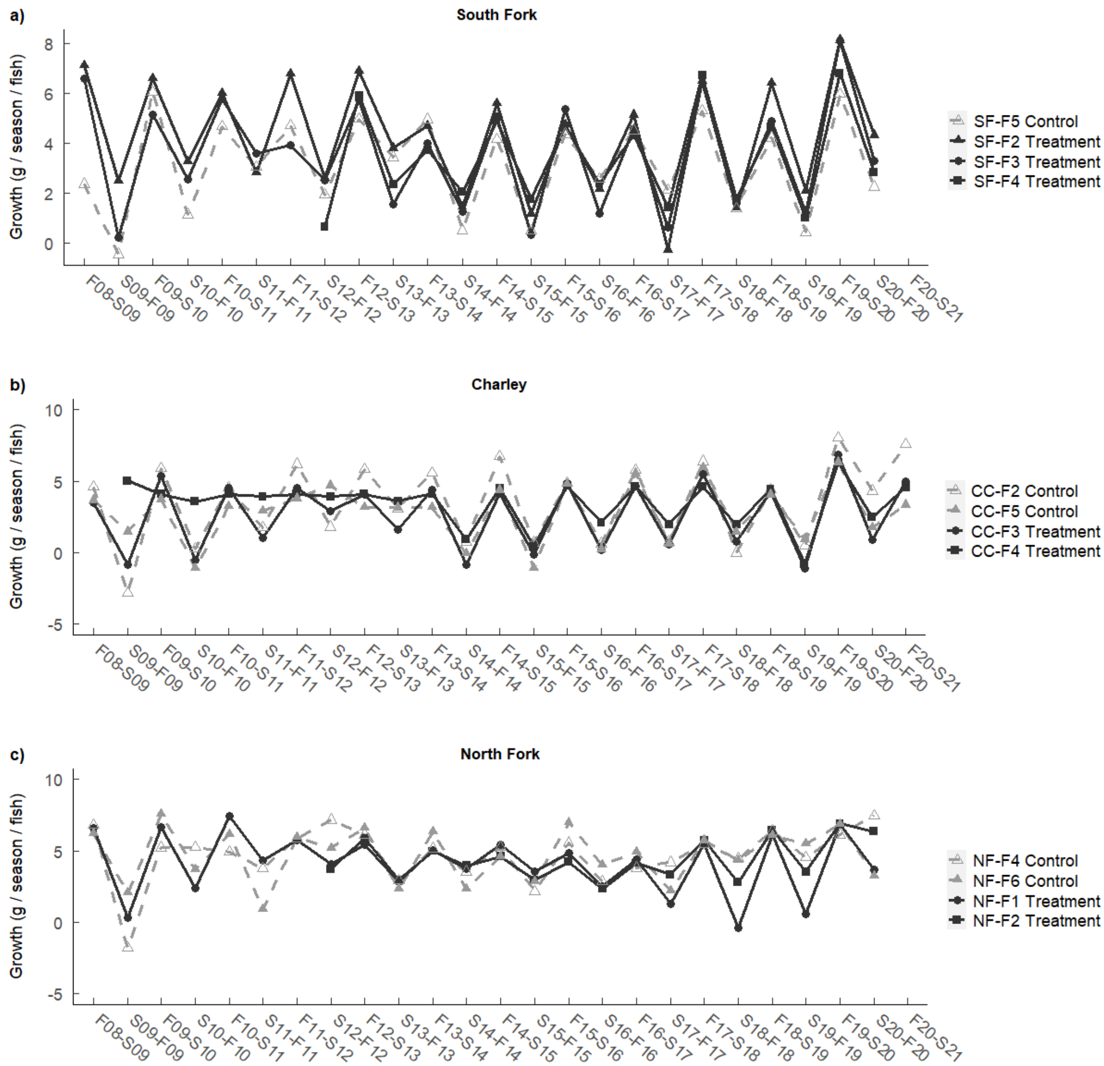


Summary Statistics

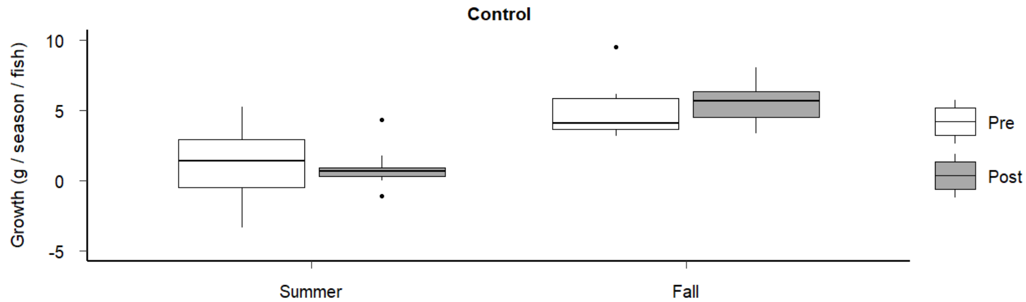
Season	Description	Status	mean	median	min	q1	q3	max	sd	CV	n
Summer	Control	Pre	1505	1544	1266	1417	1633	1665	181	0.120	4
Summer	Control	Post	1602	1467	1063	1312	2030	2159	417	0.260	8
Summer	Treatment	Pre	1140	1117	751	917	1362	1489	252	0.221	13
Summer	Treatment	Post	1395	1439	682	1159	1605	2068	354	0.254	20
Fall	Control	Pre	1450	1543	715	1497	1731	1763	427	0.294	5
Fall	Control	Post	1608	1594	987	1301	1939	2182	410	0.255	9
Fall	Treatment	Pre	1138	1178	565	857	1410	1651	355	0.312	15
Fall	Treatment	Post	1415	1290	897	1152	1742	2092	356	0.252	23

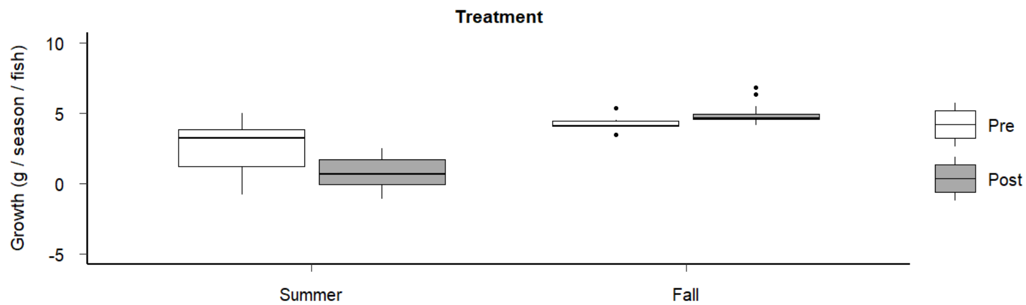
Appendix H- 4. Frequency of juvenile steelhead (fish/km) in South Fork Asotin Creek averaged by control and treatment sections, pre- and post-restoration, for each season.

Appendix I – Growth Rate of Juvenile Steelhead Data Summary



Appendix I- 1. Average growth rate (g/season/fish) by fish site in treatment and control sections: 2008-2021. Sample seasons are Summer to Fall (e.g., S09-F09) and Fall to Summer (e.g., F08-S09).

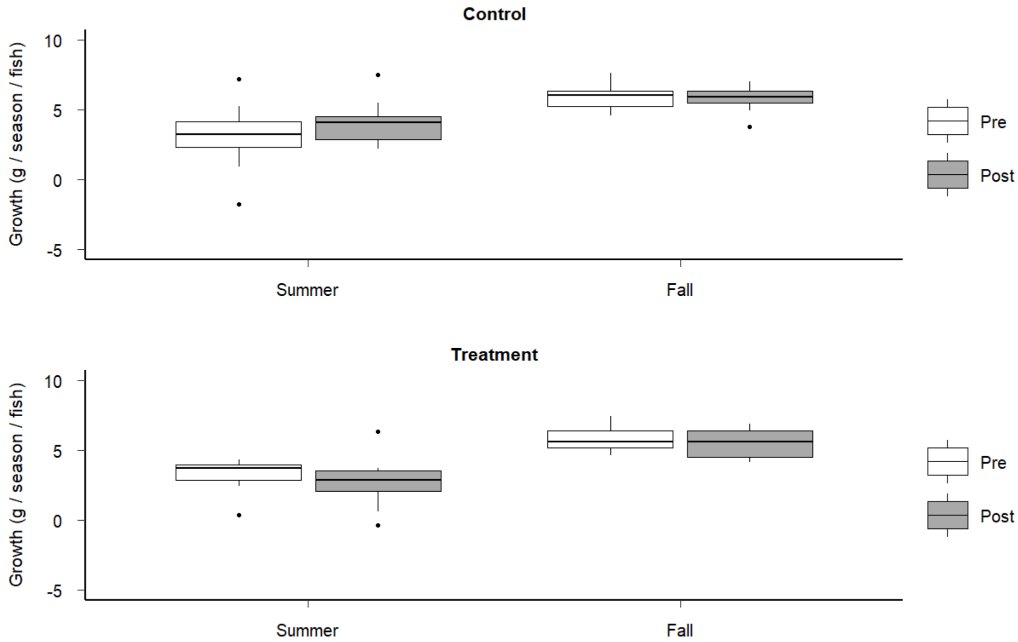




Summary Statistics

Season	Description	Status	mean	median	min	q1	q3	max	sd	CV	n
Summer	Control	Pre	1.131	1.416	-3.360	-0.519	2.925	5.239	2.372	2.097	17
Summer	Control	Post	0.828	0.673	-1.087	0.306	0.913	4.324	1.215	1.467	14
Summer	Treatment	Pre	2.434	3.235	-0.811	1.185	3.855	5.018	1.994	0.819	10
Summer	Treatment	Post	0.676	0.664	-1.091	-0.064	1.708	2.477	1.157	1.712	14
Fall	Control	Pre	4.711	4.051	3.169	3.663	5.836	9.544	1.640	0.348	19
Fall	Control	Post	5.585	5.654	3.357	4.498	6.364	8.023	1.357	0.243	14
Fall	Treatment	Pre	4.259	4.103	3.478	4.102	4.461	5.376	0.466	0.109	11
Fall	Treatment	Post	4.934	4.654	4.168	4.540	4.945	6.845	0.776	0.157	14

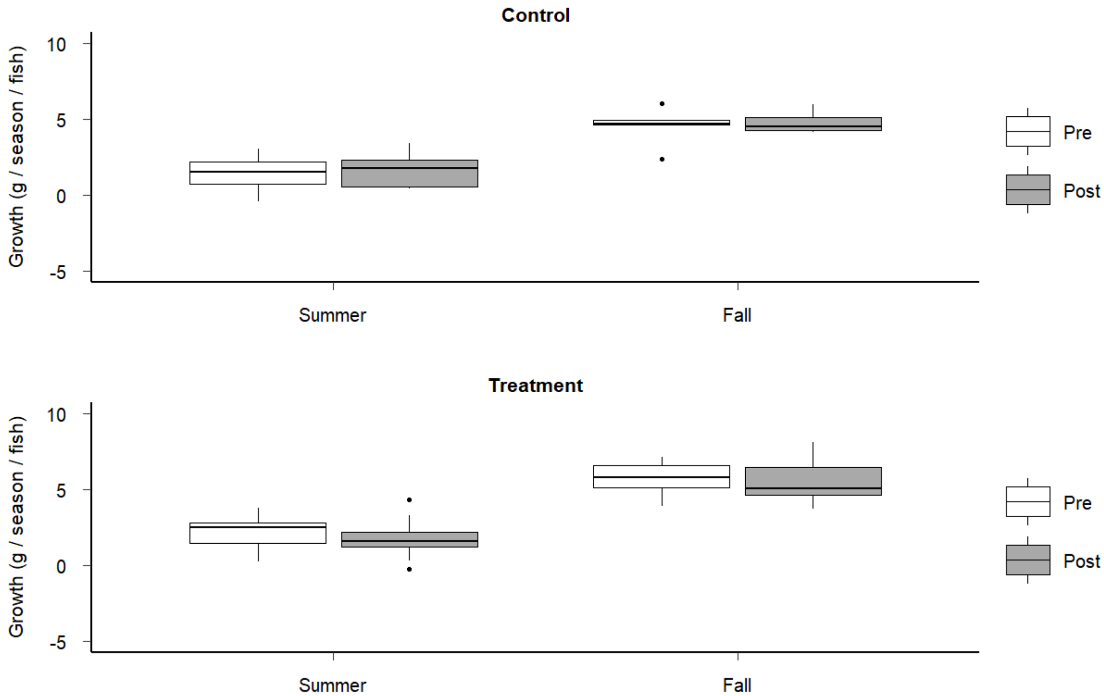
Appendix I- 2. Growth rates of juvenile steelhead (g/season/fish) in Charley Creek averaged by control and treatment sections, pre- and post-restoration, for each season: 2008-2021.



Summary Statistics

Season	Description	Status	mean	median	min	q1	q3	max	sd	CV	n
Summer	Control	Pre	3.128	3.237	-1.800	2.289	4.132	7.170	2.288	0.731	12
Summer	Control	Post	3.996	4.106	2.173	2.878	4.486	7.475	1.496	0.374	12
Summer	Treatment	Pre	3.164	3.733	0.347	2.870	3.972	4.315	1.231	0.389	9
Summer	Treatment	Post	2.719	2.872	-0.395	2.090	3.558	6.356	1.716	0.631	12
Fall	Control	Pre	5.924	6.059	4.599	5.227	6.327	7.599	0.817	0.138	14
Fall	Control	Post	5.800	5.919	3.806	5.494	6.326	7.014	0.946	0.163	12
Fall	Treatment	Pre	5.785	5.587	4.600	5.155	6.422	7.448	0.886	0.153	10
Fall	Treatment	Post	5.519	5.608	4.145	4.509	6.378	6.898	1.067	0.193	12

Appendix I- 3. Growth rates of juvenile steelhead (g/season/fish) in North Fork Asotin Creek averaged by control and treatment sections, pre- and post-restoration, for each season: 2008-2021.

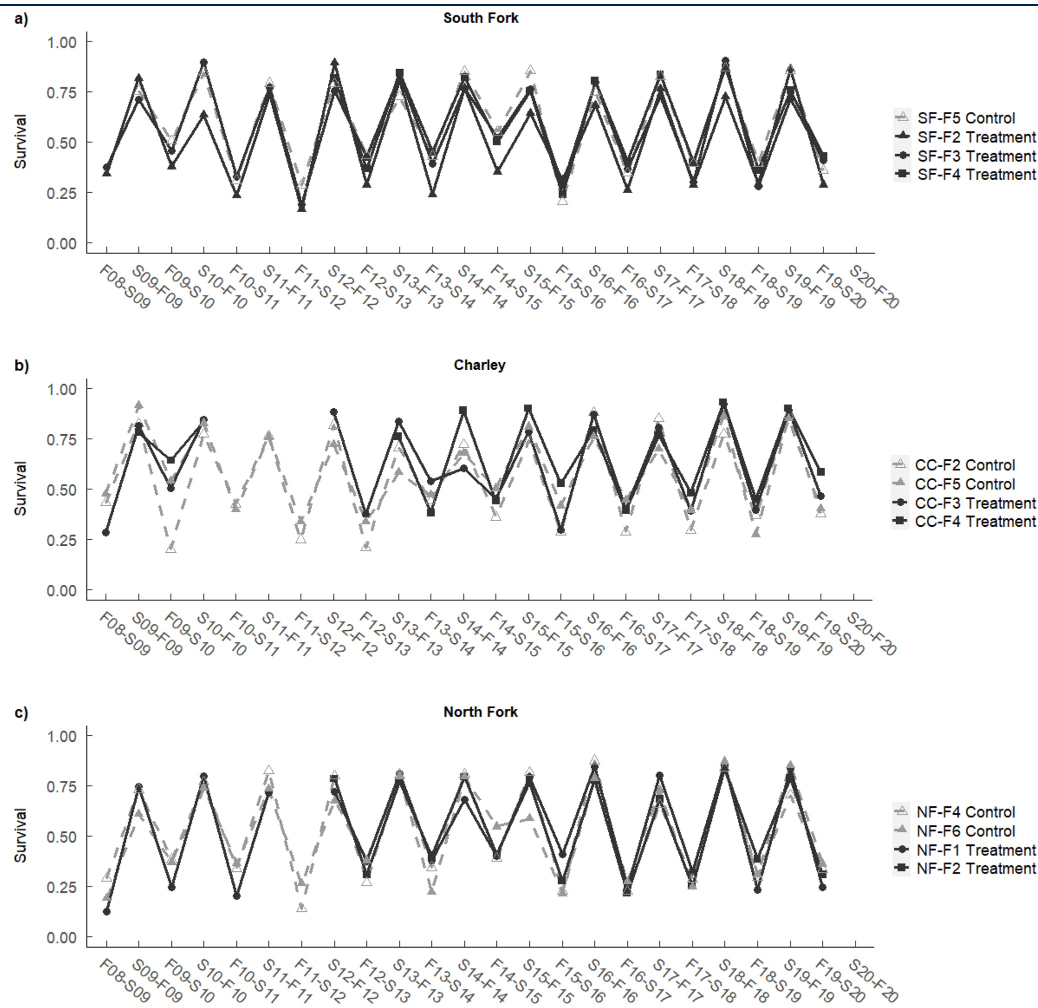


Summary Statistics

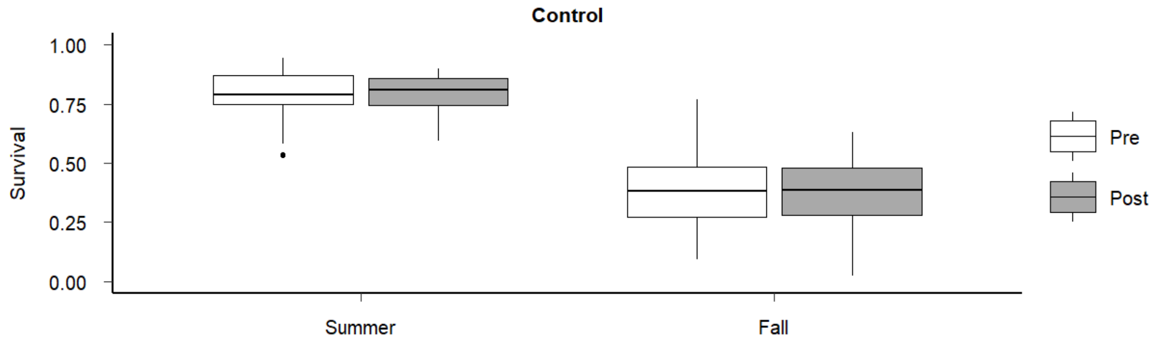
Season	Description	Status	mean	median	min	q1	q3	max	sd	CV	n
Summer	Control	Pre	1.412	1.536	-0.462	0.738	2.211	3.039	1.473	1.043	4
Summer	Control	Post	1.643	1.748	0.424	0.506	2.318	3.427	1.118	0.680	8
Summer	Treatment	Pre	2.250	2.512	0.222	1.444	2.816	3.795	1.095	0.487	13
Summer	Treatment	Post	1.706	1.566	-0.271	1.212	2.157	4.320	1.028	0.603	20
Fall	Control	Pre	4.538	4.692	2.348	4.657	4.950	6.045	1.348	0.297	5
Fall	Control	Post	4.774	4.497	4.157	4.275	5.123	5.963	0.669	0.140	8
Fall	Treatment	Pre	5.767	5.770	3.928	5.120	6.581	7.106	0.923	0.160	15
Fall	Treatment	Post	5.592	5.051	3.714	4.644	6.477	8.117	1.354	0.242	20

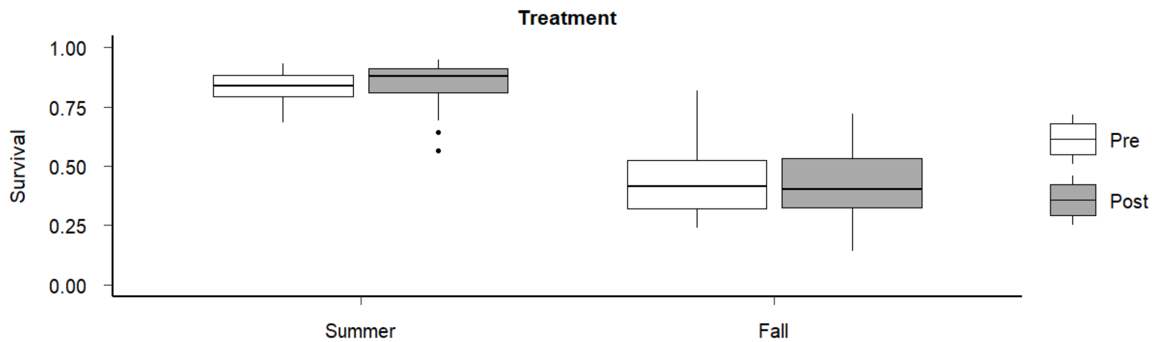
Appendix I- 4. Growth rates of juvenile steelhead (g/season/fish) in South Fork Asotin Creek averaged by control and treatment sections, pre- and post-restoration, for each season: 2008-2021.

Appendix J – Survival Rate of Juvenile Steelhead Data Summary



Appendix J- 1. Average juvenile steelhead survival rate/season by stream and fish site in treatment control sections: 2008-2020. Survival seasons are Summer to Fall (e.g., S09-F09) and Fall to Summer (e.g., F08-S09).

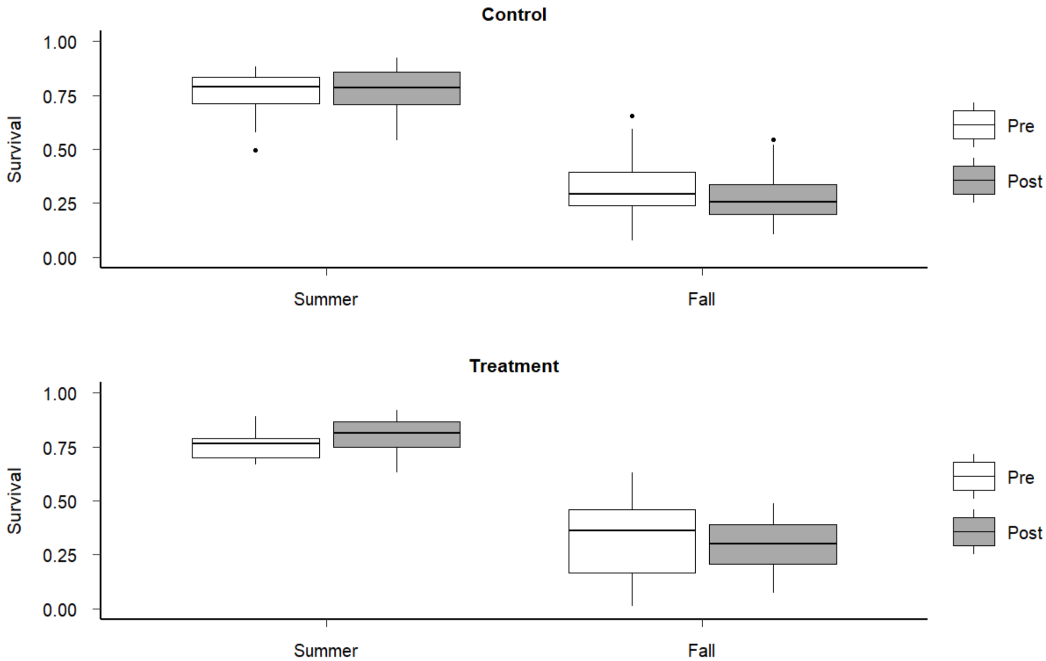




Summary Statistics

Season	Description	Status	mean	median	min	q1	q3	max	sd	CV	n
Summer	Control	Pre	0.783	0.788	0.531	0.748	0.870	0.945	0.109	0.139	34
Summer	Control	Post	0.793	0.810	0.592	0.744	0.859	0.900	0.082	0.103	28
Summer	Treatment	Pre	0.824	0.837	0.681	0.794	0.884	0.931	0.075	0.091	14
Summer	Treatment	Post	0.840	0.878	0.565	0.807	0.911	0.949	0.100	0.119	28
Fall	Control	Pre	0.387	0.380	0.091	0.273	0.485	0.766	0.179	0.463	49
Fall	Control	Post	0.369	0.384	0.022	0.281	0.478	0.632	0.148	0.401	35
Fall	Treatment	Pre	0.466	0.415	0.240	0.319	0.524	0.818	0.202	0.433	17
Fall	Treatment	Post	0.438	0.400	0.142	0.325	0.533	0.718	0.144	0.329	36

Appendix J- 2. Survival rate/season of juvenile steelhead in Charley Creek averaged by control and treatment sections, pre- and post-restoration, for summer to fall and fall to summer seasons: 2008-2020.



Summary Statistics

Season	Description	Status	mean	median	min	q1	q3	max	sd	CV	n
Summer	Control	Pre	0.758	0.788	0.495	0.710	0.835	0.881	0.100	0.132	24
Summer	Control	Post	0.773	0.786	0.539	0.705	0.857	0.923	0.104	0.135	24
Summer	Treatment	Pre	0.759	0.763	0.666	0.700	0.787	0.892	0.064	0.084	18
Summer	Treatment	Post	0.800	0.812	0.629	0.746	0.868	0.919	0.078	0.097	24
Fall	Control	Pre	0.326	0.292	0.077	0.240	0.393	0.656	0.137	0.420	40
Fall	Control	Post	0.279	0.255	0.105	0.198	0.337	0.546	0.110	0.394	30
Fall	Treatment	Pre	0.326	0.361	0.011	0.166	0.458	0.630	0.172	0.528	29
Fall	Treatment	Post	0.292	0.301	0.070	0.205	0.390	0.487	0.128	0.438	30

Appendix J- 3. Survival rate/season of juvenile steelhead in North Fork Asotin Creek averaged by control and treatment sections, pre- and post-restoration, for summer to fall and fall to summer seasons: 2008-2020.

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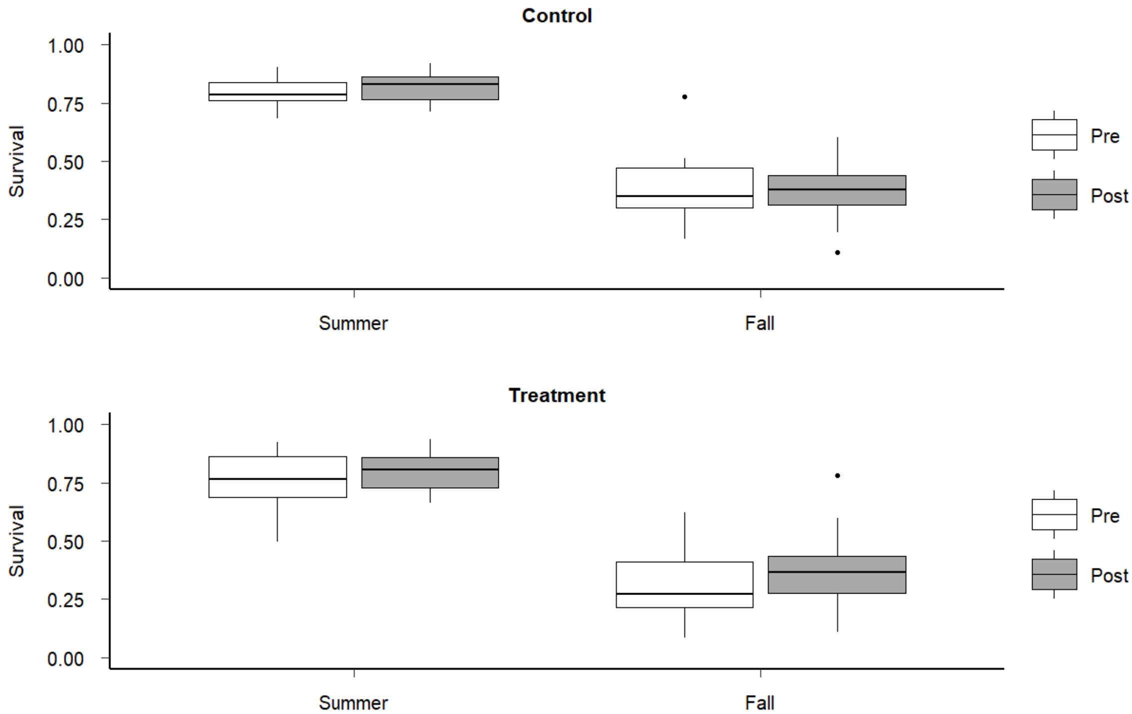
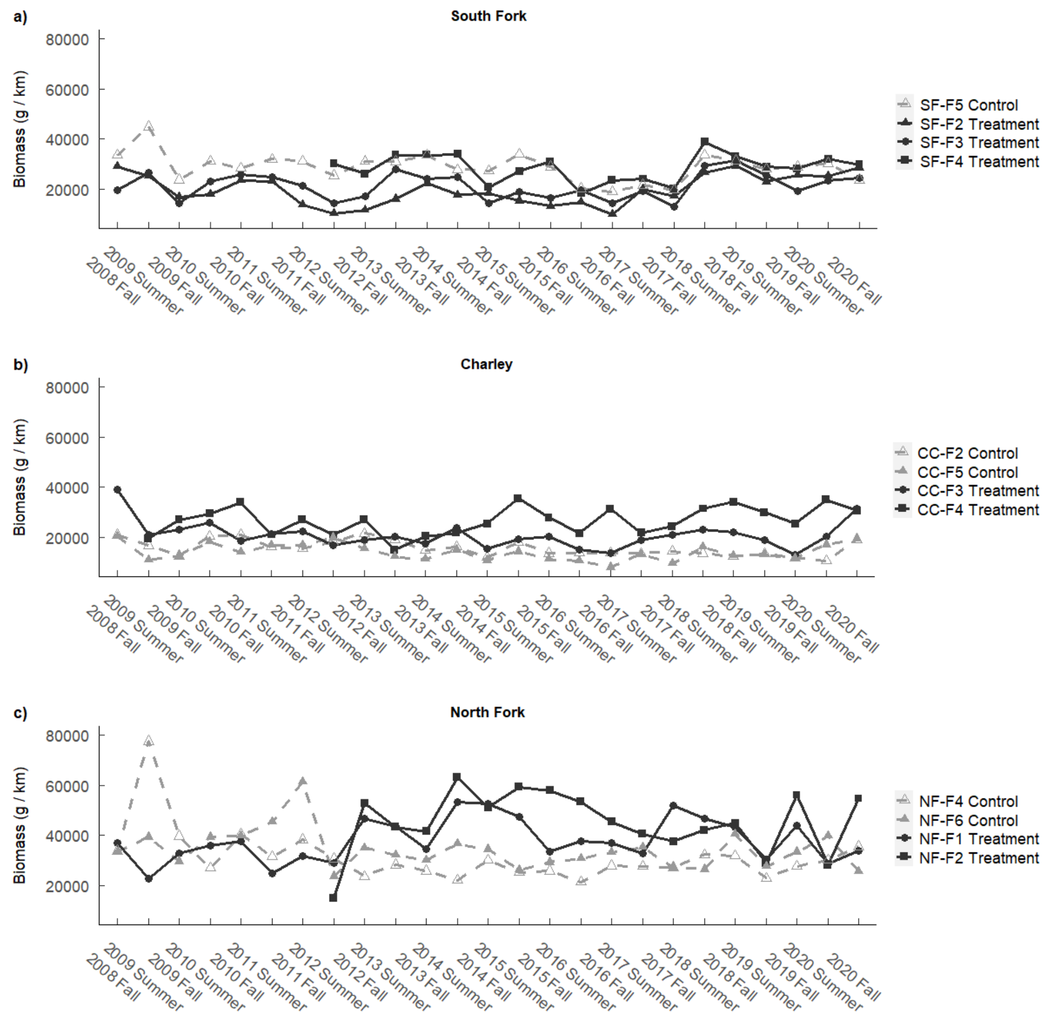


Summary Statistics

Season	Description	Status	mean	median	min	q1	q3	max	sd	CV	n
Summer	Control	Pre	0.797	0.784	0.681	0.760	0.837	0.904	0.076	0.095	8
Summer	Control	Post	0.820	0.829	0.712	0.765	0.861	0.917	0.065	0.079	16
Summer	Treatment	Pre	0.766	0.763	0.496	0.687	0.863	0.923	0.111	0.145	26
Summer	Treatment	Post	0.798	0.806	0.661	0.729	0.859	0.937	0.078	0.098	40
Fall	Control	Pre	0.385	0.351	0.167	0.300	0.471	0.778	0.167	0.434	14
Fall	Control	Post	0.384	0.378	0.110	0.313	0.440	0.601	0.120	0.312	21
Fall	Treatment	Pre	0.314	0.273	0.084	0.215	0.409	0.623	0.143	0.455	43
Fall	Treatment	Post	0.367	0.363	0.110	0.277	0.436	0.782	0.135	0.368	51

Appendix J- 4. Survival rate/season of juvenile steelhead in South Fork Asotin Creek averaged by control and treatment sections, pre- and post-restoration, for summer to fall and fall to summer season: 2008-2020.

Appendix K – Biomass of Juvenile Steelhead Data Summary

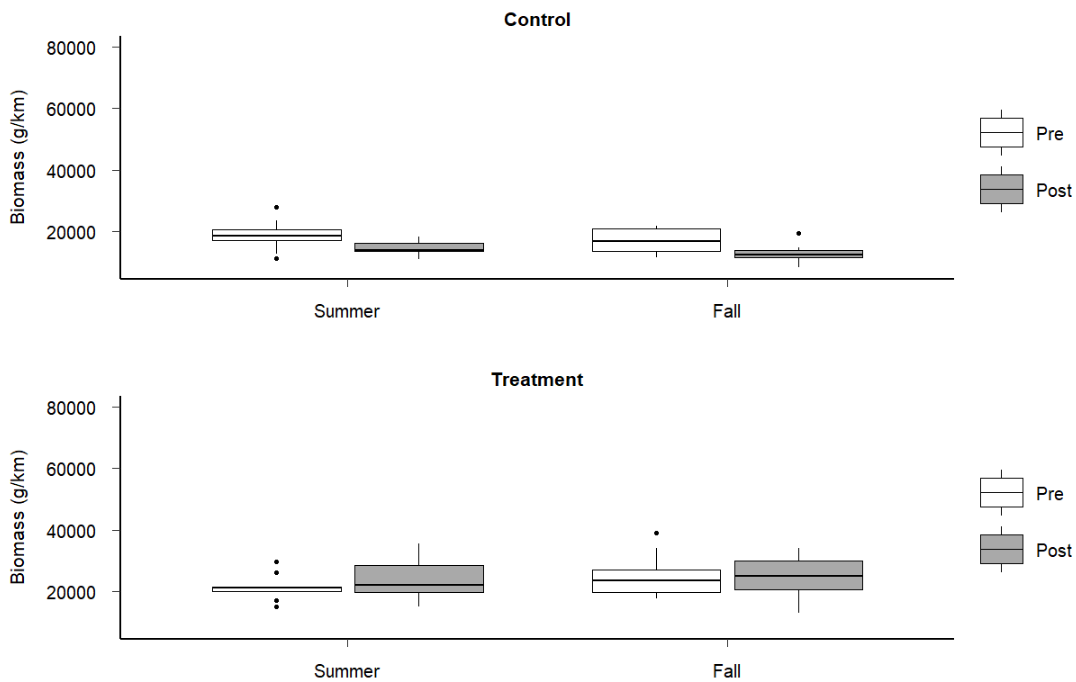


Appendix K- 1. Average biomass of juvenile steelhead (g/km) by stream and fish site in treatment control sections: 2008-2020. Biomass measured each year in the summer (e.g., S09) and Fall (e.g., F08).

Eco Logical Research

UtahState University

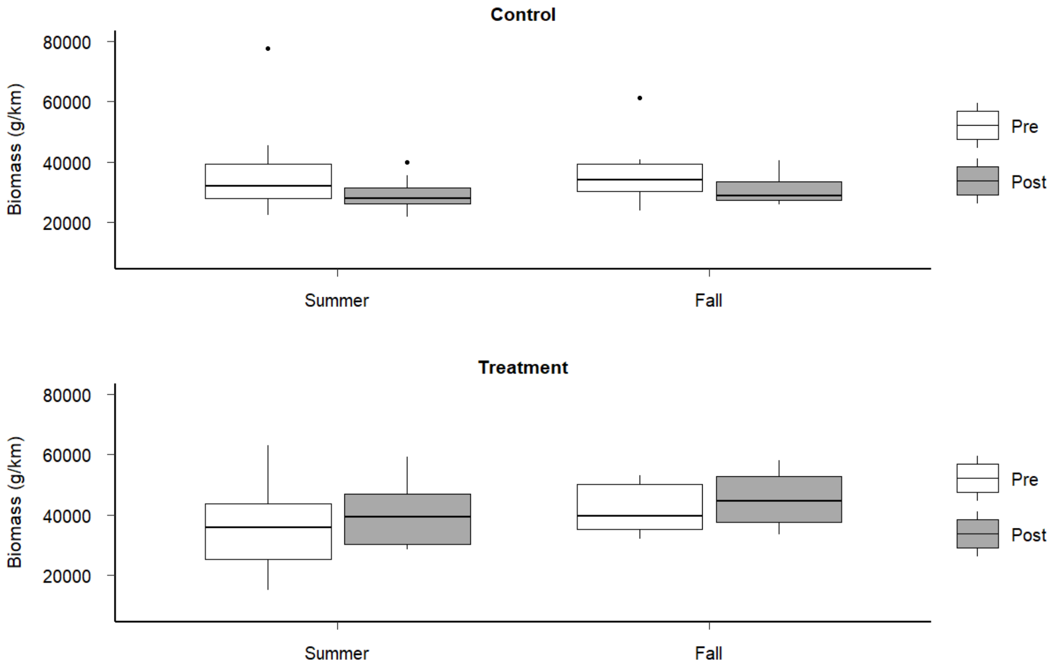
ANABRANCH SOLUTIONS



Summary Statistics

Season	Description	Status	mean	median	min	q1	q3	max	sd	CV	n
Summer	Control	Pre	18481.2	18350.6	11052.1	16851.8	20523.3	27877.1	4070.8	0.2	17
Summer	Control	Post	14285.0	13784.5	10693.1	13340.9	15947.4	18266.3	2181.6	0.2	14
Summer	Treatment	Pre	21211.4	21048.7	15065.1	19783.8	21307.5	29477.5	4096.7	0.2	10
Summer	Treatment	Post	24083.7	21890.1	15008.4	19662.6	28450.0	35569.7	6367.4	0.3	14
Fall	Control	Pre	17025.5	16729.2	11377.3	13467.1	20831.7	21599.3	3704.7	0.2	19
Fall	Control	Post	12993.0	12259.9	8196.2	11510.3	13750.7	19458.0	3154.3	0.2	14
Fall	Treatment	Pre	25023.8	23312.4	17531.5	19656.6	27016.7	39048.3	6734.8	0.3	11
Fall	Treatment	Post	24061.7	24950.2	12937.1	20532.6	29989.6	34110.2	6777.4	0.3	14

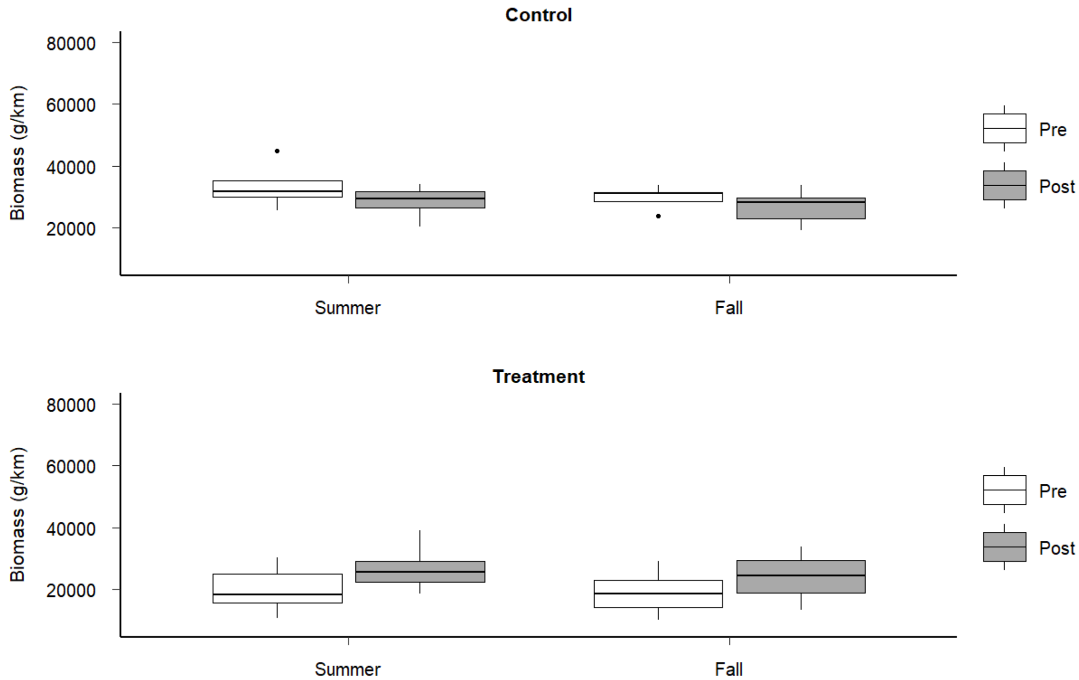
Appendix K- 2. Average biomass of juvenile steelhead (g/km) in Charley Creek by control and treatment sections, pre- and post-restoration, for summer and fall: 2008-2020.



Summary Statistics

Season	Description	Status	mean	median	min	q1	q3	max	sd	CV	n
Summer	Control	Pre	36191.5	31929.6	22195.1	27958.3	39371.0	77580.8	14712.3	0.4	12
Summer	Control	Post	28931.6	27761.0	21531.1	26139.4	31300.3	39933.9	5207.4	0.2	12
Summer	Treatment	Pre	36796.0	35863.2	15055.7	25046.6	43632.0	63153.2	15503.2	0.4	9
Summer	Treatment	Post	39742.7	39168.5	28315.8	30175.7	46993.7	59311.6	10396.1	0.3	12
Fall	Control	Pre	35438.1	34130.3	23672.7	30135.5	39396.3	61333.7	9088.2	0.3	14
Fall	Control	Post	30489.7	28612.9	25754.4	27263.5	33358.9	40533.8	4520.4	0.1	12
Fall	Treatment	Pre	41905.8	39660.3	31877.8	35195.2	50050.4	52945.8	8334.4	0.2	10
Fall	Treatment	Post	45031.8	44409.2	33389.7	37556.1	52676.3	57949.4	8595.2	0.2	12

Appendix K- 3. Average biomass of juvenile steelhead (g/km) in North Fork Asotin Creek by control and treatment sections, pre- and post-restoration, for each season: 2008-2020.

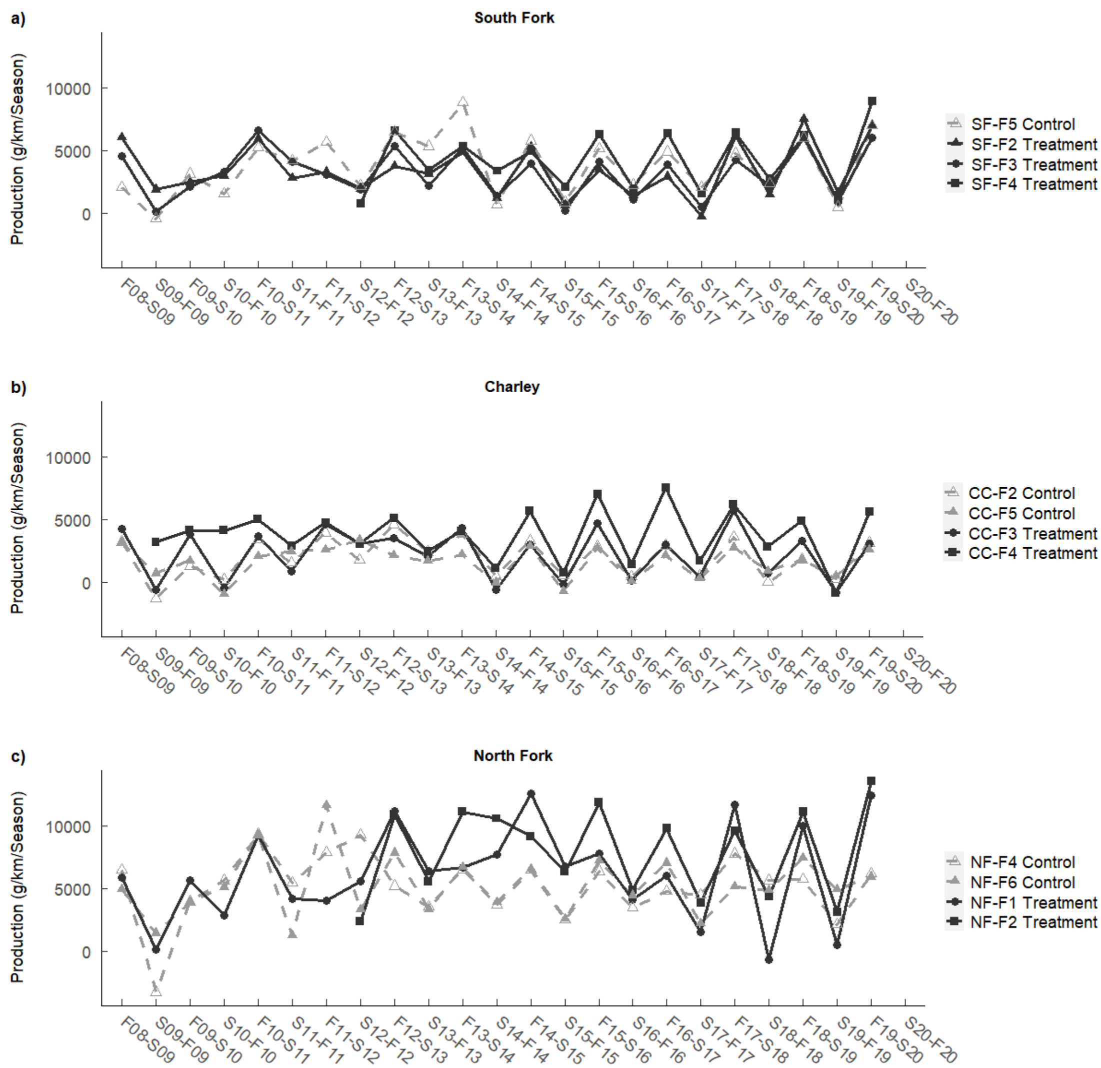


Summary Statistics

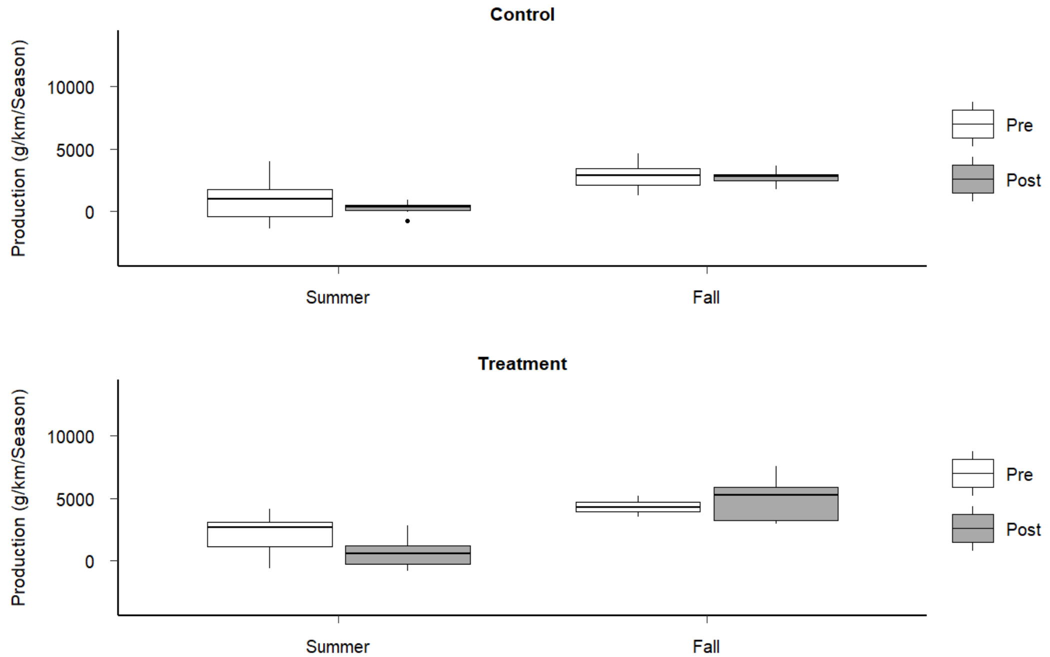
Season	Description	Status	mean	median	min	q1	q3	max	sd	CV	n
Summer	Control	Pre	33418.0	31652.9	25437.7	29827.6	35243.3	44928.5	8219.3	0.2	4
Summer	Control	Post	28326.6	29160.7	20308.3	26277.7	31647.2	33908.9	5071.8	0.2	8
Summer	Treatment	Pre	20022.0	18011.0	10451.8	15465.2	24943.0	30207.5	5861.1	0.3	13
Summer	Treatment	Post	26087.4	25393.1	18307.4	22351.9	29033.5	38880.3	5602.6	0.2	20
Fall	Control	Pre	29638.1	31142.6	23773.2	28483.1	31244.3	33547.1	3736.8	0.1	5
Fall	Control	Post	26605.5	28145.4	19074.5	22752.7	29587.8	33626.8	5292.2	0.2	8
Fall	Treatment	Pre	18916.4	18421.6	10020.2	14077.2	22929.9	29115.0	5728.6	0.3	15
Fall	Treatment	Post	23965.8	24379.0	13169.5	18734.1	29392.0	33698.5	6598.3	0.3	20

Appendix K- 4. Average biomass of juvenile steelhead (g/km) in South Fork Asotin Creek by control and treatment sections, pre- and post-restoration, for each season: 2008-2020.

Appendix L – Production Rate of Juvenile Steelhead Data Summary



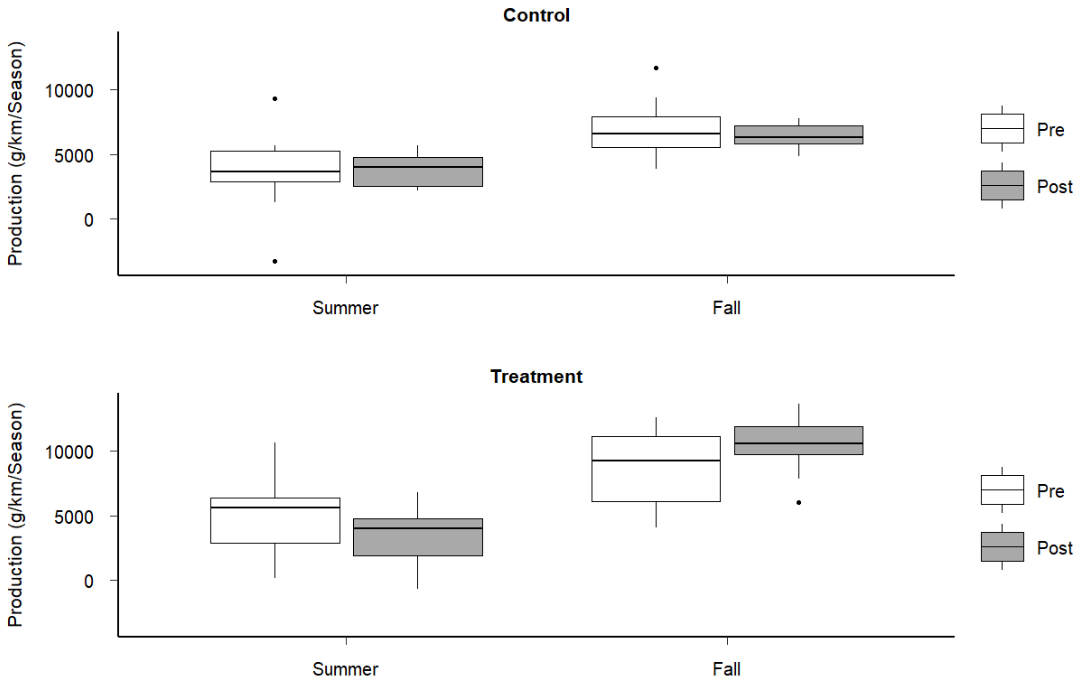
Appendix L- 1. Average production rate (g/km/season) by stream and fish site in treatment and control sections: 2008-2020. Sample seasons are Summer to Fall (e.g., S09-F09) and Fall to Summer (e.g., F08-S09).



Summary Statistics

Season	Description	Status	mean	median	min	q1	q3	max	sd	CV	n
Summer	Control	Pre	965.0	1001.4	-1334.5	-415.1	1787.2	4010.6	1624.8	1.7	17
Summer	Control	Post	275.9	380.7	-719.1	66.9	504.8	920.5	410.5	1.5	14
Summer	Treatment	Pre	2075.9	2690.9	-601.0	1157.0	3072.9	4151.3	1614.3	0.8	10
Summer	Treatment	Post	564.9	588.4	-845.3	-256.3	1208.5	2842.7	1111.7	2.0	14
Fall	Control	Pre	2854.8	2888.3	1291.2	2147.9	3438.3	4625.7	882.2	0.3	19
Fall	Control	Post	2712.4	2812.5	1776.1	2475.5	2972.3	3617.1	564.3	0.2	14
Fall	Treatment	Pre	4311.4	4280.5	3539.5	3953.4	4690.6	5147.1	537.3	0.1	11
Fall	Treatment	Post	4986.9	5262.8	2983.1	3254.7	5845.9	7547.8	1598.6	0.3	14

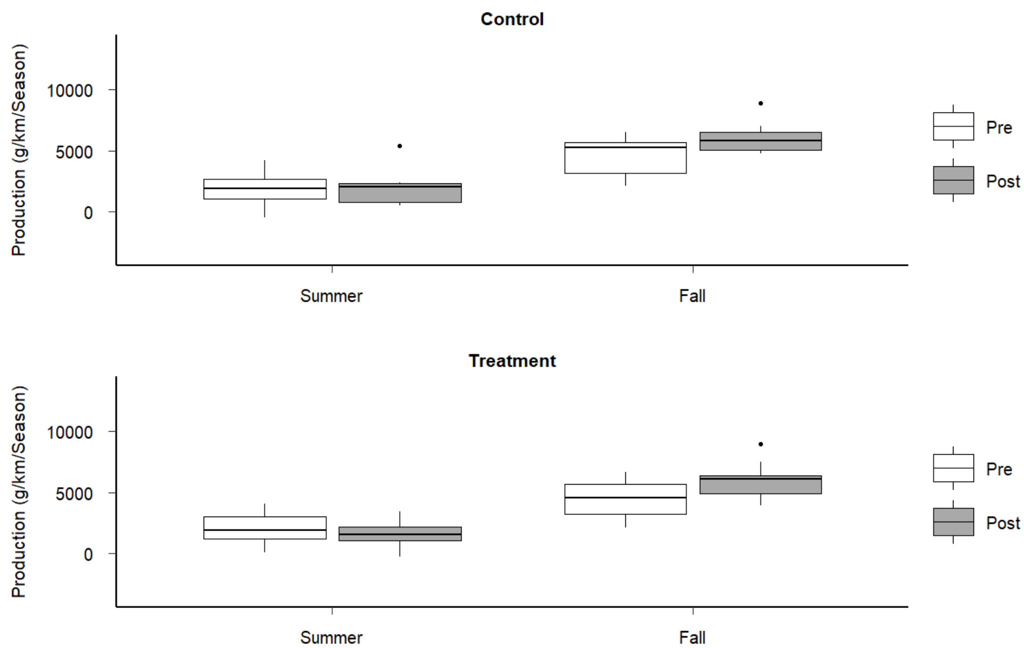
Appendix L- 2. Average production rate of juvenile steelhead (g/km/season) in Charley Creek by control and treatment sections, pre- and post-restoration, for each season: 2008-2018.



Summary Statistics

Season	Description	Status	mean	median	min	q1	q3	max	sd	CV	n
Summer	Control	Pre	3575.5	3631.4	-3263.5	2863.1	5224.5	9303.0	3014.2	0.8	12
Summer	Control	Post	3747.2	3985.9	2162.2	2539.8	4790.1	5645.3	1300.1	0.3	12
Summer	Treatment	Pre	5040.1	5564.5	155.9	2858.5	6384.3	10606.3	3101.4	0.6	9
Summer	Treatment	Post	3492.0	4010.0	-667.5	1925.9	4761.6	6786.9	2412.8	0.7	12
Fall	Control	Pre	6914.5	6562.9	3875.6	5521.6	7888.1	11638.6	2163.8	0.3	14
Fall	Control	Post	6376.4	6292.0	4802.1	5789.1	7178.9	7791.6	994.4	0.2	12
Fall	Treatment	Pre	8664.7	9237.3	4064.9	6068.9	11077.4	12596.5	2897.7	0.3	10
Fall	Treatment	Post	10412.5	10574.0	6045.3	9679.0	11842.7	13587.3	2256.1	0.2	12

Appendix L- 3. Average production rate of juvenile steelhead (g/km/season) in North Fork Asotin Creek by control and treatment sections, pre- and post-restoration, for each season: 2008-2018.



Summary Statistics

Season	Description	Status	mean	median	min	q1	q3	max	sd	CV	n
Summer	Control	Pre	1882.5	1888.9	-441.0	1072.6	2698.8	4193.0	1908.9	1.0	4
Summer	Control	Post	2013.1	2066.9	479.5	778.2	2316.8	5355.5	1672.5	0.8	8
Summer	Treatment	Pre	2022.4	1896.8	113.2	1218.4	2999.4	4093.0	1189.0	0.6	13
Summer	Treatment	Post	1624.9	1540.8	-262.4	1045.0	2186.8	3444.7	1017.5	0.6	20
Fall	Control	Pre	4531.9	5243.7	2082.7	3159.0	5674.2	6499.7	1841.7	0.4	5
Fall	Control	Post	6083.9	5805.1	4772.5	5055.8	6521.2	8855.6	1444.0	0.2	8
Fall	Treatment	Pre	4441.7	4565.2	2136.2	3205.3	5661.6	6636.6	1516.5	0.3	15
Fall	Treatment	Post	5819.4	6072.1	3923.9	4929.2	6395.7	8917.4	1338.8	0.2	20

Appendix L- 4. Average production rate of juvenile steelhead (g/km/season) in South Fork Asotin Creek by control and treatment sections, pre- and post-restoration, for each season: 2008-2018.

Appendix M – Publications, Presentations & Public Outreach

The Asotin Creek IMW coordinator has supported and helped co-author a variety of publications related to the design, monitoring and results of the IMW. We strongly believe in the importance of publishing results of the IMW and are planning to develop publications for all aspects of the restoration response and the implications for recovering ESA listed salmonids, and managing and restoring riverscape productivity.

Publications

Bennett, S., Pess, G., Bouwes, N., Roni, P., Bilby, R.E., Gallagher, S., Ruzycki, J., Buehrens, T., Krueger, K., Ehinger, W., Anderson, J., Jordan, C., Bowersox, B., and Greene, C. 2016. Progress and Challenges of Testing the Effectiveness of Stream Restoration in the Pacific Northwest Using Intensively Monitored Watersheds. Fisheries 41(2): 92-103.

Bouwes, N., Bennett, S., and Wheaton, J. 2016. Adapting Adaptive Management for Testing the Effectiveness of Stream Restoration: An Intensively Monitored Watershed Example. Fisheries 41(2): 84-91.

Bouwes, N., Moberg, J., Weber, N., Bouwes, B., Beasley, C., Bennett, S., Hill, A., Jordan, C., Miller, R., Nelle, P., Polino, M., Rentmeester, S., Semmens, B., Volk, C., Ward, M.B., Wathen, G., and White, J. 2011. Scientific protocol for salmonid habitat surveys within the Columbia Habitat Monitoring Program. Prepared by the Integrated Status and Effectiveness Monitoring Program and published by Terraqua, Inc., Wauconda, WA.

Camp, R.J. 2015. Short-term effectiveness of high density large woody debris, a cheap and cheerful restoration action, in Asotin Creek. Master's thesis. Utah State University, Logan, Utah.

Camp, R.J., and Wheaton, J.M. 2014. Streamlining field data collection with mobile apps. Eos, Transactions American Geophysical Union 95(49): 453-454.

Conner, M.M., Bennett, S.N., Saunders, W.C., and Bouwes, N. 2014. Comparison of Tributary Survival Estimates of Steelhead using Cormack–Jolly–Seber and Barker Models: Implications for Sampling Efforts and Designs. Transactions of the American Fisheries Society 144(1): 34-47.

Loughin TM, Bennett SN, Bouwes N. 2021. Comparison of staircase and asymmetrical before–after, control–impact (aBACI) experimental designs to test the effectiveness of stream restoration at increasing juvenile steelhead density. Canadian Journal of Fisheries and Aquatic Sciences 78: 670-680. DOI: 10.1139/cjfas-2020-0096.

Wall, C.E., Bouwes, N., Wheaton, J.M., Saunders, C., and Bennett, S. 2016. Net rate of energy intake predicts reach-level steelhead (Oncorhynchus mykiss) densities in diverse basins from a large monitoring program. Canadian Journal of Fisheries and Aquatic Sciences 73: 1081–1091.

Wheaton, J.M., Bennett, S.N., Bouwes, N., Maestas, J.D., and Shahverdian, S.M. 2019. Editors. Low-tech process-based restoration of riverscapes: design manual. Utah State University Restoration Consortium. Logan, UT. Available at: http://lowtechpbr.restoration.usu.edu/manual.

Bangen et al. in prep – Use of the Geomorphic unit delineation tool to quantify geomorphic change based on restoration with large woody debris.

Kramer et al. in prep – Estimating changes in juvenile steelhead capacity due to geomorphic changes forced by large wood restoration.

Sutherland D. 2020. Transport Characteristics of Large Wood in Headwater Streams: Insights From a Restoration Field Study and Physical Modelling. Ph.D. dissertation, School of Geography and Environmental Science, University of Southampton.

Presentations and Public Outreach

We coordinate and receive input from the Snake River Salmon Recovery Board (SRSRB), the SRSRB Regional Technical Team (RTT), Washington State Recreation and Conservation Office (RCO), Salmon Recovery Funding Board (SRFB), SRFB Monitoring Panel, and Pacific States Marine Fisheries Commission. We also collaborate with the US Forest Service, Washington Department of Fish and Wildlife for monitoring and restoration efforts. We meet and present to these groups and other interested parties in southeast Washington multiple times a year at the SRSRB RTT meetings in Dayton, WA. To date we have presented at least 30 times on the Asotin IMW to the SRSRB and its partners. It is through this venue in particular, that we have received valuable feedback from local groups, provided updates on the IMW progress, and sought funding when necessary to make the Asotin IMW a success. The following partial list outlines other venues we have presented Asotin IMW designs, methods, restoration approaches, results, and lessons learned.

Bouwes, et al. 2009. Presentation. Oregon Chapter of the American Fisheries Society. Bend OR. Evaluating Cormac-Jolly-Seber and Barker mark-resight models when passive instream antennae are used to collect resight data.

Bouwes et al., 2010. Presentation. American Fisheries Society 2010 Western Division. Overcoming challenges to estimating survival, movement and habitat use of fickle salmonids that may choose to emigrate, immigrate or stay at home.

Bouwes, et al. 2010. Presentation. Advances in the population ecology of stream salmonids symposium. Luarca, Spain. Large-scale stream restoration experiments: investigating what fish need in an uncertain environment.

Loughin et al. 2011. Presentation. American Fisheries Society 2011 Western Division - Development of the Asotin Creek Intensively Monitored Watershed Project with specific emphasis on experimental design and implementation considerations

Bennett et al. 2011. Presentation. American Fisheries Society 2011 Western Division - Characterizing juvenile steelhead abundance, growth, and survival at multiple spatial and temporal scales during the pretreatment period of large restoration experiment: Asotin Creek Intensively Monitored Watershed.

Bouwes, et al. 2011. Presentation. Spring Runoff Symposium. Logan, UT. Watershed restoration experiments: maximizing learning while trying to recover endangered species.

Bouwes, et al. 2011. Presentation. Pacific States Marine Fisheries Council PITTag Workshop. Stevenson WA. Using mobile and passive antennas to improve estimates of survival, tracking of movement, and habitat use of salmonids.

Camp et al. 2011. Presentation. American Fisheries Society 2011 Western Division - Rapid assessment of reach scale movement and habitat associations of juvenile steelhead using portable pit-tag antennas and low-cost geographic positioning system

Wall et al. 2011. Presentation. American Fisheries Society Annual Meeting. Seattle, WA - September 4-8, 2011. Giving fish more energy without giving them more food: Can streambed topography influence a fish's net rate of energy intake?

Wall and Bouwes. 2011. Presentation. Utah State University Water Initiative Spring Runoff Conference, Logan, UT. Can we give fish more energy without giving them more food?

Bennett et al. 2012. Presentation. Asotin County Annual Meeting. Asotin Creek Intensively Monitored Watershed: Updates and insights into restoration effectiveness.

Bennett et al. 2013. Presentation. Pacific Northwest Aquatic Monitoring Partnership, Portland, OR. Intensively Monitored Watersheds Coordination Workshop. Asotin Creek Intensively Monitored Watershed, southeast Washington: summary of approach, design, and preliminary findings.

Wall et al. 2013. Presentation. American Fisheries Society Western Division Annual Meeting. Boise, ID. Assessing the predictive ability of a process-based net rate of energy intake model for drift-feeding salmonids.

Bennett et al. 2014. Presentation. Washington State University, Pullman, WA. Does stream restoration work? How the Asotin Creek Intensively Monitored Watershed Project intends to find out.

Bennett et al. 2014. Presentation. Joint Aquatic Sciences Conference, Portland, OR. Restoration of wadeable streams with high-density large woody debris (HDLWD).

Camp, et al. 2014. Presentation. Characteristics of Benthic Winter Concealment Locations for Juvenile Steelhead (Oncorhynchus mykiss). Western Division of American Fisheries Society, Mazatlán, Sinaloa, Mexico.

Bennett et al, 2015. Presentation. Snake River Salmon Recovery Data Symposium, Dayton, WA. Asotin Creek Intensively Monitored Watershed Snake River Data Symposium Update

Bennett et al. 2015. Presentation. Asotin County Annual Meeting. Asotin Creek Intensively Monitored Watershed: Updates and insights into restoration effectiveness.

Bennett et al. 2015. Presentation. Salmon Recovery Conference, Vancouver, Washington. Intensively Monitored Watersheds: An approach towards determining restoration effectiveness

Camp, et al. 2015. Presentation. American Fisheries Society, Portland, OR. Presentation. Asotin Creek Intensively Monitored Watershed: Lessons Learned from Three Years of Restoration.

Camp, et al. 2015. Presentation. Rapid Assessment Monitoring Strategies. Snake River Salmon Recovery Board Data Symposium, Walla Wall, WA.

Wall et al. 2015. Presentation. American Fisheries Society Annual Meeting. Portland, OR. Using large-scale application of a foraging model in the interior Columbia River Basin to help understand patterns of habitat use in salmonids.

Bennett et al. 2016. Presentation. Pacific Northwest Aquatic Monitoring Partnership, Portland, OR. Intensively Monitored Watersheds Coordination Workshop. Intensively Monitored Watersheds: ideal elements, implementation challenges, and progress towards determining restoration effectiveness.

Bennett et al. 2017. Presentation. Asotin County Annual Meeting. Asotin Creek Intensively Monitored Watershed: Updates and insights into restoration effectiveness.

Bennett et al. 2017. Presentation. Salmon Recovery Conference, Wenatchee, Washington. Asotin Creek Intensively Monitored Watershed: An emerging story of restoration effectiveness

Bennett, Wheaton, and Camp. 2017. Workshop. Snake River Salmon Recovery Board Cheap and Cheerful Restoration Workshop, Dayton, WA. Sharing lessons learned and providing hands on experience in constructing post-assisted log structures (PALS) and beaver dam analogs (BDAs) developed in Asotin Creek and Bridge Creek Intensively Monitored Watersheds.

Bennett, Bouwes, Shahverdian, Maestas, Weber, and Wheaton. 2018. NRCS Workshops. Low-low process-based riverscape restoration. John Day, OR; Hailey, ID, Cedar City, UT; Lander, WY; Elko, Nevada.

Bennett, Bouwes, Wheaton, and Shahverdian. 2019. Salmon Recovery Conference, Tacoma, Washington. Low-tech process-based restoration: what is it and why do we need more of it?

Bennett, S. 2019. Landowner tour of Asotin Creek lead by Asotin County Conservation District to view post-assisted log structures and discuss low-tech restoration with landowners.

Bennett, Bouwes, Shahverdian, Maestas, Weber, and Wheaton. 2019. NRCS Workshops. Low-low process-based riverscape restoration. Gunnison, CO; Lewiston, MT, Hailey, ID; Logan, UT.

Bennett, S. 2019. Presentation. American Fisheries Society and the Wildlife Society, Reno, Nevada. Low-tech process-based restoration – Beaver Restoration Symposium.