FISHERY RESEARCH

POTLATCH RIVER STEELHEAD MONITORING AND EVALUATION PROJECT

2017 AND 2018 BIENNIAL REPORT

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ABBREVIATIONS AND ACRONYMS

BBC	Big Bear Creek
BPA	Bonneville Power Administration
EFPR	East Fork Potlatch River
EPA	Environmental Protection Agency
GRTS	Generalized Random Tessellation Stratification
ICTRT	Interior Columbia Basin Technical Recovery Team
IDFG	Idaho Department of Fish and Game
IDL	Idaho Department of Lands
IPTDS	Instream PIT-tag Detection System
ITD	Idaho Department of Transportation
IMW	Intensively Monitored Watershed
LBC	Little Bear Creek
LGR	Lower Granite Dam
LWD	Large Woody Debris
LWHAP	Low Water Habitat Availability Protocol
NOAA	National Oceanic and Atmospheric Administration
NPPC	Northwest Power and Planning Council
PIT	Passive Integrated Transponder
PTAGIS	PIT Tag Information System
PTC	Potlatch Timber Corporation
UILT	Upper Incipient Lethal Temperature
USFS	United States Forest Service
WFLBC	West Fork Little Bear Creek
WFPR	West Fork Potlatch River

FOREWORD

PROJECT OVERVIEW

The Potlatch River basin supports the largest spawning area of wild steelhead (*Oncorhynchus mykiss*) in the Lower Mainstem Clearwater River steelhead population (ICBTRT 2003; Bowersox et al. 2009) and habitat restoration efforts are underway to enhance the production and productivity of wild steelhead within the basin. The Potlatch River Steelhead Monitoring and Evaluation project (hereafter the project) has been designed to measure the success of restoration efforts and is the sole habitat restoration effectiveness monitoring program within the Potlatch River basin. Project data has documented fish response to habitat restoration (Uthe et al. 2017) and is used to prioritize future habitat restoration efforts in the basin (Resource Planning Unlimited 2007; Potlatch Implementation Group 2019). The project was initiated in 2005 with Pacific Coastal Salmon Recovery Funds (PCSRF) and was integrated into the Intensively Monitored Watershed (IMW) program in 2007. In concert with other projects funded by these two programs, the project also contributes information to guide habitat restoration of anadromous salmonids elsewhere in Idaho and across the Pacific Northwest (Bennett et al. 2016; Uthe et al. 2017; Griswold and Phillips 2018; Hillman et al. 2019).

Snake River steelhead were classified as threatened under the Endangered Species Act (ESA) in 1997. Within the Snake River steelhead distinct population segment (DPS), there are six major population groups (MPGs): Lower Snake River, Grande Ronde River, Imnaha River, Clearwater River, Salmon River, and Hells Canyon Tributaries (ICBTRT 2003; NOAA 2017). The Clearwater River MPG supports six independent populations: Lower Mainstem Clearwater, North Fork Clearwater (extirpated), Lolo Creek, Lochsa River, Selway River, and South Fork Clearwater (ICBTRT 2003). The Lower Mainstem Clearwater River steelhead population, which contains the Potlatch River basin, is genetically distinct from other wild Clearwater River steelhead groups (Nielsen et al. 2009; Ackerman et al. 2016). Furthermore, the Lower Mainstem Clearwater River steelhead population comprises the only “large” independent population in the Clearwater River MPG (ICBTRT 2003) and must achieve viability in order for the Clearwater MPG and the Snake River DPS to become viable (NOAA 2017).

The Potlatch River basin is comprised of two distinct areas with notable differences in stream morphology, hydrology, and land use (Johnson 1985; Bowersox and Brindza 2006). In this report, we use the terms lower Potlatch River watershed and upper Potlatch River watershed to characterize each area. The lower Potlatch River watershed is defined as the drainage area downstream of and including Boulder Creek (Figure 1) and is characterized by steep basaltic canyons rimmed by rolling cropland. The predominant stream type in the lower watershed is a canyon stream with relatively high gradient, large substrate size, riffle/pocket water habitat types, and a flashy hydrograph (Bowersox and Brindza 2006). The majority of land in the lower watershed is privately owned and used primarily for agriculture production. In contrast, the upper Potlatch River watershed encompasses the drainage area upstream of Boulder Creek (Figure 1) and is characterized by timbered hills and meadow terrain. The predominant stream type in the upper watershed is a forestland stream with relatively low gradient, neighboring meadow complexes, small substrate composition, and cooler water temperatures (Bowersox and Brindza 2006). The majority of land in the upper watershed is public with large tracts of private timber lands used for timber production.

Land use practices, primarily agriculture and timber harvest, have significantly altered the aquatic habitat and hydrograph in the Potlatch River basin causing limiting factors to differ between the lower and upper watersheds. Primary limiting factors in the lower watershed are low

summer base flows and fish passage barriers (Johnson 1985; Bowersox and Brindza 2006). The Potlatch River basin receives the bulk (95%) of its annual precipitation from December to June (USDA SCS 1994). Thus, there is a natural pattern of high flow periods in the late winter/early spring followed by decreasing flows through the summer. However, conversion of timbered and meadow terrain into cropland in uplands and headwaters of lower watershed tributaries has resulted in higher peak springtime flow and reduced summer base flow. Base flow conditions are significantly limited with most tributaries experiencing flows <0.5 cfs and stream reach de-watering during the summer (Banks and Bowersox 2015; Uthe et al. 2017). Fish passage barriers are the other major factor limiting steelhead rearing habitat in the lower watershed. Barriers exist on nearly every major tributary, most of which are road culverts upstream of canyon reaches.

The primary limiting factor in the upper watershed is a lack of instream complexity resulting in poor juvenile steelhead summer and winter rearing conditions (Johnson 1985; Schriever and Nelson 1999; Bowersox and Brindza 2006). Logging began in the upper Potlatch River watershed in the early 1900s and infrastructure, including rail lines and roads, were built directly in stream channels or floodplains. As a result, streams were often straightened or re-located and riparian vegetation and instream woody debris were removed. Presently, streams in the upper watershed lack large woody debris (LWD) and other complex habitats and riparian communities are not yet mature enough to actively recruit materials into streams.

Habitat restoration in the basin is guided by the Potlatch River Watershed Management Plan (Resource Planning Unlimited 2007; Potlatch Implementation Group 2019) and is a priority within Idaho Department of Fish and Game (IDFG) Fisheries Management (2019-2024) and Annual Strategic Plans (FY 2020-2023) (IDFG 2019, 2020). The Potlatch River Technical Advisory Group assisted the Latah County Soil and Water Conservation District (LCSWD) in developing the plan using fish, habitat, and water quality information obtained by local, state, and federal investigations in the basin. A prioritization of limiting factors and restoration strategies for key tributaries in the basin were incorporated into the plan.

Restoration strategies have been designed to address key limiting factors unique to each watershed. The primary restoration strategies in the lower Potlatch River watershed are to expand juvenile steelhead rearing habitat by removing barriers and increasing base-flow conditions through summer stream flow supplementation and meadow restoration. The primary restoration strategies in the upper watershed are to increase instream habitat complexity and riparian function by installing log structures, planting and protecting riparian areas, and restoring floodplain access.

PROJECT DESIGN AND OBJECTIVES

The overarching goal of the project is to evaluate fish and habitat responses to habitat restoration in the Potlatch River basin. The project is designed to assess responses in steelhead production and productivity at multiple scales: 1) broad-scale monitoring to document steelhead response within two index watersheds, Big Bear Creek (BBC) and the East Fork Potlatch River (EFPR), each with different limiting factors; 2) a finer-scale effort to assess fish and habitat responses to restoration projects at the tributary level; and 3) reach-scale monitoring to assess whether individual projects produced the intended outcome. The project design allows managers to better understand the relationship between a habitat action and fish response (Bennett et al. 2016) and how localized responses to restoration propagate up to a higher, management-scale level. To implement this design, specific monitoring objectives are:

1. Assess steelhead / resident *O. mykiss* production and productivity within two index watersheds in the Potlatch River basin.
    a. Determine abundance of juvenile steelhead emigrants.
    b. Estimate adult steelhead escapement.
    c. Estimate freshwater productivity (juvenile recruits per spawner) for the index steelhead populations.

2. Monitor juvenile steelhead density, survival, and growth in control and treatment areas within upper and lower Potlatch River watersheds.

3. Monitor change in habitat variables associated with habitat restoration in control and treatment areas within upper and lower Potlatch River watersheds.

PROJECT TIMELINE

Habitat restoration implementation and effectiveness monitoring are ongoing in the index watersheds (Figures 2 and 3). Idaho Department of Fish and Game conducted initial juvenile steelhead abundance and distribution surveys in the Potlatch River during 1995/1996 and 2003/2004. Intensive monitoring in the index watersheds began in BBC in 2005 and the EFPR in 2008. Habitat treatments that directly addressed the primary limiting factors in each index watershed began in BBC in 2013 and in the EFPR in 2009. We anticipate habitat treatment goals will be achieved in BBC by 2028 and in the EFPR by 2029. Restoration efforts are expected to result in a detectable biological response in juvenile steelhead production within five years (i.e., juvenile distribution, density, survival, growth) and productivity within ten years (i.e., smolt per female productivity) after the treatment goals are achieved in each watershed (Potlatch Implementation Group 2019; Uthe et al. 2017).

REPORT STRUCTURE

Project reporting has evolved over time. Previous years' project data was reported annually from 2006-2012 (Bowersox 2008; Bowersox et al. 2007, 2009, 2011, 2012; Banks and Bowersox 2015). Starting in 2016, annual Potlatch River steelhead production, diversity, and productivity data was included in statewide adult steelhead (Stark et al. 2016; Dobos et al. 2017, 2019; Knoth et al. 2018) and anadromous emigrant monitoring (Apperson et al. 2016, 2017; Belnap et al. 2018; Poole et al. 2019) reports. Moving forward, Potlatch River specific data will be reported in a biennial format to focus on trends and annual variation across the Potlatch River basin and to help focus analysis to inform management decisions regarding restoration efforts and monitoring program.

This report is in two chapters. Chapter 1 presents steelhead abundance and productivity data collected in index watersheds and Chapter 2 presents data on habitat conditions and juvenile steelhead production in treatment and control tributaries. Spawn years 2017 and 2018 were emphasized in some sections since they were not previously compared to past data.

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FIGURES

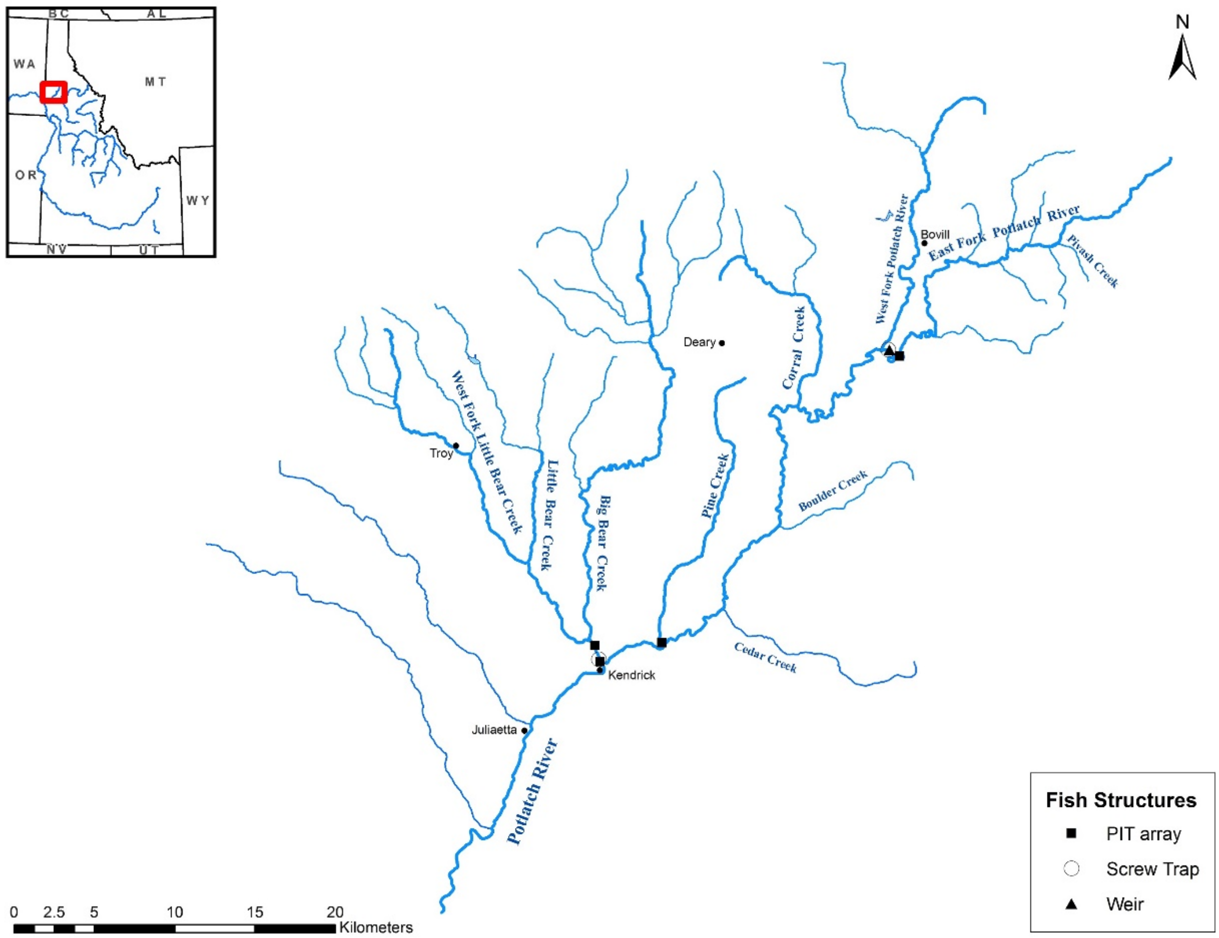

Figure 1. Key features and monitoring infrastructure in the Potlatch River basin in northern Idaho.

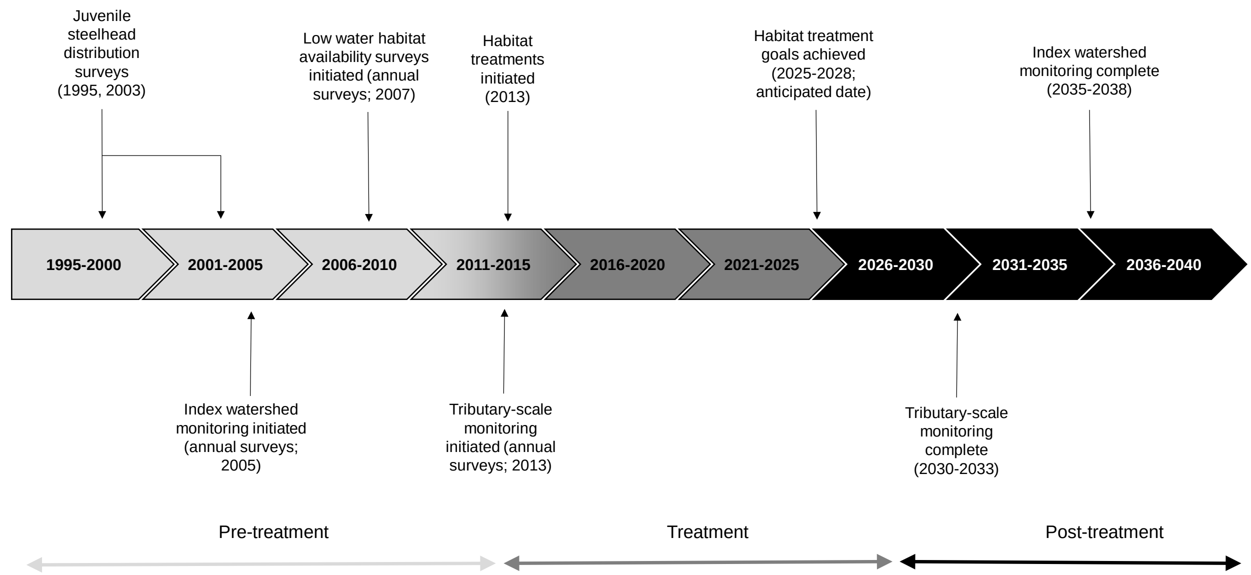

Figure 2. Timeline of project monitoring and restoration implementation in Big Bear Creek watershed in the Potlatch River Basin.

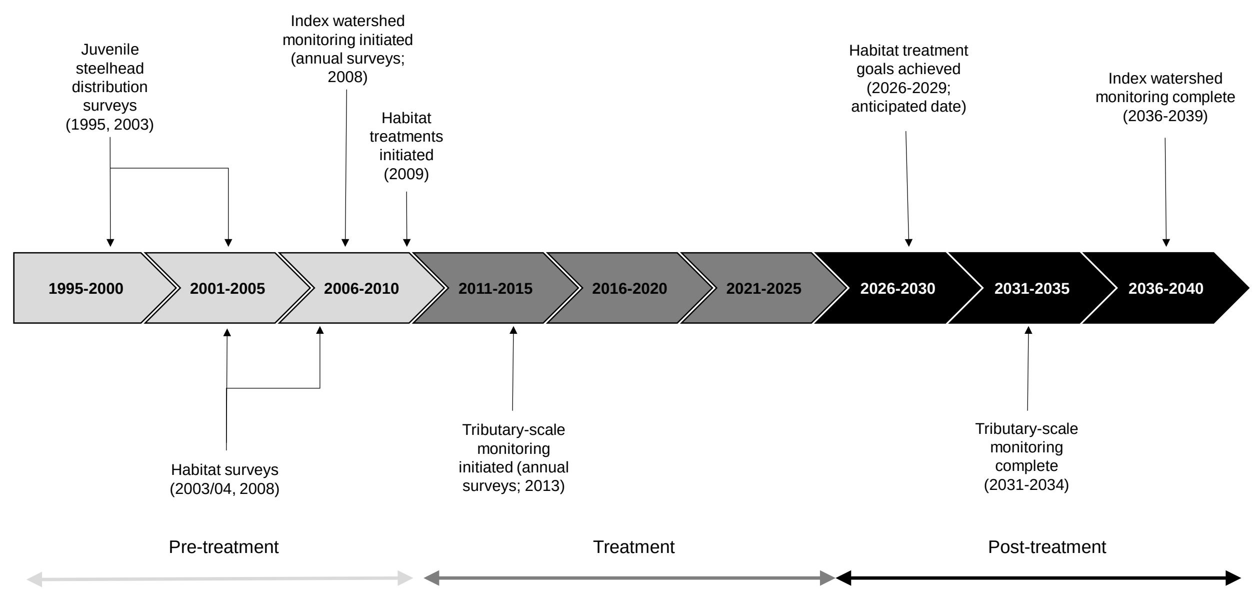

Figure 3. Timeline of project monitoring and restoration implementation in the East Fork Potlatch River watershed in the Potlatch River Basin.

CHAPTER 1: ABUNDANCE AND PRODUCTIVITY OF STEELHEAD WITHIN POTLATCH RIVER, IDAHO INDEX WATERSHEDS

ABSTRACT

The Potlatch River Steelhead Monitoring and Evaluation project operates weirs, instream PIT-tag detection systems, and rotary screw traps to monitor the annual abundance and life history characteristics of wild steelhead *Oncorhynchus mykiss* in two index watersheds, Big Bear Creek (BBC) and the East Fork Potlatch River (EFPR). In 2017 and 2018, adult steelhead escapement was below long-term averages in both watersheds and ranged from 8-19 fish in BBC and 11-18 fish in EFPR. The majority of adult steelhead in 2017 were 2-ocean fish and in 2018 were 1-ocean fish. Big Bear Creek juvenile emigration estimates in 2017 (10,928 fish) and 2018 (10,183 fish) were above the long-term average, whereas, EFPR estimates in 2017 (15,210 fish) and 2018 (9,781 fish) were slightly below the long-term average. Emigrant age structure and length-at-age estimates were relatively consistent across years in BBC, but have shifted to older and larger emigrants in the EFPR. Freshwater productivity estimates averaged 122 juvenile recruits per spawner in BBC and 362 juvenile recruits per spawner in the EFPR. Recruits per spawner decreased as female spawner abundance increased suggesting density-dependent mechanisms occurred, most notably in BBC. The observed shifts in EFPR emigrant age, growth, and survival indicate an initial watershed-scale response in steelhead within the upper Potlatch River watershed.

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INTRODUCTION

Restoring freshwater habitat conditions is a critical component of recovery efforts for Pacific salmon listed under the Endangered Species Act (ESA) (Bennett et al. 2016; Griswold and Phillips 2018; Hillman et al. 2019). Habitat restoration efforts are being implemented to improve the production and productivity of wild steelhead *Oncorhynchus mykiss* in the Potlatch River basin (Resource Planning Unlimited 2007; Uthe et al. 2017). The Potlatch River Monitoring and Evaluation project (hereafter the project) is designed to assess responses in steelhead production and productivity to restoration activities at the watershed, tributary, and reach scales (Uthe et al. 2017). At the broadest scale, the project is designed to measure the benefits of habitat restoration (sum of all projects) for steelhead in two index watersheds, Big Bear Creek (BBC) and the East Fork Potlatch River (EFPR). These efforts provide the necessary data to assess the steelhead response to restoration actions at the watershed level, which is the scale at which management decisions are focused.

The objective of this chapter is to estimate key demographic metrics for the steelhead in the two index watersheds. We are currently in the treatment phase of habitat restoration in the index watersheds (Figures 2 and 3) and preliminary results presented here include pre-treatment data (2005-2013 in BBC; 2008-2009 in EFPR) and partial data from the treatment phase (2014-2018 in BBC; 2010-2018 in EFPR). Ultimately, watershed-scale monitoring data will be assessed as a before-after comparison of steelhead production and productivity in each index watershed. The final assessment will be completed after habitat treatment goals are achieved in each watershed.

METHODS

Adult Steelhead Escapement and Diversity

Adult steelhead escapement into index watersheds was monitored using weirs and instream PIT-tag detection systems (IPTDS) (Figure 1). Picket weirs were deployed on BBC and Little Bear Creek to monitor annual adult steelhead escapement into the BBC watershed from 2005-2012. Adult steelhead escapement into the BBC watershed was monitored using an IPTDS beginning in 2013. The area monitored by picket weirs and IPTDS was similar, thus the data are comparable across time. Adult steelhead escapement into the EFPR was monitored using a resistance-board weir since 2008. Weirs were installed as early as possible, typically mid-February (BBC) or March (EFPR), and operated until the kelt (post-spawn fish) outmigration was complete. Detailed information on methods, data analysis, and annual operations for weirs and IPTDS can be found in Potlatch River Steelhead Monitoring and Evaluation Annual Reports (Bowersox 2008; Bowersox et al. 2007, 2009, 2011, 2012; Banks and Bowersox 2015) and Idaho Adult Steelhead Monitoring Annual Reports (Stark et al. 2016; Dobos et al. 2017, 2019; Knoth et al. 2018). Results are preliminary and unless noted otherwise, we used graphical comparisons for inference.

Juvenile Steelhead Emigration, Diversity, and Survival

Juvenile emigrant production and diversity metrics (i.e., emigrant age composition and size-at-age) from the index watersheds was monitored using rotary screw traps. Emigration estimates have been generated since 2005 in BBC and 2008 in EFPR. Annual trapping began as early as possible, typically late January - February (BBC) or March (EFPR), and continued until early June when low flows prevented rotary screw traps from operating. Trapping resumed during

the fall at both sites when sufficient flows and personnel allowed. Fall emigration could not be estimated across all years in either BBC or the EFPR because low flow conditions did not allow trapping or not enough juveniles were trapped to generate an estimate (Uthe et al. 2017). Detailed information on methods, data analysis, and annual operations for BBC and EFPR rotary screw traps can be found in Potlatch River Steelhead Monitoring and Evaluation Annual Reports (Bowersox 2008; Bowersox et al. 2007, 2009, 2011, 2012; Banks and Bowersox 2015) and Idaho Anadromous Emigrant Monitoring annual reports (Apperson et al. 2016, 2017; Belnap et al. 2018; Poole et al. 2019).

We examined survival rates of PIT-tagged juvenile steelhead emigrants from each rotary screw trap to Lower Granite Dam (LGR). Estimating steelhead survival is problematic because steelhead emigrate at different ages and not all fish captured at the screw trap in a given year will emigrate to LGR in the same year (Feeken et al. 2020). We estimated apparent survival as a proxy for true survival. Apparent survival estimates do not account for delayed emigration and thus are biased low since some individuals will not emigrate until subsequent years. We queried PTAGIS for detections of juvenile steelhead tagged at Potlatch River screw traps. Potential interrogation sites in the hydrosystem were LGR, Little Goose, Lower Monumental, McNary, John Day, and Bonneville dams and the estuary towed array. Juvenile survival indices to LGR were estimated using PitPro 4.19 (Westhagen and Skalski 2009). The PitPro algorithm combines capture-recapture PIT-tag interrogation data from instream arrays and hydrosystem passage facilities into a Cormack-Jolly-Seber model to estimate survival and capture probabilities to tributary and hydrosystem arrays.

Productivity Estimates

Freshwater productivity estimates, measured as juvenile recruits at the screw trap per female spawner estimated at the weirs or arrays, were computed for each index watershed. Annual abundances of female spawners were calculated by applying the observed sex ratio at the weir or array to the total adult escapement estimate. Juvenile age proportions based on juvenile scale samples were applied to annual emigration estimates at rotary screw traps to determine the total number of juvenile recruits by brood year (BY) for a given trapping year. Juveniles were summed across trapping years for each brood year to determine total juvenile recruits (i.e., BY 2011 females produce age-1 juveniles in 2012, age-2 juveniles in 2013, etc.). Total juvenile recruits for that BY was divided by number of female spawners estimated in each BY to estimate juvenile recruits per female spawner. Productivity estimates were examined in relation to female spawner abundance for indication of density-dependence in the two index watersheds.

RESULTS

Adult Steelhead Escapement and Diversity

Big Bear Creek

Adult steelhead escapement into BBC varied 40-fold across years, with a marked decline in 2017 and 2018 (Figure 4). An average of 170 adult steelhead (range = 50-317 adult steelhead) returned annually from 2005-2016, whereas 8 adult steelhead returned in 2017 and 19 adult steelhead returned in 2018. Detection probability could not be calculated in 2017 and 2018 due to the low number of PIT tag detections at the BBC array; therefore, these are considered minimum estimates (Dobos et al 2017; Knoth et al. 2018).

Sex ratio and age composition of BBC adult steelhead were variable over time. Average sex ratio of BBC adult steelhead was skewed towards females (58%, range = 35-84%; Figure 5). Ocean age of adults ranged from one to three years (Figure 6). Total ages ranged from three to seven years, with eight different freshwater-saltwater age class combinations (Table 1). On average, 2-ocean fish comprised 58% of adults; followed by 1-ocean fish at 40%, and 3-ocean fish at 1%. Repeat spawners were observed intermittently and comprised between 0-11% of adults by year. In 2017, 93% of adults were 2-ocean fish (n = 14), whereas in 2018, 78% of adults were 1-ocean fish (n = 7).

Origin of adult steelhead sampled in BBC showed minimal hatchery influence. Hatchery adult steelhead were observed in seven of 14 years at BBC. On average the raw proportion of hatchery origin adults captured at the weir or detected on the array was 2.9% (range = 0-20%). No hatchery origin fish were detected at the BBC array in 2017, whereas two of the ten adult steelhead detected at the array in 2018 were hatchery origin.

Adult steelhead migration timing at BBC varied across years (Figures 7 and 8). The average date of the first upstream spawner captured or detected was February 19 (range = February 7-March 16). The average date that 50% of run passed was March 24 (range = March 6-April 10) and the final upstream spawner arrived on April 21 (range = March 30-May 18). The average date of the first downstream kelt captured or detected was March 30 (range = February 28-April 22). The average date that 50% of the kelt run passed the weir or array was April 21 (range = April 5-May 12) and final kelts arrived on May 12 (range = April 25-May 28). Prespawn and kelt timing was not calculated in 2017 and 2018 due to the low number of PIT-tag detections at the BBC array.

East Fork Potlatch River

Adult escapement into the EFPR varied 13-fold across years and also experienced a marked decline in 2017 and 2018 (Figure 4). An average of 90 adult steelhead (range = 33-140 adult steelhead) returned annually from 2008-2016, whereas 11 adult steelhead returned in 2017 and 18 adult steelhead returned in 2018. Abundance estimates from 2017 and 2018 may be imprecise due to the small sample size of kelts to establish the mark rate at the weir (Dobos et al 2017; Knoth et al. 2018).

Sex ratio and age composition of EFPR adult steelhead varied across time. Average sex ratio of EFPR adult steelhead was skewed towards females (55%, range = 33-76%; Figure 5). Ocean age of adults, ranged from one to three years (Figure 6). Total ages ranged from three to seven years, with ten different freshwater-saltwater age class combinations (Table 1). On average, 2-ocean fish comprised 51% of adults; followed by 1-ocean fish at 48%, and 3-ocean fish at 1%. Repeat spawners were only observed in 2010 when they comprised 1% of adults. In 2017, 91% of returning adults were 2-ocean fish (n = 11), whereas in 2018, 80% were 1-ocean fish (n = 20). No hatchery origin fish have been captured at the EFPR weir.

Adult steelhead migration timing at the EFPR varied across years (Figures 7 and 8). The average date of the first upstream spawner was March 26 (range = March 7-April 18). The average date that 50% of the run passed the weir was April 16 (range = March 31-April 25) and the final upstream spawner arrived on May 9 (range = April 23-May 25). The average date of the first downstream kelt was April 27 (range = April 3-May 31). The average date that 50% of downstream kelts passed the weir was May 11 (range = April 24-June 16) and the final kelt arrived

on May 29 (range = May 4-June 29). Prespawn and kelt timing in 2017 and 2018 fell within the range of previous estimates though timing was based on low sample sizes.

Juvenile Steelhead Emigration, Diversity, and Survival

Big Bear Creek

Spring emigration from the BBC watershed varied six-fold across years (Figure 9). An average of 9,556 emigrants (range = 3,837-22,649 fish) were estimated annually from 2005-2018. Emigration estimates in 2017 (10,928 fish) and 2018 (10,183 fish) were above average. Fall estimates were generated in 6 of 14 years and ranged from 91-2,032 fish (Figure 10). Fall estimates averaged 8.5% (range = 1.0-18.6%) of the following years' spring emigration estimate.

Emigrant age composition during the spring trapping season at BBC was dominated by age-2 emigrants (Figure 11). On average, age-2 fish comprised 60.1% (range = 28.6-86.8%), age-1 fish comprised 35.4% (range = 8.8-70.7%), and age-3 fish comprised 4.6% (range = 0.6-12.3%) of spring emigrants annually. The emigrant age composition was dominated by age-1 fish in 2017 (70.7%) and age-2 fish in 2018 (66.7%). The average age composition of fall emigrants was 87.5% age-1 fish, 8.9% age-0 fish, and 3.6% age-2 fish based on four years of trapping data (Figure 12).

Emigrant length-at-age varied widely across years (Figure 13). Mean FL of age-1 emigrants was 135.8 mm (range = 118.5-149.8 mm), age-2 emigrants was 171.5 mm (range = 161.0-178.7 mm), age-3 emigrants was 187.8 mm (range = 170.1-210.6 mm) across years. Emigrant length-at-age in 2017 and 2018 fell within the previous range of estimates.

The data series shows increases in survival at three to four year intervals (Figure 14). Mean apparent survival was 49.0% (range = 26.8-80.9%), with survival highest in years with older emigrant age structure (i.e., 2011 and 2014; Figures 9 and 12). Survival for spring emigrants in 2017 and 2018 fell within the previous range of estimates.

East Fork Potlatch River

Spring emigration from the EFPR watershed varied five-fold across years, with peak estimates in 2010 and 2013 (Figure 9). An average of 16,099 emigrants (range = 7,965-40,224 fish) were estimated annually from 2008-2018. Emigration estimates in 2017 (15,210 fish) and 2018 (9,781 fish) were below the long-term average. Fall estimates were generated in 4 of 11 years and ranged from 1,296-1,866 fish (Figure 10). Fall estimates averaged 10.4% (range = 3.2-15.9%) of the following years' spring emigration estimate.

Emigrant age composition during the spring trapping season at the EFPR was dominated by age-1 emigrants (Figure 11). On average, age-1 fish comprised 70.1% (range = 53.7-86.1%), age-2 fish comprised 27.4% (range = 12.1-42.7%), and age-3 fish comprised 3.2% (range = 0.0-6.6%) of spring emigrants annually. The proportion of age-1 emigrants decreased in recent years, with the proportion of age-2 emigrants increasing over the same time period. The proportion of age-3 emigrants ranged from 0.5-6.6% across all years. The average age composition of fall emigrants was 55.0% age-1 fish, 28.9% age-0 fish, 15.2% age-2 fish, and 0.9% age-3 fish based on three years of trapping data (Figure 12).

We observed age-1 and age-2 emigrants from the EFPR increasing in length across the dataset (Figure 13). Mean FL of age-1 emigrants increased from 90.0 mm in 2008-2014 to 99.7

mm in 2015-2018. Similarly, mean FL of age-2 emigrants increased from 134.9 mm to 146.7 mm over the same time period. The average size of age-3 emigrants also showed an upward trend over time, but the dataset is limited due to low sample size (≤10 fish per year).

Apparent survival for spring emigrants from the EFPR trap to LGR ranged from 5.0-17.0% annually, but has increased in recent years (Figure 14). Apparent survival has increased from an average of 8.3% from 2008-2012 to 13.2% from 2013-2018.

<u>Population Productivity</u>

Big Bear Creek

Complete BY productivity estimates have been generated for 11 BYs for the BBC watershed. Estimates ranged from 48 juvenile recruits per spawner (BY 2010) to 277 juvenile recruits per spawner (BY 2006) and averaged 122 juvenile recruits per spawner across all complete BYs (Figure 15). A partial (missing age-3) estimate has been generated for BY 2016 with 84 juvenile recruits per spawner. Productivity estimates for BBC displayed a strong density-dependent relationship (Figure 16).

East Fork Potlatch River

Complete BY productivity estimates have been generated for seven BYs for the EFPR watershed. Estimates ranged from 130 juvenile recruits per spawner (BY 2015) to 740 juvenile recruits per spawner (BY 2012) and averaged 362 juvenile recruits per spawner for all complete BYs (Figure 15). A partial (missing age-3) estimate has been generated for BY 2016 with 289 juvenile recruits per spawner. Brood year 2011 was excluded because an expanded adult escapement estimate was not generated. Productivity estimates for EFPR did not display a density-dependent relationship (Figure 16).

DISCUSSION

To date, we have garnered an extensive understanding of the steelhead life histories in the index watersheds and established baseline levels of production and productivity to compare against future evaluations. Adult steelhead escapement was generally higher in BBC relative to the EFPR, but both watersheds experienced sharp declines in 2017 and 2018. The age composition and sex ratio of adult steelhead was relatively similar in both watersheds. Hatchery adult steelhead were observed fairly frequently in BBC but never in the EFPR. The adult steelhead migration was generally one month earlier in BBC compared to the EFPR. Emigrant abundance was generally higher in the EFPR relative to BBC, though differences in emigrant age composition confound direct comparisons. We observed no discernable trends in emigrant size, age, or survival in BBC. Conversely, we noted an increase in emigrant size, age, and survival during recent years in the EFPR. Population productivity estimates (juvenile recruits per spawner) displayed a strong density-dependent relationship in BBC, but not in the EFPR. The index watershed monitoring framework appears robust, but modifications discussed below will help strengthen our ability to monitor watershed-scale responses in steelhead production and productivity to restoration actions in the watersheds.

Environmental conditions in both the marine and freshwater environments can influence the productivity of anadromous salmonid populations. Adult steelhead escapement within Potlatch River index watersheds was highly variable over time, but both watersheds experienced

sharp declines in recent years. We were unable to produce expanded escapement estimates in 2017 and 2018 due to low population abundance and low mark-recapture parameters (Knoth et al. 2018; Dobos et al. 2019) and need to develop new analytical techniques to produce expanded estimates during years with low population abundance. Nonetheless, a commensurate decline was observed in steelhead populations throughout Idaho (Knoth et al. 2018; Dobos et al. 2019) and largely attributed to poor conditions during outmigration of smolts (Faulkner et al. 2016) and at ocean entry (Peterson et al. 2017). We did not observe a noticeable decline in emigrant abundance or survival from the index watersheds that may have contributed to the low adult returns in 2017 and 2018. While recent declines in adult steelhead escapement are discouraging, the plausible mechanisms causing declines likely occurred outside the Potlatch River basin.

Freshwater habitat conditions can be a key driver influencing salmon population dynamics (Jones et al. 2020) and improvements to freshwater habitat can improve population resilience even when out of basin conditions are poor (Justice et al. 2017). Restoration efforts in the Potlatch River basin are focused on improving freshwater rearing habitat conditions and the monitoring framework is focused on freshwater life history to accurately assess effectiveness of restoration efforts. Monitoring through the entire life cycle of steelhead inherently includes out of basin factors (i.e. ocean conditions, hydrosystem) which confound results associated with adult returns. The response in adult steelhead to restoration actions will be most evident when improvements to juvenile steelhead growth, survival, and abundance coincide with favorable conditions outside the basin. Continued evaluation of freshwater productivity within the Potlatch River basin will provide meaningful restoration effectiveness monitoring independent of adult returns.

Increased juvenile survival during periods of low adult spawner density provides a buffer within natural populations allowing them to persist through periods of low adult abundance. Juvenile emigration data from 2017 and 2018 attest to this, given the relatively stable emigrant abundances and low adult abundance. Conversely, peak emigrant abundance did not follow years of high adult abundance, likely as a result of density dependent factors such as resource limitation (food or space) which regulate emigrant production. The upcoming years (2019 and 2020) will add to this discussion as they contain the lowest adult steelhead abundance in the dataset. Continued monitoring of emigrant production during a variety of adult returns will provide a better understanding of spawner per recruit relationships and their ability to persist through low adult abundance periods as well as an understanding of the capacity of the habitat to support juvenile steelhead.

Restoration efforts that improve the quantity and quality of rearing habitat in the Potlatch River should reduce competition for resources (i.e., food or habitat) and improve freshwater productivity. Freshwater productivity improvements may manifest in higher emigrant abundance or fitter (i.e., larger or older) emigrants (Roni 2005), resulting in higher overall population productivity. We hypothesize emigrant age structure may shift older in the EFPR as juveniles rear longer in the watershed instead of emigrating early and rearing downstream. Emigrant length-at-age may also increase as a result of improved feeding resources or opportunities. Pool habitat and riparian vegetation have recently increased in the EFPR, likely as a result of both restoration treatments and natural beaver recolonization (Uthe et al. 2017). Although we are currently in the treatment phase of restoration in the EFPR, we have already documented positive trends in emigrant age structure, length-at-age, and apparent survival. The observed shifts in EFPR emigrant age, growth, and survival indicate an initial watershed-scale response within the upper Potlatch River watershed consistent with our hypotheses. These findings are encouraging and continued monitoring of the EFPR emigrant population will further elucidate the relationship between habitat actions and steelhead response in the upper Potlatch River watershed.

Steelhead exhibit diverse life histories and delayed juvenile out-migration has been documented by numerous studies (Maher and Larkin 1955; Chapman 1958; Ward and Slaney 1988; Peven et al. 1994). Current methods to estimate emigrant steelhead survival to LGR do not account for subsequent year emigration, which is common within steelhead populations, resulting in low survival estimates during the transition from natal reaches to the migration corridor. This issue exists in both index watersheds, though estimating survival in the EFPR is more problematic since a large proportion of emigrants are age-1 fish that rear an additional year outside the EFPR watershed before ocean migration (Bowersox et al. 2011). University of Washington researchers have developed the Basin TribPIT model to estimate brood year survival by accommodating the variation in age at migration of steelhead (Lady et al. 2014; Buchanan et al. 2015). This model was recently evaluated using steelhead emigration data from BBC (Feeken et al. 2020) and provided initial estimates of cohort survival of wild juvenile steelhead from the Potlatch River to LGR. We plan to utilize the model to estimate emigrant brood year survival for each index watershed moving forward. Generating brood year smolt survival estimates to LGR will standardize smolt abundance estimates between both index watersheds, as well as with other Idaho steelhead monitoring locations, for large-scale evaluations and improved comparisons among steelhead sub-populations. Estimating age-specific survival of juvenile steelhead will also add to understanding of the response of fish production to restoration efforts at smaller spatial scales.

Estimating the contribution of all life history characteristics and strategies is imperative when estimating population productivity. The importance of juvenile steelhead emigration in the fall has been documented in other Idaho populations (Dobos et al. 2020). We have experienced considerable challenges monitoring juvenile emigration during the fall because low flow conditions limit the operation of juvenile screw traps. The limited data we collected suggests fall juvenile emigration from index watersheds may be considerable in some years (up to 15-18% of following year emigration). In addition, the fall trapping dataset shows the majority of fall emigrants out of the EFPR are age-0 and age-1 fish, which supports the assumption that juvenile steelhead emigrate early from the EFPR as parr due to a lack of suitable over-winter rearing habitat. We plan to explore alternative techniques to monitor juvenile steelhead emigration during low flow periods in the fall. Improving the project's ability to estimate fall emigrant abundance and life history will refine productivity metrics.

Life cycle modeling simulations indicate planned restoration projects have the potential to significantly increase juvenile steelhead production in the index watersheds over the next 10 years (Uthe et al. 2017). In the BBC watershed, three large-scale barrier removal and flow supplementation projects could reconnect nearly 35 km of additional rearing habitat, effectively doubling the linear amount of rearing habitat currently available in the watershed. Given the positive fish and habitat responses to these types of projects (Uthe et al. 2017) and the extensive size of the treatments, we expect to observe a detectable increase in smolt production following implementation. In the EFPR watershed, multiple smaller-scale restoration projects are planned to increase instream habitat complexity. We are encouraged by the positive shifts in the EFPR emigrant age, growth, and survival and expect continued improvements as more projects are implemented. An increase in emigrant abundance and/or shifts to fitter emigrants should result in higher steelhead productivity in the watersheds. Continued implementation of high priority habitat restoration projects within the Potlatch River drainage will move the needle towards those changes.

In summary, habitat restoration and effectiveness monitoring activities are ongoing in the Potlatch River basin. We have established baseline levels of steelhead production and productivity in the index watersheds to compare against future evaluations and developed an

understanding of the life histories of the steelhead in the index watersheds (Uthe et al. 2017). We anticipate habitat treatment goals will be achieved by 2028 in BBC and 2029 in the EFPR. Once treatment goals are achieved, we anticipate a 10-year post-treatment monitoring period will be needed to ensure an adequate data set to detect changes in productivity related to restoration efforts.

We continue to refine our index-watershed monitoring efforts to strengthen our ability to detect a watershed-scale response in steelhead to restoration efforts in the basin. Recommendations outlined below will improve the effectiveness of the index-watershed monitoring framework and increase our understanding of the status and trends of the steelhead populations in the index watersheds.

RECOMMENDATIONS

1. Develop analytical techniques to generate expanded adult steelhead escapement estimates during periods of low adult abundance.
2. Estimate juvenile steelhead survival estimates from natal reaches to LGR for the EFPR using Basin TribPIT model.
3. Investigate the feasibility of operating low flow fyke traps to monitor juvenile steelhead emigrants from index watersheds during fall season.
4. Install main-stem PIT-tag array infrastructure to monitor adult escapement in the entire Potlatch River basin and assess the extent of mainstem spawning and rearing.

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TABLES

Table 1. Age frequencies of wild adult steelhead captured at Potlatch River weirs and known destination wild adult steelhead sampled at Lower Granite Dam, 2008-2018. Partially aged fish were indicated by an X and repeat spawners were signified by R.

	Adult Steelhead Age (FW:SW)													
Year	**X:1**	**1:1**	**2:1**	**3:1**	**X:2**	**1:2**	**2:2**	**3:2**	**2:3**	**3:3**	**4:1**	**5:0**	**R**	**Total aged**
Big Bear Creek														
2008	5	1	14	2	3	5	17	4	6	1	0	0	0	58
2009	2	1	26	4	5	1	36	2	0	0	0	0	0	77
2010	11	7	115	7	14	17	79	9	0	0	0	0	1	260
2011	0	4	11	0	3	11	32	0	1	0	0	0	1	63
2012	8	6	42	2	11	14	126	2	0	0	0	0	0	211
2013	0	1	3	0	2	4	9	0	0	0	0	0	0	19
2014	0	2	9	1	0	1	5	1	0	0	0	0	0	19
2015	1	3	11	1	2	4	8	0	0	0	0	0	1	31
2016	0	1	8	1	2	7	15	0	0	0	0	0	0	34
2017	0	0	1	0	0	2	10	2	0	0	0	0	0	15
2018	0	0	7	0	0	0	0	1	0	0	0	0	1	9
East Fork Potlatch River														
2008	1	0	33	2	2	1	15	1	2	1	0	0	0	58
2009	8	0	25	12	4	0	20	0	0	0	0	0	0	69
2010	3	0	21	13	3	0	18	10	0	0	0	0	1	69
2011	0	1	8	2	2	0	15	5	0	0	0	0	0	33
2012	3	2	15	11	5	1	24	5	2	0	0	0	0	68
2013	1	0	12	3	4	1	48	8	0	0	0	1	0	78
2014	5	8	38	10	3	4	15	0	0	0	0	0	0	83
2015	3	0	20	12	10	1	29	10	0	0	0	0	0	85
2016	0	1	26	6	1	1	33	7	0	0	1	0	0	76
2017	0	0	1	0	0	0	9	1	0	0	0	0	0	11
2018	0	0	11	5	0	0	3	1	0	0	0	0	0	20

FIGURES

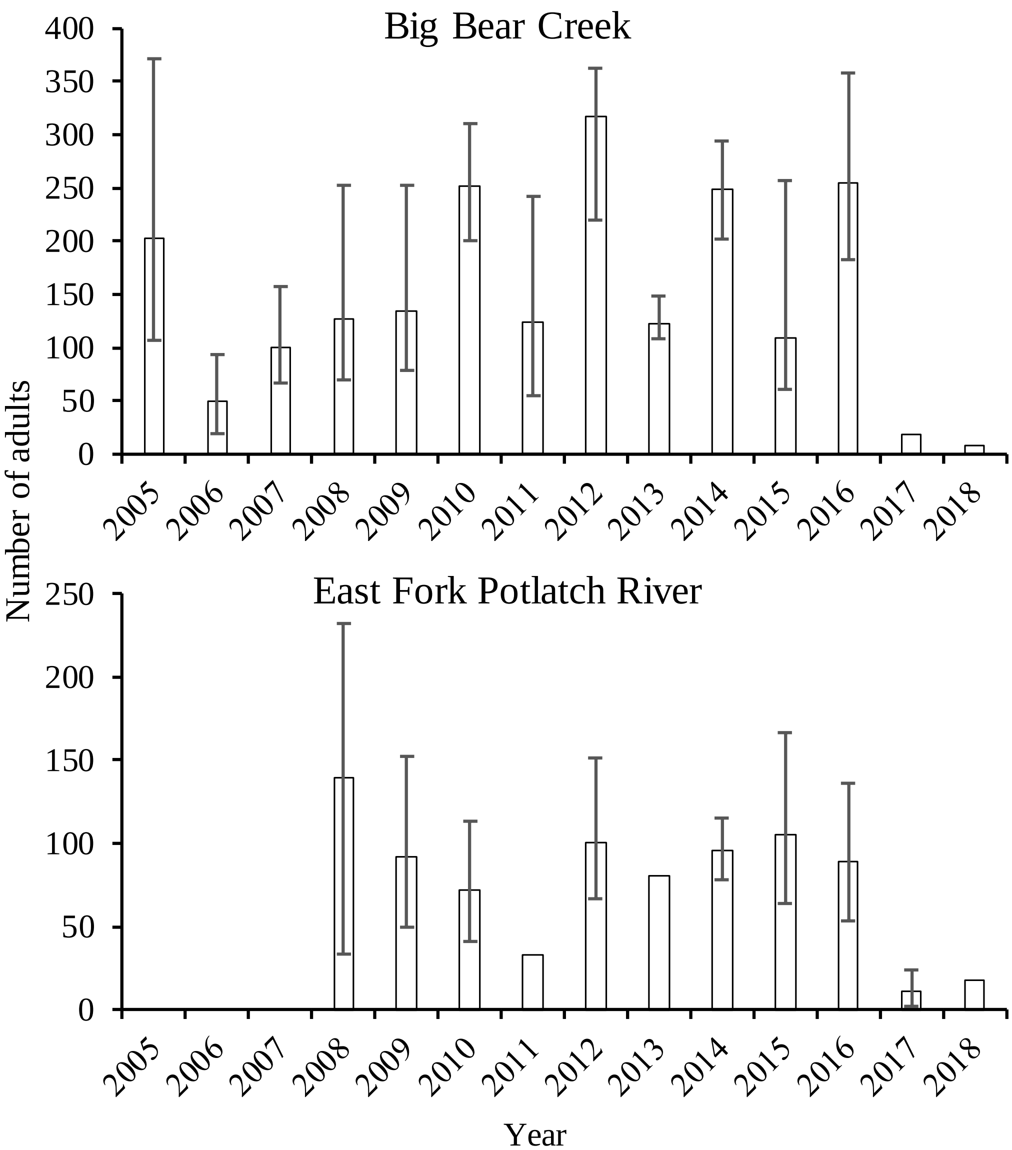

Figure 4. Abundance of wild adult steelhead in Big Bear Creek and the East Fork Potlatch River watersheds, 2005-2018. East Fork Potlatch River estimates begin in 2008. Confidence intervals are at 95%, but could not be calculated in some years due to low detections at PIT-tag arrays.

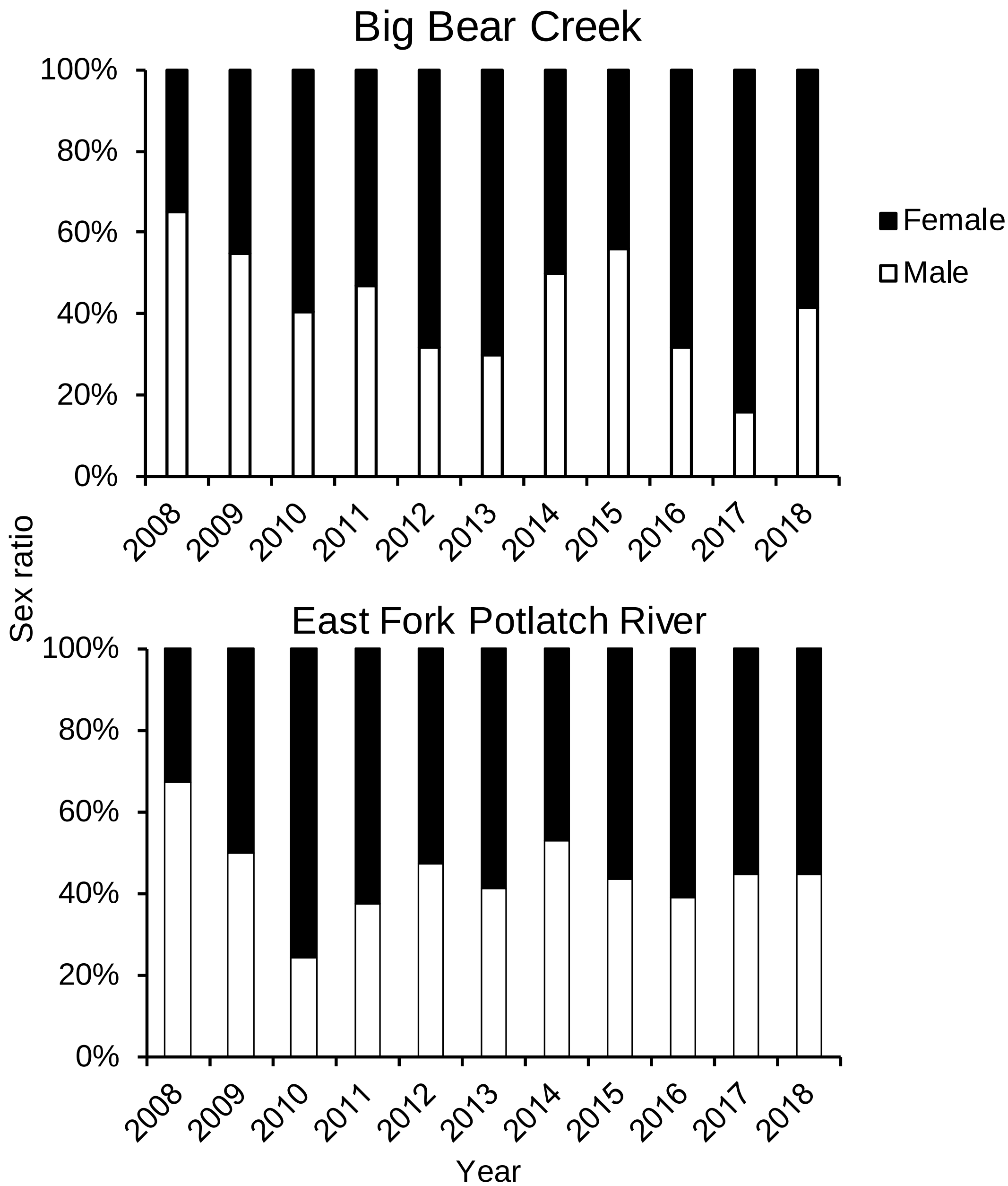

Figure 5. Sex ratio of wild adult steelhead at Big Bear Creek and the East Fork Potlatch River watersheds, 2005-2018.

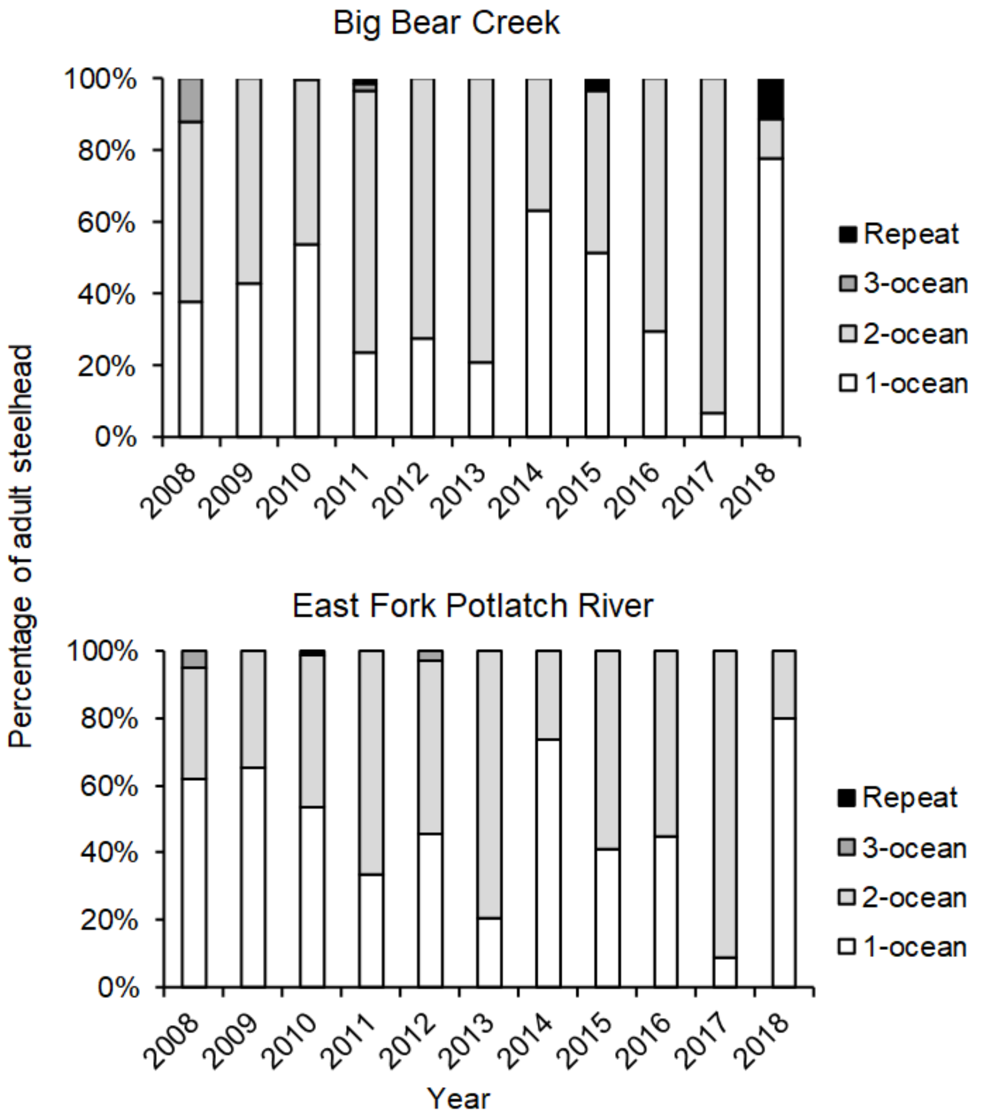

Figure 6. Age composition of wild adult steelhead at Big Bear Creek and the East Fork Potlatch River watersheds, 2008-2018.

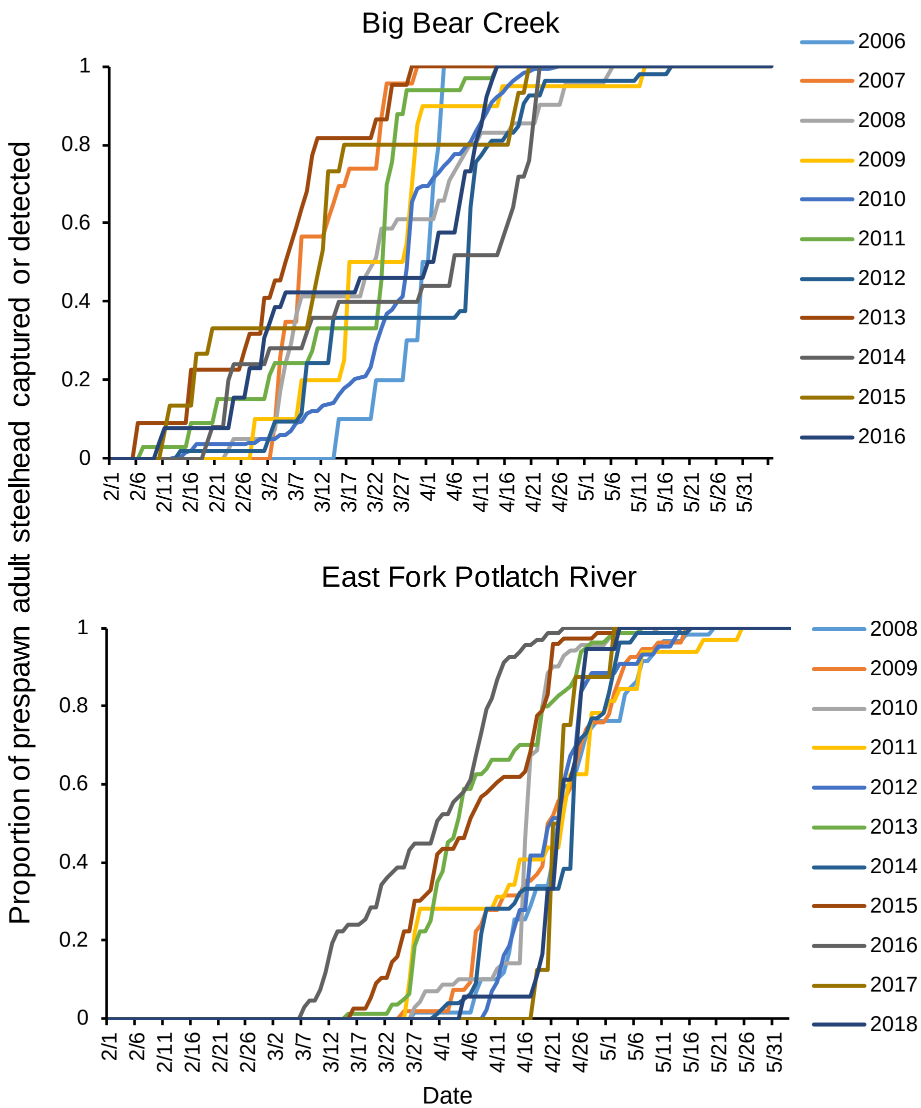

Figure 7. Cumulative run-timing curves for wild adult prespawn steelhead captured at a weir or detected on an array at Big Bear Creek and the East Fork Potlatch River watersheds, 2005-2018.

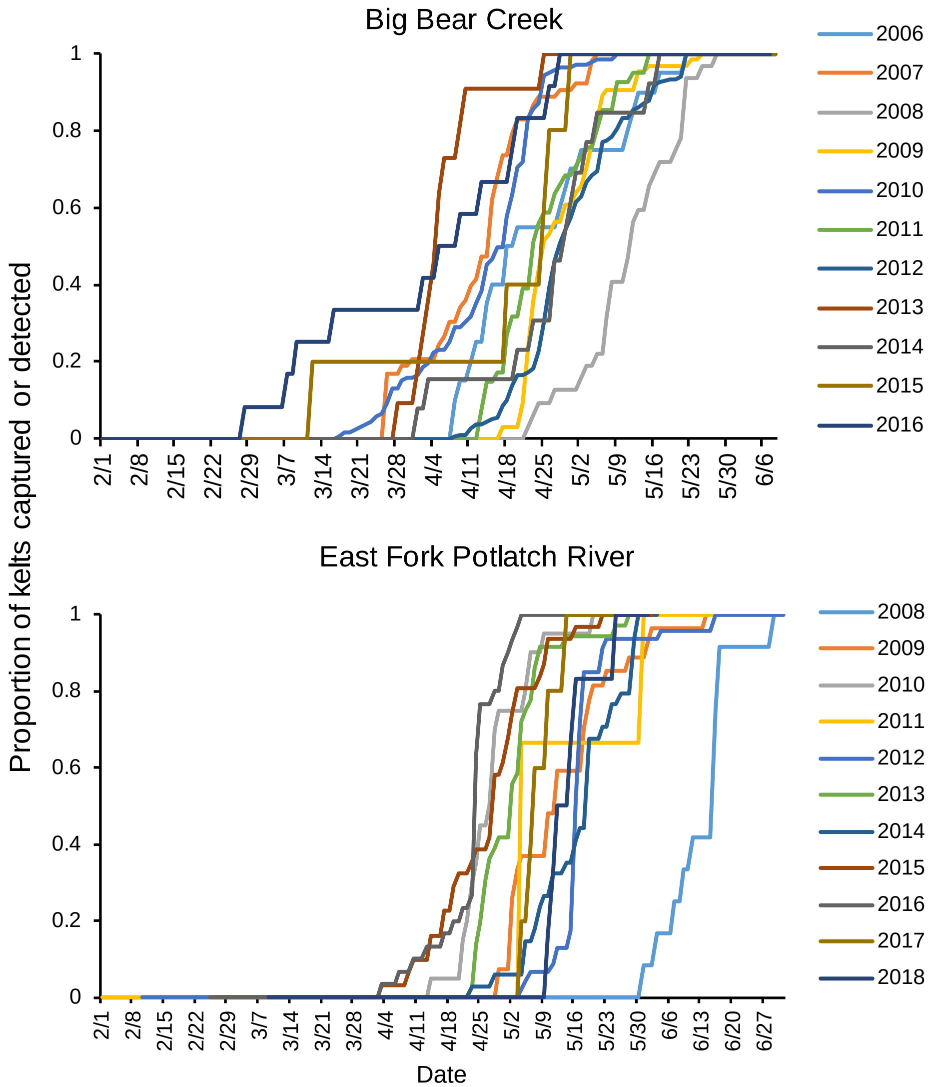

Figure 8. Cumulative run-timing curves for wild adult steelhead kelts captured at a weir or detected on an array at Big Bear Creek and the East Fork Potlatch River watersheds, 2005-2018.

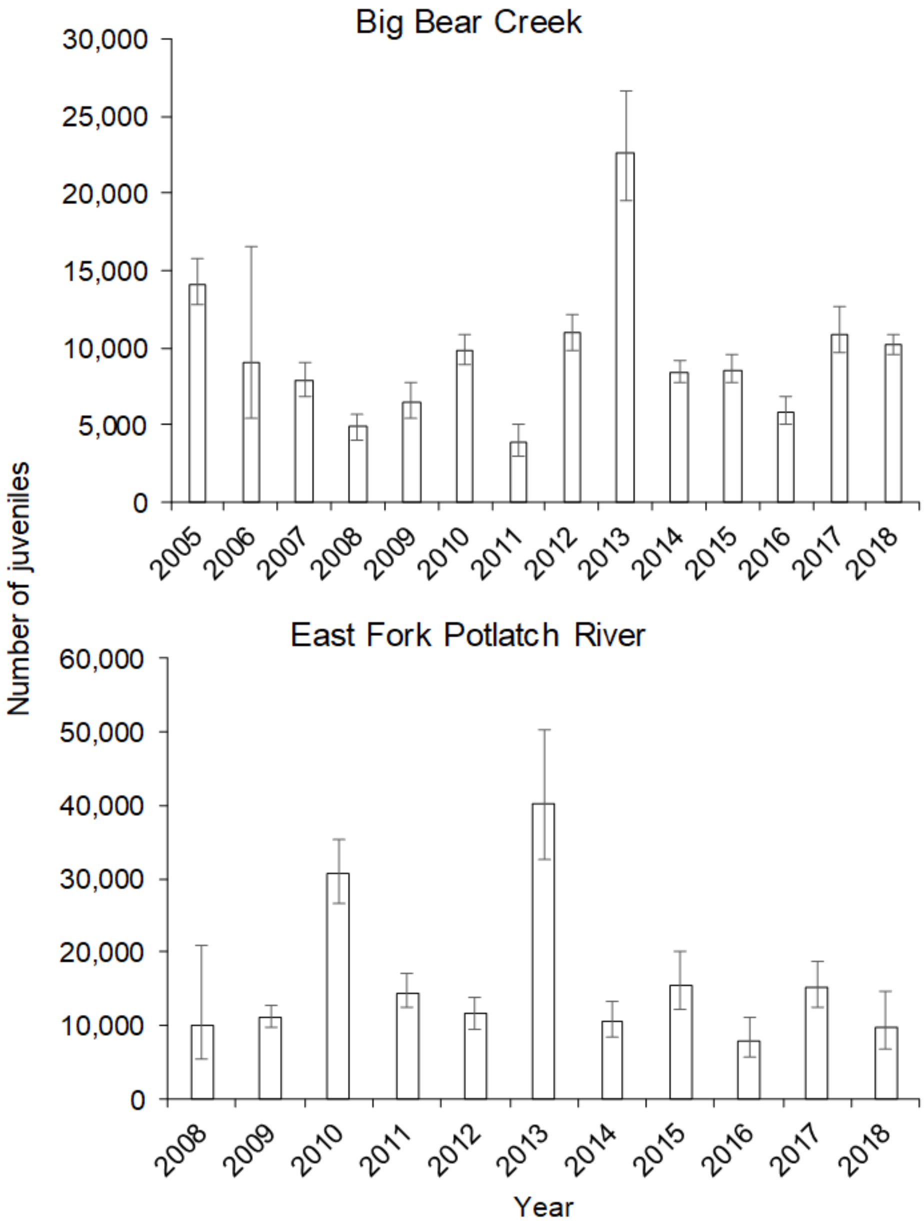

Figure 9. Estimated abundance of wild juvenile steelhead emigrants from spring trapping season at Big Bear Creek and the East Fork Potlatch River watersheds, 2005-2018.

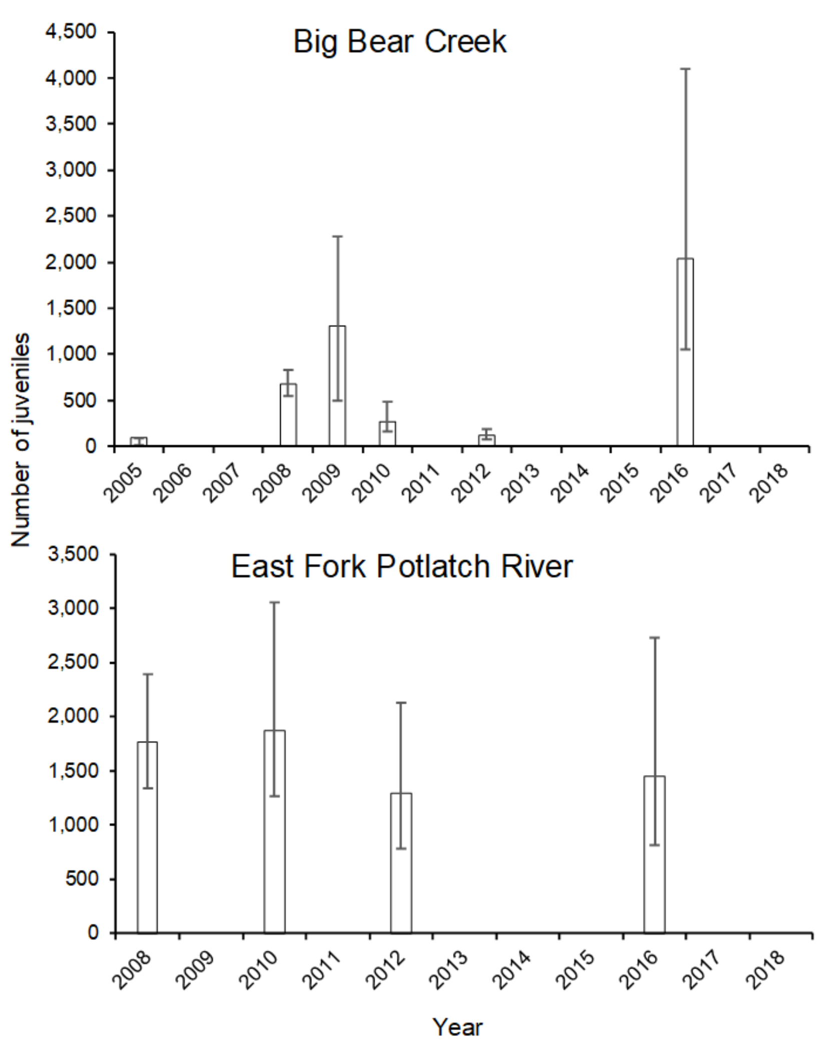

Figure 10. Estimated abundance of wild juvenile steelhead emigrants from the fall trapping season at Big Bear Creek and the East Fork Potlatch River watersheds, 2005-2018. Traps were not operated in years without estimates.

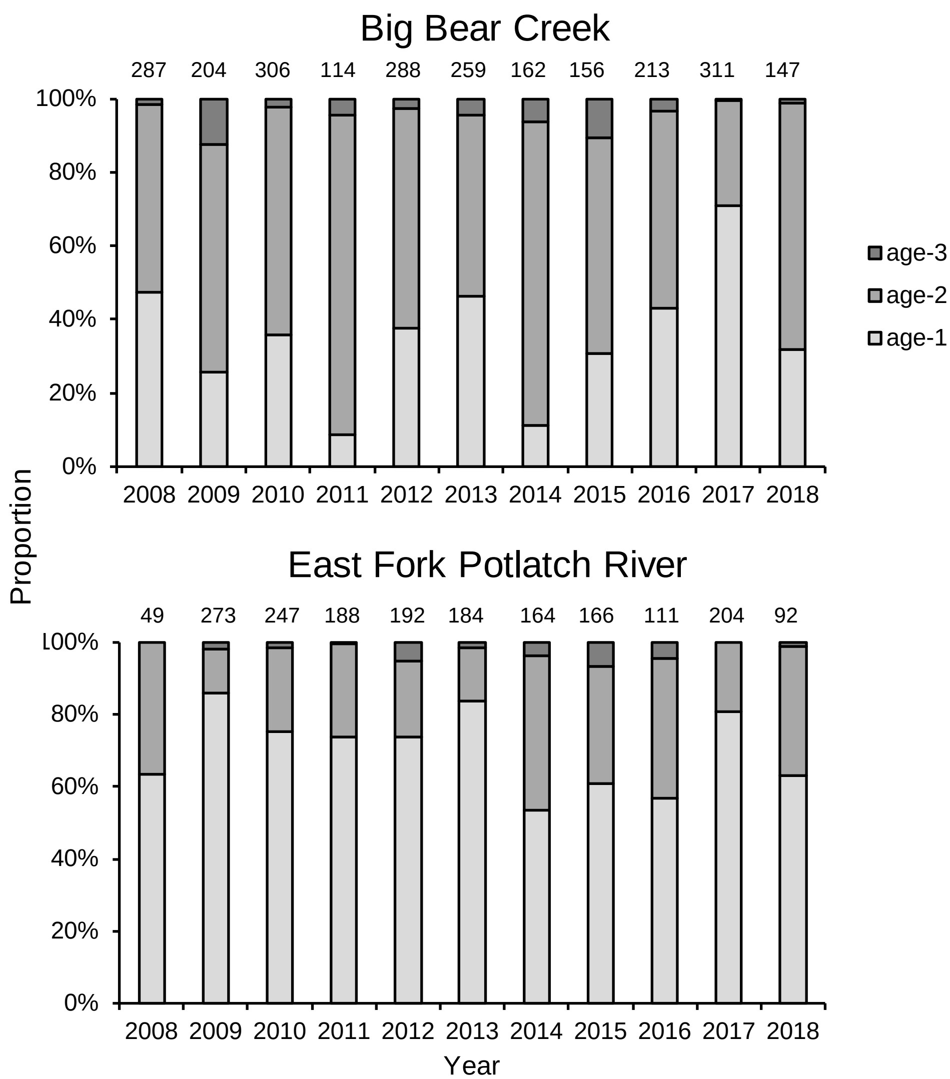

Figure 11. Age composition of wild juvenile steelhead emigrants captured during spring trapping season at Big Bear Creek and East Fork Potlatch River watersheds, 2008-2018. Numbers above bars represent sample size.

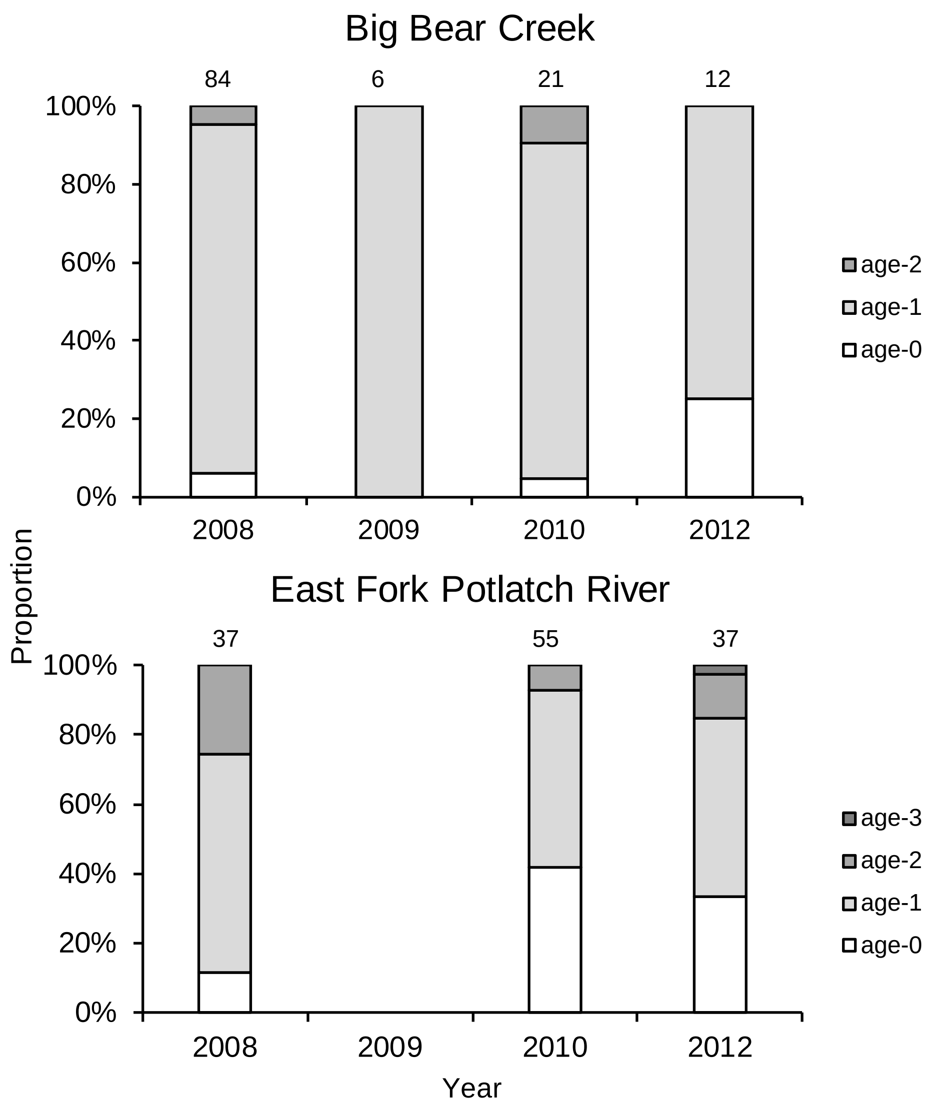

Figure 12. Age composition of wild juvenile steelhead emigrants captured during fall trapping season at Big Bear Creek and East Fork Potlatch River watersheds, 2008-2012. Fall trapping did not occur in East Fork Potlatch River in 2009. Numbers above bars represent sample size.

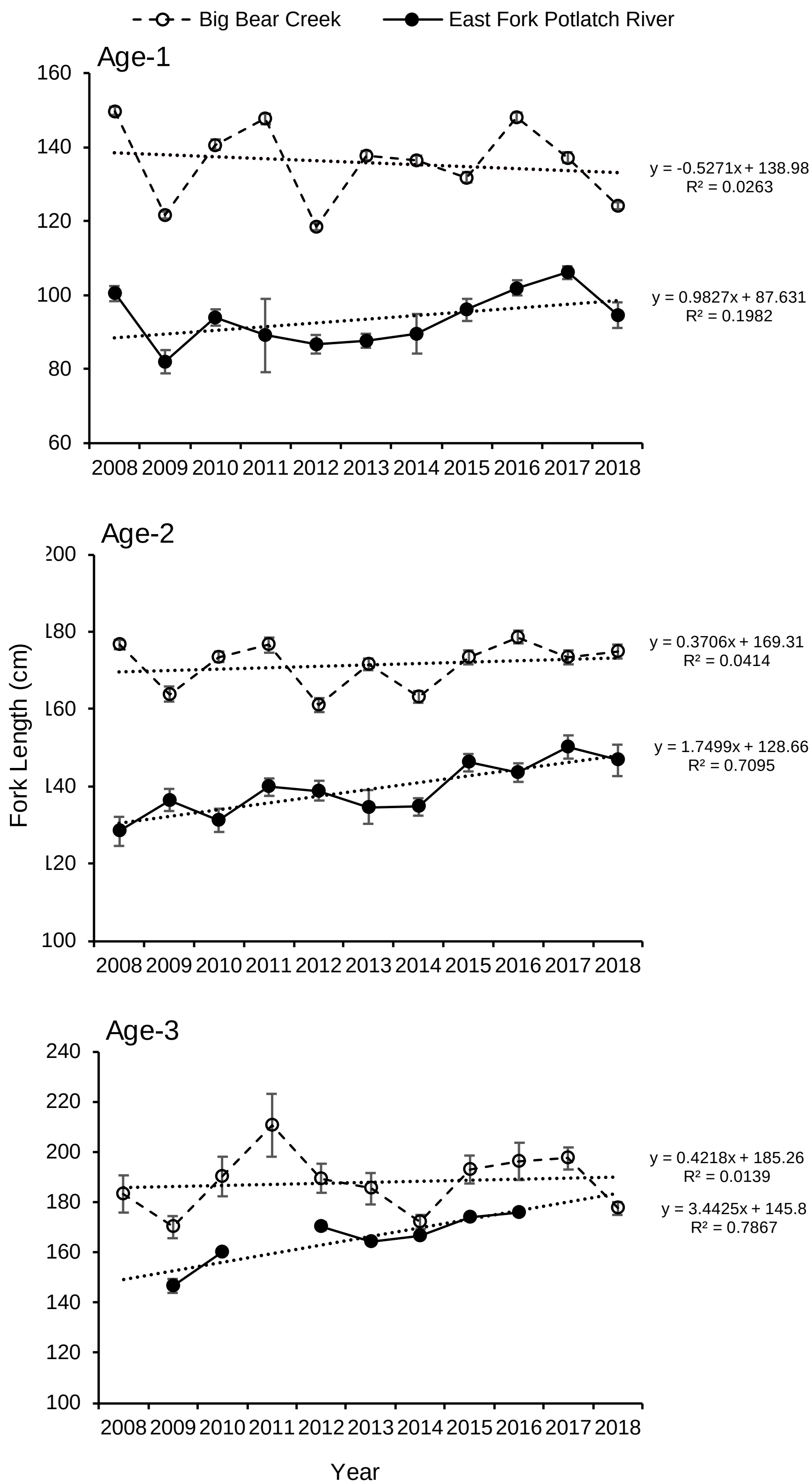

Figure 13. Average length at age of wild juvenile steelhead emigrants captured during the spring trapping season at Big Bear Creek and East Fork Potlatch River watersheds, 2008-2018. Error bars are S.E.

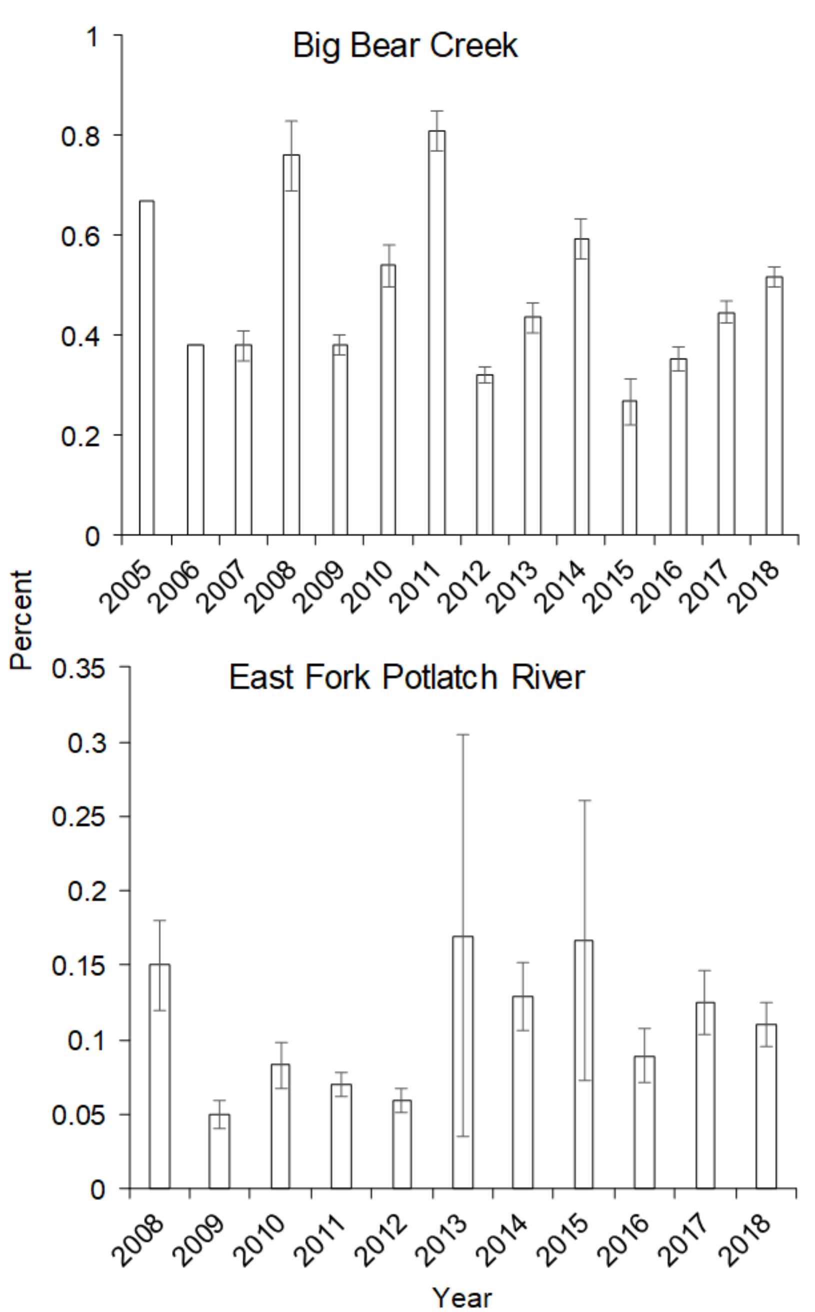

Figure 14. Apparent survival of spring emigrants from Big Bear Creek (top panel) and East Fork Potlatch River (bottom panel) traps downstream to Lower Granite Dam, 2005-2018.

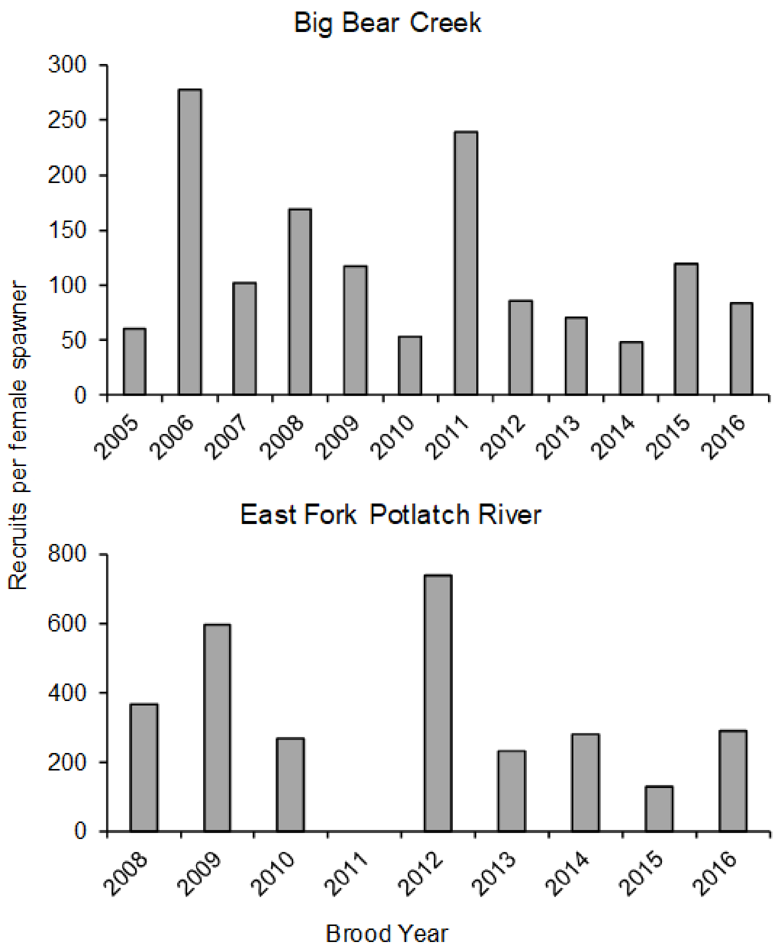

Figure 15. Productivity (juvenile recruits per female spawner) of Big Bear Creek and East Fork Potlatch River steelhead populations for BYs 2005-2016. Brood year 2011 for the East Fork Potlatch River was excluded because the parent estimate is incomplete.

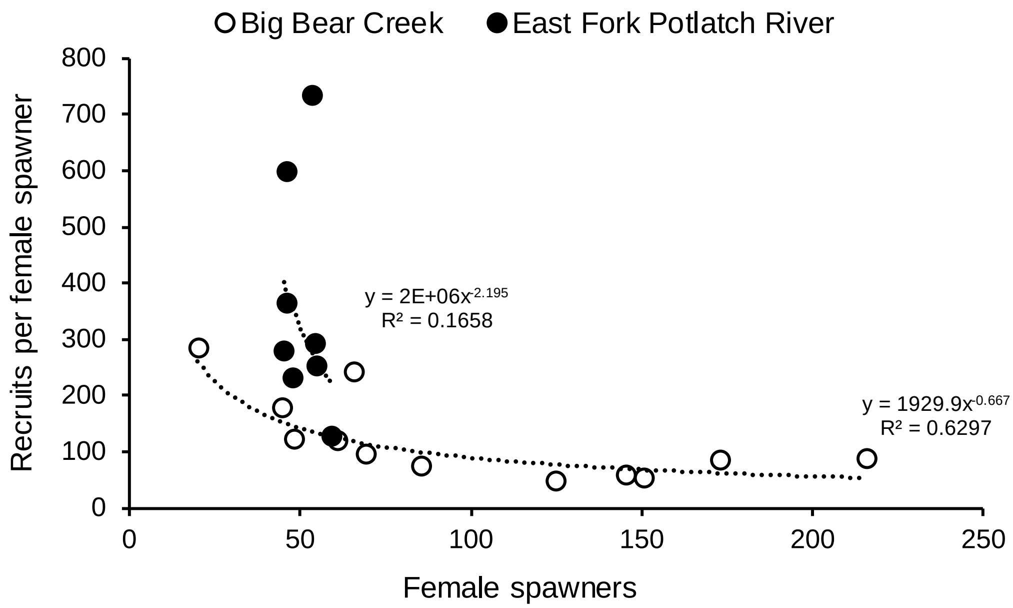

Figure 16. Productivity (juvenile recruits per female spawner) versus number of female spawners for the Big Bear Creek and East Fork Potlatch River watersheds. Big Bear Creek data are BYs 2005-2016 and the East Fork Potlatch River data are BYs 2008-2016. Brood year 2011 for the East Fork Potlatch River was excluded because the parent estimate is incomplete.

CHAPTER 2: JUVENILE STEELHEAD PRODUCTIVITY AND HABITAT CONDITION RESPONSE TO HABITAT RESTORATION IN SELECT TRIBUTARIES WITHIN THE POTLATCH RIVER, IDAHO

ABSTRACT

Within the Potlatch River Steelhead Monitoring and Evaluation project we conduct habitat and electrofishing surveys to monitor rearing habitat conditions and juvenile steelhead production metrics in treatment and control areas in the Potlatch River basin. Data from low water habitat surveys highlight the extent of de-watering in lower watershed tributaries, and data from 2017 and 2018 fell within the range of previous estimates. We have observed improvements in the extent of canopy cover and pool density in the EFPR treatment area relative to control areas during recent years. Trends in juvenile steelhead density have tracked closely across treatment and control tributaries and all tributaries showed a marked decrease in 2015. Density estimates in 2017 and 2018 were within the range of previous estimates. Similarly, parr-to-smolt survival estimates were the lowest across all tributaries during 2013-2015, but have increased since. We documented a positive response in juvenile steelhead growth, survival, and density following a flow supplementation pilot project in Little Bear Creek. In addition, the positive correlations between juvenile steelhead growth and survival with the amount of wetted habitat validates the need to improve base flow conditions in the lower Potlatch River watershed. In the upper watershed, a positive correlation between juvenile steelhead density and large wood highlights the need to improve habitat complexity in the treatment area.

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INTRODUCTION

Tributary-scale monitoring was incorporated into the project's study design to measure the response in juvenile steelhead production and habitat conditions in treatment areas where habitat treatments occurred relative to control areas where no habitat treatments occurred. These monitoring efforts are complementary to index-watershed monitoring efforts described in Chapter 1 and provide the necessary data to isolate responses to specific restoration techniques which should allow us to better understand mechanisms behind a response. Understanding the causal link between a habitat treatment and fish response is a fundamental step towards replicating restoration efforts elsewhere within and outside the basin (Bennett et al. 2016).

The objective of this chapter is to link habitat restoration efforts to changes in juvenile steelhead production metrics and habitat conditions within monitored tributaries. We are currently in the treatment phase of habitat restoration efforts in the Potlatch River basin (Figures 2 and 3). Preliminary results presented here include pre-treatment data and partial data from the treatment phase. Ultimately, tributary-scale monitoring data will be assessed using a before-after-control-impact (BACI) analysis with in-basin and out of basin controls (Roni 2005). The final assessment will be completed after habitat treatment goals are achieved in the basin.

METHODS

Tributary-scale monitoring efforts were conducted concurrently in treatment and control areas within the lower and upper Potlatch River watersheds (Figure 17). In the lower watershed, treatment tributaries included Big Bear Creek (BBC), Little Bear Creek, and the West Fork Little Bear Creek, and the control tributary was Pine Creek. In the upper watershed, the treatment area was the main-stem East Fork Potlatch River (EFPR) downstream of Pivash Creek (lower 22 km) and control areas were the main-stem EFPR upstream of Pivash Creek and the West Fork Potlatch River. We defined the West Fork Potlatch River as the area upstream of the confluence with the EFPR, which included portions of the main-stem Potlatch River as well as major tributaries Cougar Creek, Feather Creek, and Moose Creek. For habitat surveys in the lower Potlatch River watershed, Corral Creek was monitored as a treatment tributary to evaluate changes in base flow conditions in response to meadow restoration projects in the drainage and Cedar Creek was monitored as an additional control tributary.

Habitat Surveys

We monitored variables associated with the primary limiting factor of low summer base flows in the lower watershed. Low Water Habitat Availability Protocol (LWHAP) surveys (Bowersox et al. 2009) were conducted to evaluate the amount of wetted habitat and pool density within treatment and control tributaries. Sample sites were selected using a Generalized Random Tessellation Stratified (GRTS) design, where tributaries were stratified into upland and canyon reaches to disperse sites throughout each tributary. Two 500 m sites were surveyed within each reach (upland and canyon), resulting in four sites per tributary and a total of 26 sites surveyed annually (Figure 18). There were seven years (2007-2013) of pre-treatment data and five years (2014-2018) of treatment data collected across the tributaries in the lower watershed. The LWAP surveys were designed to be a rapid assessment of base flow conditions and were conducted during the first week of August each year to provide temporal consistency. Length (m) of wetted habitat and number of pools were recorded at each site. Wetted habitat was defined as any area where there was standing water and pools were delineated as any wetted stream with a maximum

depth exceeding 30 cm. We calculated the average proportion of wetted habitat (linear %) and pool density (number per 100 m) for each tributary annually.

Habitat surveys were conducted in the upper Potlatch River watershed to monitor variables associated with the primary limiting factor of low in-stream habitat complexity. Primary response variables included large woody debris (LWD) quantity (number per km), pool density (number per km), and percent canopy cover. Protocols by Moore et al. (2006) and Bouwes et al. (2011) were modified to focus on these response variables. Briefly, all LWD pieces (≥10 cm in diameter and 1 m in length) were enumerated within the wetted channel. Pools were defined as depressions in the streambed that were concave in profile, laterally and longitudinally, and were bound by a 'head' crest and 'tail' crest. Only main channel pools were enumerated. The analysis was restricted to pools with a modal depth ≥40 cm because they represent typical winter rearing depths of juvenile *Oncorhynchus spp.* (Huusko et al. 2007). Canopy cover was visually estimated within 5-10 m of bankfull during the 2003-2004 and 2008 surveys. From 2013-2018, canopy cover was measured with a densiometer at four points along 10 sub-transects equally distributed throughout each 100 m site, for a total of 40 measurements per 100 m site. Each technique generated a percentage.

Effort placed on habitat surveys in the upper watershed before and during the treatment periods varied. However, the number of sites sampled per area was similar between treatment and control areas within each time frame. Earlier sample sites (2003, 2004, and 2008) were included in the analysis to bolster pre-treatment data and were selected using a stratified random sampling technique (Schriever and Nelson 1999). Data from 2003 and 2004 were combined for the analyses because sites were sampled in both years for a given area. Current sample sites (2013-2018) were selected using a GRTS design and were co-located with electrofishing sites (Figure 19). Total number of sample sites were 40 in 2003/2004, 19 in 2008, and 23-25 in 2013-2018. Data collected in 2003, 2004, and 2008 were pre-treatment and data collected in 2013-2018 were treatment.

Trends in habitat variables collected in the treatment and control areas in the upper watershed were compared across study years. Data were averaged annually for each variable across all sites within a given area. In addition, each habitat variable was analyzed as a ratio (treatment:control in a given year) to better illustrate the relative change between treatment and control areas. Within this analysis, a value of 1 would indicate equal quantities/proportions between treatment and control areas. A value >1 indicates the treatment area has a higher value than the control area. Over time, an increasing trend in the ratio indicates improvement in the treatment reach relative to the control, and vice versa for a negative trend in the value.

Juvenile Steelhead Density, Parr-to-Smolt Survival, and Growth

Juvenile steelhead density was the primary fish response metric in the tributary-scale monitoring. Pre-treatment data were limited so surveys conducted prior to the start of the project were incorporated into the analyses. Specifically, surveys conducted in 1996, 2003, and 2004 were included to bolster the pre-treatment data set (Figures 19 and 20). The EFPR was not sampled in 1996. There were four years (1996, 2003, 2004, and 2013) of pre-treatment data and five years (2014-2018) of treatment data collected in the lower watershed. There were two years (1996 and 2004) of pre-treatment data and six years (2013-2018) of treatment data collected in the upper watershed.

Single-pass electrofishing was used to estimate trends in juvenile steelhead density within treatment and control tributaries (Kruse et al. 1998). Surveys were conducted during May-July

each year to provide temporal consistency. Site boundaries were established at stream habitat breaks 80-120 m apart. Crews began at the lower boundary and electrofished upstream. Fish captured were identified to species and enumerated. All steelhead ≥80 mm were weighed (g), measured (FL; mm), and scanned for the presence of PIT-tags. Juvenile steelhead (≥80 mm) not previously tagged were anesthetized using MS-222 solution and tagged in the abdomen with a 12 mm PIT tag. Site length and five widths were measured at each location to estimate area. Mean annual density estimates (fish per 100 m^2) were calculated for each tributary by averaging density from each site within a tributary. Trends in juvenile density in treatment and control areas were compared across the study years. In addition, density data were analyzed as a ratio (treatment:control in a given year) to better illustrate the relative change between treatment and control tributaries (see ratio explanation above).

Apparent survival of PIT-tagged steelhead from Potlatch River tributaries during the previous summer to LGR the following spring was used as an index of parr-to-smolt survival. Methods for estimating apparent survival were similar to methods described in Chapter 1. We conducted roving electrofishing surveys in addition to single-pass surveys during the summer months to increase the number of PIT-tagged juvenile steelhead in treatment and control tributaries. Our goal was to tag 300 juvenile steelhead in each tributary annually for survival and growth analyses. All captured juvenile steelhead ≥80 mm were anesthetized using MS-222 solution, measured (FL; mm), weighed (g), and PIT tagged. We assumed all steelhead PIT tagged during the summer would emigrate the following spring. There were six years (2008-2013) of pre-treatment data and five years (2014-2018) of treatment data collected in the lower watershed. In the upper watershed, parr-to-smolt survival estimates were only generated for the EFPR because too few juvenile steelhead were tagged and subsequently detected in the West Fork Potlatch River to generate an estimate. Trends in apparent survival for tag groups in treatment and control tributaries were compared across years.

Juvenile steelhead growth (summer to fall) was monitored as a response to restoration treatments in the lower watershed. Electrofishing surveys were conducted during late October through early November annually to recapture previously PIT-tagged juvenile steelhead. Surveys were only conducted in the West Fork Little Bear Creek and Little Bear Creek (treatment tributaries) and Pine Creek (control tributary) where the recapture rate was sufficient (n >10). All captured juvenile steelhead ≥80 mm were scanned for PIT tags and measured (FL; mm). Growth (mm per d) was calculated as the change in fork length between time of tagging and time of recapture for each recaptured PIT-tagged fish. Means and standard deviations were calculated for each tributary to compare growth rates between treatment and control tributaries across years.

A Pearson's correlation analysis was used to examine the relationship(s) between juvenile steelhead production metrics (density, growth, and survival) and key habitat metrics in each watershed. In the lower watershed, we examined the relationships between juvenile steelhead density, growth, and survival with the amount of wetted habitat. In the upper watershed, we examined the relationships between juvenile steelhead density and survival with LWD and pool density. In addition, we examined the relationship(s) between juvenile survival and growth with the density of juvenile steelhead (age 1+) in each watershed to assess the influence of density-dependent factors on these metrics. In most instances, data used in the analyses were averages across sites and tributaries for each watershed. One exception was the analyses between juvenile steelhead density and habitat metrics in the upper watershed where site specific values were used because density and habitat sites were co-located.

RESULTS

Habitat Surveys

Lower Potlatch River Watershed

Low water habitat surveys were conducted to monitor variables associated with the primary limiting factor of low summer base flows in the lower watershed (Figure 21). The amount of wetted habitat in the lower watershed (all tributaries combined) averaged 74% across years (range = 59-88%). On average, the West Fork Little Bear Creek (treatment tributary) had the most wetted habitat (92%) and Cedar Creek (control tributary) had the highest average pool density (5.1 pools per 100 m) among tributaries. Conversely, Corral Creek (treatment tributary) had the least amount of wetted habitat (41%) and the lowest pool density (1.0 pools per 100 m) among tributaries. Wetted habitat and pool density estimates tracked relatively closely over time among three treatment tributaries (BBC, West Fork Little Bear Creek, and Little Bear Creek) and Cedar Creek (control), but not the other tributaries. Pine Creek displayed little variation in either the amount of wetted habitat or pool density across years. Wetted habitat and pool density estimates in 2017 and 2018 fell within the range of previous estimates for all tributaries.

Upper Potlatch River Watershed

Habitat surveys were conducted to monitor variables associated with the limiting factors of low in-stream habitat complexity and poor riparian condition in upper watershed tributaries (Table 2; Figure 22). Canopy cover and pool density in the EFPR treatment reach showed a positive increase compared to the West Fork Potlatch River (control), but not the EFPR control reach, across years. Pool density ranged widely across years and was negatively correlated with flow conditions in the EFPR ($r = -0.73$), indicating less pools were identified and counted during high flow years. Large wood density in the EFPR treatment area has remained relatively constant in relation to both control areas across years. Habitat data were not collected in the West Fork Potlatch River in 2017 and LWD data in 2015 were not included in the analysis due to inconsistencies in data collection.

Juvenile Steelhead Density, Parr-to-Smolt Survival, and Growth

Lower Potlatch River Watershed

Juvenile Steelhead Density—Trends in juvenile steelhead density estimates were relatively similar across years for the treatment and control tributaries (Figure 23). In general, high densities were observed in 2013 and 2017 for all tributaries, except the West Fork Little Bear Creek in 2003 and Pine Creek in 2018. Density estimates decreased across all tributaries in 2015. On average, juvenile steelhead density was 10.9 fish per 100 m^2 in the West Fork Little Bear Creek (range = 3.4-19.5 fish per 100 m^2), 9.2 fish per 100 m^2 in Little Bear Creek (3.9-20.0 fish per 100 m^2), 6.7 fish per 100 m^2 in Pine Creek (range = 3.0-13.2 fish per 100 m^2), and 6.0 fish per 100 m^2 in BBC (range = 2.0-10.9 fish per 100 m^2). Juvenile steelhead density in the West Fork Little Bear Creek and BBC has decreased relative to Pine Creek whereas juvenile density in Little Bear Creek has increased relative to Pine Creek across years (Figure 24). There was no correlation ($r = -0.01$) between juvenile steelhead density and the amount of wetted habitat in the lower watershed (Figure 25).

Parr to Smolt Survival—On average, the West Fork Little Bear Creek and Little Bear Creek had both the highest number of fish tagged and tags detected in the hydrosystem among

tributaries in the lower watershed (Table 3). The majority (98%) of the tags detected in the hydrosystem were detected the following spring after tagging.

Apparent survival from tributary to LGR the following spring (parr-to-smolt survival) varied among tributaries, but showed relatively similar trends over time (Figure 26). Estimates decreased across all tributaries in tag years 2013-2015, but have increased in recent years. Estimates could not be generated for six years in BBC, one year in the West Fork Little Bear Creek and Little Bear Creek, and three years in Pine Creek because of low detections in the hydrosystem. Parr to smolt survival averaged 14.7% in Little Bear Creek (range = 3.2-35.0%), 13.6% in Pine Creek (range = 2.5-22.5%), 13.0% in the West Fork Little Bear Creek (range = 3.1-25.0%), and 12.4% in BBC (range = 9.0-16%). Parr to smolt survival was positively correlated with the amount of wetted habitat (r = 0.42) and negatively correlated with fish density (r = -0.54) in the lower watershed (Figure 27).

<u>Growth Rates</u>—The number of fish recaptured during fall electrofishing surveys varied across tributaries and Pine Creek averaged the highest number of recaptures at 38 fish (range = 17-62 fish) and Little Bear Creek averaged the lowest at 26 fish (range = 0-77 fish) (Table 4). Average time at large ranged from 121 d in the West Fork Little Bear Creek to 137 d in Pine Creek (Table 4).

Juvenile steelhead summer growth averaged 9.2 mm (range = 5.7-12.4 mm) in Pine Creek, 6.2 mm (range = 1.1-17.0 mm) in Little Bear Creek, and 3.2 mm (range = 0.6-7.5 mm) in West Fork Little Bear Creek. Daily summer growth rates showed relatively similar trends over time but growth rates were consistently higher in the control stream (Pine Creek), than the treatment streams (Little Bear Creek and West Fork Little Bear Creek) from 2016 to 2018. (Figure 28, Table 4). Growth rates were similar in the West Fork Little Bear Creek and Little Bear Creek in 2017 and 2018, but not 2016 when growth was four times higher in Little Bear Creek. Little Bear Creek growth rates were not estimated in 2014 and 2015 because of the lack of recaptured fish (Table 4). Juvenile steelhead growth was positively correlated with the amount of wetted habitat (r = 0.33) and negatively correlated with fish density (r = -0.28) in the lower watershed (Figure 29).

Upper Potlatch River Watershed

<u>Juvenile Density</u>—Juvenile steelhead density estimates in treatment and control areas displayed similar trends over time (Figure 30). On average, juvenile steelhead density was 2.4 fish per 100 m^2 in the EFPR treatment area (range = 0.5-5.3 fish per 100 m^2), 7.9 fish per 100 m^2 in the EFPR control area (range = 4.4-10.8 fish per 100 m^2), and 0.9 fish per 100 m^2 in the West Fork Potlatch River (range = 0.0-2.0 fish per 100 m^2). Density estimates decreased across all tributaries in 2015. Juvenile steelhead density in the EFPR treatment reach increased relative to the West Fork Potlatch River through 2015, but has decreased from 2016 to 2018 (Figure 31). Juvenile steelhead density in the EFPR treatment reach has remained stable in relation to the EFPR control reach across years (Figure 31). Juvenile steelhead density was positively correlated with the density of LWD (r = 0.54) but was not correlated with pool density (r = 0.05) in the upper watershed (Figure 32).

<u>Parr to Smolt Survival</u>—On average, 280 juvenile steelhead were tagged annually in the EFPR during roving surveys (Table 3). An average of 17 tags were detected in the hydrosystem annually, 87% of which were detected the following spring after tagging. We were able to tag only a few steelhead in the West Fork Potlatch River (<25 fish total) across the years. Of those few tags, only one was detected in the hydrosystem so no results are presented for this group.

Apparent survival from EFPR to LGR the following spring (parr-to-smolt survival) varied three-fold across years (Figure 33). Parr to smolt survival averaged 9.0% (range = 5.3-14.9%). Estimates could not be generated for tag groups in 2010, 2014, and 2015 because of low detections in the hydrosystem. Survival estimates could not be generated for the West Fork Potlatch River because of the low number of fish captured and tagged. Parr-to-smolt survival was positively correlated with pool density (r = 0.62), negatively correlated with juvenile steelhead density (r = -0.77), and not correlated with LWD (r = 0.02) in the EFPR (Figure 34).

DISCUSSION

To date, we have collected over six years of data that characterize habitat conditions and juvenile steelhead production in the treatment and control tributaries in the Potlatch River. In the lower watershed, LWAP surveys have documented the severity of low summer base flow conditions. Trends in juvenile steelhead density have tracked closely across treatment and control tributaries and were the lowest in 2015, one of the hottest and driest years on record. We observed positive correlations between juvenile steelhead growth and survival with the amount of wetted habitat which validates the need to improve base flow conditions in the lower watershed. In the upper watershed, we have observed slight improvements in canopy cover and pool density but not LWD in the treatment areas. The high variability in pool density estimates appears to be correlated with flow conditions and needs to be addressed for future analyses. The positive correlation between juvenile steelhead density and LWD in the upper watershed highlights the importance of improving habitat complexity in the area. Modifications to our tributary-scale monitoring framework discussed below will enhance our ability to detect and isolate responses to particular habitat actions and provide a better understanding of the cause of a response.

De-watering of rearing habitat limits space and food resources for juvenile steelhead and negatively impacts overall productivity. This issue is well documented within the lower Potlatch River watershed, where only 5 of 72 sample sites were 100% wetted in 12 years of monitoring. The percent of dry streambed (non-wetted habitat) documented from LWAP surveys ranged from 2-39% annually, which would equate to 2.4-47.4 km of dry streambed when applied to the entire tributary. Multiple studies have documented a strong association between stream discharge and juvenile salmonid abundance (Jager et al. 1997; Mitro et al. 2003; Beecher et al. 2010). For example, Coho salmon smolt production was positively related to increasing summer flows in Washington streams (Beecher et al. 2010). Likewise, juvenile steelhead survival increased with higher summer flows in California streams (Grantham et al. 2012). Stream flows can mediate the size and suitability of habitat for fish (Dewson et al. 2007). Thus, higher summer flows can benefit rearing conditions by preserving connectivity and pool depth, moderating stream temperatures and dissolved oxygen levels, and maintaining the production and delivery of food resources for juvenile fish (Myrick and Cech 2004; Hayes et al. 2008; Nilsson and Renofalt 2008). Given the importance of instream flow to juvenile salmonid production, restoration emphasis in the lower Potlatch River watershed should continue to focus on increasing baseflow conditions and expanding rearing habitat availability.

Flow supplementation has been identified as a restoration approach to increase summer base flows within the lower Potlatch River watershed (Resource Planning Unlimited 2007). Flow supplementation was evaluated by IDFG in Little Bear Creek during 2015 and 2016 as part of a pilot study (Uthe et al. 2017; Hand et al. 2020). Water releases increased the amount of available rearing habitat by 8 km, provided 100% connectivity in >16 km of stream, increased pool density, and improved water quality by decreasing water temperature and increasing DO levels (Uthe et al. 2017; Hand et al. 2020). In 2016, the amount of wetted habitat surveyed in Little Bear Creek

was 100% as a direct result of the water releases. The response of juvenile steelhead to water releases was also positive. We observed juvenile steelhead growth rates that were four times higher in Little Bear Creek relative to West Fork Little Bear Creek in 2016, but nearly identical growth rates in the two tributaries during subsequent years of no water releases. In addition, parr-to-smolt survival rates were the highest in Little Bear Creek in 2016. Lastly, juvenile steelhead densities peaked in Little Bear Creek in 2017, the year following the water releases and were the highest on record. Flow supplementation can rapidly improve juvenile rearing conditions and productivity and should be used as a tool to enhance juvenile steelhead rearing habitat where applicable.

Life cycle modeling simulations suggest the implementation of three large-scale restoration projects could generate significant increases in juvenile steelhead production in the lower Potlatch River watershed (Uthe et al. 2017). To date, only one of three projects has been completed. The Big Meadow Creek culvert enhancement project was completed in 2017 and opened access to an additional 9 km of juvenile rearing habitat. The Big Bear Falls barrier modification project is scheduled to be implemented in 2021, while funding and implementation of the Little Bear Creek flow supplementation project remains uncertain. Together, these projects would reconnect nearly 35 km of additional rearing habitat, effectively doubling the linear amount of rearing habitat currently available in the lower watershed. Once access and/or flow is restored, additional instream and riparian restoration work will help to fully maximize the intrinsic potential of the watershed. We anticipate these projects will generate a detectable response in juvenile steelhead production considering the extensive size of planned projects and positive fish and habitat responses to these techniques.

Meadow restoration has also been identified as a potential restoration approach to improve low base flow conditions in the Potlatch River basin (Resource Planning Unlimited 2007; Potlatch Implementation Group 2019). The premise behind this technique is that restoring natural prairies and meadow systems will minimize peak storm discharge and increase water infiltration and storage, thereby maintaining adequate summer stream flows. Corral Creek is the primary drainage where this approach is being tested and the first meadow restoration project was implemented in 2013. The amount of wetted habitat in Corral Creek has not shown a detectable increase during the treatment years. It is likely LWAP surveys are not at the proper scale to detect fine scale changes in water storage while work within treated meadows has provided some indication of positive response. For example, post-treatment monitoring of the Racetrack Meadow restoration project in the Corral Creek drainage noted increases in both aquifer and ponded water storage, as well as positive improvements to channel and riparian conditions (Dansart 2018 as cited in Potlatch Implementation Group 2019). Nonetheless, we have not documented an improvement in the quantity of summer flow conditions in Corral Creek on the broad scale that LWAP surveys monitor. A more detailed analysis is needed if this approach is prioritized in other drainages in the Potlatch River basin.

Restoration treatments in the upper watershed are focused on increasing instream habitat complexity and riparian function which will in turn benefit juvenile steelhead production. Habitat characteristics that provide shelter may positively impact the overwinter survival of juvenile salmonids by mitigating predation risk and decreasing energy costs (Whalen and Parrish 1999; Armstrong and Griffiths 2001; Bradford and Higgins 2001). For example, Mitro and Zale (2002) found that overwinter survival of age-0 rainbow trout was 18–23% greater in reaches with complex bank habitat, high gradient, and large substrate than in reaches with simple bank habitat. Solazzi et al. (2000) found overwinter survival of juvenile coho salmon and steelhead increased following habitat modifications that increased the complexity and quantity of winter rearing habitat. Steelhead parr-to-smolt survival rates are low in the EFPR (average, 9%) and have not increased

during treatment years. However, we have observed trends towards older and larger emigrants out of EFPR and have documented recent increases in canopy cover and pool density, suggesting positive changes are occurring. An additional 7 km of stream in the EFPR treatment area will be treated with intensive LWD installations by 2020. Monitoring of these projects post implementation will determine if the positive trends in emigrant age/size composition and habitat conditions continue.

We assumed density-dependent mechanisms influence juvenile steelhead growth and survival, and would be most evident in the lower Potlatch River watershed given the limited amount of rearing habitat in the late-summer due to flow and tributary blockages. We observed negative relationships between juvenile steelhead growth and survival with the density of juvenile steelhead in the lower watershed. Density-dependent growth, mortality, and emigration have been widely reported in stream dwelling salmonid populations (Grant and Kramer 1990; Elliott 1994). Walters et al. (2013) found evidence of density-dependent survival and growth in multiple Chinook Salmon populations in Idaho. In Lapwai Creek, Idaho, subyearling steelhead growth rates were negatively related to densities of yearling steelhead, but not vice versa (Myrvold and Kennedy 2015). Similarly, Sogard et al. (2009) found that survival of age-0 steelhead was strongly density dependent but not age-1+ fish in a California coastal stream. Although we found evidence of density-dependent growth and survival for juvenile steelhead in the lower watershed, further investigations are needed to clarify the strength and relative importance of these processes.

Juvenile steelhead growth was minimal during the summer in lower Potlatch River tributaries. Multiple studies have investigated seasonal growth patterns of juvenile steelhead in temperate regions and a pattern of rapid growth in winter-spring and minimal growth in summer has been documented in juvenile steelhead populations in California (Hayes et al. 2008; Sogard et al. 2009), Oregon (Tattam et al. 2017), and Idaho (Myrvold and Kennedy 2015). Reduced growth during the dry summer season may be a function of minimum flow rates and low delivery of prey via drift (Sogard et al. 2009). Similarly, Hayes et al. (2008) speculated reduced growth rates during periods of low summer flows were a function of reduced prey availability during a time when warmer temperatures increased metabolic demands of fish. Furthermore, high water temperatures were a strong factor limiting growth in juvenile steelhead during summer in Lapwai Creek, Idaho (Myrvold and Kennedy 2015). Banks and Bowersox (2015) documented summer water temperatures in excess of 20°C in lower Potlatch River tributaries, which approach reported stressful or lethal limits for steelhead (e.g., ≥25°C) (Myrick and Cech 2004). These findings suggests high water temperatures may limit juvenile steelhead growth during summer in lower Potlatch River tributaries. We plan to implement more robust water temperature monitoring to better assess the role of high summer water temperatures in regulating juvenile steelhead growth in Potlatch River tributaries and how future restoration efforts influence this relationship.

We have made a number of changes to the tributary-scale monitoring framework over time to enhance our ability to detect a fish and habitat response to restoration efforts in the basin. In the upper watershed, we recently incorporated an additional control area in the EFPR to reduce the post-treatment monitoring time needed to detect a response (Uthe et al. 2017). Under the new design, we plan to conduct a power analysis on electrofishing data to determine the number of sample sites and years needed to detect a statistically significant difference in parr densities in treatment and control areas in the upper watershed. In addition, we need to establish new PIT-tagging goals for juveniles in the upper watershed in order to assess juvenile growth and survival in the treatment and control areas. Lastly, we plan to re-examine the habitat monitoring protocols in the upper watershed, specifically the pool monitoring protocols, to minimize the influence of flow conditions on pool identification and enumeration. These changes will increase our power to detect a response and subsequently reduce the timeframe of post-treatment monitoring.

Tributary-scale monitoring data provides valuable information on trends in juvenile steelhead production and habitat conditions in the treatment and control areas. We have gained valuable insights into the relationships between juvenile steelhead production (density, growth, and survival) and habitat conditions throughout the basin. Some of the data sets used in the correlation analyses were limited and results should be viewed critically. Our degree of confidence in detecting patterns in the data will increase as we continue to add data in the future. Nonetheless, positive correlations between juvenile growth and survival with the amount of wetted habitat validates the need to improve base flow conditions. Flow supplementation projects can rapidly improve juvenile steelhead rearing conditions and productivity, but meadow restoration projects need further evaluation to quantify the benefits to stream flow conditions. In the upper watershed, the positive correlation between juvenile density and LWD highlights the need to improve instream habitat complexity. We have documented slight improvements to canopy cover and pool density, which is encouraging. We expect to see improvements in canopy cover, pool density, and LWD density as more habitat projects are implemented in the EFPR. We are taking an adaptive management approach to our tributary-scale monitoring framework, and the changes discussed will increase our ability to detect a response to restoration projects and provide more detailed information to help guide future project implementation.

RECOMMENDATIONS

1. Use Basin TribPIT model with roving electrofishing data to re-evaluate juvenile steelhead parr-to-smolt survival estimates in treatment and control areas.
2. Work with Potlatch Implementation Group collaborators to develop predictive models to assess the impacts of meadow restoration projects on base flow conditions in the Corral Creek sub-watershed.
3. Develop and implement a water temperature monitoring framework for treatment and control areas in Potlatch River basin.
4. Run power analysis on electrofishing data in the upper watershed to determine the sampling effort needed to detect a statistically significant difference in parr densities in treatment and control tributaries.
5. Re-examine habitat monitoring protocols and analyses in the upper basin and revise if necessary to reduce inconsistencies in data collection related to flow conditions and provide more reliable estimates.

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TABLES

Table 2. Large wood density, pool density, and canopy cover within the East Fork Potlatch River treatment reach (EFPR treatment), the East Fork Potlatch River control reach (EFPR control), and West Fork Potlatch River control tributary (WFPR control) in the upper Potlatch River watershed during 2003–2018. Dashes indicate no data collected.

	EFPR Treatment			WFPR Control			EFPR Control		
Year	LWD/km	Pools/km	Canopy Percent	LWD/km	Pools/km	Canopy Percent	LWD/km	Pools/km	Canopy Percent
2003/04	56	5	19	32	15	36	-	-	-
2008	-	-	8	-	-	27	-	-	27
2013	94	11	24	30	23	20	176	25	45
2014	60	-	33	61	-	33	259	-	51
2015	-	-	28	-	-	22	-	-	59
2016	97	21	26	70	6	21	267	33	58
2017	60	10	34	11	0	23	362	16	64
2018	49	7	39	42	1	35	213	17	60
Treatment year average	72	12	31	43	8	26	255	23	56

Table 3. Number of juvenile steelhead (>80 cm) PIT tagged in Potlatch River tributaries for parr-to-smolt survival analyses from 2008-2018. Values in parenthesis indicate number of tagged fish subsequently detected in the hydrosystem.

Tag Year	Big Bear Creek	Little Bear Creek	WFK Little Bear Creek	Pine Creek	East Fork Potlatch River	West Fork Potlatch River
2008	123 (13)	113 (13)	113 (7)	285 (47)	293 (14)	0 (0)
2009	189 (5)	341 (25)	499 (35)	613 (44)	212 (11)	0 (0)
2010	252 (16)	298 (34)	526 (101)	0 (0)	151 (21)	0 (0)
2011	25 (4)	383 (66)	380 (45)	410 (48)	430 (29)	0 (0)
2012	201 (11)	408 (56)	302 (38)	0 (0)	66 (7)	0 (0)
2013	157 (3)	219 (7)	247 (14)	259 (8)	337 (6)	15 (0)
2014	47 (1)	229 (9)	385 (6)	203 (5)	432 (7)	5 (0)
2015	39 (0)	311 (12)	160 (4)	242 (5)	120 (6)	0 (0)
2016	23 (1)	446 (60)	385 (40)	308 (33)	380 (47)	2 (0)
2017	156 (10)	477 (26)	437 (40)	475 (60)	381 (18)	2 (1)
2018	168 (160	435 (22)	492 (23)	452 (24)	280 (21)	0 (0)

Table 4. Summer-fall growth of juvenile steelhead (≥80 mm) in select tributaries in the lower watershed of the Potlatch River, Idaho from 2014-2018. West Fork Little Bear Creek (WFLBC) and Little Bear Creek (LBC) are treatment tributaries and Pine Creek (PNC) is the control tributary.

Year	Tributary	n	Mean growth (mm)	S.D.	Average time at large (d)	Mean daily growth (mm/d)
2014	PNC	29	8.30	8.00	147	0.057
	WFLBC	26	7.50	7.67	123	0.059
	LBC	0	nd	nd	nd	nd
2015	PNC	17	12.35	16.24	141	0.086
	WFLBC	10	3.70	4.27	132	0.028
	LBC	2	17.00	5.66	138	0.124
2016	PNC	62	5.68	8.36	130	0.044
	WFLBC	44	0.64	4.36	117	0.006
	LBC	77	2.90	5.66	127	0.023
2017	PNC	54	8.26	7.28	133	0.062
	WFLBC	41	1.15	4.77	118	0.009
	LBC	18	1.06	4.18	124	0.008
2018	PNC	29	11.17	6.81	134	0.083
	WFLBC	33	2.91	4.24	116	0.025
	LBC	32	3.75	5.45	141	0.026

FIGURES

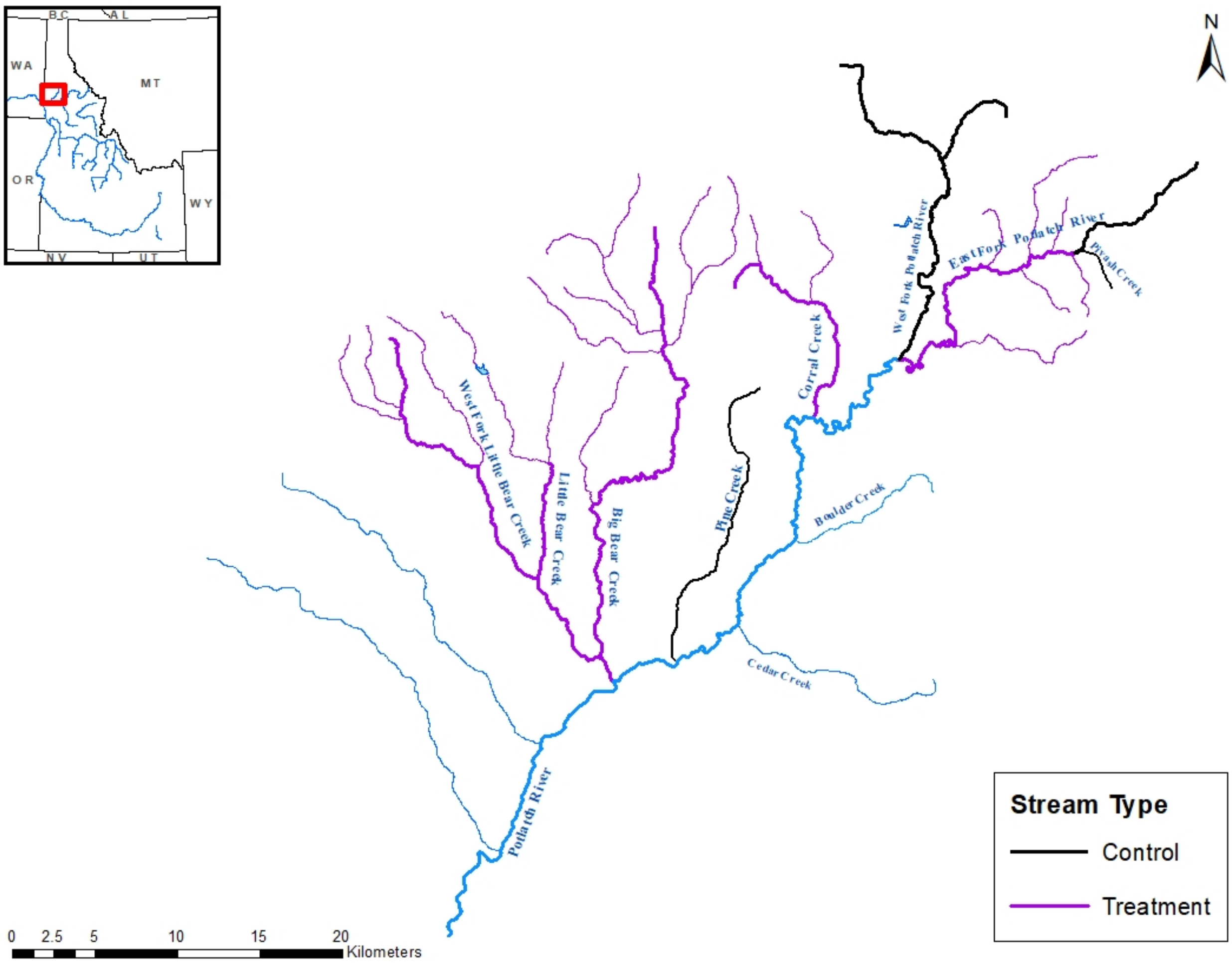

Figure 17. Treatment and control areas within the tributary-scale study design in the Potlatch River basin.

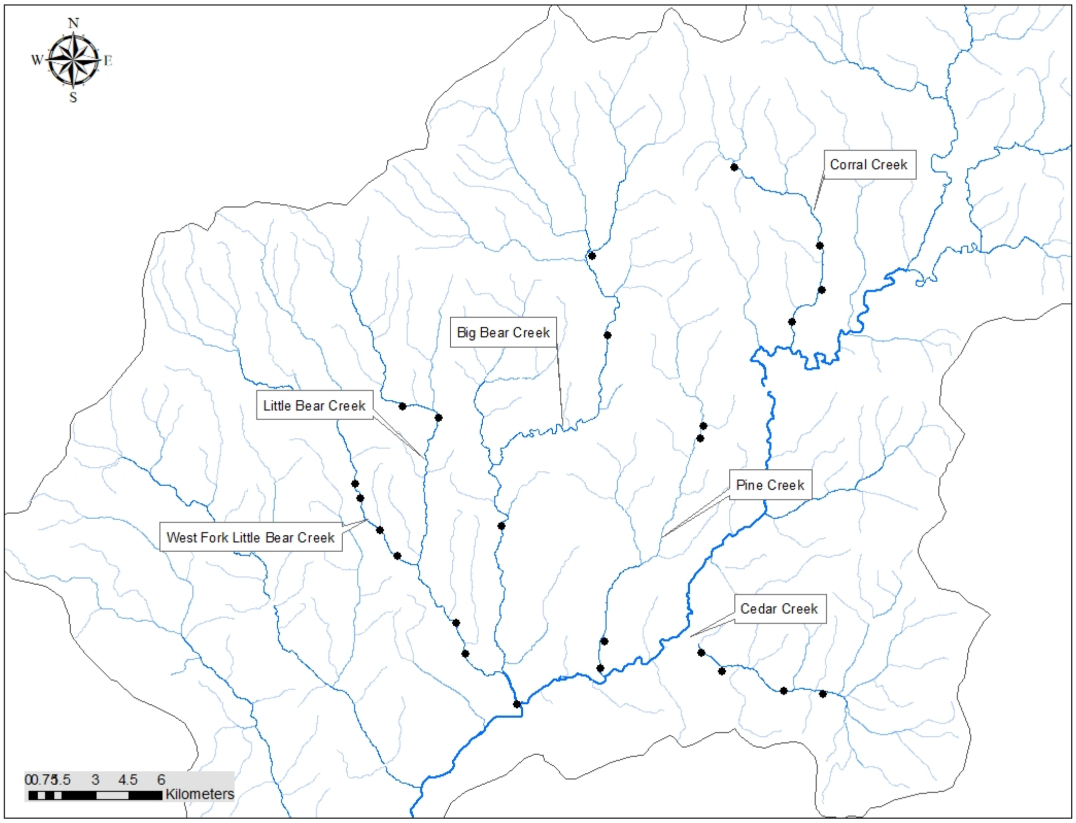

Figure 18. Locations of sites sampled annually 2007-2018 for wetted habitat and pool density in the lower Potlatch River watershed. Treatment tributaries are West Fork Little Bear Creek, Little Bear Creek, Big Bear Creek, and Corral Creek and the control tributaries are Pine Creek and Cedar Creek.

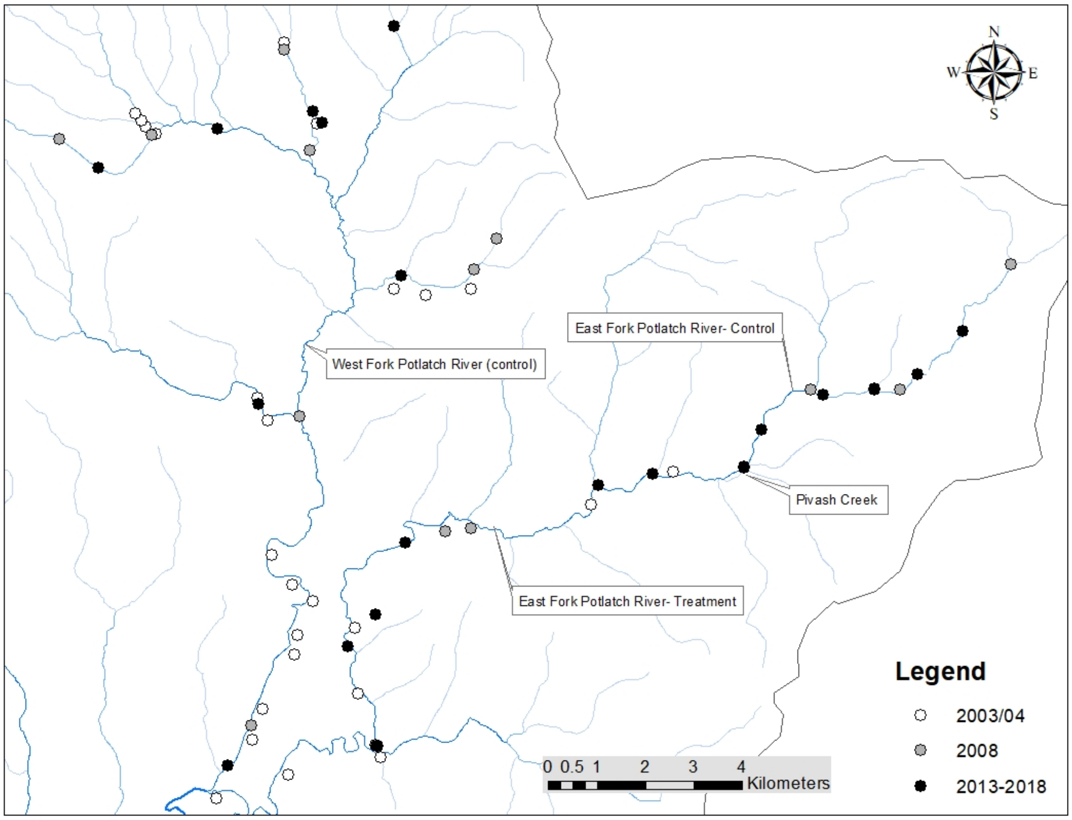

Figure 19. Locations of habitat and electrofishing sites within treatment and control areas in the upper Potlatch River watershed. Sites were surveyed during three time periods (2003/04, 2008, 2013-2018). The treatment area is the East Fork Potlatch River downstream of Pivash Creek and control areas are the West Fork Potlatch River and the East Fork Potlatch River upstream of Pivash Creek.

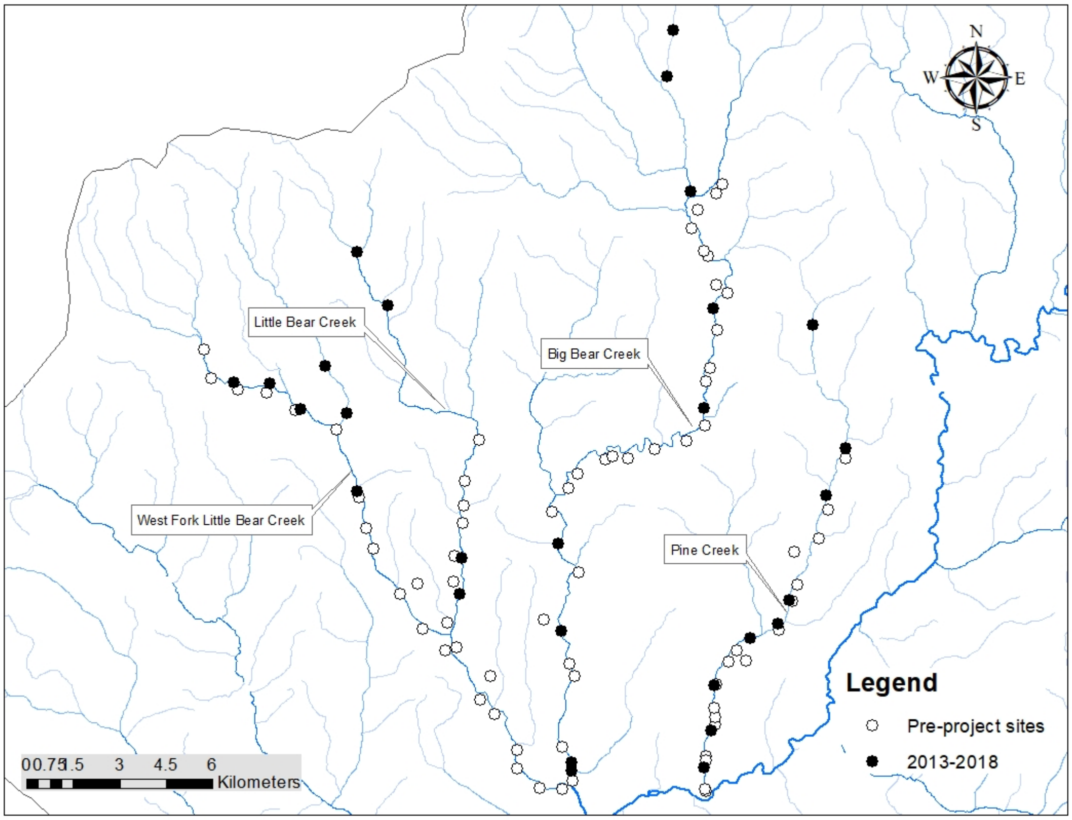

Figure 20. Locations of electrofishing sites within treatment and control tributaries in the lower Potlatch River watershed. Treatment tributaries are West Fork Little Bear Creek, Little Bear Creek, and Big Bear Creek and the control tributary is Pine Creek. Sites surveyed before the current study are distinguished from currently sampled sites.

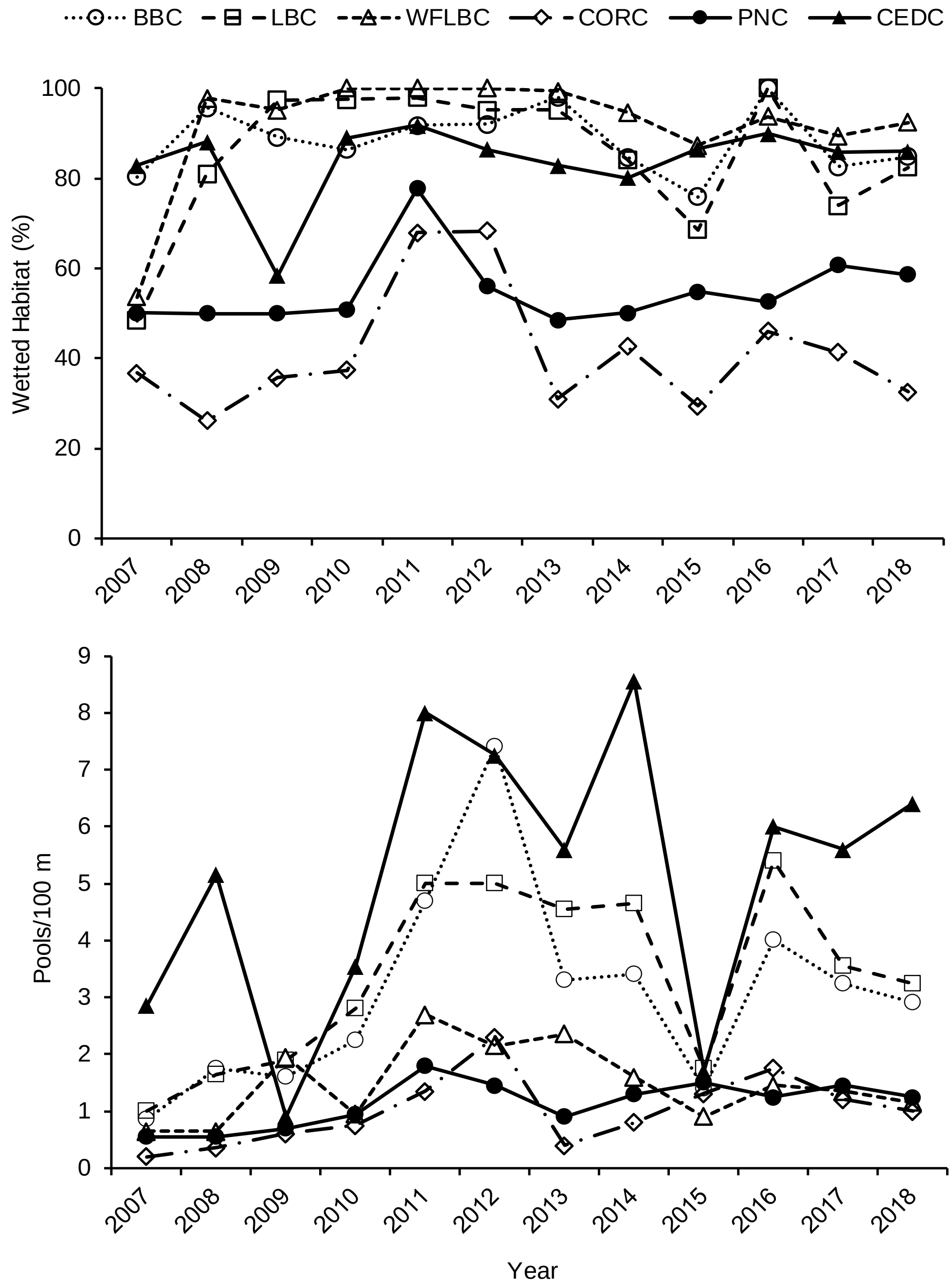

Figure 21. The amount of wetted habitat (panel A) and pool density (panel B) in treatment and control tributaries in lower Potlatch River watershed during 2007-2018. Treatment tributaries include Big Bear Creek (BBC), Little Bear Creek (LBC), West Fork Little Bear Creek (WFLBC), and Corral Creek (CORC) and are indicated by dashed lines and open symbols. Control tributaries include Pine Creek (PNC) and Cedar Creek (CEDC) and are indicated by solid lines and symbols. Restoration treatments began in 2013.

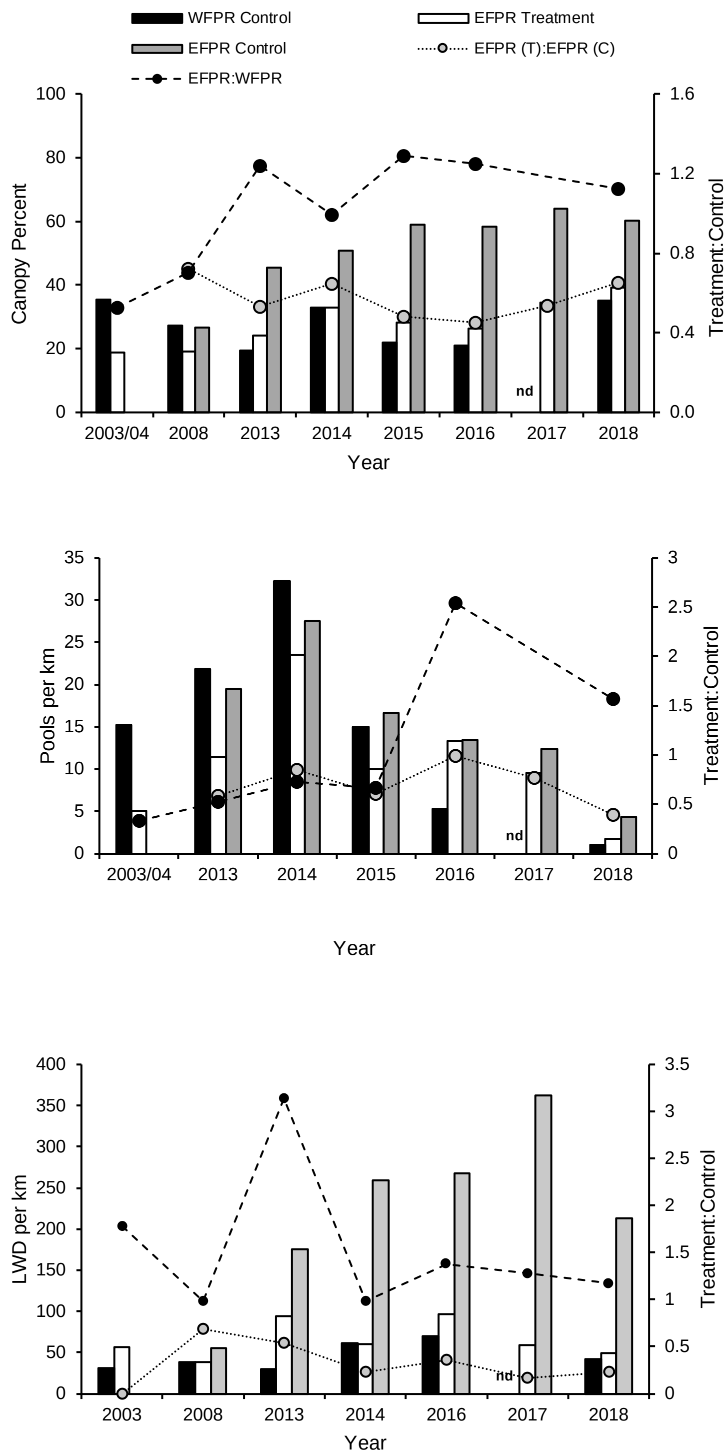

Figure 22. Canopy cover, pool density, and large wood density (LWD) within the treatment area (EFPR Treatment) and control areas (WFPR and EFPR Control) in the upper Potlatch River watershed during 2003–2018. Restoration treatments began in 2009. The dashed line on the secondary axis indicates the EFPR (treatment):WFPR ratio value and the dotted line indicates the EFPR (treatment):EFPR (control) ratio value for each habitat metric in each year.

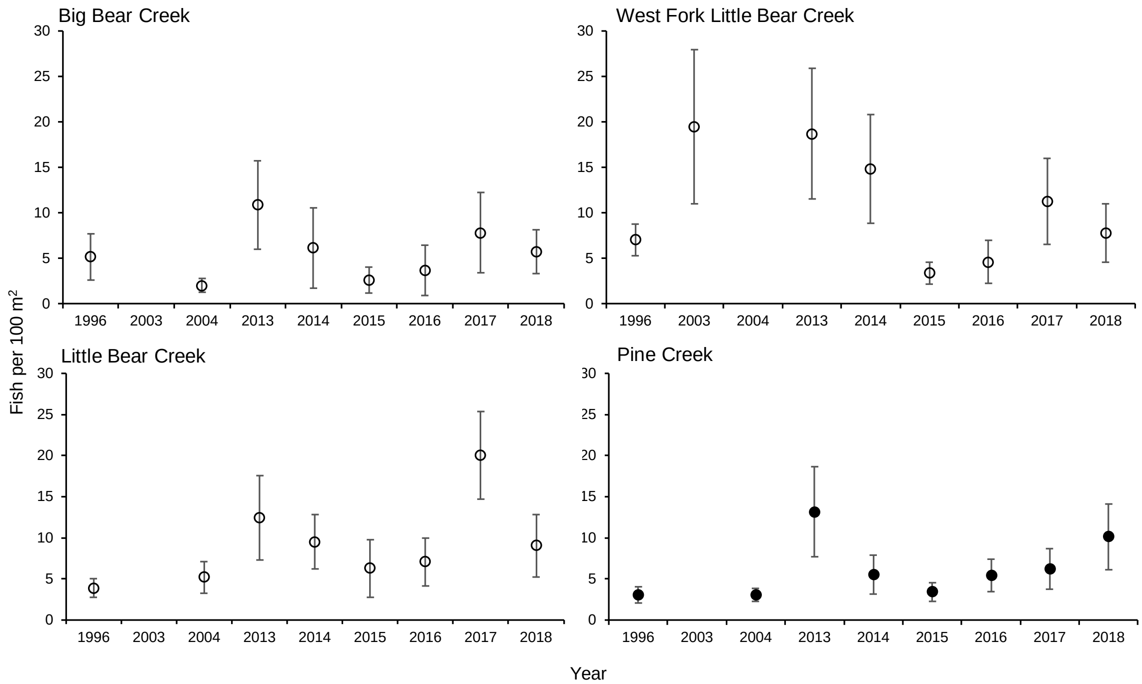

Figure 23. Density of juvenile steelhead ≥80 mm based on single-pass electrofishing surveys in Big Bear Creek, Little Bear Creek, West Fork Little Bear Creek (treatment tributaries) and Pine Creek (control tributary) in the lower Potlatch River watershed during 1996-2018.

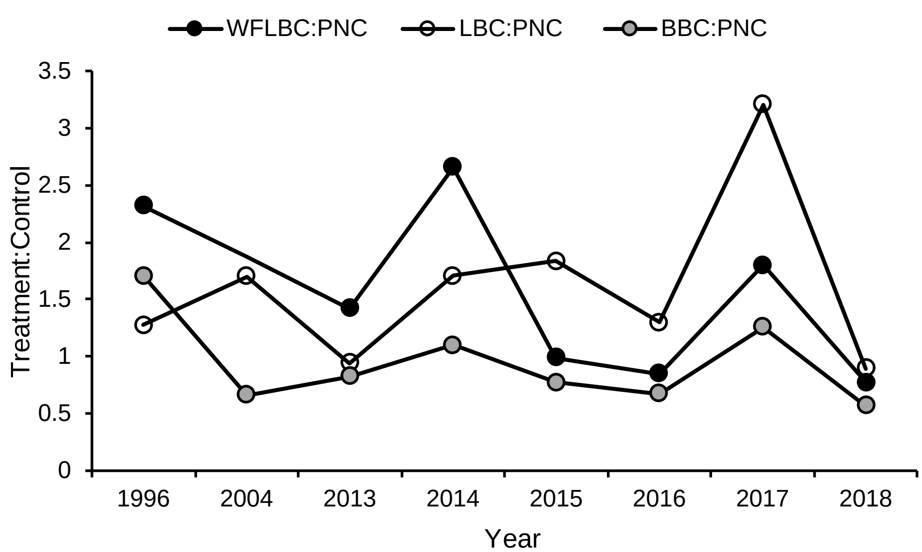

Figure 24. Juvenile steelhead density ratio values (treatment:control) for treatment tributaries West Fork Little Bear Creek (WFLBC), Little Bear Creek (LBC), and Big Bear Creek (BBC) and the control tributary Pine Creek (PNC) in the lower Potlatch River watershed during 1996-2018.

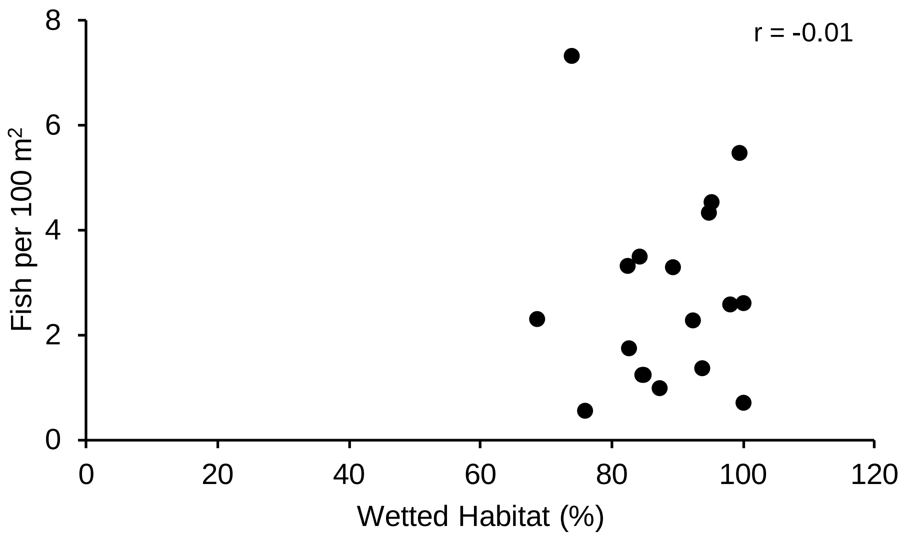

Figure 25. Relationship between juvenile steelhead density and percent wetted habitat in lower Potlatch River watershed.

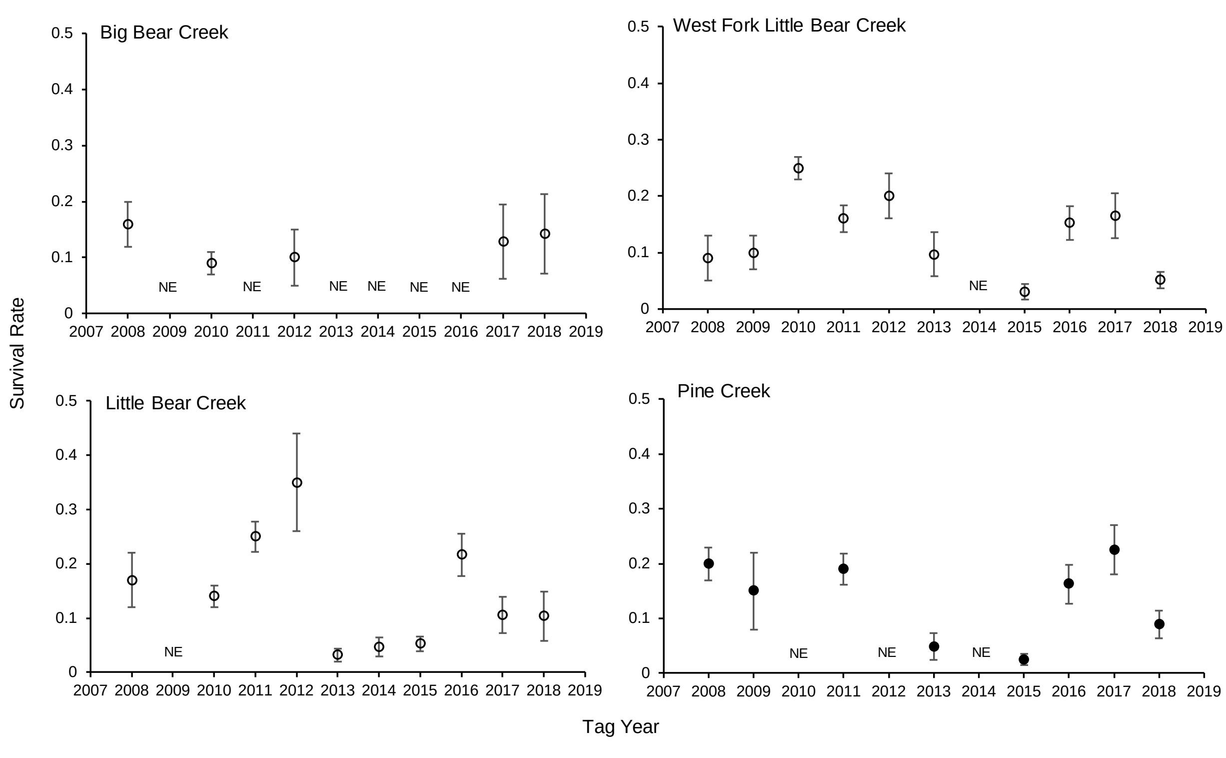

Figure 26. Apparent survival to Lower Granite Dam from Big Bear Creek, Little Bear Creek, and the West Fork Little Bear Creek (treatment tributaries) and Pine Creek (control tributary) in the lower Potlatch River watershed during 2008-2018. No estimate (NE) indicates insufficient detections to generate an estimate.

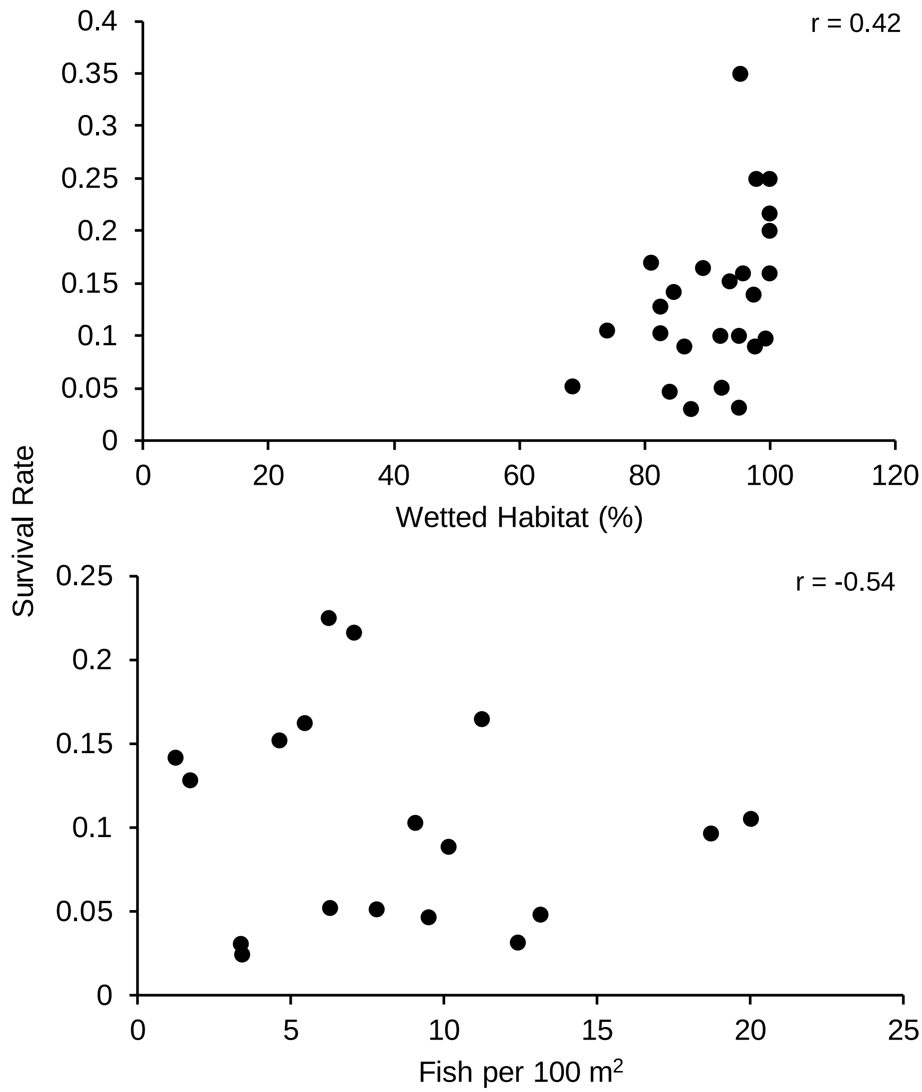

Figure 27. Relationships between juvenile steelhead apparent survival and the amount of wetted habitat (top panel) and juvenile steelhead density (bottom panel) in the lower Potlatch River watershed.

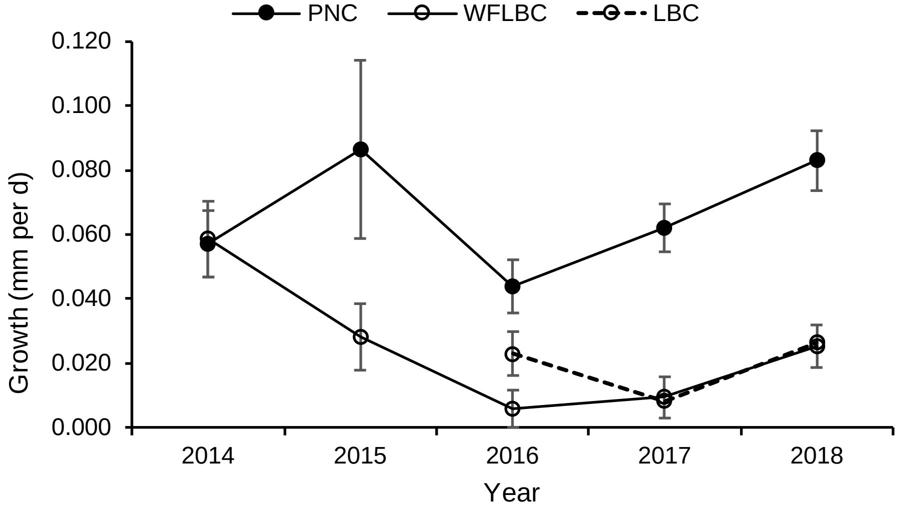

Figure 28. Summer-fall growth rates (mm per d) of juvenile steelhead (≥80 mm) in select treatment tributaries in the lower watershed of the Potlatch River, Idaho from 2014-2018. West Fork Little Bear Creek (WFLBC) and Little Bear Creek (LBC) are treatment tributaries and Pine Creek (PNC) is the control tributary.

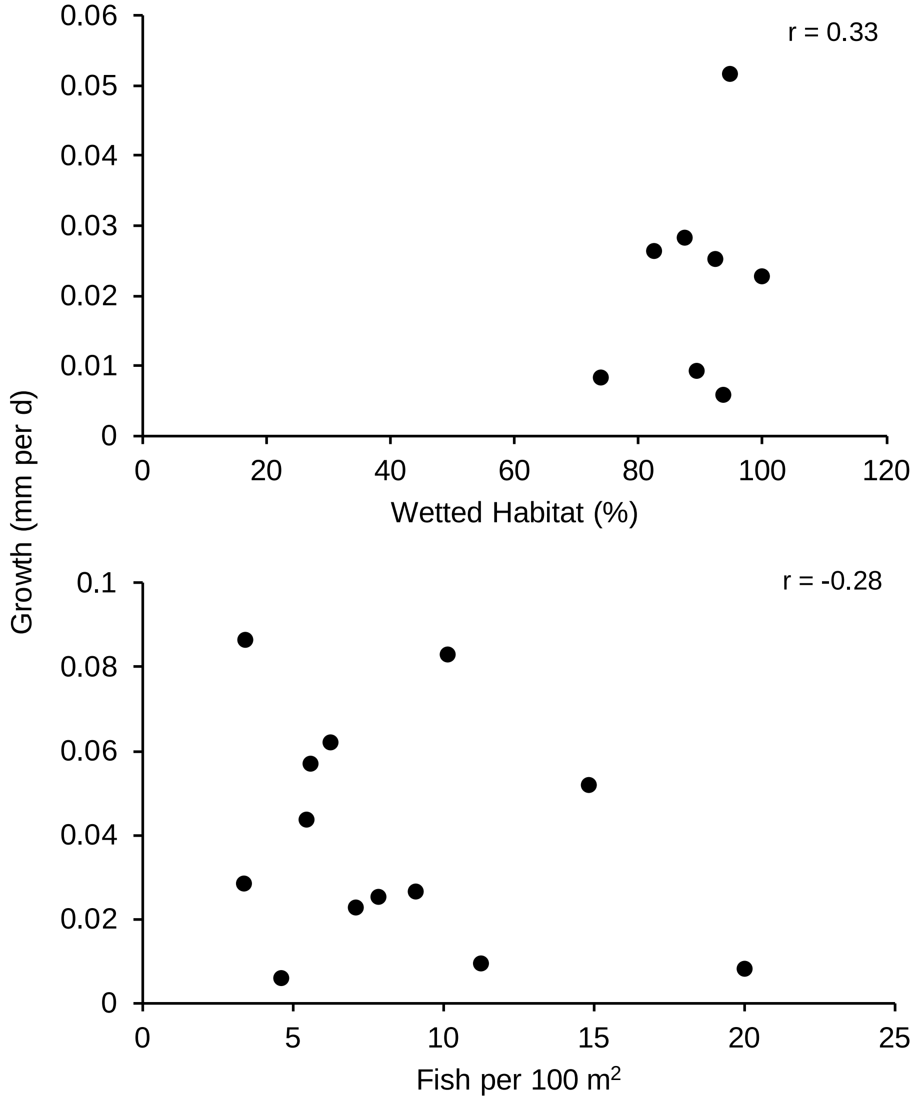

Figure 29. Relationships between juvenile steelhead growth and the amount of wetted habitat (Top panel) and juvenile steelhead density (Bottom panel) in the lower Potlatch River watershed.

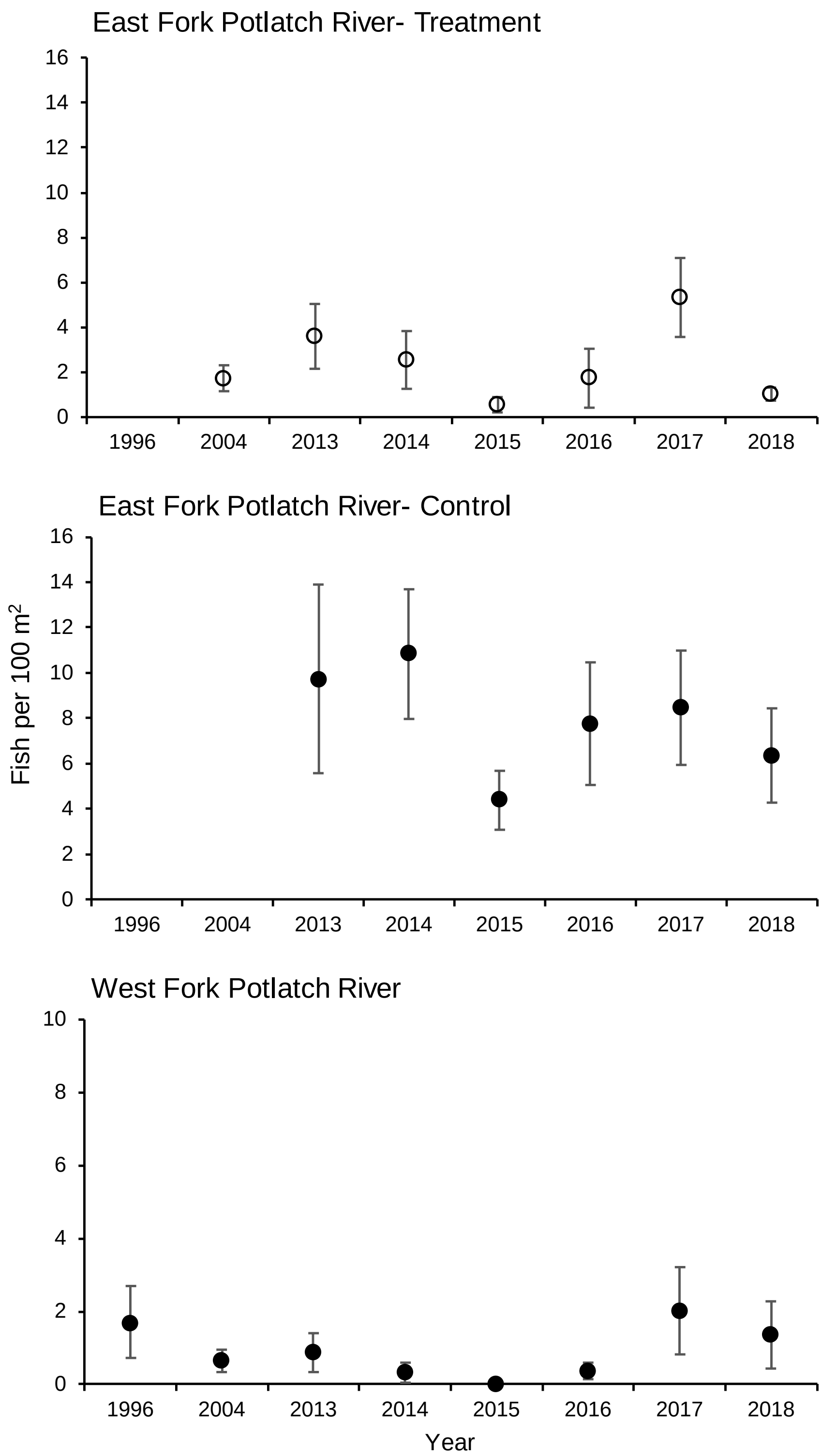

Figure 30. Density of juvenile steelhead ≥80 mm based on single-pass electrofishing surveys in the East Fork Potlatch River treatment area, the East Fork Potlatch River control area, and the West Fork Potlatch River control tributary in the upper Potlatch River watershed during 1996–2018.

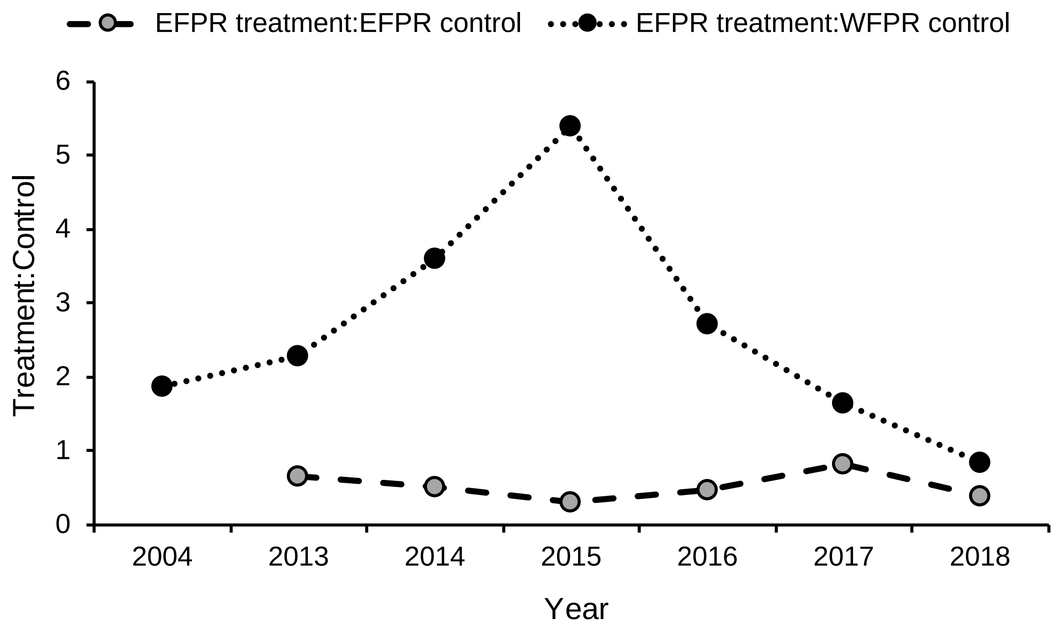

Figure 31. Juvenile steelhead density ratio values (treatment:control) for East Fork Potlatch River treatment reach (EFPR treatment), the East Fork Potlatch River control reach (EFPR control), and West Fork Potlatch River control tributary (WFPR control).

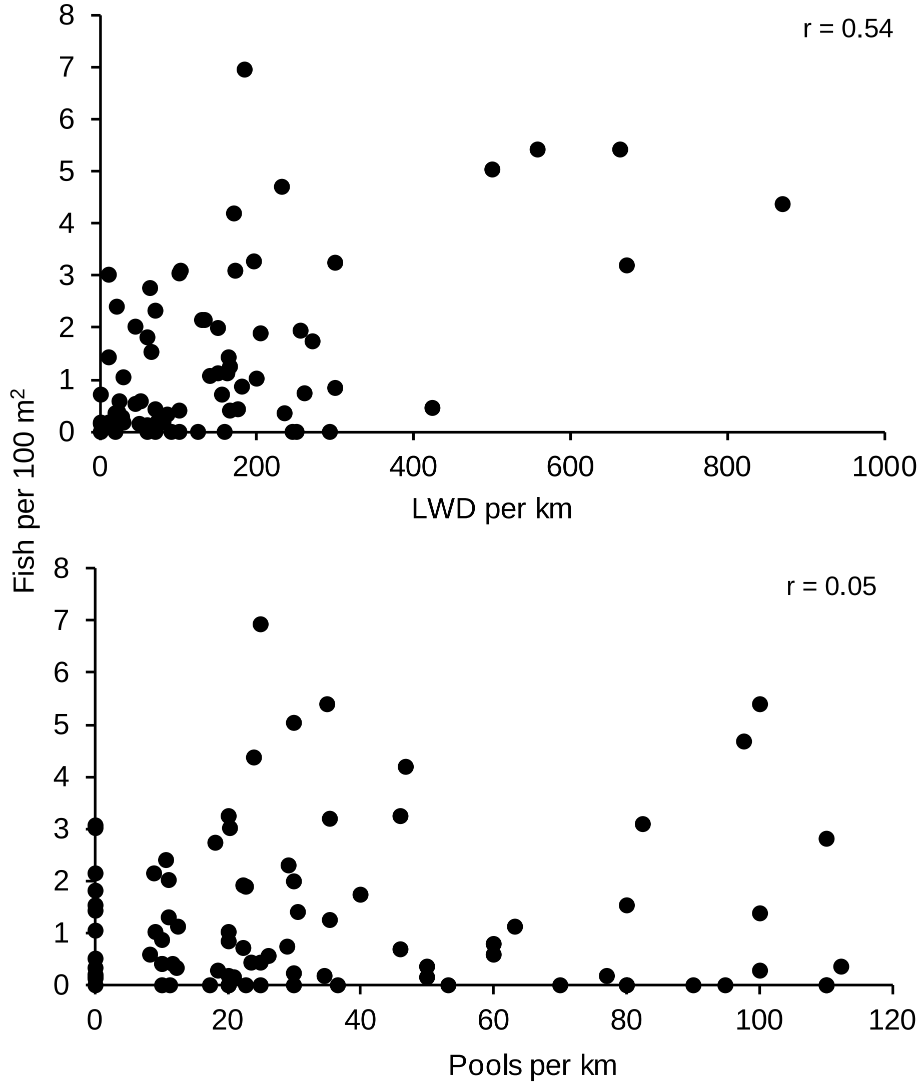

Figure 32. Relationships between juvenile steelhead density and LWD density (Top panel) and pool density (Bottom panel) in the upper Potlatch River watershed.

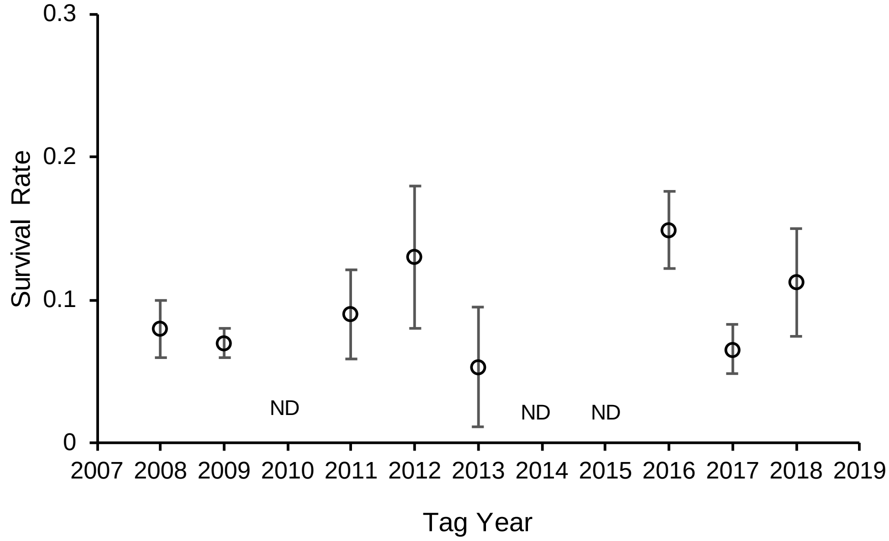

Figure 33. Apparent survival to Lower Granite Dam of juvenile steelhead tagged upstream in the East Fork Potlatch River during 2008-2015. ND = no data.

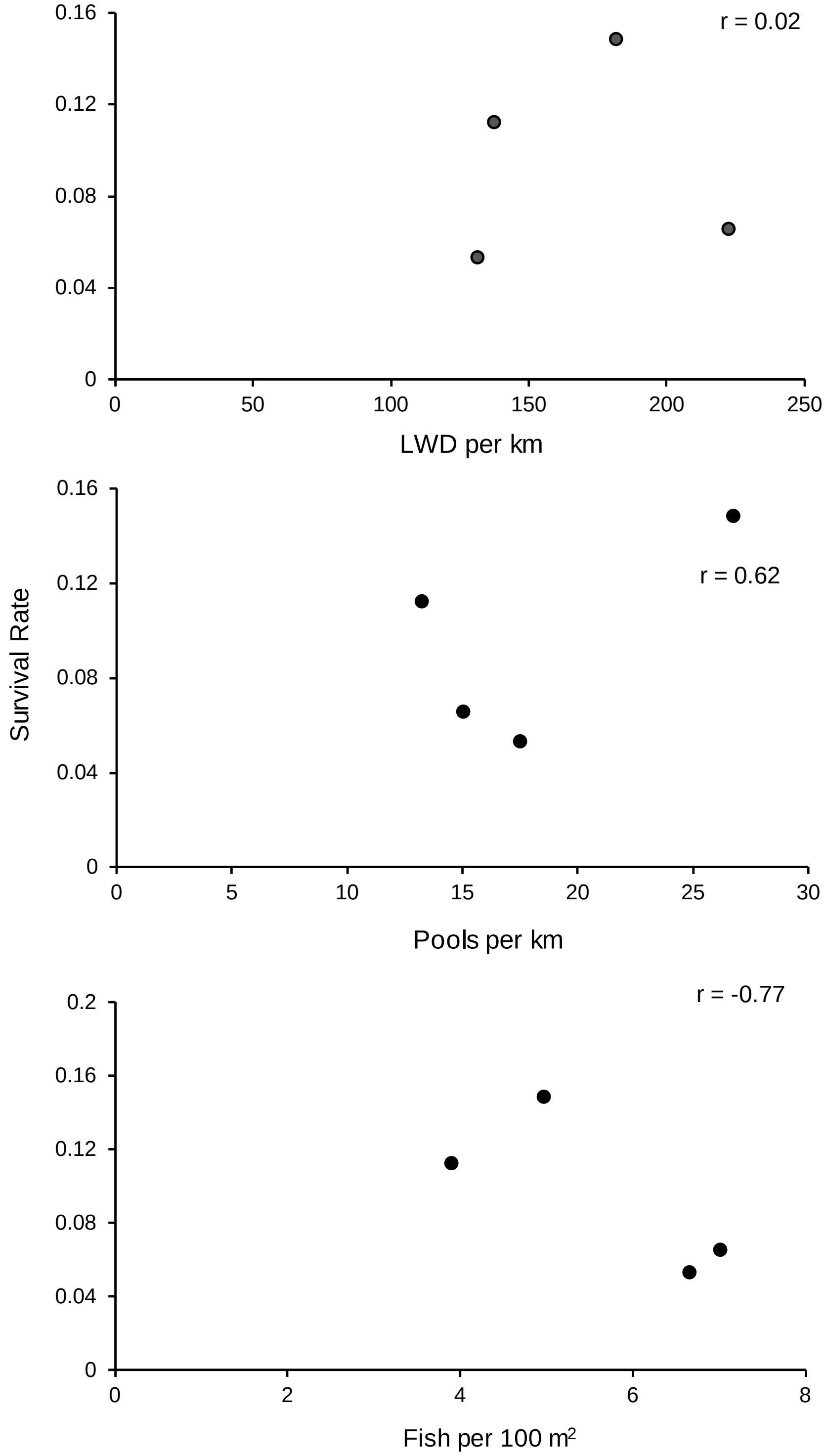

Figure 34. Relationships between juvenile steelhead apparent survival and LWD density (Top panel), pool density (Middle panel), and juvenile steelhead density (Bottom panel) in the East Fork Potlatch River.

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