Salmon Recovery Funding Board Effectiveness Monitoring Program

2017 Annual Report

WASHINGTON STATE
RECREATION AND CONSERVATION OFFICE
Salmon Recovery
Funding Board

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REACH-SCALE PROJECT EFFECTIVENESS MONITORING PROGRAM

2017 ANNUAL REPORT

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February 2018

EXECUTIVE SUMMARY

In 1999, the Washington State legislature created the Governor's Salmon Recovery Office (GSRO) to provide a statewide salmon recovery plan and the Salmon Recovery Funding Board (SRFB) to distribute funds earmarked for salmon habitat restoration and protection. Since 2000, the SRFB has invested more than 1 billion dollars in salmon recovery and habitat restoration efforts. In 2004, the SRFB established a standardized effectiveness monitoring program to consistently assess the response of stream habitat and localized salmon populations to restoration efforts. The SRFB project effectiveness monitoring (PE) program originally included monitoring and evaluation for nine discrete categories including fish passage (MC-1), instream habitat (MC-2), riparian planting (MC-3), riparian livestock exclusion (MC-4), constrained channel (MC-5), channel connectivity (MC-6), spawning gravel (MC-7), diversion screening (MC-8), estuary restoration (MC-9), and habitat protection (MC-10). In 2010 the constrained channel and channel connectivity categories and protocols were combined into a single category, floodplain enhancement (MC-5/6). Of these categories, MC-2 instream habitat (placement of rock or wood in the active channel), MC-4 riparian livestock exclusion (livestock exclusion to protect riparian zone and reduce erosion), and MC-5/6 floodplain enhancement (e.g., floodplain connectivity, reconnection/creation of off-channel habitat, removal of bank armor) are still actively monitored and were sampled in 2017. In this report, we summarize the findings to date for MC-2 and MC-5/6 project types and recommendations for monitoring in 2018 and beyond. Monitoring of MC-4 projects, which are monitored as part of a cooperative program with the Oregon Watershed Enhancement Board, was completed in 2017 and the final results are provided in a separate report.

The goal of SRFB PE monitoring of MC-2 and MC-5/6 projects is to determine if actions specific to the category are improving stream morphology and habitat and increasing reach-scale juvenile salmonid abundance. A multiple before-after control-impact (MBACI) study design was used for monitoring of all project types. The MBACI design includes data collection in impact (restored) and control (unrestored) reaches before project implementation (Year 0), and after project implementation (Years 1, 3, 5, and 10). Monitoring followed protocols, objectives, analysis, and study design developed by the SRFB for each project type. SRFB monitoring protocols were adapted from U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program. Physical metrics collected included vertical pool area, residual depth, large woody debris (LWD), and juvenile fish densities. In addition, monitoring at MC-5/6 sites included measuring bank canopy cover, riparian vegetation structure, channel capacity, and floodprone width. Projects were initially selected for monitoring from those that had been funded but not implemented for the given baseline sampling year. Beginning in 2004, data from 23 instream and 23 floodplain projects were collected on a rotating schedule across a range of rivers throughout Washington State. Monitoring start dates were staggered depending upon date of restoration (impact) implementation, with the final year of monitoring data for both project types expected in 2018. Data from all years of monitoring of projects were analyzed using a combination of paired *t*-tests and regression analysis. Selection of study sites and impact and control reaches, as well as data collection prior to 2017, were conducted by Tetra Tech. Cramer Fish Sciences was contracted to finish data collection, analyze data, and provide recommendations for future PE monitoring.

For instream habitat projects, results to date indicate significantly increased physical habitat variables (vertical pool area, residual depth, large woody debris volume) while fish densities have not yet significantly increased or met management targets (20% increase). Large woody debris volume increases were expected due to project type (LWD additions, ELJs), though wood volume varied among sites, likely due to individual project variables such as funding and goals. Increased vertical pool area and residual depth are consistent with previous studies that document geomorphic response to wood placement and recruitment. Many studies on LWD placement have reported increases in juvenile salmonids, particularly Coho Salmon *Oncorhynchus kisutch* and steelhead *O. mykiss*. The lack of a significant increase in juvenile fish response to SRFB projects may simply be due to the low number of projects that have been monitored five or more years post-treatment. It may also be due to the sample timing, variability in treatments, the lack of geographic stratification, poorly matched control and impact reaches, or the chosen fish abundance metric. The completion of monitoring in 2018 should help answer some of these questions.

While 23 floodplain enhancement projects were monitored, data from ten sites were excluded from the analysis due to inconsistencies with impact or control reaches or data collection. Results for the remaining floodplain enhancement projects were highly variable by metric and year with significant changes in vertical pool area in Year 1 and 10, mean residual depth in all years except Year 3, average channel capacity in Year 3, and juvenile Coho Salmon in Year 1 and 5. No significant changes were found for bank canopy cover, riparian vegetation structure, or Chinook Salmon *O. tshawytscha* and steelhead densities. Adequate sample sizes were not available to analyze floodprone width. The positive changes in vertical pool area, residual depth, and Coho Salmon are consistent with previous studies on floodplain restoration, though results from SRFB projects have been relatively modest. Densities for juvenile fish were low across most sites, with several sites having no fish of a particular species found across several years of sampling. Moreover, the monitoring of fish, channel capacity, and floodprone width was not done consistently within and among projects across years making detection of differences due to restoration more difficult. Because floodplain enhancement projects typically involve a large impact to the riparian conditions, more time post-restoration may be needed for riparian vegetation to establish and colonize and reach the canopy threshold height. Mixed results across all metrics and the inability to assess data using more rigorous statistical methods (mixed-effects models) may be due to a variety of other factors including: sample timing, variability in restoration treatments, need for geographic stratification, and added variability from controls that were not well matched with impact reaches. Because of inconsistencies in data collection across years including lack of fish and riparian data, sampling in different seasons, and in some cases poorly matched impact and control reaches, we do not recommend additional data collection for floodplain projects in 2018.

Future monitoring of both instream habitat and floodplain enhancement projects should consider stratifying projects by ecoregion, seasonal fish sampling (summer, winter), more rigorous selection of treatment and controls, improved habitat survey methods, either collecting more pre-project data or using a post-treatment design, and improved data management and quality control methods.

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BACKGROUND

Need for the Project Effectiveness Monitoring Program

Pacific salmon are a cornerstone of the culture and economy in the Pacific Northwest and historically supported large tribal, commercial, and recreational fisheries. Due to various factors adversely impacting salmon including overharvest, hatchery production, impassible dams, changing environmental conditions, disease, interspecific competition, and widespread habitat degradation and loss, salmon stocks in Washington State have experienced dramatic declines in the last 100 years (Chapman 1986; Nehlsen et al. 1991; Lichatowich 2001; Collins and Montgomery 2002; Connors et al. 2012). In response to population declines, the federal government listed several Evolutionary Significant Units of salmonids under the Endangered Species Act during the 1990's, which provided protection for the declining populations and their critical habitat. To address salmon declines, it was incumbent that Washington State produce recovery plans for the listed stocks and their habitat.

In 1999, the Washington State legislature created the Governor's Salmon Recovery Office (GSRO) to provide a statewide salmon recovery plan and the Salmon Recovery Funding Board (SRFB) to distribute funds earmarked for salmon habitat restoration and protection. Since 2000, the SRFB has invested more than 1 billion dollars in salmon recovery and habitat restoration efforts (GSRO 2016). Federal and state funding agencies needed a way to document success of these sponsored actions. To meet this need, in 2002, the SRFB provided criteria for the monitoring and evaluation of salmon recovery in their Washington Comprehensive Monitoring Strategy and Action Plan for Watershed Health and Salmon Recovery (MOC 2002). The monitoring strategy aimed to identify monitoring efforts and priority needs and also described the need for statewide project monitoring coordination and a succinct monitoring strategy. In 2004, Washington State established a reach-scale effectiveness monitoring program (Project Effectiveness Monitoring, PE) designed to assess the response of stream habitat and localized salmon populations to these restoration efforts and to track the results of salmon habitat restoration efforts.

Monitoring Goals and Objectives

Monitoring and evaluation provides a critical measure of restoration effectiveness, project execution, implementation, and intended habitat enhancements and fish response. Restoration effectiveness monitoring is an important component of a monitoring and evaluation program that determines whether the restoration action had the desired effect on the physical habitat and the impact those changes have on biota (MacDonald et al. 1991; Roni 2005). Determining project effectiveness is an integral component in a monitoring program to ensure that projects selected for funding are effective in the restorative action and also to help lead to the success and improvement of future restoration. The goals of the PE program are to address several management questions developed by the GSRO and SRFB, which include:

1. Are restoration treatments having the intended effects regarding local habitats and their use by salmon?
2. Are some treatments types more effective than others at achieving specific results?
3. Can project monitoring results be used to improve the design of future projects?

The monitoring program is designed to provide feedback on the efficacy of restoration actions at improving stream habitat and local salmonid abundance, with the goal of informing and improving restoration science and practices. The proposed questions allow for projects receiving similar treatments, such as project types involving artificially placed instream structures (AIS) or floodplain reconnection, to be evaluated using a consistent protocol. Restoration projects were categorically assigned based on the restorative action, and the expected outcomes regarding habitat and fish metrics. For example, while livestock exclusion and AIS projects both aim to improve habitat, the restoration actions are different and the responses to these actions are quantified using different success indicators which constitutes different monitoring categories. Eight discrete categories of commonly implemented project types were chosen for monitoring, and can be generally described as:

- MC-1: Fish Passage (removal/replacement of culverts, bridges, and dams)
- MC-2: Instream Habitat (placement of rock or wood in the active channel)*
- MC-3: Riparian Planting (riparian planting to increase stream shade)
- MC-4: Riparian Livestock Exclusion (livestock exclusion to protect riparian zone and reduce erosion)*
- MC-5/6: Floodplain Enhancement (floodplain connectivity, reconnection/creation of off-channel habitat, removal of bank armor)*
- MC-7: Spawning Gravel (supplementation of natural gravels in spawning-limited systems)
- MC-8: Diversion Screening (prevention of fish entrainment into water diversions)
- MC-10: Habitat Protection (protection of high-quality habitat)

Estuary monitoring (MC-9) was never implemented. Because the monitoring is programmatic, it uses standardized protocols to measure and evaluate each project within a given restoration category. The intent of the standardization is to allow for conclusions to be drawn across entire categories of projects and collaboration with other monitoring entities in the region. Specific criteria were established for each project indicator, and the combination of indicators that meet those criteria are used to provide feedback on whether the projects as a category are achieving their overarching goals as defined by the monitoring protocols.

Monitoring Design

Each restoration category protocol contains a specific objective and target metrics used during analysis to assess project effectiveness by applying a multiple before-after control-impact (MBACI) study design (Stewart-Oaten et al. 1986; Crawford 2011a, 2011b). Due to the large quantity of statewide restoration projects funded each year, the program monitors a subset of restoration projects funded by the SRFB. The MBACI study design utilizes an “impact site”, which is selected for a restoration treatment (ex. cattle exclusion, wood placement, side channel creation, etc.), and a control site located upstream that is analogous to the impact site due to its proximity within the watershed and is also representative of the environmental conditions (ex. precipitation patterns, flow regime, channel morphology, riparian conditions, etc.), but excludes the restorative action. The MBACI design provides the ability test how the impact reach has changed relative to the control reach and therefore, it is assumed that any significant difference detected between the impact and control site metrics is a result of the restoration action. Effectiveness monitoring at the control and impact sites are also evaluated temporally on a rotating schedule Years 0, 1, 3, 5, and 10 for all actively monitored categories (i.e., Year 0 is prior to project implementation and subsequent years are post-project implementation). Because the MBACI design involves sampling multiple restoration projects before and after restoration, it is considered one of the most rigorous designs for evaluating restoration project effectiveness (Downes et al. 2002; Roni 2005).

Three restoration action categories (MC-2, MC-4, and MC-5/6) are currently monitored in the program (see categories above, noted by asterisks); however, only MC-2 and MC-5/6 will be discussed in this report. Monitoring for MC-2 and MC-5/6 sites include physical habitat and biological evaluations based on categorically specific goals. Effectiveness monitoring for instream habitat restoration projects (MC-2) aim to quantify changes in habitat as they relate to local fish abundance. The MC-2 monitoring goal is to determine if placement of instream structures, such as rock weirs, boulders, and engineered log jams (ELJs), improve stream morphology and local fish abundance within the restoration reach. Monitoring of floodplain enhancement projects (MC-5/6) seeks to quantify changes in habitat (morphology, hydrology, connectivity) and local fish abundance. The goal of floodplain enhancement is to determine if projects which remove stream bank modifications (ex. dikes, riprap) and/or reconnect off-channel habitats, provide additional fish habitat and increase local fish densities.

Elimination, consolidation, and postponement of monitoring categories have occurred in the remaining five restoration categories due to various reasons. Fish passage projects (MC-1) are no longer monitored because results indicated that fish recolonize upstream of a removed barrier occupying newly available habitat provided that suitable habitat was present. Likewise, diversion screenings (MC-8) are no longer monitored because the projects were considered to have been successfully executed and functional. Additionally, MC-3 and MC-10 were unlikely to have quantifiable effects found within the monitoring period, and as a result monitoring was deferred. Finally, an inadequate number of spawning gravel projects (MC-7) was originally included in the sample pool to provide for a proper statistical analysis, therefore monitoring was discontinued.

2017 Monitoring

Cramer Fish Sciences (CFS) was contracted to complete data collection in 2017 and 2018, analyze data, and provide recommendations to help design future SRFB project effectiveness monitoring for 2019 and beyond. Tetra Tech, the previous contractor, completed all project effectiveness monitoring from 2004 through 2016. Restoration project implementation and monitoring occurred over a protracted period for MC-2 and MC-5/6, ranging from 2004 to 2014; therefore, site visits occur on a rotating schedule. Instream habitat (MC-2) and floodplain enhancement (MC-5/6) projects had a much longer schedule of construction, occurring from 2004 to 2014 for both restoration project types. There were ten MC-2 and three MC-5/6 sites contracted to CFS for monitoring in 2017 (Table 1).

Table 1. Restoration categories with sites contracted for monitoring for the 2017 field season.

MC-2 Instream Habitat	MC-5/6 Floodplain Enhancement
04-1338 Lower Newaukum	06-2190 Riverview Park
04-1589 Dungeness River	11-1354 Lower Dosewallips
05-1533 Doty Edwards	12-1438 Lower Nason Creek
11-1315 Eagle Island	
11-1354 Lower Dosewallips	
12-1334 Upper Elochoman	
SF Asotin Creek Lower 1	
SF Asotin Creek Lower 2	
SF Asotin Creek Upper 1	
SF Asotin Creek Upper 2	

Document Organization

This report details the monitoring, analysis, and recommendations for all MC-2 and MC-5/6 projects. Each chapter provides detailed background information and methods, as well as results and interpretation of findings. Each chapter also includes recommendations for specific restoration categories. The report closes with a summary of overall findings for the monitoring program, as well as recommendations and objectives for the monitoring program in 2018. Data collection for MC-4 was completed in 2017 and results are provided in separate final report.

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CHAPTER ONE: MC-2 INSTREAM HABITAT

Summary

The placement of large woody debris (LWD), boulders, and other instream structures is one of the oldest and most common stream restoration techniques used in Washington State and the Pacific Northwest. In 2004, the Salmon Recovery Funding Board (SRFB) established a standardized effectiveness monitoring (PE) program to consistently assess the response of stream habitat and localized salmon populations to restoration efforts. The SRFB PE program includes monitoring and evaluation of instream habitat projects (MC-2) which includes placement of LWD and boulder structures. Beginning in 2004, data from 23 instream projects was collected across a range of rivers throughout Washington State using a before-after control-impact (BACI) design. Project selection, impact and control reach selection, and data collection prior to 2017 were completed by a previous contractor. Cramer Fish Sciences continued monitoring projects in 2017 and will complete this phase of monitoring in 2018. This chapter summarizes the data collected and results for those projects through 2017. Each project was monitored once before project implementation and then after project implementation on a rotating schedule. Physical habitat (vertical pool area, residual depth, and LWD) and juvenile fish density data were collected during summer low flow using SRFB protocols. Data from all years of monitoring of instream projects were analyzed using a combination of paired *t*-tests and regression analysis. Results indicate that instream projects have significantly increased physical habitat variables (vertical pool area, residual depth, large woody debris volume), while fish densities have not significantly increased or met management targets (20% increase in fish density). Large woody debris volume increases were expected due to project type (LWD additions, ELJs), though volume varied among sites likely due to individual project variables such as funding and goals and project design. Increased vertical pool area and residual depth are consistent with previous studies that document geomorphic response to wood placement and recruitment. Many studies on LWD placement have reported increases in juvenile salmonids, particularly Coho Salmon *Oncorhynchus kisutch*. The lack of a significant increase in juvenile fish response to SRFB projects may simply be due to the low number of projects that have been monitored for five or more years post-treatment. It may also be due to the sample timing, variability in treatments, the lack of geographic stratification, poorly matched control and impact reaches, or the chosen fish abundance metric. The completion of monitoring in 2018 should help answer some of the questions regarding fish response. Based on monitoring to date, future monitoring of instream projects should consider stratifying projects by ecoregion, seasonal fish sampling (summer and winter), more rigorous selection of treatment and controls, improved habitat survey methods, and either collecting more pre-project data or using a post-treatment design.

Introduction

In response to aquatic habitat degradation from human activities and the listing of many Pacific Northwest salmon populations as threatened or endangered under the Endangered Species Act, rehabilitation of salmonid habitats has become commonplace in Washington State and throughout the world (NRC 1992; Cowx and Welcomme 1998; Roni and Beechie 2013). In an effort to mitigate for degradation and loss of fish habitat from human disturbance and reverse declines in salmonid populations, a variety of habitat restoration actions—including instream habitat improvement projects—are often undertaken. Placement of instream structures to increase channel complexity, cover, pool area, and improve spawning and rearing habitat for salmon and other fish is one of the oldest and most common habitat improvement techniques (Tarzwell 1934; Roni et al. 2002, 2008). Common instream habitat improvement techniques include placement of natural structures such as large woody debris (single or multiple logs), constructed or engineered logjams (ELJs), and artificial structures (e.g., weirs, deflectors). Instream structures can be effective at increasing habitat heterogeneity (complexity), pool depth, and woody debris (see Roni et al. 2008, 2015 for detailed review). Similarly, several studies have demonstrated that instream habitat restoration can result in increased reach-scale juvenile salmon and trout abundance particularly for species that prefer pool habitats (Cederholm et al. 1997; Roni and Quinn 2001; Whiteway et al. 2010; Roni et al. 2015). Despite the long history of LWD placement and other structures in streams to improve fish habitat, they remain controversial and little data exists on their effectiveness, especially for species such as Chinook Salmon *Oncorhynchus tshawytscha* or interior Columbia River steelhead *O. mykiss*, over extended time periods (Roni et al. 2008, 2014; Clark et al. 2018).

In 2004, SRFB established an effectiveness monitoring program to assess the response of stream habitat and localized salmon populations to the restoration efforts implemented throughout Washington State. Effectiveness monitoring of these restoration projects is critical to evaluate project performance and provide information to better inform future project designs and future funding decisions. As part of the program, monitoring has been conducted on projects from 2004 to the present, with the current phase of the Program scheduled to be completed in 2018. Detailed study plans have been prepared for each major restoration category in the SRFB Project Effectiveness Monitoring (PE) plan, including the evaluation of instream structures (MC-2) (Crawford 2011). Here we report the results from all years of monitoring through 2017. The instream habitat project category mostly focuses on instream large woody debris (LWD) and engineered log jam (ELJ) placement, but there are some projects that also include boulder placement, deflectors, and weirs. Rather than examine these artificial instream structures (AIS) separately, we examine instream restoration structure projects collectively and refer to them as instream projects.

A common goal for instream work in Washington State is to modify or add elements to the stream habitat where anthropogenic actions have altered and degraded the habitat. Habitat restoration practitioners implementing instream improvement projects aim for changes that will benefit local fish populations and ecosystem services. The primary monitoring goal is to determine the effectiveness of instream restoration projects and placement of AIS at improving habitat conditions, stream morphology, and fish densities in fish bearing streams by addressing:

1. Have AIS as designed remained in the stream following implementation;
2. Have treatments led to improved stream morphology for the benefit of salmonids; and
3. Has juvenile salmon abundance increased in the impact reach?

Methods

Monitoring Design and Replication

Here we provide a summary of the methods and design but refer readers to Crawford (2011) for details. Instream habitat projects were evaluated using a before-after control-impact (BACI) experimental design (Green 1979; Stewart-Oaten et al. 1986). Each project was monitored one year before implementation (Year 0) and 1, 3, 5, and 10 years after implementation. Occasionally, some projects were monitored by the previous contractor for multiple years prior to project implementation (Year 0*, Year 0**) and in the second year post implementation (Year 2). Sites are at different stages of the monitoring schedule depending on when the restoration (impact) and monitoring was implemented (Table 2).

Table 2. Monitoring schedule for instream projects. Light grey are years that were not monitored due. Cramer Fish Sciences took over monitoring in 2017. Year 0* and 0** represent additional years of pre-project data collected at some projects.

Site Number	Site Name	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
02-1444	Little Skookum Valley	Yr 0		Yr 1		Yr 3		Yr 5					Yr 10			
02-1463	Salmon Creek	Yr 0	Yr 1		Yr 3		Yr 5					Yr 10				
02-1515	Upper Trout Creek						Yr 1		Yr 3		Yr 5					Yr 10
02-1561IS	Edgewater Park	Yr 0	Yr 1			Yr 3	Yr 5					Yr 10				
04-1209IS	Chico Creek		Yr 0	Yr 0*			Yr 1		Yr 3		Yr 5					Yr 10
04-1338	Lower Newaukum					Yr 0, Yr 1		Yr 3		Yr 5					Yr 10	
04-1448	PUD Bar Habitat		Yr 0	Yr 1		Yr 3		Yr 5					Yr 10			
04-1575	Upper Washougal		Yr 0	Yr 1		Yr 3		Yr 5					Yr 10			
04-1589	Dungeness River		Yr 0	Yr 0*		Yr 1		Yr 3		Yr 5					Yr 10	
04-1660IS	Cedar Rapids		Yr 0	Yr 0*			Yr 1		Yr 3		Yr 5					Yr 10
05-1533	Doty Edwards			Yr 0		Yr 1		Yr 3		Yr 5					Yr 10	
07-1803	Skookum Reach					Yr 0		Yr 1		Yr 3		Yr 5				Yr 9
11-1315	Eagle Island										Yr 0		Yr 1		Yr 3	
11-1354	Lower Dosewallips										Yr 0		Yr 0*		Yr0**	
12-1334	Elochoman										Yr 0					
12-1657	George Creek										Yr 0	Yr 1		Yr 3		Yr 5
SF-F3 P2BR	SF Asotin Creek Lower 1									Yr 0	Yr 1		Yr 3		Yr 5	
SF-F3 P3BR	SF Asotin Creek Lower 2									Yr 0	Yr 1		Yr 3		Yr 5	
SF-F4 P1	SF Asotin Creek Upper 1									Yr 0	Yr 1		Yr 3		Yr 5	
SF-F4 P2	SF Asotin Creek Upper 2									Yr 0	Yr 1		Yr 3		Yr 5	
Tucannon PA 14	Tucannon PA 14										Yr 0	Yr 1	Yr 2	Yr 3		Yr 5
Tucannon PA 26	Tucannon PA 26										Yr 0	Yr 1		Yr 3		Yr 5
Tucannon PA 3	Tucannon PA 3										Yr 0	Yr 1	Yr 2	Yr 3		Yr 5

Projects were initially selected for monitoring from those that had been funded but not implemented for the given baseline sampling year (Figure 1). All site selection and data collection prior to 2017 were conducted by the previous contractor (Tetra Tech 2016). Study sites ranged in average wetted width from 1.2 m to 31.5 m and in elevation from 3 m to 844 m. Annual precipitation at sites varied from 69 cm to 297 cm per year and dominant geology was either sedimentary or volcanic (Table 3). Instream projects had various techniques applied within the project reach ranging from ELJs to single log placement (Table 4; Figure 2). An impact reach was selected within the project area where change was expected to result from project implementation (e.g., LWD installation). A control reach was selected upstream and within close proximity of the impact reach with assistance from project sponsors and regional experts (Figure 2). Selection of adequate controls is critical to account for natural variability in riparian and stream habitat that is occurring throughout a stream and not the result of project implementation. In 2017, monitoring included seven instream projects: 04-1338 Lower Newaukum, 05-1533 Doty Edwards, 11-1315 Eagle Island, SF-F3 P2BR SF Asotin Lower 1, SF-F3 P3BR SF Asotin Lower 2, SF-F4 P1 SF Asotin Upper 1, and SF-F4 P2 SF Asotin Upper 2. Monitoring was not completed for 04-1589 Dungeness River in 2017 because LWD was placed in the control reach between 2012 and 2017. Restoration was never implemented at 12-1334 Elochoman project so it was not monitored either.

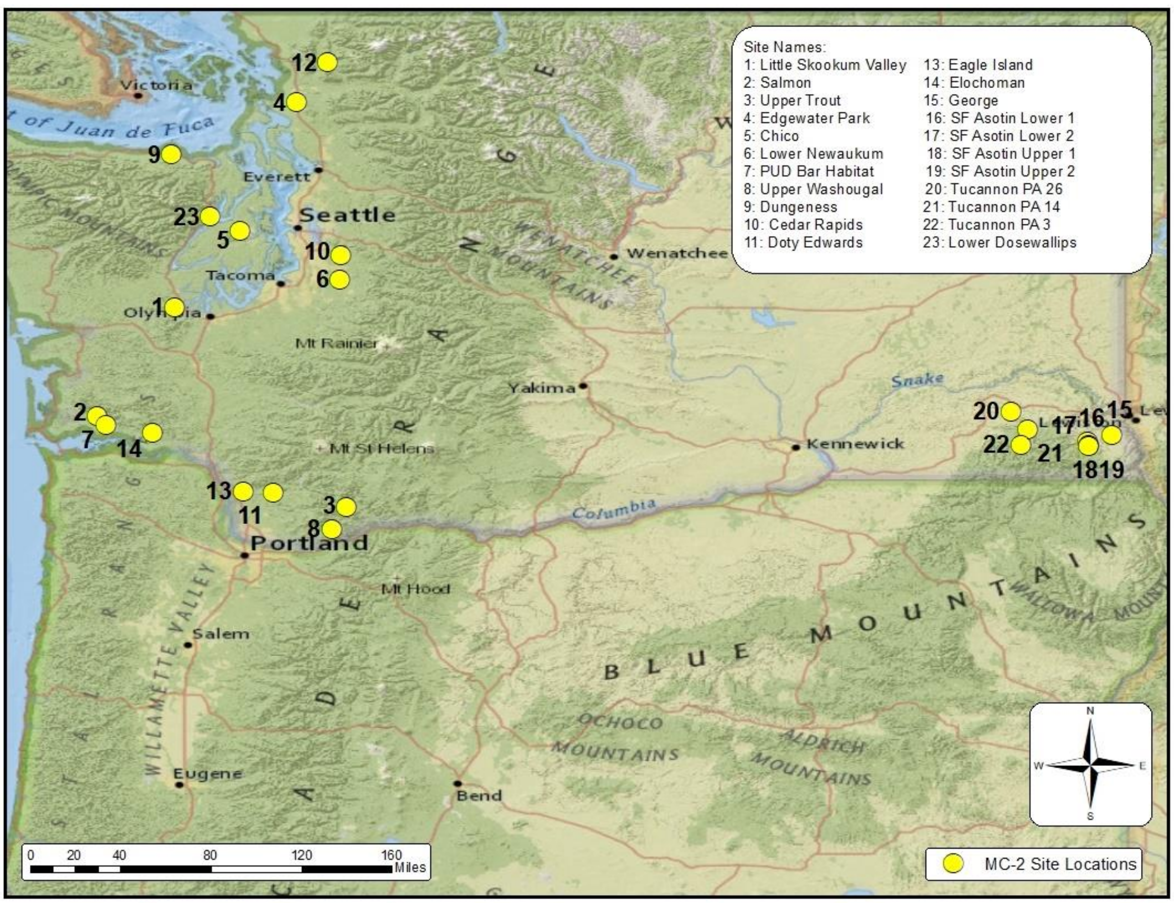

Figure 1. Instream project locations monitored throughout Washington.

Table 3. Physical characteristics of instream habitat restoration sites. Geology is dominant geology (unpublished Washington State Department of Ecology) where Sed. = sedimentary and Vol. = volcanic. Average annual precipitation was obtained from the USGS StreamStats Program (https://water.usgs.gov/osw/streamstats/). Wetted width (WW) is the average the wetted width measurements over all sampling years.

Site ID	Site Name	County	Basin	Year 0	Geology	Site Elev (m)	Precip (cm/yr)	Wetted Width (m)	Impact Site Length (m)	Control Site Length (m)
02-1444	Little Skookum Valley	Mason	Skookum	2004	Sed.	25	152.4	1.2	150	150
02-1463	Salmon Creek	Pacific	Naselle	2004	Sed.	114	250.4	6.1	180	180
02-1515	Upper Trout Creek	Skamania	Wind	---	Vol.	561	297.2	12.1	360	150
02-1561IS	Edgewater Park	Skagit	Skagit	2004	Sed.	5	256.5	6.4	318	220
04-1209IS	Chico Creek	Kitsap	Chico	2005	Sed.	12	134.9	6.7	250	250
04-1338	Lower Newaukum	King	Green	2008	Sed.	55	150.9	7.6	220	220
04-1448	PUD Bar Habitat	Wahkiakum	Grays	2005	Sed.	8	284.5	31.5	320	320
04-1575	Upper Washougal	Skamania	Washougal	2005	Vol.	241	276.9	22.2	500	500
04-1589	Dungeness River	Clallam	Dungeness	2005	Sed.	58	154.9	18.5	500	500
04-1660IS	Cedar Rapids	King	Cedar	2005	Sed.	69	236.2	23.3	400	500
05-1533	Doty Edwards	Clark	Lewis	2006	Sed.	92	194.6	14.0	300	300
07-1803	Skookum Reach	Whatcom	Nooksack	2008	Sed.	116	232.7	29.6	500	500
11-1315	Eagle Island	Clark	Lewis	2013	Sed.	3	269.2	12.8	155	165
11-1354	Lower Dosewallips	Kitsap	Dosewallips	2013	Sed.	2	227.6	42.0	500	500
12-1334	Elochoman	Wahkiakum	Elochoman	2013	Sed.	98	245.6	28.2	400	400
12-1657	George Creek	Asotin	Asotin	2013	Sed.	372	56.1	5.3	168	203
SF-F3 P2BR	SF Asotin Creek Lower 1	Asotin	Asotin	2012	Sed.	570	69.9	3.4	167	181
SF-F3 P3BR	SF Asotin Creek Lower 2	Asotin	Asotin	2012	Sed.	576	69.9	4.0	186	183
SF-F4 P1	SF Asotin Creek Upper 1	Asotin	Asotin	2012	Sed.	716	71.6	3.8	166	178
SF-F4 P2	SF Asotin Creek Upper 2	Asotin	Asotin	2012	Sed.	753	74.2	4.4	156	178
Tucannon PA 26	Tucannon PA 26	Columbia	Tucannon	2013	Sed.	427	75.2	11.2	350	398
Tucannon PA 14	Tucannon PA 14	Columbia	Tucannon	2013	Sed.	634	85.1	9.7	244	281
Tucannon PA 3	Tucannon PA 3	Columbia	Tucannon	2013	Sed.	844	90.4	11.3	279	288

Table 4. Description of treatments implemented at each project and which sites were sampled in 2017. 04-1589 Dungeness River and 12-1334 Elochoman projects were dropped because of issues with treatment or controls. Target salmonid species were Chinook Salmon for the Tucannon sites, but Chinook, Coho, steelhead and other salmonids present for all other sites.

Site Number	Site Name	Description	2017
02-1444	Little Skookum Valley	LWD placement and planting on Little Skookum Creek near Shelton, WA	No
02-1463	Salmon Creek	Channel regrading and LWD placement in Pacific County	No
02-1515	Upper Trout Creek	LWD placement and riparian planting tributary on Wind River	No
02-1561IS	Edgewater Park	Side channel creation and LWD placement on Skagit River	No
04-1209IS	Chico Creek	LWD placement project near Shelton, WA	No
04-1338	Lower Newaukum	LWD placement on tributary to Green River near Auburn, WA	Yes
04-1448	PUD Bar Habitat	Wood and rock veins with planting on Grays River near Roseburg, WA	No
04-1575	Upper Washougal	Sediment trapping ELJs on Washougal River	No
04-1589	Dungeness River	ELJ placement on Lower Dungeness River in Sequim, WA	Yes
04-1660IS	Cedar Rapids	LWD and ELJ placement with planting on Cedar River near Renton, WA	No
05-1533	Doty Edwards	LWD and rock placement on Cedar Creek, tributary to NF Lewis River	Yes
07-1803	Skookum Reach	Bank LWD structures on South Fork Nooksack River near Acme, WA	No
11-1315	Eagle Island	LWD and ELJ placements on a side channel of the NF Lewis River	Yes
11-1354	Lower Dosewallips	Levee removal and ELJ placement on the lower Dosewallips River	Yes
12-1334	Elochoman	LWD and rock placement and riparian planting on Elochoman River	Yes
12-1657	George Creek	LWD placement channel re-meander on tributary to Asotin Creek	No
SF-F3 P2BR	SF Asotin Creek Lower 1	LWD placement in Asotin Creek IMW	Yes
SF-F3 P3BR	SF Asotin Creek Lower 2	LWD placement in Asotin Creek IMW	Yes
SF-F4 P1	SF Asotin Creek Upper 1	LWD placement in Asotin Creek IMW	Yes
SF-F4 P2	SF Asotin Creek Upper 2	LWD placement in Asotin Creek IMW	Yes
Tucannon PA 26	Tucannon PA 26	LWD placement and levee removal on middle Tucannon River	No
Tucannon PA 14	Tucannon PA 14	LWD and ELJ placement on middle Tucannon River	No
Tucannon PA 3	Tucannon PA 3	LWD and ELJ placement in upper Tucannon River	No

Figure 2. Impact (left) and control (right) reaches for (a) 04-1209 Chico Creek, (b) 04-1660 Cedar Rapids, (c) 05-1533 Doty Edwards, and (d) 11-1315 Eagle Island.

Field Methods

The SRFB project effectiveness program for instream structures uses field sampling indicators and techniques that were adapted from U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program (Lazorchak et al. 1998; Peck et al. 2003). Specific indicators and protocols were developed in 2003 by the SRFB and modified in 2008 and 2010 by Tetra Tech (Washington Salmon Recovery Funding Board 2003; Tetra Tech 2009; Tetra Tech 2012; Tetra Tech 2017). The detailed protocol used to monitor these projects is Crawford (2011). The protocol includes goals and objectives for the monitoring category, success criteria, detailed field data collection descriptions, functional assessment methods, summary statistics, and data analysis procedures. Here we provide a summary but refer readers to Crawford (2011) for details.

Site Layout

Once impact and control reaches were selected, the total reach length was calculated using bankfull measurements in the impact reach (Crawford 2011). Five bankfull measurements were recorded and averaged around the center of the reach (X-site). The total reach length was calculated by multiplying the mean bankfull width by twenty (minimum of 150 m and maximum of 500 m). This same reach length was then to be used for the control reach and was to remain the same for each year of monitoring; however, there were several projects monitored by the previous contractor where reach lengths varied among years and were different between the control and impact reaches. Once a site length was calculated, the reach layout was completed by location Transects A-K (Figure 3). Transects were placed at a distance of one-tenth the average bankfull widths (i.e., if a reach length is 150 m, the distance between transects will be 15 m).

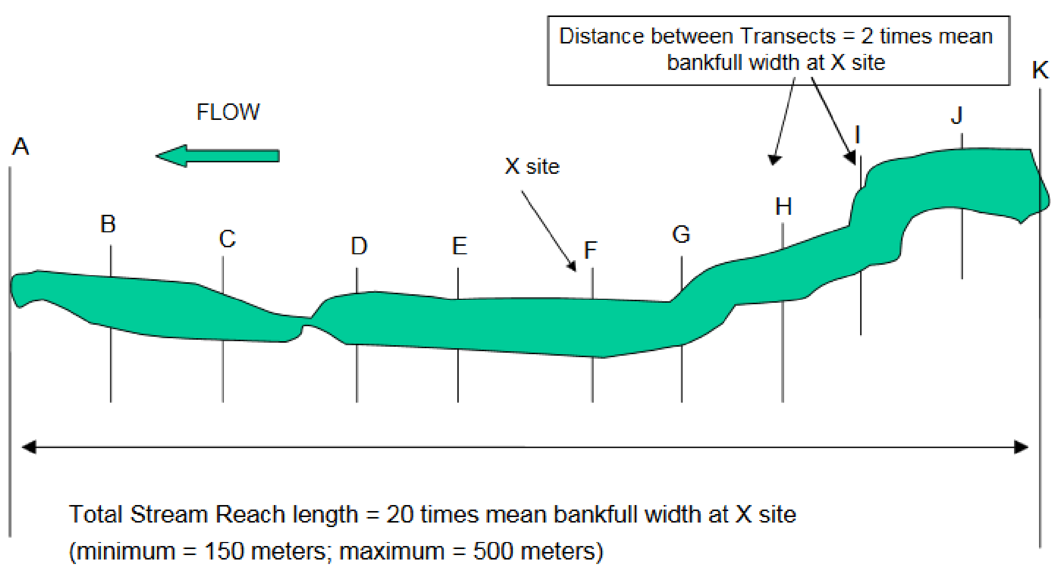

Figure 3. Project reach layout as adopted from Crawford (2011).

Habitat Surveys

Large Woody Debris (LWD)

Natural and artificially placed LWD was quantified at treatment and control reaches in each site (Crawford 2011). Large woody debris was defined as all pieces within the active, or bankfull channel that were greater than 1 m in length and 10 cm in diameter one-third of the way up from the base. The length, diameter, and if the piece of LWD was placed (either by noting the tag number, anchoring, or if the piece was cut at an end) were recorded for each piece. Only dead pieces were counted and pieces embedded in the streambank were counted if the exposed portion met the length and width requirements. Between each transect, the length and diameter of the first ten pieces was estimated and measured. Following the initial ten measurements, every 5th (if fewer than 100 pieces in the entire reach) or 10th (if greater than 100 pieces in the entire reach) piece was physically measured while the length and diameter of all other pieces was visually estimated and placed into size classes. Size classes were as follows:

Diameter

- Small: 0.1 m < 0.3 m
- Medium: 0.3 m < 0.6 m
- Large: 0.6 m < 0.8 m
- X-Large: >0.8 m

Length

- Small: 1.0 m < 5.0 m
- Medium: 5.0 m < 15.0 m
- Large: >15 m

The volume of LWD within the study reach was calculated for analysis using the minimum value of the assigned diameter and length classes and the following equation as described in Crawford (2011):

$$LWD\ Volume = \pi \times (1.33 \times \left(\frac{CMD}{2}\right)^2) \times (1.33 \times CML)$$

Where *CMD* is class minimum diameter and *CML* is class minimum length.

The volume of each piece of LWD is calculated using this equation and then the total nominal volume is the sum of all the pieces in the reach. The total nominal value is then multiplied by 100, divided by the total reach length, and the base 10 logarithm is taken to get the final LWD response metric used in the analyses (Crawford 2011).

Characterizing Stream Morphology

A longitudinal thalweg profile survey was used to classify residual water depth and habitat type (pool, riffle, glide, etc.) at 100 equally spaced intervals along the thalweg between the top and bottom of the sampling reach (Crawford 2011). Wetted widths were measured at 21 equally spaced cross-sections (at 11 primary transects A through K, plus 10 supplemental cross-sections spaced mid-way between each primary transect). For each pool encountered along the thalweg, the pool-tail crest depth, maximum pool depth, and maximum pool width were measured. If a side channel was present and contained between 16 and 49% of the total flow, secondary cross-section transects were established and wetted widths were measured. From the longitudinal profiles, average reach width, thalweg length, mean residual pool vertical profile area, and mean residual depth were calculated. If a stream were dry at the time of survey, vertical pool area, mean residual depth, and reach width would be zero.

Slope and Bearing

The water surface slope and bearing between each transect (A-K) was measured to help calculate residual pool depth and vertical profile area in each reach (Crawford 2011). One surveyor stood at the wetted edge of the downstream transect with a stadia rod at a known height. The other surveyor stood on the same bank at the next immediate upstream transect. Using a laser range finder at a known height, the upstream surveyor shot to the downstream transect and recorded the vertical and horizontal difference to calculate the slope between the two transects. Standing mid-channel at the upstream transect, the bearing to the downstream transect at mid-channel was recorded. If there was a meander bend and a full line of sight was not available between transects, a supplementary slope and bearing was recorded between transects (Crawford 2011).

Topographic Surveys

Beginning in 2012, the previous contractor selected new and old projects to collect topographic data using methodology adopted from the Columbia Habitat Monitoring Program and available at monitoringmethods.org (e.g., Scientific Protocol for Salmonid Habitat Surveys within the Columbia Habitat Monitoring Program) (CHaMP 2013; Table 5). The River Bathymetry Toolkit console was also integrated into data processing to produce EMAP metrics that are compatible with the SRFB Program protocol and metrics for consistent use in data analysis (McKean et al. 2009).

Table 5. Project sites and whether they had been monitored use topographic surveys.

Site Number	Site Name	Topo Implemented	Monitoring Year Implemented
02-1444	Little Skookum Valley	No	n/a
02-1463	Salmon Creek	No	n/a
02-1515	Upper Trout Creek	No	n/a
02-1561IS	Edgewater Park	No	n/a
04-1209IS	Chico Creek	No	n/a
04-1338	Lower Newaukum	No	n/a
04-1448	PUD Bar Habitat	No	n/a
04-1575	Upper Washougal	No	n/a
04-1589	Dungeness River	No	n/a
04-1660IS	Cedar Rapids	No	n/a
05-1533	Doty Edwards	No	n/a
07-1803	Skookum Reach	No	n/a
11-1315	Eagle Island	2015	Year 1
11-1354	Lower Dosewallips	2013	Year 0
12-1334	Elochoman	2013	Year 0
12-1657	George Creek	2013	Year 0
SF-F3 P2BR	SF Asotin Creek Lower 1	2012	Year 0
SF-F3 P3BR	SF Asotin Creek Lower 2	2012	Year 0
SF-F4 P1	SF Asotin Creek Upper 1	2012	Year 0
SF-F4 P2	SF Asotin Creek Upper 2	2012	Year 0
Tucannon PA 26	Tucannon PA 26	2013	Year 0
Tucannon PA 14	Tucannon PA 14	2013	Year 0
Tucannon PA 3	Tucannon PA 3	2013	Year 0

Fish Surveys

Snorkel surveys were conducted to quantify the number of fish in each impact and control reach during summer low flow (Crawford 2011). One to four divers, depending on stream width, entered the downstream end of a reach and slowly moved upstream through each transect, stopping to occasionally relay the number, sizes, fish species, and observed micro-habitat characteristics (e.g., slow or fast water, off-channel or side channel habitat, LWD or boulder association). Fish length was visually estimated to the nearest 10 mm. Prior to fish surveys, stream temperature was measured, and visibility was recorded (low, medium, high). Fish species encountered during snorkel surveys included several species of Pacific salmon *Oncorhynchus* spp., sculpin *Cottus* spp., sucker *Catostomus* spp., and dace *Rhinichthys* spp., as well as Bull Trout *Salvelinus confluentus*, Threespine Stickleback *Gasterosteus aculeatus*, and Mountain Whitefish *Prosopium williamsoni*. The analysis focused on juvenile (<250 mm) Coho Salmon, steelhead, and Chinook Salmon because these fish were the intended target species for the restoration projects (Crawford 2011).

Data Analysis Methods

All projects were evaluated together as a category to assess trends in indicator response from year to year and the change between pre-project (Year 0) and post-project (Year 1, 3, 5, and 10) conditions. Because monitoring began in different years for projects, some do not have the full ten years of monitoring completed as of 2017; however, the analyses included all years of data collected through 2017. Nineteen sites were included in the analysis and four sites were completely excluded for various reasons (Table 6). Statistical analysis was not conducted on individual projects.

Table 6. Instream projects and sampling years included in data analysis.

Site Number	Site Name	Pre Sampling	Years to include in analysis	Reason for removal
02-1444	Little Skookum Valley	2004	0, 1, 3, 5, 10	
02-1463	Salmon Creek	2004	0, 1, 3, 5, 10	
02-1515	Upper Trout Creek	n/a	None	No Year 0 data in impact reach
02-1561IS	Edgewater Park	2004	None	Reach locations changed since Year 0
04-1209IS	Chico Creek	2005, 2006	0, 0*, 1, 3, 5	
04-1338	Lower Newaukum	2008	0, 1, 3, 5, 10	
04-1448	PUD Bar Habitat	2005	0, 1, 3, 5, 10	
04-1575	Upper Washougal	2005	0, 1, 3, 5, 10	
04-1589	Dungeness River	2005, 2006	0, 0*, 1, 3, 5	No Year 10 since control reach treated
04-1660IS	Cedar Rapids	2005, 2006	0, 0*, 1, 3, 5	
05-1533	Doty Edwards	2006	0, 1, 3, 5, 10	
07-1803	Skookum Reach	2008	0, 1, 3, 5	
11-1315	Eagle Island	2013	0, 1, 3	
11-1354	Lower Dosewallips	2013, 2015, 2017	None	No post-project data; not implemented
12-1334	Elochoman	2013	None	No post-project data; not implemented
12-1657	George Creek	2013	0, 1, 3	
SF-F3 P2BR	SF Asotin Creek Lower 1	2012	0, 1, 3	No Year 5 since control reach treated
SF-F3 P3BR	SF Asotin Creek Lower 2	2012	0, 1, 3	No Year 5 since control reach treated
SF-F4 P1	SF Asotin Creek Upper 1	2012	0, 1, 3, 5	
SF-F4 P2	SF Asotin Creek Upper 2	2012	0, 1, 3, 5	
Tucannon PA 14	Tucannon PA 14	2013	0, 1, 2, 3	
Tucannon PA 26	Tucannon PA 26	2013	0, 1, 3	
Tucannon PA 3	Tucannon PA 3	2013	0, 1, 2, 3	

Vertical Pool Area, Residual Depth, LWD Volume, and Fish Density

We conducted two basic statistical methods as described in Crawford (2011), previous annual reports (Tetra Tech 2016), and required under our contract. The required analyses include a mean difference analysis and a trend analysis to test whether projects were effective each monitoring year and remained effective through Year 10 (Crawford 2011). In addition, we attempted to analyze data using a mixed effects model, which is considered a robust approach for analyzing BACI design data (Underwood 1992; Downes et al. 2002; Miller et al. 2010; Muller et al. 2015). However, the data were skewed and no transformation we applied resulted in a normal or nearly normal distribution. Thus, we were not able to analyze the data with a mixed-effects MBACI model.

For the mean difference method, the Year 0 values were compared to each year of post-project (Year 1, 3, 5, and 10) data using a paired one-sided *t*-test with $\alpha = 0.10$. If the data was not normally distributed, a paired one-sided nonparametric *t*-test (Wilcoxon) with $\alpha = 0.10$ was used. For each response variable, our unit of analysis was the paired difference between the impact reach compared to the control reach for each sample year. The null hypothesis is that the mean of the impact metrics across sites is equal to 0. This analysis was conducted on three habitat response variables (vertical pool profile area, mean residual depth, $\log_{10}$ LWD volume) and three fish response variables (juvenile Chinook Salmon, Coho Salmon, and steelhead densities). Year 0*, Year 0**, and Year 2 were not included in this first analysis because they were only collected at a few projects.

For the second method, the slopes of linear trend lines through time (Year 0 to Year 10) for each indicator at each project site were estimated. Then, using these slopes, a *t*-test or nonparametric equivalent (Wilcoxon) test with $\alpha = 0.10$ was used to test if the average of the slopes differed from 0 for each metric (Crawford 2011; Tetra Tech 2016; O'Neal et al. 2016). All years of data were included in the second analysis. Sites were excluded from this analysis if there were only two years of data collected. The second analysis was conducted on the same three habitat response variables (vertical pool profile area, mean residual depth, $\log_{10}$ LWD volume) and three fish response variables (juvenile Chinook Salmon, Coho Salmon, and steelhead densities).

Decision Criteria

In addition to statistical analysis, minimum management targets (decision success criteria) defined in Crawford (2011) were used to examine project effectiveness. The management decision criteria were set for each metric and include an evaluation of the percent change in the mean differences between impact and control reaches for each analyzed metric. For physical habitat (vertical pool areas, mean residual depth, $\log_{10}$ LWD) and fish metrics (Chinook Salmon, Coho Salmon, and steelhead densities) the management decision criteria for success are: 1) a statistically significant change ($\alpha < 0.10$) between impact and control by Year 10 and 2) a positive change of >20% from Year 0. Because we did not have Year 10 data for all projects, we examined whether projects met minimum management targets in years 1, 3, 5, and 10.

The following equation was used to determine if a 20% change from baseline occurred for each project:

$$\%\ diff_{site:i,year:j} = \frac{Difference_{i,0} - Difference_{i,j}}{Difference_{i,0}}$$

Percent difference was determined for each site for a given year. Then the average percent difference for a given year was computed by taking the mean of all percent differences (all sites) for a given year.

$$\%\ AvDiff_{year:j} = mean(\%\ diff_{i,j})$$

Results

Physical Habitat

Mean Differences and Trend Analyses

There was a large amount of variability in all three physical habitat metrics across years (Figure 4). The impact minus the control reach of all three metrics also varied across years and among sites (see Appendices A and E). Vertical pool area increased significantly in all years when compared to Year 0 ($P < 0.08$) (Table 7). Mean residual depth increased significantly in all years when compared to Year 0 ($P < 0.10$) (Table 7). The linear trend analysis found a significant increase in both vertical pool area and mean residual depth over time ($P = 0.007$ and $P = 0.001$, respectively) (Table 8).

When comparing the difference between the control and impact reaches for each year of monitoring using the mean difference analysis, there was a significant increase in $\log_{10}$ LWD volume in each year following project implementation when compared to Year 0 (Table 7). Similar results were found for LWD in the linear trend analysis where LWD increased significantly over time (P = 0.005) (Table 8).

Based on the management decision criteria presented in Crawford (2011), by Year 10, instream projects were effective in increasing vertical pool area, mean residual depth, and LWD (Table 9).

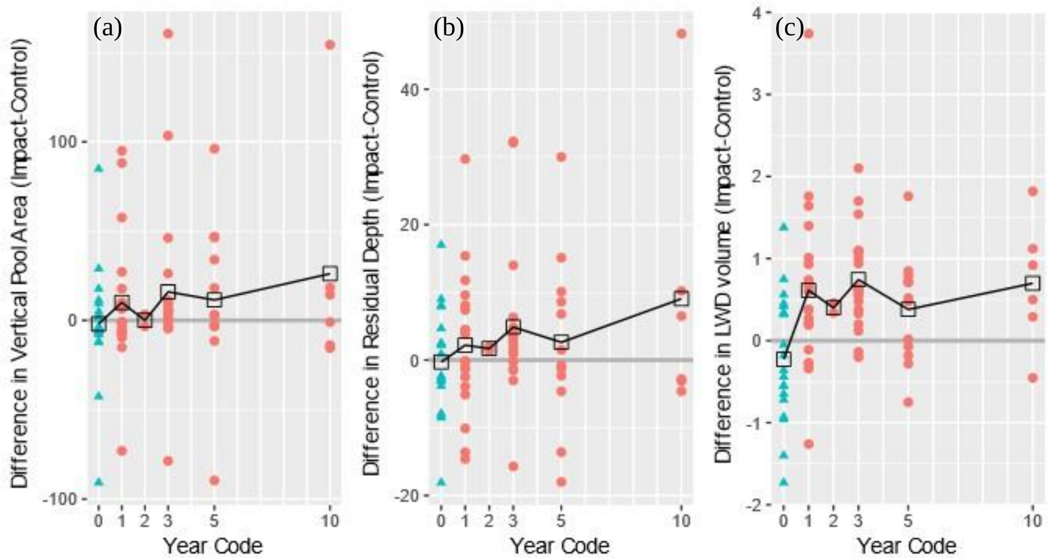

Figure 4. Mean difference for vertical pool area (a), residual depth (b), and $\log_{10}$ LWD volume (c) between the impact and control reaches for instream projects. The blue triangles and red circles represent before and (Year 0) after monitoring data (Year > 0), respectively.

Table 7. Summary results for paired one-tailed test of the difference between the impact and control reaches for physical habitat metrics within instream projects. Bolded P-values indicate statistical significance (α = 0.10).

Metric	Years Compared	Sample Size (sites)	Test	P-value
Vertical Pool Area (m^2)	0↔1	19	Paired Wilcoxon	**0.04**
	0↔3	19	Paired Wilcoxon	**0.001**
	0↔5	12	Paired *t*-test	**0.08**
	0↔10	6	Paired Wilcoxon	**0.08**
Mean Residual Depth (cm)	0↔1	19	Paired *t*-test	**0.10**
	0↔3	19	Paired Wilcoxon	**0.002**
	0↔5	12	Paired *t*-test	**0.06**
	0↔10	6	Paired Wilcoxon	**0.03**
$\log_{10}$ LWD Volume (m^3)	0↔1	19	Paired *t*-test	**< 0.001**
	0↔3	19	Paired *t*-test	**< 0.001**
	0↔5	12	Paired *t*-test	**0.09**
	0↔10	6	Paired Wilcoxon	**0.03**

Table 8. Summary results for paired one-tailed test of the linear trend analysis for physical habitat metrics within instream projects. Bolded P-values indicate statistical significance (α = 0.10).

Metric	Sample Size	Mean Slope of differences (I-C)	Test	P-value
Vertical Pool Area (m^2)	19	2.490	Wilcoxon	**0.007**
Mean Residual Depth (cm)	19	0.858	Wilcoxon	**0.001**
$\log_{10}$ LWD Volume (m^3)	19	0.149	*t*-test	**0.005**

Table 9. Summary of instream project physical success based on management decision criteria outlined in Crawford (2011).

Metric	Year	*t*-test or Wilcoxon test met	% Change from Baseline
Vertical Pool Area (m^2)	Year 1	Yes	159
	Year 3	Yes	188
	Year 5	Yes	101
	Year 10	Yes	122
Mean Residual Depth (cm)	Year 1	Yes	106
	Year 3	Yes	130
	Year 5	Yes	99
	Year 10	Yes	151
Log_{10} LWD Volume (m^3)	Year 1	Yes	173
	Year 3	Yes	213
	Year 5	Yes	106
	Year 10	Yes	169

Fish Densities

Mean Difference and Trend Analyses

Prior to project implementation (Year 0), there was a large amount of variability in fish densities between control and impact reaches, with several sites having low densities of all three fish species analyzed in this report (Figure 5). The impact minus the control reach of all three fish densities also varied across years and among sites (see Appendices A, C, and E). There were no significant increases in fish densities for any species in any year following project implementation when compared to Year 0 (P > 0.14) (Table 10). Similarly, there were no significant changes in the three fish densities over time using the linear trend analysis (Table 11). Based on the management decision criteria presented in Crawford (2011), to date instream projects are not meeting management decision success criteria for Chinook Salmon, Coho Salmon, or steelhead densities (Table 12).

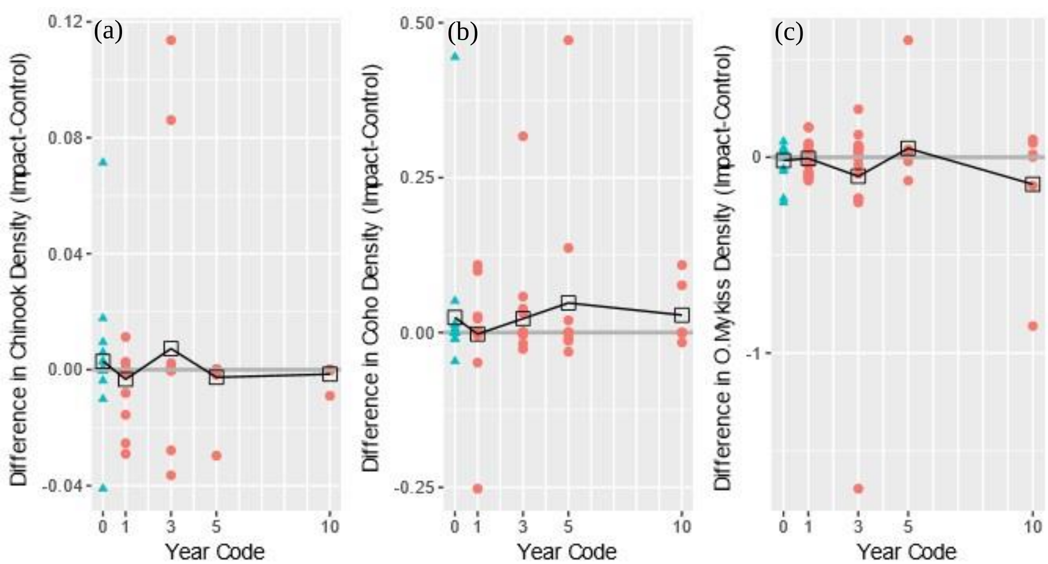

Figure 5. Mean difference for densities of Chinook Salmon (a), Coho Salmon (b), and steelhead (c) between the impact and control reaches. The blue triangles and red circles represent before and (Year 0) after monitoring data (Year > 0), respectively.

Table 10. Summary results for paired one-tailed test of the difference between the impact and control reaches for juvenile fish densities within instream projects.

Metric	Years Compared	Sample Size (sites)	Test	P-value
Chinook Density (fish/m^2)	0↔1	19	Paired Wilcoxon	0.66
	0↔3	19	Paired Wilcoxon	0.31
	0↔5	12	Paired Wilcoxon	0.76
	0↔10	6	Paired Wilcoxon	0.61
Coho Density (fish/m^2)	0↔1	19	Paired Wilcoxon	0.89
	0↔3	19	Paired Wilcoxon	0.66
	0↔5	12	Paired Wilcoxon	0.14
	0↔10	6	Paired Wilcoxon	0.90
Steelhead Density (fish/m^2)	0↔1	19	Paired Wilcoxon	0.32
	0↔3	19	Paired Wilcoxon	0.65
	0↔5	12	Paired Wilcoxon	0.28
	0↔10	6	Paired Wilcoxon	0.50

Table 11. Summary results for paired one-tailed test of the linear trend analysis for juvenile fish densities within instream projects.

Metric	Sample Size	Mean Slope of differences (I-C)	Test	P-value
Chinook Density (fish/m^2)	19	0.010	Paired Wilcoxon	0.24
Coho Density (fish/m^2)	19	0.003	Paired Wilcoxon	0.45
Steelhead Density (fish/m^2)	19	-0.020	Paired Wilcoxon	0.81

Table 12. Summary of instream project biological success based on management decision criteria outlined in Crawford (2011).

Metric	Year	*t*-test or Wilcoxon test met	% Change from Baseline
Chinook Density (fish/m^2)	Year 1	No	-109
	Year 3	No	70
	Year 5	No	-54
	Year 10	No	-42
Coho Density (fish/m^2)	Year 1	No	113
	Year 3	No	-39
	Year 5	No	96
	Year 10	No	288
Steelhead Density (fish/m^2)	Year 1	No	3,058
	Year 3	No	12,183
	Year 5	No	255
	Year 10	No	-195

Discussion

A total of 23 instream habitat projects were sampled since 2004, with 19 included in the analysis. While Year 10 data have not been collected for all projects, significant increases have been detected in the three physical habitat variables measured as part of the SRFB PE monitoring (vertical pool area, residual depth, $\log_{10}$ LWD volume). However, no significant increase in juvenile salmonid abundance (Coho and Chinook salmon, steelhead) have been found. The results for physical habitat are consistent with previous studies on LWD and instream structure placement which have generally shown an increase in pool area, depth, and LWD (Roni and Quinn 2001; Jones et al. 2014; see also Roni et al. 2015 for detailed review).

A common goal related to placement of LWD is the creation and enhancement of slow water habitat. Previous studies have documented the positive relationship between LWD loading and pool frequency and residual depth (Beechie and Sibley 1997; Rosenfeld and Huato 2003; Collins et al. 2002; Roni et al. 2015). This type of geomorphic response to natural LWD recruitment or LWD placement may occur within the first year or two depending upon the timing of high flows (e.g., Cederholm et al. 1997; Pess et al. 2012), which is demonstrated in the significant increase measured in the first year following project implementation. The magnitude of the habitat response may also be linked to a variety of other factors such as the size and amount of LWD, the longevity of the LWD, and the geomorphic setting of the LWD (Beechie and Sibley 1997; Roni et al. 2015). The volume of LWD varied widely among our study streams, which is not surprising given the different amounts of LWD placed in impact reaches, as well as the large study area and variety of ecoregions. However, as expected, the volume of LWD was higher in impact than control reaches following project implementation, with LWD volume—averaged across post-project years—being over two times higher in impact reaches compared to control reaches. Our results are similar to other studies that found placed LWD to persist and remain stable over many years (Whiteway et al. 2010; White et al. 2011; Carah et al. 2014; Roni et al. 2015). Some reaches also continued to increase in LWD volume, suggesting the recruitment of natural wood into the project reaches.

The lack of significant fish response at SRFB instream projects is surprising given that we detected significant increases in pool area, depth, and LWD levels and that LWD and pool area have been shown to be correlated with fish response to instream restoration (Roni and Quinn 2001; Roni et al. 2006; Whiteway et al. 2010; Roni et al. 2015). Failure to detect a significant fish response may simply be related to the fact that fish response is lagging beyond the physical response and not enough time has elapsed since restoration has occurred. Thus, additional data collection in 2018 should adequately address that through increasing the number of sites for which there will be 5 to 10 years of post-project data. However, other factors may also explain the lack of significant response to date. These include sampling during summer low flow conditions, species and fish sizes sampled, high variability across sites in the magnitude of changes in both physical habitat and fish densities, possible issues with selection of control and impact reaches, inconsistent sample timing from year-to-year (e.g., June for one year and October for another), the lack of stratifying sites by geographic region, and the metric chosen to illustrate fish abundance. We discuss each of these potential factors below.

SRFB instream projects were typically sampled during summer low flow, with a few sites sampled in late fall, though not consistently across years within and among projects. Other studies that sampled during summer and winter have shown stronger responses of juvenile steelhead and Coho Salmon during winter months or when examining overwinter survival (Cederholm et al. 1997; Roni and Quinn 2001). Habitat preferences of salmonid species are known to change seasonally (e.g., Bustard and Narver 1975; Nickelson et al. 1992). Thus, we might have detected an increase in fish response had we also sampled during winter or looked at additional life stages. In addition, while juvenile salmonid densities are driven in part by adult escapement and densities of salmonids varied among years and streams, the MBACI design accounts for this by examining the difference between paired treatment and controls in each site (stream). The purpose of the paired control is to help account for interannual variability in escapement and other environmental factors. Thus, it is unlikely that differences in escapement among streams and years prevented us from detected a significant fish response.

Fish response to LWD placement varies by species and life stage, presumably due to differences in habitat preferences (Roni et al. 2002, 2008). For example, juvenile Coho Salmon are commonly found in pool habitats and often show the largest response to LWD placement (Bisson et al. 1988; Roni and

Quinn 2001). Habitat characteristics such as pool area, depth, quality, and fish cover are important drivers of fish habitat selection and distribution, particularly for species like steelhead and Chinook Salmon that are less focused on slow water habitat than Coho Salmon (e.g., Bisson et al. 1988; Nickelson et al. 1992). Additionally, different salmonid life stages and size classes utilize wood more than others (Whiteway et al. 2010; Pess et al. 2012). For example, Pess et al. (2012) found trout utilizations of engineered log jams to vary by size class, with trout greater than 100 mm significantly associated with wood while trout less than 100 mm were not. Similarly, others have shown differences in trout response to LWD placement for different size and age classes (Cederholm et al. 1997; Solazzi et al. 2000; Roni and Quinn 2001). The SRFB protocol for fish surveys pools all fish less than 250 mm together (Crawford 2011). Future monitoring and analysis may benefit by dividing fish sizes into more size classes to capture the utilization of habitat and fish response to instream restoration based on size and age.

Using a BACI monitoring approach helps to account for environmental variability and temporal trends found in both impact and control reaches to better discern instream structure placement effects from natural variability (Underwood 1992; Roni et al. 2005). However, selection of appropriate controls is critical to increase the probability of detecting restoration response if one exists (Roni et al. 2013). If control and impact reaches are not selected properly and variation is not accounted for in monitoring, there is a risk that the impact might be masked by underlying natural variation (Underwood 1992; Downes et al. 2002; Roni et al. 2005). A control reach should be selected to be as similar as possible in all respects to the impact reach and considered beyond the influence of the treatment (Downes et al. 2002). The underlying assumption is that the impact reach would have behaved approximately the same as the control reach in the absence of the treatment (i.e., LWD placement) (Underwood 1992). However, there were several sites that had issues regarding the control reach selection, which could have ultimately masked significant results. In addition, there were three sites (04-1589 Dungeness River; 05-1533 Doty Edwards, 11-1315 Eagle Island) where the control reach had wood structures placed within the monitoring reach either before or after monitoring was initiated. The Dungeness River site had wood placed in the control sometime after Year 5, and no data after Year 5 for this site was included in the analysis. The Doty Edwards site had wood placed in the lower portion of the control at an unknown time after Year 0 and Eagle Island the control reach had wood placed in it prior to any monitoring Year 0. However, excluding these two sites in the analysis slightly changed p-values, but made no overall difference in significance or findings.

SRFB instream projects monitored covered a large geographic region of Washington state and varied in stream size as well as the amount of wood placed into the stream (single log placement to engineered log jams) and fish species present. Responses may have varied among ecoregions and projects that we were unable to account for, adding additional variability to the data and reducing the possibility of detecting statistically significant responses. We did not have adequate representation of sites in eastern and western Washington to stratify by region, but this should be a consideration for site selection for any future project effectiveness monitoring program.

We attempted to analyze the data using three different statistical methods including: 1) a mean difference using paired *t*-tests or a non-parametric equivalent (Wilcoxon test), 2) a trend analysis using a *t*-test on the slopes of individual sites 3) a mixed-effects BACI model. The first two tests were required as part of the SRFB protocols, while the mixed-effects BACI model is a more standard approach for analyzing BACI data. We were not able to conduct a mixed-effects BACI model because the data were skewed and no transformation we tried made the data nearly normal. The paired *t*-test and the trend analysis produced similar, but not necessarily identical results (Table 13). In the future, it would be more straightforward to use one statistical test. Each of the three potential ways of analyzing the data have strengths and weaknesses. The paired *t*-test looks only at individual years post-treatment (1, 3, 5, and 10) compared to Year 0. The analysis is structured in this way largely because there is only one year of pre-project data and the response to restoration is expected to change over time. Additionally, taking an average of all post-years and comparing it to Year 0 would mask temporal changes (improvements with time). The trend analysis seems attractive because it can provide insight into temporal changes. However, with only one year of pre-project data it is highly dependent upon that one year of data for setting the trend. Moreover, while calculating the slope of each individual project and then running a *t*-test on the slopes is not incorrect, it is an unorthodox approach for examining trends in data. The mixed-effects BACI model would appear to be the ideal approach, except that there was only one year of pre-project data. This model works best with a more balanced design and would be most appropriate if there were at least two years of pre-project data (Smokorowski and Randall 2017). Given the design used by the SRFB, we have the most confidence in the paired *t*-test analysis. The *t*-test is a simple analysis, easily understood by managers, and is robust to minor violations of assumptions of normality (Zar 2009). Moreover, we feel *t*-tests are the most appropriate analysis given that there is only one year of pre-project data. Thus, the final analysis for the monitoring design used should focus on examining the response in Year 10 compared to Year 0, using a simple paired *t*-test.

Table 13. Summary results for the two analysis methods (mean difference and trend analyses) for instream habitat projects. Bolded P-values indicate statistical significance at a 0.10 level.

Metric	Mean Difference Analysis (n = 6; Year 10 only)	Trend Analysis (n = 19)
Vertical Pool Area (m^2)	**0.08**	**0.007**
Mean Residual Depth (cm)	**0.03**	**0.001**
Log_{10} LWD Volume (m^3)	**0.03**	**0.005**
Chinook Density (fish/m^2)	0.61	0.24
Coho Density (fish/m^2)	0.90	0.45
Steelhead Density (fish/m^2)	0.50	0.90

In summary, we detected significant changes in physical habitat variables following project implementation. However, there were not significant increases in fish densities found for the instream projects monitored, potentially because few projects have yet been monitored more than 5 years, or factors related to study design, fish and habitat sampling protocols, and other factors that may have increased variability among study sites. Completion of Year 10 monitoring for several sites will be completed in 2018 and should help provide more definitive results. Future monitoring of instream projects should consider stratifying projects by ecoregion, seasonal fish sampling (summer and winter), more rigorous selection of treatment and controls, improved habitat survey methods, and either collecting more pre-project data or using a post-treatment design.

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CHAPTER TWO: MC-5/6 FLOODPLAIN ENHANCEMENT

Summary

Floodplain or off-channel habitat restoration has become a critical component of river ecosystem rehabilitation in Washington State. In 2004, the Salmon Recovery Funding Board (SRFB) established a standardized effectiveness monitoring program to consistently assess the response of stream habitat and localized salmon populations to restoration efforts. The SRFB project effectiveness monitoring (PE) program included monitoring and evaluation of floodplain enhancement (MC-5/6) including levee setbacks, reconnection of habitats (ponds, side channels), and creation of off-channel habitats (ponds, side channels). Beginning in 2004, data from 23 floodplain enhancement projects was collected throughout Washington State using a before-after control-impact design (BACI). Project selection, impact and control reaches, and data collection prior to 2017 were collected by a previous contractor. Cramer Fish Sciences continued monitoring projects in 2017 and will complete this phase of monitoring in 2018. This chapter summarizes the data collected and results for those projects through 2017. Each project was monitored once before project implementation and then after project implementation on a rotating schedule. Physical habitat (vertical pool area, residual depth, bank canopy cover, riparian vegetation structure, channel capacity, and floodprone width) and juvenile fish density data were collected during summer low flow using SRFB protocols. Data from all years of monitoring of floodplain projects were analyzed using paired *t*-tests, though data from ten sites were excluded from the analysis because of inconsistencies in data collection or impact and control reaches. Results to date were highly variable by metric and year with significant changes in vertical pool area in Year 1 and 10, mean residual depth in Year 1, 5, and 10, average channel capacity in Year 3, and juvenile Coho Salmon in Year 1 and Year 5. No significant changes were found for bank canopy cover, riparian vegetation structure, or Chinook Salmon and steelhead densities. Adequate sample sizes were not available to analyze floodprone width. The positive changes in pool area, residual depth, and Coho Salmon are consistent with previous studies on floodplain restoration though results from SRFB projects have been relatively modest. Densities for juvenile fish were low across most sites, with several sites having no fish of a particular species found across several years of sampling. Moreover, the monitoring of fish, channel capacity, and floodprone width was not done consistently within and among projects across years, making detection of differences due to restoration more difficult. Because floodplain enhancement projects typically involve a large impact to the riparian conditions, more time post-restoration may be needed for riparian vegetation to establish, colonize, and reach the riparian structure canopy threshold (5-m). Mixed results across all metrics and the inability to assess data using more rigorous statistical methods (mixed-effects models) may be due to a variety of other factors including: sample timing, variability in restoration treatments, need for geographic stratification, and added variability from controls that were not well matched with impact reaches. Because of inconsistencies in data collection across years including lack of fish and riparian data, sampling in different seasons, and in some cases poorly matched impact and control reaches, we do not recommend additional data collection for floodplain projects in 2018. Future monitoring of floodplain enhancement projects should consider stratifying projects by ecoregion, seasonal fish sampling (summer, winter), more rigorous selection of treatment and controls, improved habitat survey methods, and either collecting more pre-project data or using a post-treatment design.

Introduction

Dams, levees, and the development of the floodplain for agricultural, residential, and industrial use have disrupted the natural connection between main channels and their floodplains (Ward and Stanford 1995;

Ward et al. 1999). These disturbances alter floodplain inundation and frequency and the input of sediments, nutrients, and wood into the floodplain (Junk et al. 1989; Collins et al. 2002), and reduce the availability of habitat for fishes and other aquatic biota (Collins et al. 2002). Salmonids benefit from access to floodplains and slow-water habitats for rearing and spawning, and as a refuge from high water velocities. Floodplain habitats—including off-channel ponds, side-channel, backwaters, and alcoves—are particularly important to juvenile Coho Salmon *Oncorhynchus kisutch* for winter rearing habitat (Peterson 1982; Nickelson et al. 1992; Rosenfeld et al. 2008), and are also used by juvenile Sockeye Salmon *O. nerka*, Chinook Salmon *O. tshawytscha*, and steelhead *O. mykiss* (Swales and Levings 1989; Morley et al. 2005). Fish that rear in off-channel and floodplain habitats grow faster than those rearing in mainstem habitats (Jeffres et al. 2008; Limm and Marchetti 2009). This is likely due to favorable velocities, water temperatures across seasons, and increased availability of food resources (Sommer et al. 2001; Sommer et al. 2005; Urabe et al. 2010; Limm and Marchetti 2009).

A variety of methods have been developed to reconnect and restore floodplain habitats including side channel reconnection, culvert or dam removal, channel aggradation structures, levee removal or setback, remeandering straightened channels, constructed groundwater channels and other methods of creating new floodplain habitats or wetlands (Cowx and Welcome 1998; Pess et al. 2005; Roni and Beechie 2013). The approaches to and scale of floodplain enhancement and restoration projects vary widely depending on project objectives, local river or stream settings, and individual techniques used. However, floodplain enhancement projects are generally designed to reconnect isolated habitat, improve channel form, increase off-channel area, and restore natural river processes to confined river systems. Baseline information on channel and floodplain form and condition is a critical foundation upon which to evaluate the effects of floodplain reconnection and enhancement efforts (Pess et al. 2005). Floodplain enhancement, creation, and connection has been shown to increase survival and provide high quality rearing habitat for young Chinook Salmon, steelhead, Coho Salmon, and other fish species (Cederholm et al. 1988; Swales and Levings 1989; Nickelson et al. 1992; Giannico and Hinch 2003; Morley et al. 2005; Sommer et al. 2005). New floodplain channels have also been associated with high abundances and increased production of juvenile Coho Salmon, Cutthroat Trout *O. clarki*, Chinook Salmon, and steelhead (Richards et al. 1992; Decker and Lightly 2004).

In 2004, SRFB established an effectiveness monitoring program to assess the response of habitat and localized salmon populations to restoration efforts. Numerous floodplain enhancement projects have been implemented throughout Washington State to reconnect isolated habitat, improve channel form, increase off-channel area, and restore natural river processes. Effectiveness monitoring of these restoration projects is critical to evaluate project performance and provide information to better inform future project designs and future funding decisions. As part of the program, monitoring has been conducted on projects from 2004 to the present, with the current phase of the Program scheduled to be completed in 2018. Detailed study plans have been prepared for each major restoration category in the SRFB Project Effectiveness Monitoring (PE) plan, including the evaluation of floodplain restoration projects (MC-5/6) (Crawford 2011). Here we report the results from all years of monitoring up through 2017.

The primary monitoring goal of SRFB monitoring of floodplain enhancement projects is to determine the effectiveness of projects that are intended to restore floodplain morphology and to eliminate channel constraints in fish bearing streams. Specifically, the program was designed to answer the following questions:

1) What is the effect of floodplain enhancement on flood capacity;
2) What is the effect of floodplain enhancement on slow water habitats and habitat complexity;

3) What is the effect of floodplain enhancement on juvenile salmon and steelhead abundance; and
4) Has the removal and/or setback reduced channel constraints and increased flood flow capacity for ten years?

Methods

Monitoring Design and Replication

Here we provide a summary of the methods and design but refer readers to Crawford (2011) for details. Floodplain enhancement projects were evaluated using a before-after control-impact (BACI) design (Green 1979; Stewart-Oaten et al. 1986). Each project was monitored before implementation (Year 0) and after implementation on a rotating schedule. Occasionally, some projects were monitored for multiple years prior to project implementation (Year 0*). The post-project implementation monitoring schedule was typically Years 1, 3, 5, and 10; however, there were nine projects monitored by the previous contractor in Year 2 instead of Year 3. Sites are at different stages of the monitoring schedule depending on when they were implemented (Table 14).

Projects were initially selected for monitoring from those that had been funded but had not yet been implemented for the given baseline sampling year (Figure 6). All site selection and data collection prior to 2017 were conducted by the previous contractor (Tetra Tech 2016). Study sites ranged from 2.6 m to 135.6 m in average wetted width and in elevation from 2 m to 957 m. Annual precipitation at sites varied from 56 cm to 256 cm per year and dominant geology was either sedimentary or volcanic (Table 15). Floodplain enhancement techniques varied across projects. For example, side channel creation and/or levee removal were used in order to reconnect floodplain habitats (Table 16; Figure 7). Control reaches were selected with assistance from project sponsors and regional experts (Figure 7). Selection of adequate controls is critical to account for natural variability in riparian and stream habitat that is occurring throughout a stream and not related to project implementation. In 2017, three projects were contracted for monitoring, though only one was sampled. Monitoring was not completed for 06-2190 Riverview Park or 12-1438 Lower Nason Creek due to inadequate pairing of impact and control reaches (Table 17).

Field Methods

The SRFB monitoring program uses field sampling indicators and techniques that were adapted from U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program (Lazorchak et al. 1998; Peck et al. 2003). Specific indicators and protocols were developed in 2003 by the SRFB and modified in 2008 and 2010 by Tetra Tech (Washington Salmon Recovery Funding Board 2003; Tetra Tech 2009; Tetra Tech 2012). In 2010, the two floodplain project types, MC-5 constrained channel and MC-6 channel connectivity, were combined into the single category MC-5/6 floodplain enhancement. The MC-5 protocol did not collect fish or riparian data and the MC-6 protocol did not collect channel constraints. Because of these protocol differences, not all projects have data of all response metrics. The detailed protocol used to monitor these projects is Crawford (2011) MC-5/6 Floodplain Enhancement Projects and can be found at monitoringmethods.org (e.g., SRFB – Protocol for Monitoring Effectiveness of Floodplain Enhancement Projects). The protocol includes goals and objectives for the monitoring category, success criteria, detailed field data collection descriptions, functional assessment methods, summary statistics, and data analysis procedures. Here we provide a summary but refer readers to Crawford (2011) for details.

Table 14. Monitoring schedule for floodplain enhancement projects. Light grey are years that were not monitored due. Cramer Fish Sciences took over monitoring in 2017.

Site Number	Site Name	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
02-1561CC	Edgewater Park	Yr 0	Yr 1	Yr 2			Yr 5					Yr 10				
02-1625	SF Skagit Levee Setback	Yr 0	Yr 1		Yr 3		Yr 5					Yr 10				
04-1461	Dryden		Yr 0		Yr 1	Yr 2			Yr 5					Yr 10		
04-1563	Germany Creek					Yr 0	Yr 1	Yr 2			Yr 5					Yr 10
04-1573	Lower Washougal		Yr 0		Yr 1	Yr 2			Yr 5					Yr 10		
04-1596	Lower Tolt River		Yr 0	Yr 0*			Yr 1		Yr 3		Yr 5					Yr 10
05-1398	Fenster Levee			Yr 0			Yr 1		Yr 3		Yr 5					Yr 10
05-1466	Lower Boise Creek			Yr 0					Yr 1		Yr 3		Yr 5			Yr 8
05-1521	Raging River			Yr 0	Yr 1		Yr 3		Yr 5					Yr 10		
05-1546	Gagnon			Yr 0	Yr 1	Yr 2			Yr 5					Yr 10		
06-2190	Riverview Park				Yr 0						Yr 1	Yr 2			Yr 5	
06-2223	Greenwater River				Yr 0				Yr 1		Yr 3		Yr 5			Yr 8
06-2239CC	Fender Mill - Methow				Yr 0			Yr 1	Yr 2			Yr 5				Yr 9
06-2250	Chinook Bend				Yr 0		Yr 1		Yr 3		Yr 5					Yr 10
06-2277	Upper Klickitat				Yr 0				Yr 1	Yr 2			Yr 5			Yr 8
07-1519	Reecer Creek					Yr 0			Yr 1		Yr 3		Yr 5			Yr 8
07-1691	Lockwood Creek					Yr 0	Yr 1	Yr 2			Yr 5					Yr 10
10-1765	Eschbach Park										Yr 0	Yr 1		Yr 3		Yr 5
11-1354	Lower Dosewallips										Yr 0		Yr 0*		Yr0**	
12-1307	Billy's Pond										Yr 0			Yr 1		
12-1438	Lower Nason											Yr 0	Yr 1		Yr 3	
12-1657	George Creek										Yr 0	Yr 1		Yr 3		Yr 5
Tucannon PA 26	Tucannon PA 26										Yr 0	Yr 1		Yr 3		Yr 5

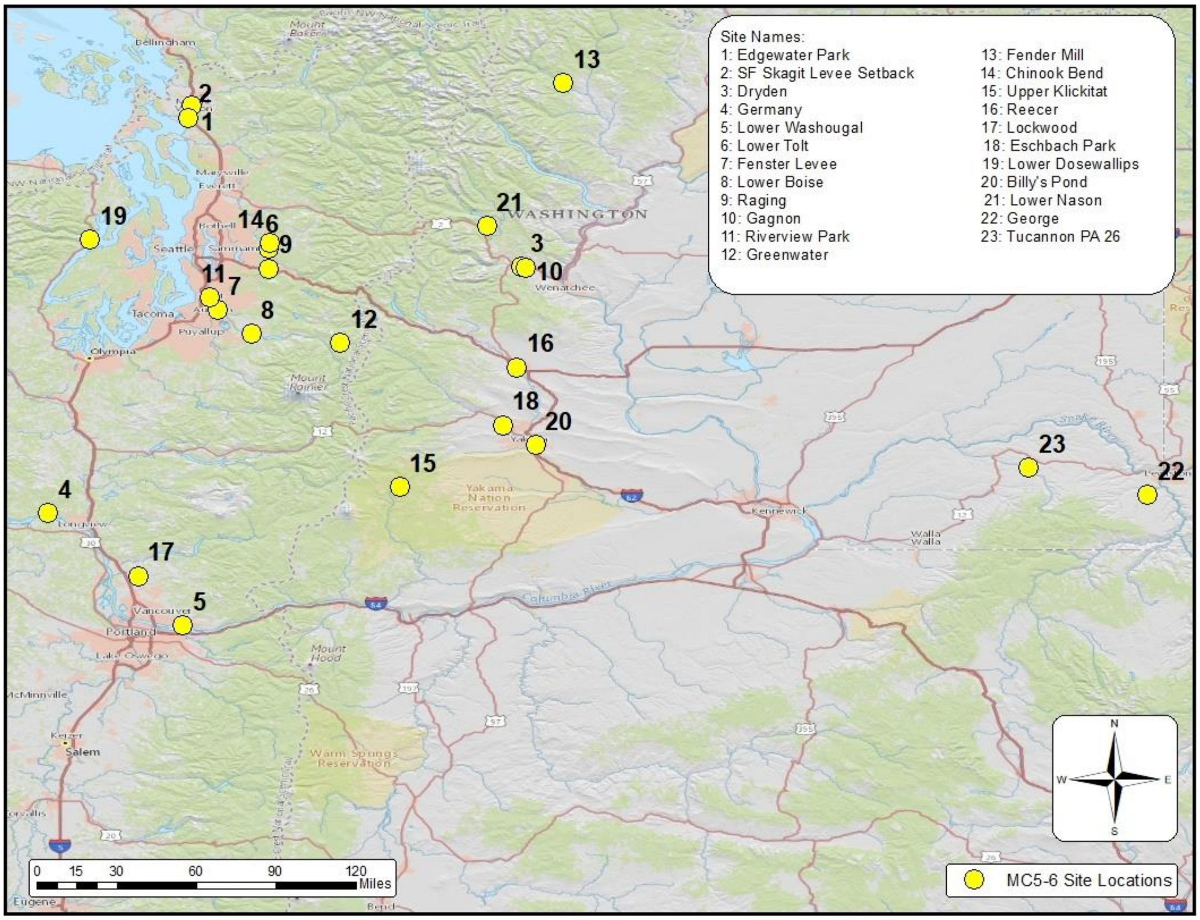

Figure 6. Floodplain project locations monitored throughout Washington. 11-1354 Lower Dosewallips was sampled in 2017.

Table 15. Physical characteristics of floodplain project study sites. Several sites are scheduled for monitoring in 2018. Site lengths are determined from the latest monitoring year if lengths varied between years. Geology is dominant geology (unpublished Washington State Department of Ecology) where Sed. = sedimentary and Vol. = volcanic. Average annual precipitation was obtained from the USGS StreamStats Program (https://water.usgs.gov/osw/streamstats/). Bankfull width is from the most recent year of data collection of the impact reach. n/a = data was not collected.

Site ID	Site Name	Original Protocol	County	Basin	Year 0	Geology	Site Elev (m)	Precip (cm/yr)	Bankfull Width (m)	Impact Site Length (m)	Control Site Length (m)
02-1561CC	Edgewater Park	MC-6	Skagit	Skagit	2004	Sed.	5	256.5	10.6	318	220
02-1625	SF Skagit Levee Setback	MC-5	Skagit	Skagit	2004	Sed.	3	78.7	146.6	500	500
04-1461	Dryden	MC-6	Chelan	Wenatchee	2005	Sed.	271	171.5	n/a	175	150
04-1563	Germany Creek	MC-6	Cowlitz	Germany	2008	Vol.	9	208.3	2.6	160	160
04-1573	Lower Washougal	MC-6	Clark	Washougal	2005	Sed.	5	236.7	40.7	160	500
04-1596	Lower Tolt River	MC-5	King	Snoqualmie	2005	Sed.	18	216.9	43.1	500	500
05-1398	Fenster Levee	MC-5	King	Green	2006	Sed.	17	184.2	43.4	180	180
05-1466	Lower Boise Creek	MC-5	King	White	2006	Sed.	195	149.6	12.3	200	200
05-1521	Raging River	MC-5	King	Snoqualmie	2006	Sed.	116	200.2	18.6	500	500
05-1546	Gagnon	MC-6	Chelan	Wenatchee	2006	Sed.	256	170.2	n/a	200	150
06-2190	Riverview Park	MC-6	King	Green	2008	Sed.	7	179.8	11.0	230	350
06-2223	Greenwater River	MC-5	Pierce	White	2007	Sed.	655	243.1	15.3	430	430
06-2239CC	Fender Mill	MC-6	Okanagan	Methow	2007	Sed.	585	113.5	5.0	150	150
06-2250	Chinook Bend	MC-5	King	Snoqualmie	2007	Sed.	14	250.7	97.1	500	500
06-2277	Upper Klickitat	MC-6	Yakima	Klickitat	2007	Vol.	957	158.2	8.0	150	150
07-1519	Reecer Creek	MC-5	Kittitas	Yakima	2008	Sed.	463	43.2	23.7	170	170
07-1691	Lockwood Creek	MC-6	Clark	Lewis	2008	Sed.	15	159.3	4.5	150	150
10-1765	Eschbach Park	MC-5/6	Yakima	Yakima	2013	Sed.	398	136.9	116.6	173	189
11-1354	Lower Dosewallips	MC-5/6	Kitsap	Dosewallips	2013	Sed.	2	227.6	42.1	500	500
12-1307	Billy's Pond	MC-5/6	Yakima	Yakima	2013	Sed.	300	100.1	102.7	141	124
12-1438	Lower Nason Creek	MC-5/6	Chelan	Wenatchee	2014	Sed.	601	172.5	4.3	591	577
12-1657	George Creek	MC-5/6	Asotin	Asotin	2013	Sed.	372	56.1	13.6	159	203
Tucannon PA 26	Tucannon PA 26	MC-5/6	Columbia	Tucannon	2013	Sed.	427	75.2	17.3	350	398

Table 16. Description of treatments implemented at each project and which sites were sampled in 2017. 06-2190 Riverview Park and 12-1438 Lower Nason projects were dropped because of issues with treatment or controls. Target salmonid species were Chinook Salmon for the Tucannon sites, and Chinook, Coho, steelhead, and other salmonids present for all other sites.

Site ID	Site Name	Original Protocol	Next Sampling Year	Description
02-1561CC	Edgewater Park	MC-6	Completed (2014)	Side channel creation and LWD placement on Skagit River in Mt. Vernon, WA
02-1625	SF Skagit Levee Setback	MC-5	Completed (2014)	Levee setback near Conway, WA; tidally influenced
04-1461	Dryden	MC-6	Completed (2016)	Off-channel ponds at river mile 15 on the Wenatchee River
04-1563	Germany Creek	MC-6	2018	Off-channel rearing habitat in Lower Columbia
04-1573	Lower Washougal	MC-6	Completed (2016)	Convert gravel quarries to off-channel habitat near Camas, WA
04-1596	Lower Tolt River	MC-5	2018	Levee removal near Carnation, WA
05-1398	Fenster Levee	MC-5	2018	Levee setback on Green River in Auburn, WA
05-1466	Lower Boise Creek	MC-5	2018	Relocation of confined channel at confluence with White River
05-1521	Raging River	MC-5	Completed (2016)	Levee removal near Preston, WA
05-1546	Gagnon	MC-6	Completed (2016)	Creation of off-channel pond on Wenatchee River
06-2190	Riverview Park	MC-6	2017	Side channel creation project on Green River in Kent, WA
06-2223	Greenwater River	MC-5	2018	Levee removal and ELJ placement
06-2239CC	Fender Mill	MC-6	Dropped (2014)	Dike/road removal and side channel initiation on Upper Methow River
06-2250	Chinook Bend	MC-5	2018	Levee removal on Snoqualmie River near Carnation River confluence
06-2277	Upper Klickitat	MC-6	2018	Side channel reconnection on Klickitat River
07-1519	Reecer Creek	MC-5	2018	ELJ's and rock placement in reconnected floodplain channel in Reecer Creek
07-1691	Lockwood Creek	MC-6	2018	Off-channel creation near La Center, WA
10-1765	Eschbach Park	MC-5/6	2018	Side channel creation on Naches River
11-1354	Lower Dosewallips	MC-5/6	2017/18	Levee removal ELJ construction and riparian planting on the Lower Dosewallips River
12-1307	Billy's Pond	MC-5/6	2018	Off-channel pond reconnection on Yakima River in Yakima, WA
12-1438	Lower Nason Creek	MC-5/6	2017/18	Floodplain fill removal and oxbow enhancement on Lower Nason Creek
12-1657	George Creek	MC-5/6	2018	Channel remeander and floodplain connection in Asotin County
Tucannon PA 26	Tucannon PA 26	MC-5/6	2018	Levee removal and LWD placement on Tucannon River

MC-5: no fish or riparian data collected, except for 05-1466
MC-6: no channel constraints data collected

(a) (b) (c) (d)

Figure 7. Impact (left) and control (right) reaches for (a) 04-1596 Lower Tolt, (b) 06-2223 Greenwater River, (c) 06-2277 Upper Klickitat, and (d) 07-1519 Reecer Creek.

Table 17. Floodplain enhancement projects contracted for monitoring in 2017, whether they were sampled, and why they were dropped from sampling if it was not conducted.

Site ID	Site Name	Monitoring Year	Sampled	Notes
11-1354	Lower Dosewallips	Year 0**	Yes	Project has not been implemented; A third year of pre-project data was collected
06-2190	Riverview Park	Year 5	No	Site dropped because poor control and impact reach comparison (side channel vs. main channel Green River); dry side channel
12-1438	Lower Nason Creek	Year 3	No	Site dropped because poor control and impact reach comparison

Site Layout

Once impact and control reaches were selected, the total reach length was calculated using bankfull measurements in the impact reach (Crawford 2011). Five bankfull measurements were recorded and averaged around the center of the reach (X-site). The total reach length was calculated by multiplying the mean bankfull width by twenty (minimum of 150 m and maximum of 500 m). This same reach length was then to be used for the control reach and was to remain the same for each year of monitoring; however, there were several projects monitored by the previous contractor where reach lengths varied among years and were different between the control and impact reaches of the same project. Once a site length was calculated, the reach layout was completed by location Transects A-K (Figure 8). Transects were placed at a distance of one-tenth the average bankfull widths (i.e., if a reach length is 150 m, the distance between transects will be 15 m).

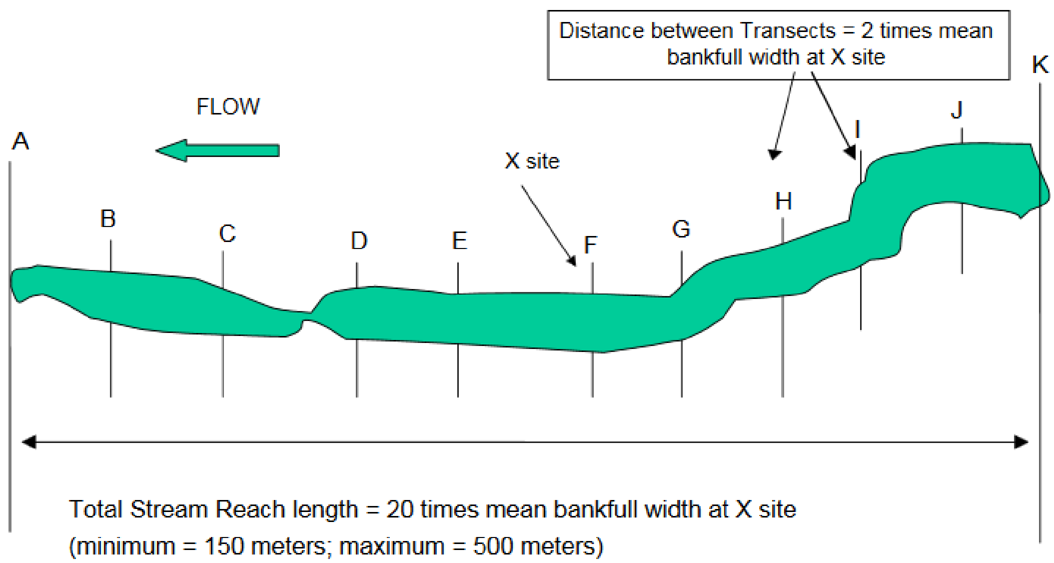

Figure 8. Project reach layout as adopted from Crawford (2011).

Habitat Surveys

Channel Constraints

Channel constrains were evaluated along the entire stream reach to assess if constraints were reduced following project implementation (Crawford 2011). First, the stream channel was classified as either predominantly single channel, anastomosing channel, or braided channel. It was then determined whether the channel was either 1) constrained within a narrow valley, 2) constrained by local features within a broad valley, 3) free to move about but within a relatively narrow valley floor, or 4) unconstrained and free to move about within a broad floodplain. Constraining features were recorded as bedrock, hillslopes, terraces/alluvial fans, and human use (e.g., road, dike, landfill, riprap, etc.).

The percent of the channel margin in contact with constraining features was estimated and the height of the constraining feature measured as the vertical distance from the wetted edge to the top of the constraining feature (Figure 9). At Transects A, F, and K, bankfull depth, bankfull height, and the floodprone width were measured. Bankfull width was also measured at each of the 21 transects (11 primary, 10 intermediate) and the entire valley width was measured. Channel constraint measurements were then used to calculate average channel capacity in the reach (Crawford 2011).

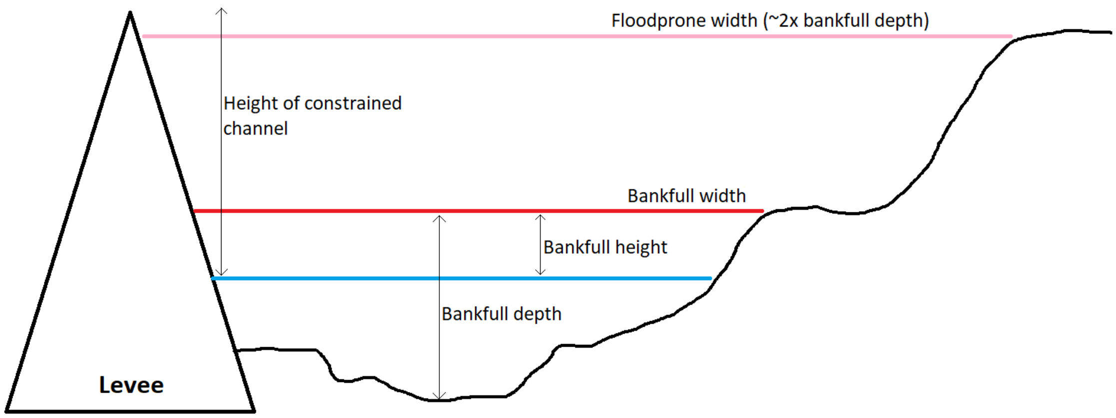

Figure 9. Channel survey measurements for channel constraints as adopted from Crawford (2011).

Riparian Vegetation Structure

At both the right and left banks at each Transect A-K, a plot measuring 5 m upstream and downstream and a distance of 10 m back from the stream bank, into the riparian vegetation, was estimated. This results in a 10 m by 10 m survey area on both banks at each transect. Within the area, vegetation was visually divided into three distinct layers: the canopy layer (>5 m high), the understory layer (0.5 to 5 m high), and the ground cover layer (<0.5 m high) (Crawford 2011).

Within the canopy layer, the dominant vegetation type was first determined as either deciduous, coniferous, broadleaf evergreen, mixed, or none. The aerial cover of large trees (>0.3 m diameter breast height (DBH)) and small trees (<0.3 m DBH) was also visually estimated in the canopy layer. Aerial cover was determined as the amount of shadow that would be cast by that particular layer of the riparian zone if the sun was directly overhead. Cover percentages were grouped into varying cover classes (0 = absent or 0%, 1 = <10%, 2 = 10%-40%, 3 = 40%-75%, or 4 = >75%) (Crawford 2011).

The dominant vegetation type was also determined in the understory layer as done in the canopy (Crawford 2011). In the understory and ground cover layers, aerial cover class was determined for woody shrubs and non-woody vegetation rather than large and small trees as was done in the canopy layer. Cover percentages were grouped similarly to the canopy layer. Finally, in the ground cover layer, cover was also estimated for bare ground and duff. All steps were repeated on the right and left bank at each transect.

Riparian vegetation structure was then summarized for analysis as the proportion of each reach containing all three layers of riparian vegetation (canopy, understory, and ground cover). A layer was counted as containing riparian vegetation if either of the two vegetation types (canopy: small or large trees; understory/ground: woody and non-woody vegetation) were present (greater than 0%). The percentage of the 22 possible locations (right and left bank at Transects A-K) in the reach that had each of the three layers of riparian vegetation present was then calculated. If any layer at a measurement location was absent, this location did not contribute to the percentage of riparian vegetation structure within the reach.

Canopy Cover Density

Canopy cover was determined at each Transect A-K using a convex spherical densiometer. The densiometer was taped so that there was a "V" at the bottom and there were 17 visible grid intersections (Mulvey et al. 1992; Figure 10). Six measurements were taken at each transect: four from mid-channel (facing upstream, river left, downstream, and river right) and one at each wetted edge facing away from the main channel. The densiometer was held level at 0.3 m above the water level with the recorder's face just below the apex of the taped "V". The number of grid intersection points that were covered by a tree, leaf, high branch, or any other shade providing feature (i.e., reed canary grass *Phalaris arundinacea*, river bank, bridge or other fixed structure) was counted. The value (0-17) was then recorded. For each project and within each reach, canopy cover density was averaged across all transects, for measurements taken on the right and left banks only, to get a mean value for each monitoring year. The mean canopy cover density from each year of monitoring was then used in the statistical analysis (Crawford 2011).

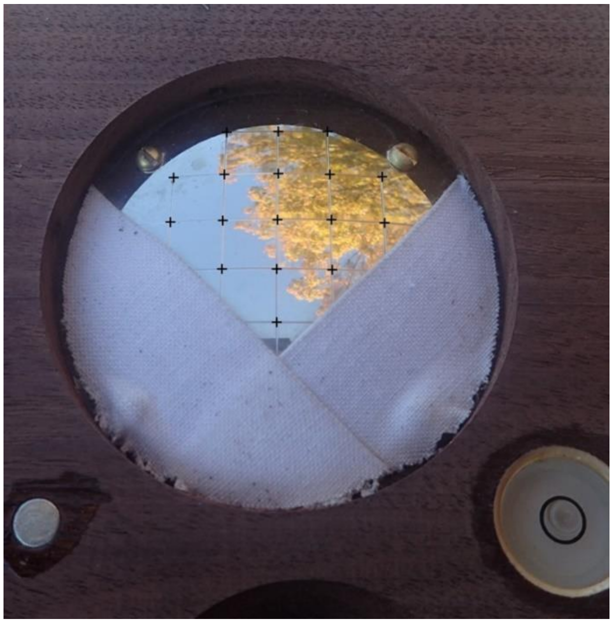

Figure 10. Imagine of modified densiometer reading and the remaining 17 grid intersections. In this example, 12 of the 17 intersections show canopy cover, giving a densiometer reading of 12.

Characterizing Stream Morphology

A longitudinal thalweg profile survey was used to classify residual water depth, habitat type (pool, riffle, glide, etc.), presence of soft/small sediment (<16 mm) deposits, and off-channel habitat at 100 equally spaced intervals along the thalweg between the top and bottom of the sampling reach (Crawford 2011). Wetted widths were also measured at 21 equally spaced cross-sections (at 11 regular Transects A through K, plus 10 supplemental cross-sections spaced mid-way between each of these). For each pool encountered along the thalweg, the pool-tail crest depth and maximum pool depth were measured and maximum pool width was also measured. If a side channel was present and contained between 16 and

49% of the total flow, secondary cross-section transects were established and wetted widths were measured. From the longitudinal profiles, we calculated the average reach width and thalweg length, the mean residual pool vertical profile area, and the mean residual depth.

Slope and Bearing

The water surface slope and bearing between each transect (A-K) was measured to be used to calculate residual depth and volume in each reach (Crawford 2011). Residual pool volume is the amount of water that would remain in the pools if there were not flow and the pools were impermeable basins. One surveyor stood at the wetted edge of the downstream transect with a stadia rod at a known height. The other surveyor stood on the same bank at the next immediate upstream transect. Using a laser range finder at a known height, the upstream surveyor shot to the downstream transect and recorded the vertical and horizontal difference in order to calculate the slope between the two transects. Standing mid-channel at the upstream transect, the bearing to the downstream transect at mid-channel was recorded. If there was a meander bend and a full line of sight was not available between transects, a supplementary slope and bearing was recorded between transects (Crawford 2011).

Topographic Surveys

Beginning in 2012, the previous contractor selected new and old projects to collect topographic data using methodology adopted from the Columbia Habitat Monitoring Program and available at monitoringmethods.org (e.g., Scientific Protocol for Salmonid Habitat Surveys within the Columbia Habitat Monitoring Program) (CHaMP 2013; Table 18). The River Bathymetry Toolkit console was also integrated into data processing to produce EMAP metrics that are compatible with the SRFB Program protocol for consistent metrics for use in data analysis (McKean et al. 2009).

Table 18. Project sites and topographic survey monitoring status.

Site Number	Site Name	Topo Implemented	Monitoring Year Implemented
02-1561CC	Edgewater Park	No	n/a
02-1625	SF Skagit Levee Setback	No	n/a
04-1461	Dryden	No	n/a
04-1563	Germany Creek	2013	Year 5
04-1573	Lower Washougal	No	n/a
04-1596	Lower Tolt River	2013	Year 5
05-1398	Fenster Levee	2013	Year 5
05-1466	Lower Boise Creek	2013	Year 3
05-1521	Raging River	No	n/a
05-1546	Gagnon	No	n/a
06-2190	Riverview Park	2013	Year 1
06-2223	Greenwater River	2013	Year 3
06-2239CC	Fender Mill	No	n/a
06-2250	Chinook Bend	2013	Year 5
06-2277	Upper Klickitat	No	n/a
07-1519	Reecer Creek	2013	Year 3
07-1691	Lockwood Creek	2013	Year 5
10-1765	Eschbach Park	2013	Year 0
11-1354	Lower Dosewallips	2013	Year 0
12-1307	Billy's Pond	2013	Year 0
12-1438	Lower Nason Creek	2013	Year 0
12-1657	George Creek	2013	Year 0
Tucannon PA 26	Tucannon PA 26	2013	Year 0

Fish Surveys

Snorkel surveys were conducted to quantify the number of fish in each impact and control reach during summer low flow (Crawford 2011). Two divers entered the downstream end of a reach and slowly moved upstream through each transect, stopping to occasionally relay the number, sizes, fish species, and observed micro-habitat characteristics (e.g., slow or fast water, off-channel or side channel habitat, large woody debris or boulder association). Only one snorkeler conducted the fish survey in streams smaller than 6 m wetted width and up to four snorkelers in larger streams. Fish length was visually estimated to the nearest 10 mm. Prior to fish surveys, stream temperature was measured, and visibility was recorded (low, medium, high).

Fish species encountered during snorkel surveys included several species of Pacific salmon *Oncorhynchus* spp., sculpin *Cottus* spp., sucker *Catostomus* spp., and dace *Rhinichthys* spp., as well as Threespine Stickleback *Gasterosteus aculeatus* and Mountain Whitefish *Prosopium williamsoni*. The analysis focused on juvenile (<250 mm) Coho Salmon, steelhead *O. mykiss*, and Chinook Salmon *O. tshawytscha* because these fish were the intended target species for the restoration projects (Crawford 2011).

Data Analysis Methods

All projects were evaluated together as a category to assess trends in indicator response from year to year and the change between pre-project (Year 0) and post-project (Year 1, 2, 3, 5, and 10) conditions. Because monitoring began in different years for projects, some do not have the full ten years of monitoring completed as of 2017; however, the analyses included all years of data collected through 2017 (Table 19). Thirteen sites were included in the data analysis and ten sites were excluded (Table 19). Statistical analysis was not conducted on individual projects.

Physical Habitat and Fish Density

We conducted two required basic statistical analyses described by Crawford (2011), previous annual reports (Tetra Tech 2016), and required under our contract. The required analyses include a mean difference analysis and a trend analysis to test whether projects were effective each monitoring year and remained effective through Year 10 (Crawford 2011).

For the mean difference method, the Year 0 values were compared to each year of post-project (Years 1, 3, 5, and 10) data using a paired one-sided *t*-test with $\alpha = 0.10$. If the data was not normally distributed, a paired one-sided nonparametric *t*-test (Wilcoxon) with $\alpha = 0.10$ was used. For each response variable, our unit of analysis was the paired difference between the impact reach compared to the control reach for each sample year. The null hypothesis is that the mean of the impact metrics across sites is equal to 0. This analysis was conducted on six habitat response variables (vertical pool area, mean residual depth, bank canopy cover, riparian vegetation structure, channel capacity, and floodprone width) and three fish response variables (juvenile Chinook Salmon, Coho Salmon, and steelhead densities). Year 0*, Year 0**, and Year 2 were not included in this first analysis because they were not described in Crawford (2011).

The protocol for floodplain enhancement projects also calls for a trend analysis where the slopes of linear trend lines through time (Year 0 to Year 10), for each indicator at each project site, were estimated. Then, using these slopes, a *t*-test or nonparametric equivalent (Wilcoxon) test with $\alpha = 0.10$ was to be used to test if the average of the slopes differed from 0 for each metric (Crawford 2011; Tetra Tech 2016; O'Neal et al. 2016). However, because many sites had only three years of data, we did not feel there was enough years of data to fit trend lines and complete this analysis.

Table 19. Floodplain projects and sampling years included in data analysis.

Site Number	Site Name	Year 0 Sampling	Original Protocol	Years included in analysis	Reason for full removal
02-1561CC	Edgewater Park	2004	MC-6	None	Reach locations changed since Year 0
02-1625	SF Skagit Levee Setback	2004	MC-5	0, 1, 3, 5, 10	
04-1461	Dryden	2005	MC-6	0, 1, 2, 5, 10	
04-1563	Germany Creek	2008	MC-6	None	Reach locations changed since Year 0
04-1573	Lower Washougal	2005	MC-6	0, 1, 2, 5, 10	
04-1596	Lower Tolt River	2006	MC-5	0, 1, 3, 5	
05-1398	Fenster Levee	2006	MC-5	0, 1, 3, 5	
05-1466	Lower Boise Creek	2006	MC-5	0, 1, 3, 5	
05-1521	Raging River	2006	MC-5	0, 1, 3, 5, 10	
05-1546	Gagnon	2006	MC-6	0, 1, 2, 5, 10	
06-2190	Riverview Park	2008	MC-6	None	Side channel vs. main channel comparison
06-2223	Greenwater River	2007	MC-5	0, 1, 3, 5	
06-2239CC	Fender Mill	2007	MC-6	None	Dropped by previous contractor due to project implementation issues
06-2250	Chinook Bend	2007	MC-5	0, 1, 3, 5	
06-2277	Upper Klickitat	2007	MC-6	None	Impact and control reach problems
07-1519	Reecer Creek	2008	MC-5	None	Impact and control reach problems
07-1691	Lockwood Creek	2008	MC-6	0, 1, 2, 5	
10-1765	Eschbach Park	2013	MC-5/6	None	Impact reach changed since Year 0
11-1354	Lower Dosewallips	2013, 2015, 2017	MC-5/6	None	No post-project data; not implemented
12-1307	Billy's Pond	2013	MC-5/6	None	Impact and control reach problems
12-1438	Lower Nason	2014	MC-5/6	None	Impact and control reach problems
12-1657	George Creek	2013	MC-5/6	0, 1, 3	
Tucannon PA 26	Tucannon PA 26	2013	MC-5/6	0, 1, 3	

Decision Criteria

An additional approach set by managers was used to examine project effectiveness based on minimum standards (Crawford 2011). The management decision criteria were set for each metric and include an evaluation of the percent change in the mean differences between impact and control reaches for each analyzed metric (Table 20).

The following equation was used to determine if a 20% change from baseline occurred for each project:

$$\%\ diff_{site:i,year:j} = \frac{Difference_{i,0} - Difference_{i,j}}{Difference_{i,0}}$$

Percent difference was determined for each site for a given year. Then the average percent difference for a given year was computed by taking the mean of all percent differences (all sites) for a given year:

$$\%\ AvDiff_{year:j} = mean(\%\ diff_{i,j})$$

Table 20. Decision criteria for habitat and fish metrics collected for floodplain enhancement projects.

Metric	Decision Criteria
Physical Habitat Metrics	
Vertical pool area (m^2)	Paired *t*-test for pre-project mean vs. each year of post-monitoring, α = 0.10 for one-sided test. Detect a ≥20% change between impact and control by Year 10.
Mean Residual Depth (cm)	Paired *t*-test for pre-project mean vs. each year of post-monitoring, α = 0.10 for one-sided test. Detect a ≥20% change between impact and control by Year 10.
Bank Canopy Cover (1-17)	Paired *t*-test for pre-project mean vs. each year of post-monitoring, α = 0.10 for one-sided test. Detect a ≥20% change between impact and control by Year 10.
Riparian Vegetation Structure (%)	Paired *t*-test for pre-project mean vs. each year of post-monitoring, α = 0.10 for one-sided test. Detect a ≥20% change between impact and control by Year 10.
Average Channel Capacity (m^2)	Paired *t*-test for pre-project mean vs. each year of post-monitoring, α = 0.10 for one-sided test. Detect a ≥20% decrease between Year 0 and Year 10.
Floodprone Width (m)	Paired *t*-test for pre-project mean vs. each year of post-monitoring, α = 0.10 for one-sided test. Detect a ≥20% increase between Year 0 and Year 10.
Juvenile Fish Abundance Metrics	
Chinook Salmon density (fish/m^2) Coho Salmon density (fish/m^2) Steelhead density (fish/m^2)	Paired *t*-test for pre-project mean vs. each year of post-monitoring, α = 0.10 for one-sided test. Detect a ≥20% increase between Year 0 and Year 10.

Results

Physical Habitat

There was a large amount of variability in the physical habitat metrics across all years of sampling and among projects and not all metrics were sampled in all years for all projects (see Appendices B and F). Analysis was only conducted if sample size (number of projects with suitable data) was five sites or higher. Relative to the control reach, vertical pool area increased significantly in Years 1 and 10 (P = 0.05), but not other years (P > 0.29), while residual pool depth increased in all years except Year 3 (P = 0.82) (Figure 11; Table 21). Bank canopy cover and riparian vegetation structure did not increase following treatment in any of the post-project years (P > 0.5) (Figure 11, 12; Table 21), though this could not be analyzed in Years 3 and 10 due to small sample sizes. Overall average channel capacity remained relatively stable following project implementation (Figure 12). Only Year 3 was significantly lower following project implementation when compared to Year 0 (P = 0.08) (Table 21). Average channel capacity could not be analyzed in Year 10 because the sample size was not large enough to run an analysis. Failure to reduce the average channel capacity would indicate that the project is not effectively functioning at increasing floodplain connection (Crawford 2011). While floodprone width decreases in Year 1 compared to Year 0, no statistical analysis was conducted because sample sizes with suitable data was less than five sites for all years (Figure 12; Table 21).

Floodplain enhancement projects were successful at meeting Crawford (2011) management decision criteria for success for vertical pool area and residual water depth for the latest sampling year with a large enough sample size (Year 10). However, projects have not yet met management targets for canopy cover, riparian vegetation structure, or average channel capacity by the latest sampling year with a large enough sample size (Table 22). Floodprone width was not assessed because samples sizes were too small for all sampling years.

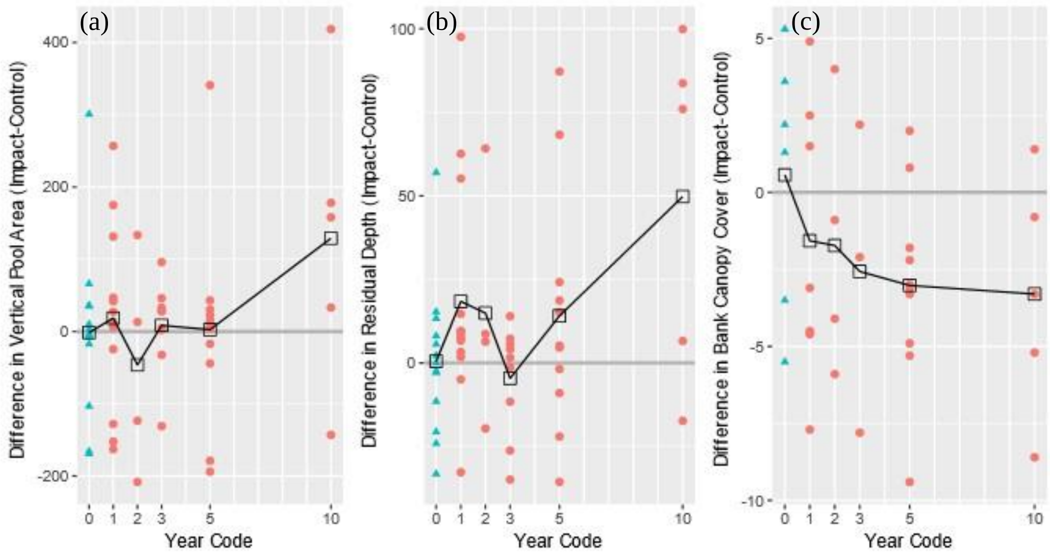

Figure 11. Mean difference for vertical pool area (a), mean residual depth (b), and bank canopy cover (c) between the control and impact reaches for floodplain enhancement projects. The blue triangles and red circles represent before and (Year 0) after monitoring data (Year > 0), respectively.

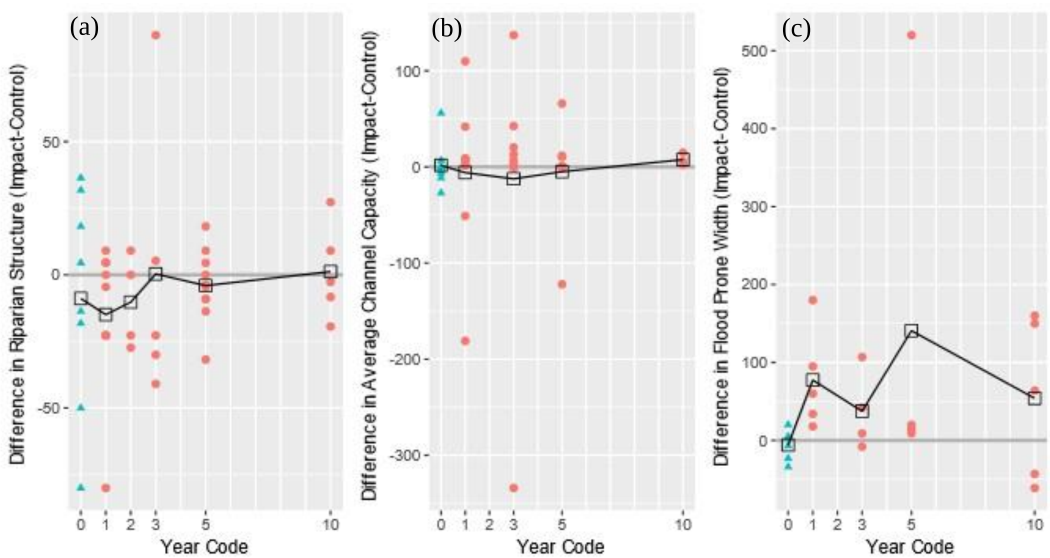

Figure 12. Mean difference for riparian vegetation structure (a), average channel capacity (b), and floodprone width (c) between the control and impact reaches for floodplain enhancement projects. The blue triangles and red circles represent before and (Year 0) after monitoring data (Year > 0), respectively.

Table 21. Summary results for paired one-tailed test of the difference between the impact and control reaches for six physical habitat metrics within floodplain enhancement projects. Bolded P-values indicate statistical significance (α = 0.10). Projects that had data collected in Year 2 were not included in this analysis (Crawford 2011). Statistical analysis was only performed if sample size (projects with suitable data) was 5 or higher (n/a).

Metric	Years Compared	Sample Size (sites)	Test	P-value
Vertical Pool Area (m^2)	0↔1	13	Paired Wilcoxon	**0.05**
	0↔3	9	Paired Wilcoxon	0.75
	0↔5	11	Paired Wilcoxon	0.29
	0↔10	5	Paired *t*-test	**0.05**
Mean Residual Depth (cm)	0↔1	13	Paired Wilcoxon	**0.01**
	0↔3	9	Paired Wilcoxon	0.82
	0↔5	11	Paired *t*-test	**0.09**
	0↔10	5	Paired *t*-test	**0.06**
Bank Canopy Cover (1-17)	0↔1	5	Paired *t*-test	0.70
	0↔3	0	n/a	n/a
	0↔5	5	Paired *t*-test	0.85
	0↔10	4	n/a	n/a
Riparian Vegetation Structure (%)	0↔1	7	Paired Wilcoxon	0.50
	0↔3	0	n/a	n/a
	0↔5	5	Paired *t*-test	0.77
	0↔10	4	n/a	n/a
Average Channel Capacity (m^2)	0↔1	9	Paired Wilcoxon	0.21
	0↔3	9	Paired Wilcoxon	**0.08**
	0↔5	7	Paired Wilcoxon	0.15
	0↔10	0	n/a	n/a
Floodprone Width (m)	0↔1	4	n/a	n/a
	0↔3	4	n/a	n/a
	0↔5	3	n/a	n/a
	0↔10	0	n/a	n/a

Table 22. Summary of floodplain enhancement project physical success based on management decision criteria outlined in Crawford (2011). Criteria were not assessed (n/a) if sample sizes were too small.

Metric	Year	*t*-test or Wilcoxon test met	% Change from Baseline
Vertical Pool Area (m^2)	Year 1	Yes	349
	Year 3	No	240
	Year 5	No	-90
	Year 10	Yes	315
Mean Residual Depth (cm)	Year 1	Yes	1,423
	Year 3	No	1,053
	Year 5	Yes	-1,263
	Year 10	Yes	2,355
Bank Canopy Cover (1-17)	Year 1	No	-50
	Year 3	n/a	n/a
	Year 5	No	-83
	Year 10	n/a	n/a
Riparian Vegetation Structure (%)	Year 1	No	-1
	Year 3	n/a	n/a
	Year 5	No	-11
	Year 10	n/a	n/a
Average Channel Capacity (m^2)	Year 1	No	746
	Year 3	Yes	176
	Year 5	No	83
	Year 10	n/a	n/a
Floodprone Width (m)	Year 1	n/a	n/a
	Year 3	n/a	n/a
	Year 5	n/a	n/a
	Year 10	n/a	n/a

Fish Densities

There was a large amount of variability in fish densities between control and impact reaches across all years and sites, with several sites having low densities of all three fish species or no fish present at all (see Appendices B, D, and F). Many sites had one or more fish species not present in all years of project monitoring and fish surveys were not conducted in all years of post-project monitoring completed to date, making sample sizes too small for analysis in Years 3 and 10. Chinook Salmon densities were lower in each year following project implementation and no significant response to restoration was detected in any post-project year of monitoring ($P > 0.57$) (Figure 13; Table 23). In contrast, Coho Salmon densities were higher in each year following project implementation and significant response to restoration was detected in Years 1 and 5 when compared to Year 0 ($P < 0.06$) (Figure 13; Table 23). Steelhead densities were higher in all post-project monitoring years except Year 1, though no significant response to restoration was detected (Figure 13; Table 23). Based on the management decision criteria for project success presented in Crawford (2011), by the latest sampling year with a large enough sample size, floodplain projects were effective in increasing Coho Salmon, though were not effective in increasing Chinook Salmon and steelhead densities (Table 24).

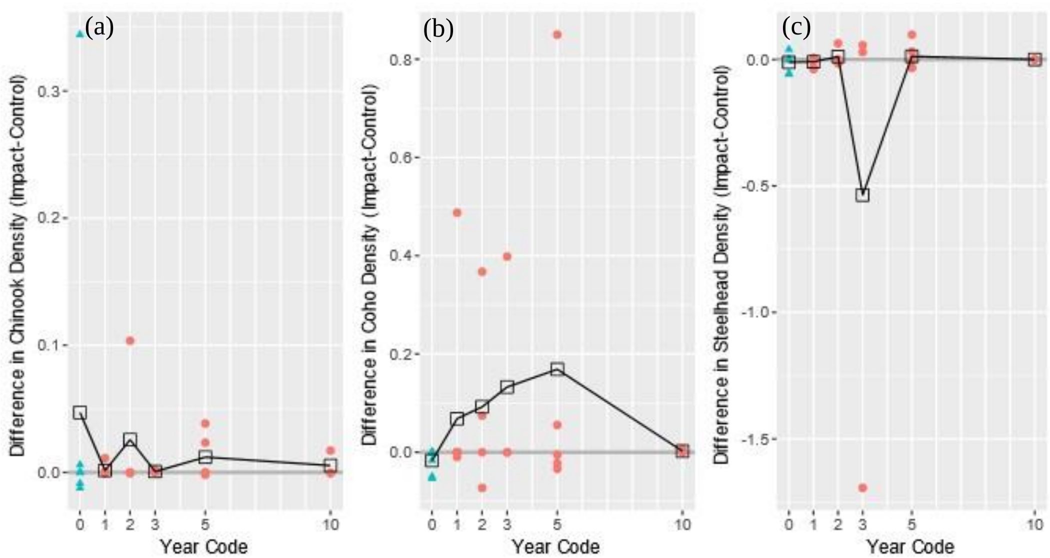

Figure 13. Mean difference for densities of Chinook Salmon (a), Coho Salmon (b), and steelhead (c) between the control and impact reaches for floodplain enhancement projects. The blue triangles represent pre-treatment monitoring data (Year 0) while the red circles represent post-treatment monitoring data (Year > 0).

Table 23. Summary results for paired one-tailed test of the difference between the impact and control reaches for juvenile fish densities within floodplain projects. Bolded P-values indicate statistical significance (α = 0.10). Projects that had data collected in Year 2 were not included in this analysis (Crawford 2011). Statistical analysis was only performed if sample size (projects with suitable data) was 5 or higher (n/a).

Metric	Years Compared	Sample Size (sites)	Test	P-value
Chinook Density (fish/m^2)	0↔1	7	Paired Wilcoxon	0.61
	0↔3	3	n/a	n/a
	0↔5	5	Paired Wilcoxon	0.57
	0↔10	3	n/a	n/a
Coho Density (fish/m^2)	0↔1	7	Paired Wilcoxon	**0.05**
	0↔3	3	n/a	n/a
	0↔5	5	Paired Wilcoxon	**0.06**
	0↔10	3	n/a	n/a
Steelhead Density (fish/m^2)	0↔1	7	Paired Wilcoxon	0.19
	0↔3	3	n/a	n/a
	0↔5	5	Paired Wilcoxon	0.22
	0↔10	3	n/a	n/a

Table 24. Summary results of the mean differences analysis and change detection results of fish densities based on decision criteria in Crawford (2011).

Metric	Year	*t*-test or Wilcoxon test met	% Change from Baseline
Chinook Density (fish/m^2)	Year 1	No	31
	Year 3	n/a	n/a
	Year 5	No	93
	Year 10	n/a	n/a
Coho Density (fish/m^2)	Year 1	Yes	47
	Year 3	n/a	n/a
	Year 5	Yes	1,781
	Year 10	n/a	n/a
Steelhead Density (fish/m^2)	Year 1	No	116
	Year 3	n/a	n/a
	Year 5	No	3,199
	Year 10	n/a	n/a

Discussion

A total of 23 floodplain enhancement projects were sampled over the entire monitoring schedule that began in 2004; thirteen projects were included in our analysis of floodplain enhancement projects as a category, though several metrics had a smaller sample size due to two different protocols (MC-5 and MC-6) being combined into one in 2010. Because only a handful of projects included data for Year 10, our analysis and results are preliminary. Results to date suggest floodplain projects are successfully increasing vertical pool area and residual pool depth by Year 10 (n = 5). Increases in vertical pool area and residual depth were expected and consistent with previous studies on floodplain enhancement (e.g., Morley et al. 2005; Weber et al. 2009; ISEMP 2013). Several projects also included the addition of large woody debris (LWD) within the project reach, which can be effective at increasing habitat heterogeneity and pool depth (Roni et al. 2008; Jones et al. 2014; Roni et al. 2015). Wood is an important component of channel structure and can have dramatic effects on channel pattern (Collins and Montgomery 2002); however, LWD was not monitored in floodplain enhancement project category (Crawford 2011).

Bank canopy cover has decreased over time since implementation with six out of nine projects with post-project data having a measured decrease in canopy cover in the most recent year of sampling when compared to Year 0. The results for riparian vegetation structure and bank canopy cover may have not shown significant increase due to the numerous project types (levee setback, floodplain reconnection, creation of floodplain, etc.) within the floodplain enhancement category and the many degrees to which construction may impact the riparian habitat. Some projects clear vegetation prior to a large levee removal or creation of a new channel, while other projects may experience little impact if the project involved reconnection of the main channel to an existing off-channel habitat. Additionally, several floodplain enhancement projects were paired with riparian plantings while others were not, which may lead to a more rapid response in some projects and not others. To date, there are only four floodplain projects with Year 10 data and five with Year 5 data included in the analysis. In addition, the current SRFB metrics require all three layers of riparian vegetation (canopy, understory, and ground cover) to be present in order to be counted as riparian structure (Crawford 2011), and thus may not be very sensitive to small changes in riparian cover and structure. More than ten years may be needed for some riparian plant species to reach the 5-m canopy height threshold required in the riparian vegetation structure metric of the protocol as well as to increase overall sample size. Therefore, it may not be surprising that significant differences in riparian structure have not yet been observed. Other metrics frequently used to monitor change in riparian vegetation due to floodplain restoration include ground cover, taxa richness and diversity, canopy heights, and overall riparian area (Pess et al. 2005). These metrics should be considered for monitoring changes in riparian conditions at future SRFB floodplain enhancement projects to capture more rapid change.

While there was some indication that floodprone width increased in Year 1 following project implementation, data were available for only three or four suitable projects in any given year, making analysis and interpretation of results difficult. An increase in floodprone width would indicate projects are increasing connectivity of the main channel to the floodplain and therefore increasing the amount of area engaged during high flow events. Because floodprone width was initially only measured in MC-5 projects, there were several projects without Year 0 data. As the connection with the floodplain increases, the average channel capacity is also expected to decrease (Crawford 2011), yet we did not see significant results for decreasing channel capacity. Average channel capacity should decrease once the constraining feature is removed, indicating that over bank flows will occur more frequently, and floodplain connection should be improved. As more time passes after implementation and more high flow events continue to engage and change the floodplain, it is possible that more projects will see a decrease in channel capacity.

Floodplain enhancement projects did not show any evidence of significant changes in Chinook Salmon or steelhead densities, while there were some positive results for Coho Salmon by Year 5. Levee removal/setback, new channel creation, channel reconnection, and channel remeandering has been shown to increase Chinook Salmon, Coho Salmon, and in some cases steelhead numbers, while improving the health and productivity of river ecosystems (Nickelson et al. 1992; Richards et al. 1992; Morley et al. 2005; Klein et al. 2007; Levell and Chang 2008; Hillman et al. 2016). Salmonids and other fishes rapidly colonize newly accessible habitats following floodplain habitat reconnection of critical rearing habitat (Sommer et al. 2001; Roni et al. 2008). Thus, the SRFB results in Year 5 for Coho Salmon are consistent with previous studies. The varying fish results detected at SRFB projects, particularly for Chinook Salmon, are likely due to low sample size (fish were not enumerated at all sites or years) and season sampled. They may also be reflective of high inter-annual variability in juvenile salmonid numbers, inconsistencies in season sampled, interproject variability, differences in species targeted for restoration, and control and impact reach inconsistencies.

There was high variability in fish use (densities) among sites and sampling years, which may be partly attributed to high variability in habitat conditions. While juvenile salmonid densities are driven in part by adult escapement and densities of salmonids varied among years and streams, the MBACI design in part accounts for this by examining the difference between paired treatment and controls in each site (stream). The purpose of the paired control is to help account for interannual variability in escapement and other environmental factors. However, the timing and consistency of fish sampling may have also added to the variability and reduced the likelihood of detecting differences. While the SRFB protocol calls for monitoring either at summer low flow or winter high flows, most projects were sampled between April and September, though the month and sometimes the season varied within and among projects. Consistent seasonal sampling and sampling for multiple life stages may help to increase detection of targeted species and other fish species. Many floodplain enhancement projects were constructed to increase and enhance winter spawning and rearing habitat for salmonids and would benefit from sampling during winter months presumably during winter low flow as sampling at winter high flows is generally not possible. The timing of the seasonal monitoring also needs to be confined to a smaller sample window, as fish surveys at several projects varied from May until December. Finally, multiple years of pre-project fish monitoring would help to distinguish project effects from natural baseline variability (Roni et al. 2005; O'Neal et al. 2016).

Based on the SRFB management targets (Crawford 2011), floodplain enhancement projects are not yet meeting minimum targets for success for many metrics. The mixed outcome for many of the floodplain enhancement project metrics suggests the need for more robust or nuanced statistical analyses. However, data for all physical habitat (vertical pool area, mean residual depth, bank canopy cover, riparian vegetation structure, average channel capacity, floodprone width) and fish metrics (Chinook and Coho Salmon, steelhead) were highly skewed and no transformation was adequate to meet assumptions of normality required to run a mixed effects BACI analysis. Several projects had to be dropped completely from analysis due to reach locations monitored shifting across years. Other projects had to be dropped from certain metric analysis due to inconsistencies in data values leading to large outliers (i.e., 06-2277 Upper Klickitat control reach – average channel capacity in Year 2 is 14,629 m^2 and in Year 5 is 4 m^2; 07-1519 Reecer Creek control reach – floodprone width in Year 0 is 2,500 m and in Year 5 is 11.5 m) and the merging of the MC-5 and MC-6 protocols leading to a lack of Year 0 values in certain metrics.

Some of the lack of response of both fish and physical habitat to SRFB floodplain enhancement projects monitored is likely due to inconsistencies in data collection and changes in protocols. Four of the six physical habitat metrics and the three fish density metrics were not initially collected in both floodplain protocols (MC-5 constrained channel and MC-6 channel connectivity) when the monitoring program began in 2004. Therefore, once the two protocols were combined in 2010 and projects were to be analyzed together, many projects were missing Year 0 metrics to compare to all post-project years (Table 25). The post-project sampling schedule was also different for both protocols where MC-5 was monitored in Years 1, 3, 5, and 10 and MC-6 in Years 1, 2, 5, and 10. Similar issues of data collection and consistency arose with the addition of topographic surveys under the combined MC-5/6 floodplain enhancement protocol. The topographic survey, which is an improvement over the original habitat survey protocol, provides a complete topographic map and allows calculation of changes in habitat conditions such as pool area and depth, channel capacity, volume of newly created habitat, and floodplain connectivity. However, the topographic survey was implemented after Year 0 on many projects, leaving few projects available to assess changes in newly created off-channel habitat or other floodplain topography metrics before and after restoration (see Table 18). Thus, the full benefit of the costlier and more detailed topographic surveys cannot be fully realized. Additionally, many of the projects that began monitoring after the two protocols were combined into MC-5/6, and would therefore have topographic data and many other metrics collected in Year 0, had to be excluded from the analysis due inconsistencies in impact and control reaches or other issues (see Table 19).

While the added topographic surveys attempt to capture the multitude of changes taking place throughout the floodplain, some surveys still did not capture the full extent of the floodplain and fish response in the entire reach (mainstem and side-channels). Floodplain enhancement projects should extend identification of channel physical habitat metrics and fish measurements beyond the main channel and should include the floodplain and all of its channels (Pess et al. 2005). We recommend monitoring an entire floodplain reach (main channel and side-channels) both before and after the restoration action to better capture changes in physical habitat and fish use. Several projects only monitored the created or enhanced side channel and not the main channel or other existing habitat (i.e., 04-1461 Dryden, 04-1563 Germany Creek, 05-1466 Lower Boise Creek, 05-1546 Gagnon, 06-2190 Riverview Park, 07-1519 Reecer Creek, 11-1354 Lower Dosewallips).

Using a BACI monitoring approach helps to account for environmental variability and temporal trends found in both impact and control reaches to better discern floodplain enhancement effects from natural variability (Underwood 1992; Roni et al. 2005). However, selection of appropriate controls is critical to increase the probability of detecting restoration response if one exists (Roni et al. 2013). A control reach should be selected to be as similar as possible in all respects to the impact reach and considered beyond the influence of the treatment (Downes et al. 2002). The underlying assumption is that the impact reach would have behaved approximately the same as the control reach in the absence of the floodplain enhancement (Underwood 1992). There were several sites in this study that had issues regarding the control reach selection and Year 0 monitoring, which could have ultimately masked significant results. Several projects included the creation a new channel in an area where no channel was previously located. These constructed floodplain habitats would also have immediate results following project implementation if Year 0 was sampled where the channel would be constructed because all values would be zero (02-1561 Edgewater Park, 04-1461 Dryden, 06-2190 Riverview Park). In contrast, other projects that included the construction of a new channel used an existing channel in Year 0 and post-project data was collected in the newly constructed channel, though the old channel that was still active (05-1466 Lower Boise Creek, 07-1519 Reecer Creek, 10-1765 Eschbach Park). Many other projects had poor impact and control reach comparisons, either by comparing a side channel to the mainstem or comparing a backwater alcove to a mainstem flow-through side-channel.

Stratifying sites by geographic or climatic region, channel size, target fish species, or other factors may help account for differences among floodplain enhancement sites. The geographic extent of sites in this monitoring program extended throughout Washington State and east and west of the Cascade Mountains where mean rainfall varied from 56 to 257 cm/yr. Vegetation type, growing season characteristics, fish species distribution and use, and regional weather patterns varied across this extent and could influence site specific results. Similarly, type of floodplain enhancement at the sites varied considerably. For example, 06-2250 Chinook Bend was a levee removal project on the Snoqualmie River intended to connect the river to the floodplain at lower flows than pre-project, targeting fall Chinook Salmon. The 05-1546 Gagnon project reconnected an isolated off-channel pond habitat, targeting spring Chinook Salmon, Coho Salmon, and steelhead. Stratifying by ecoregion or targeted fish species could help alleviate some of the influences these factors may have on the results and our understanding of the effectiveness of floodplain enhancement.

Table 25. Availability of Year 0 data for each floodplain enhancement project. Projects below the dark bar and shaded in grey have been dropped from the analysis (see Table 19). Y = Metric has Year 0 data for that project. D = Metric has Year 0 data for that project, but project was dropped from analysis.

Site Number	Site Name	Original Protocol	Pool Area	Residual Depth	Canopy Cover	Riparian Structure	Channel Capacity	Floodprone Width	Chinook Density	Coho Density	Steelhead Density	CHaMP Topo
02-1625	SF Skagit Levee Setback	MC-5	Y	Y	Y	Y	Y	Y	---	---	---	---
04-1461	Dryden	MC-6	Y	Y	Y	Y	---	---	Y	Y	Y	---
04-1573	Lower Washougal	MC-6	Y	Y	Y	Y	---	---	Y	Y	Y	---
04-1596	Lower Tolt River	MC-5	Y	Y	Y	Y	Y	---	---	---	---	---
05-1398	Fenster Levee	MC-5	Y	Y	---	---	Y	Y	---	---	---	---
05-1466	Lower Boise Creek	MC-5	Y	Y	---	---	Y	Y	Y	Y	Y	---
05-1521	Raging River	MC-5	Y	Y	---	---	Y	Y	---	---	---	---
05-1546	Gagnon	MC-6	Y	Y	Y	Y	---	---	Y	Y	Y	---
06-2223	Greenwater River	MC-5	Y	Y	---	---	Y	Y	---	---	---	---
06-2250	Chinook Bend	MC-5	Y	Y	---	---	Y	Y	---	---	---	---
07-1691	Lockwood Creek	MC-6	Y	Y	Y	Y	---	---	Y	Y	Y	---
12-1657	George Creek	MC-5/6	Y	Y	---	Y	Y	---	Y	Y	Y	Y
Tucannon PA 26	Tucannon PA 26	MC-5/6	Y	Y	---	Y	Y	---	Y	Y	Y	Y
02-1561CC	Edgewater Park	MC-6	D	D	D	D	---	---	D	D	D	---
04-1563	Germany Creek	MC-6	D	D	D	D	---	---	D	D	D	---
06-2190	Riverview Park	MC-6	D	D	D	D	---	---	D	D	D	---
06-2239CC	Fender Mill	MC-6	D	D	D	D	---	---	D	D	D	---
06-2277	Upper Klickitat	MC-6	D	D	D	D	---	---	D	D	D	---
07-1519	Reecer Creek	MC-5	D	D	---	---	D	D	---	---	---	---
10-1765	Eschbach Park	MC-5/6	D	D	D	D	---	---	D	D	D	D
11-1354	Lower Dosewallips	MC-5/6	D	D	D	D	D	D	D	D	D	D
12-1307	Billy's Pond	MC-5/6	D	D	D	D	D	D	D	D	D	D
12-1438	Lower Nason	MC-5/6	D	D	D	D	D	D	D	D	D	D

Previous studies have clearly demonstrated that it is possible to monitor and detect fish response to floodplain, instream and other restoration techniques (e.g., Swales and Levings 1989; Morley et al. 2006; Roni et al. 2008). However, the inconsistencies in data collection across years, including lack of fish and riparian data, sampling in different seasons, poorly matched impact and control reaches in some cases, and limitations of current protocols, likely prevented us from detecting a significant response to restoration. It could also be that some projects were not successful at improving habitat or fish numbers, but it is more likely that the monitoring was not adequate to detect a response to floodplain restoration rather than the restoration was not effective. Of the 15 floodplain enhancement sites scheduled for sampling in 2018, two have not been implemented, one control has been restored (impact), and five should be dropped because of clear problems with data in previous years or impact and control issues. That leaves seven projects, which would help increase samples sizes in Year 10 for some metrics, though fish data have not been collected on three of these seven projects. Because of these issues, and the low sample size (four projects), we do not recommend collecting data on the remaining floodplain projects scheduled for monitoring in 2018.

Future monitoring of floodplain enhancement projects should consider stratifying projects by ecoregion, seasonal fish sampling (summer, winter), more rigorous selection of treatment and controls, improved habitat survey methods, consistent seasonal sampling periods among sites and years, monitoring an entire floodplain reach rather than just the project location (e.g., constructed side-channel), and either collecting more pre-project data or using a post-treatment design.

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SUMMARY AND RECOMMENDATIONS

Summary of Results through 2017

Based on results to date, instream habitat (MC-2) and floodplain enhancement projects (MC-5/6) have shown significant improvements in instream habitat metrics of vertical pool area and mean residual depth. Biological responses have been modest, with only floodplain enhancement projects demonstrating increased juvenile Coho Salmon in Year 1 and Year 5. The physical habitat response and biological response in some years for floodplain enhancement projects are consistent with previous studies. However, it is surprising that there was not a stronger fish response for both project types and that there were not significant changes in floodprone width, channel capacity, and riparian metrics for floodplain enhancement projects. Data from ten floodplain enhancement projects and two instream projects were excluded from the analysis due to inconsistencies with impact or control reaches or data collection, or restoration of the control reach during post-project monitoring.

Recommendations for 2018

Ten MC-2 instream projects and 15 MC-5/6 floodplain enhancement projects are scheduled for sampling in 2018 (Table 26). After visiting the project sites in 2017 and reviewing and analyzing data from each site, we recommend discontinuing monitoring at three MC-2 projects in 2018. This is in addition to the handful of sites dropped from monitoring in 2017. An additional year of monitoring of instream habitat projects should help confirm some of these responses.

For MC-5/6 projects, because of inconsistencies in data collection across years, including lack of fish and riparian data, sampling in different seasons, poorly matched impact and control reaches in some cases, and limitations of current protocols, we do not recommend monitoring of the remaining MC-5/6 projects in 2018.

We examined three different statistical methods for analyzing the instream and floodplain data including: 1) a mean difference using paired *t*-tests or a non-parametric equivalent (Wilcoxon test), 2) a trend analysis using a *t*-test on the slopes of individual sites, and 3) a mixed-effects BACI model. These produced similar results, but given the monitoring design used by the SRFB, we have the most confidence in the paired *t*-test analysis. The *t*-test is a simple analysis, easily understood by managers, and is robust to minor violations of assumptions of normality. Moreover, we feel *t*-tests are the most appropriate analysis given that there is only one year of pre-project data. Thus, the final analysis in 2018 should focus on examining the response in Year 10 compared to Year 0, using a simple paired *t*-test.

Recommendations for Phase II

Programmatic project effectiveness monitoring has many benefits over traditional effectiveness monitoring, which has focused on individual restoration projects (Weber et al. 2017). The SRFB PE Program represents one of the few comprehensive long-term programmatic approaches to evaluating a regional restoration program ever implemented. It also has produced some useful results (O’Neal et al. 2016; Roni et al. 2017). However, programmatic effectiveness monitoring is not without challenges which include: selecting appropriate treatments and controls, selecting appropriate protocols and metrics, consistent data collection across years and crews, controlling restoration timing and location, data management, and others (Roni et al. 2017). The SRFB PE program has run into some of the challenges seen in other large monitoring programs (Bennett et al. 2016; Roni et al. 2017) including inconsistent protocols, poor pairing of treatments and controls, assuring control reaches are not treated, data management problems, and inconsistent or changing sampling protocols. Many of these are implementation or procedural rather than design issues, which have limited the usefulness of data and made detecting significant differences due to restoration difficult. These are all factors which need to be addressed when designing Phase II of PE. The lack of response seen in SRFB PE program to date should not be seen as evidence that fish or habitat responses to floodplain or instream habitat restoration measures can’t be measured, but rather the emphasize the importance of proper design and implementation of effectiveness monitoring.

The MBACI design has long been considered an optimal design for monitoring habitat change or evaluating restoration effectiveness (Downes et al. 2002; Roni 2005; Bennett et al. 2016), though it has rarely been implemented at a broad scale due to the cost, need for diligent project coordination and management, and the lengthy time frame needed to produce results. It is also difficult to change the program once it is initiated and, as suggested by the results of the SRFB PE program to date, it is critical that those selecting sites and collecting data understand the ramifications to the study design, results, and analysis of making changes to protocols, treatments and controls, or timing of sampling. Much of this can be overcome by diligent coordination and assuring that those who designed the program remain involved in data collection, analysis, and reporting. Some alternative designs, such as an extensive post-treatment (EPT) design, have been successfully used to evaluate restoration programs both in Europe and North America (Roni et al. 2017), but require a large population of completed projects with suitable controls to choose from. Some type of hybrid design, where many projects are monitored post-treatment and a handful of projects are monitored as BACI case studies, is probably most tractable and cost effective.

Before choosing a study design for Phase II of PE, we would recommend that the SRFB look at the scale of projects funded by the SRFB in recent years and proposed for 2018 and beyond. The original SRFB PE monitoring was designed back in 2003 when many projects were relatively small (100 to 1,000 m in length) and often included one or two techniques. These types of projects and their size lend themselves to the monitoring approach historically utilized by the SRFB. Based on our experience, the length (size) and complexity of floodplain projects in particular, has been increasing. It is not uncommon to see projects that cover several kilometers and incorporate riparian planting, instream structures, levee setbacks, side channel reconnection, and other techniques. Thus, monitoring a few hundred meters of the project area or monitoring each individual project component separately, will not tell one much about the effectiveness across the entire project area. We contend that newer, larger, and more complex restoration projects would be best monitored as reach-scale case studies at a handful of sites across the state. These could be evaluated using a simple before and after restoration design and modern remote sensing techniques (e.g., Lidar, drone-based aerial photography) combined with efficient sampling protocols (e.g., long-profiles, habitat surveys using RTK units, snorkel surveys, eDNA). This could be coupled with an EPT monitoring design to evaluate a subset of more traditional projects completed prior to 2018 that are less than a kilometer long and incorporate one or two simple techniques. Finally, the SRFB should consider what type of projects in what ecoregion are still in need of PE monitoring. Clearly, additional information is needed on floodplain, estuarine, and nearshore restoration projects, but additional monitoring of LWD placement, riparian fencing, barrier removal, and other categories may not be necessary.

Table 26. MC-2 instream projects and MC-5/6 floodplain enhancement projects scheduled for monitoring in 2018 and whether we recommend dropping the site from monitoring.

Site	Site Name	Protocol	Topo	Monitoring Year	Drop	Reason
02-1515	Upper Trout Creek	MC-2	No	Year 10	Yes	No Year 0 data was collected in the impact reach
04-1209IS	Chico Creek	MC-2	No	Year 10	No	
04-1660IS	Cedar Rapids	MC-2	No	Year 10	No	
07-1803	Skookum	MC-2	No	Year 9	No	
11-1315	Eagle Island	MC-2	No	Year 4	Yes	More placed LWD in control reach; boat access
Tucannon PA 3	Tucannon PA 3	MC-2	Yes	Year 5	No	
Tucannon PA 14	Tucannon PA 14	MC-2	Yes	Year 5	No	
Tucannon PA 26	Tucannon PA 26	MC-2 & MC-5/6	Yes	Year 5	No	
11-1354	Lower Dosewallips	MC-2 & MC-5/6	Yes	4th Year Pre	Yes	Project not yet implemented
12-1657	George Creek	MC-2 & MC-5/6	Yes	Year 5	No	
04-1563	Germany	MC-5/6	Yes	Year 10	Yes	Year 0 data was collected in a different location than post-project
04-1596*	Lower Tolt	MC-5/6	Yes	Year 10	No	
05-1398*	Fenster Levee	MC-5/6	Yes	Year 10	Yes	Levee was removed in the control reach after 2013 monitoring
05-1466	Lower Boise	MC-5/6	Yes	Year 8	No	
06-2223*	Greenwater	MC-5/6	Yes	Year 8	No	
06-2250*	Chinook Bend	MC-5/6	Yes	Year 10	No	Non-wadeable; will likely conduct bathymetry at site
06-2277	Upper Klickitat	MC-5/6	No	Year 8	Yes	Poor control vs. impact comparison
07-1519*	Reecer Creek	MC-5/6	Yes	Year 8	Yes	No fish data; poor control vs. impact comparison
07-1691	Lockwood Creek	MC-5/6	Yes	Year 10	No	
10-1765	Eschbach Park	MC-5/6	Yes	Year 5	Yes	Year 0 data was collected in a different location than post-project
12-1307	Billy's Pond	MC-5/6	Yes	Year 5	Yes	Non-wadeable
12-1438	Lower Nason	MC-5/6	Yes	Year 4	Yes	Poor control vs. impact comparison

* Sites do not have Year 0 fish data

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APPENDIX A: MC-2 METRIC DATA

Table A-1. Difference in average vertical pool area (m^2) between impact and control reach for all sampling years for instream projects. Missing values were not measured in that year of sampling for a particular site.

Site Number	Site Name	Year 0	Year 0*	Year 1	Year 2	Year 3	Year 5	Year 10
02-1444	Little Skookum Valley	-11.9	---	-15.1	---	-4.5	2.6	-1.0
02-1463	Salmon Creek	4.9	---	7.9	---	11.3	18.2	18.5
02-1515*	Upper Trout Creek	---	---	57.1	---	63.1	49.4	---
02-1561IS*	Edgewater Park	0.0	---	21.7	---	25.9	24.2	11.3
04-1209IS	Chico Creek	-7.7	-13.8	-3.3	---	-3.6	-11.5	---
04-1338	Lower Newaukum	17.7	---	17.7	---	-0.6	3.3	14.4
04-1448	PUD Bar Habitat	29.0	---	95.0	---	103.4	96.1	154.3
04-1575	Upper Washougal	-42.6	---	-6.1	---	9.7	34.0	-15.4
04-1589	Dungeness River	-12.3	-16.5	88.0	---	26.3	46.9	---
04-1660IS	Cedar Rapids	84.8	48.8	57.6	---	160.4	46.4	---
05-1533	Doty Edwards	-6.4	---	-6.8	---	3.8	-3.4	-13.8
07-1803	Skookum Reach	-90.8	---	-73.0	---	-78.6	-89.6	---
11-1315	Eagle Island	11.3	---	-5.9	---	5.8	---	---
11-1354*	Lower Dosewallips	65.0	151.1	---	---	---	---	---
12-1334*	Elochoman	-7.9	---	---	---	---	---	---
12-1657	George Creek	-6.3	---	9.7	---	5.0	---	---
SF-F3 P2BR	SF Asotin Creek Lower 1	9.5	---	-9.5	---	6.2	---	---
SF-F3 P3BR	SF Asotin Creek Lower 2	-5.5	---	-7.2	---	5.0	---	---
SF-F4 P1	SF Asotin Creek Upper 1	-4.9	---	-0.7	---	0.7	-2.9	---
SF-F4 P2	SF Asotin Creek Upper 2	-5.6	---	-1.4	---	-3.4	-2.8	---
Tucannon PA 14	Tucannon PA 14	1.9	---	6.5	-3.3	2.0	---	---
Tucannon PA 26	Tucannon PA 26	-3.5	---	27.2	---	46.2	---	---
Tucannon PA 3	Tucannon PA 3	1.3	---	10.1	3.4	9.2	---	---

* denotes sites that were not included in analysis.

Table A-2. Difference in mean residual depth (cm) between impact and control reach for all sampling years for instream projects. Missing values were not measured in that year of sampling for a particular site.

Site Number	Site Name	Year 0	Year 0*	Year 1	Year 2	Year 3	Year 5	Year 10
02-1444	Little Skookum Valley	-7.9	---	-10.1	---	-3.0	-2.3	-2.8
02-1463	Salmon Creek	2.4	---	4.4	---	6.3	10.1	10.3
02-1515*	Upper Trout Creek	---	---	7.6	---	8.4	2.2	---
02-1561IS*	Edgewater Park	0.0	---	6.8	---	8.2	1.6	3.5
04-1209IS	Chico Creek	-3.1	-5.5	-1.3	---	-1.5	-4.6	---
04-1338	Lower Newaukum	8.1	---	8.1	---	-0.3	1.5	6.5
04-1448	PUD Bar Habitat	9.1	---	29.7	---	32.3	30.0	48.2
04-1575	Upper Washougal	-8.5	---	-1.2	---	1.9	6.8	-3.1
04-1589	Dungeness River	-2.5	-3.3	15.4	---	4.8	8.7	---
04-1660IS	Cedar Rapids	17.0	9.8	11.8	---	32.1	15.1	---
05-1533	Doty Edwards	-8.1	---	-13.5	---	1.3	-13.7	-4.6
07-1803	Skookum Reach	-18.2	---	-14.6	---	-15.7	-17.9	---
11-1315	Eagle Island	7.9	---	-2.6	---	3.6	---	---
11-1354*	Lower Dosewallips	11.7	24.6	---	---	---	---	---
12-1334*	Elochoman	-1.1	---	---	---	---	---	---
12-1657	George Creek	-2.4	---	7.4	---	4.1	---	---
SF-F3 P2BR	SF Asotin Creek Lower 1	4.8	---	-5.1	---	4.4	---	---
SF-F3 P3BR	SF Asotin Creek Lower 2	-2.8	---	-3.9	---	2.7	---	---
SF-F4 P1	SF Asotin Creek Upper 1	-3.0	---	-0.1	---	1.0	-1.2	---
SF-F4 P2	SF Asotin Creek Upper 2	-3.8	---	-0.4	---	-1.5	-0.8	---
Tucannon PA 14	Tucannon PA 14	2.6	---	4.5	1.9	2.8	---	---
Tucannon PA 26	Tucannon PA 26	2.3	---	9.6	---	14.0	---	---
Tucannon PA 3	Tucannon PA 3	0.9	---	3.9	1.4	3.5	---	---

* denotes sites that were not included in analysis.

Table A-3. Difference in volume of LWD (m^3) between impact and control reach for all sampling years for instream projects. Missing values were not measured in that year of sampling for a particular site.

Site Number	Site Name	Year 0	Year 0*	Year 1	Year 2	Year 3	Year 5	Year 10
02-1444	Little Skookum Valley	1.38	---	1.40	---	1.54	0.48	1.11
02-1463	Salmon Creek	-0.72	---	0.37	---	0.11	-0.75	0.50
02-1515*	Upper Trout Creek	---	---	0.59	---	0.12	0.49	---
02-1561IS*	Edgewater Park	-0.22	---	0.78	---	0.67	0.70	0.30
04-1209IS	Chico Creek	-0.55	-0.34	0.67	---	0.64	0.53	---
04-1338	Lower Newaukum	-0.36	---	1.01	---	2.09	0.78	0.92
04-1448	PUD Bar Habitat	-0.43	---	-0.34	---	-0.20	0.86	0.29
04-1575	Upper Washougal	-0.95	---	1.76	---	1.08	1.76	1.82
04-1589	Dungeness River	-0.18	-0.49	0.74	---	1.01	0.72	---
04-1660IS	Cedar Rapids	0.55	0.82	3.74	---	1.70	0.71	---
05-1533	Doty Edwards	-0.93	---	-0.27	---	0.58	-0.28	-0.45
07-1803	Skookum Reach	0.33	---	0.38	---	0.20	-0.18	---
11-1315	Eagle Island	-1.72	---	-1.26	---	-0.14	---	---
11-1354*	Lower Dosewallips	1.07	1.32	---	---	---	---	---
12-1334*	Elochoman	-0.87	---	---	---	---	---	---
12-1657	George Creek	-0.55	---	1.64	---	0.37	---	---
SF-F3 P2BR	SF Asotin Creek Lower 1	-0.65	---	0.22	---	1.10	---	---
SF-F3 P3BR	SF Asotin Creek Lower 2	-1.40	---	-0.29	---	0.62	---	---
SF-F4 P1	SF Asotin Creek Upper 1	0.75	---	0.60	---	0.55	-0.07	---
SF-F4 P2	SF Asotin Creek Upper 2	0.45	---	0.26	---	0.48	0.02	---
Tucannon PA 14	Tucannon PA 14	0.42	---	0.93	0.46	0.94	---	---
Tucannon PA 26	Tucannon PA 26	0.34	---	-0.12	---	1.09	---	---
Tucannon PA 3	Tucannon PA 3	-0.05	---	0.19	0.34	0.33	---	---

* denotes sites that were not included in analysis.

Table A-4. Difference in Chinook Salmon densities (fish/m^2) between impact and control reach for all sampling years for instream projects. Missing values were not measured in that year of sampling for a particular site.

Site Number	Site Name	Year 0	Year 0*	Year 1	Year 3	Year 5	Year 10
02-1444	Little Skookum Valley	0	---	0	0	0	0
02-1463	Salmon Creek	0.0095	---	0	0	-0.0018	0
02-1515*	Upper Trout Creek	---	---	0	0	0	---
02-1561IS*	Edgewater Park	0	---	0.0221	0	0	0
04-1209IS	Chico Creek	0	0	0	0	0	---
04-1338	Lower Newaukum	0.0027	---	-0.0155	-0.0364	0	-0.0003
04-1448	PUD Bar Habitat	0	---	-0.0002	-0.0001	0	-0.0090
04-1575	Upper Washougal	0	---	0	0	0	0
04-1589	Dungeness River	0.0177	-0.0012	0.0023	0.0007	-0.0296	---
04-1660IS	Cedar Rapids	-0.0101	0	0.0027	0	0	---
05-1533	Doty Edwards	0	---	0	0.0005	0.0002	0
07-1803	Skookum Reach	0.0029	---	-0.0011	-0.0004	-0.0001	---
11-1315	Eagle Island	0.0714	---	-0.0081	-0.0278	---	---
11-1354*	Lower Dosewallips	0.0002	0.0150	---	---	---	---
12-1334*	Elochoman	-0.0056	---	---	---	---	---
12-1657	George Creek	0	---	0	0	---	---
SF-F3 P2BR	SF Asotin Creek Lower 1	0	---	0	0	---	---
SF-F3 P3BR	SF Asotin Creek Lower 2	0	---	0	0	---	---
SF-F4 P1	SF Asotin Creek Upper 1	0	---	0	0	---	---
SF-F4 P2	SF Asotin Creek Upper 2	0	---	0	0	---	---
Tucannon PA 14	Tucannon PA 14	-0.0410	---	-0.0256	0.1137	---	---
Tucannon PA 26	Tucannon PA 26	0.0060	---	0.0113	0.0023	---	---
Tucannon PA 3	Tucannon PA 3	-0.0038	---	-0.0290	0.0861	---	---

* denotes sites that were not included in analysis.

Table A-5. Difference in Coho Salmon densities (fish/m^2) between impact and control reach for all sampling years for instream projects. Missing values were not measured in that year of sampling for a particular site.

Site Number	Site Name	Year 0	Year 0*	Year 1	Year 3	Year 5	Year 10
02-1444	Little Skookum Valley	-0.0094	---	0	-0.0268	0	0
02-1463	Salmon Creek	0.4447	---	0.0260	0.0317	0.1364	0.0764
02-1515*	Upper Trout Creek	---	---	0	0	0	---
02-1561IS*	Edgewater Park	0	---	0.0004	0	0	0
04-1209IS	Chico Creek	-0.0462	-0.0611	-0.2522	-0.0180	0.4720	---
04-1338	Lower Newaukum	0.0066	---	0.0995	0.0581	-0.0007	0.1092
04-1448	PUD Bar Habitat	0	---	-0.0042	-0.0009	-0.0133	-0.0005
04-1575	Upper Washougal	0	---	0	0	0	0
04-1589	Dungeness River	0.0141	-0.1790	-0.0484	0.0334	-0.0310	---
04-1660IS	Cedar Rapids	-0.0106	-0.0052	0.0015	-0.0017	-0.0098	---
05-1533	Doty Edwards	0.0511	---	0.0223	0.0386	0.0197	-0.0160
07-1803	Skookum Reach	-0.0001	---	0.0001	-0.0039	0.0001	---
11-1315	Eagle Island	0.0122	---	0.1093	0.3169	---	---
11-1354*	Lower Dosewallips	0.1436	-0.0299	---	---	---	---
12-1334*	Elochoman	-0.0151	---	---	---	---	---
12-1657	George Creek	0	---	0	0	---	---
SF-F3 P2BR	SF Asotin Creek Lower 1	0	---	0	0	---	---
SF-F3 P3BR	SF Asotin Creek Lower 2	0	---	0	0	---	---
SF-F4 P1	SF Asotin Creek Upper 1	0	---	0	0	---	---
SF-F4 P2	SF Asotin Creek Upper 2	0	---	0	0	---	---
Tucannon PA 14	Tucannon PA 14	0	---	0	0	---	---
Tucannon PA 26	Tucannon PA 26	0	---	0	0	---	---
Tucannon PA 3	Tucannon PA 3	0	---	0	0	---	---

* denotes sites that were not included in analysis.

Table A-6. Difference in steelhead densities (fish/m^2) between impact and control reach for all sampling years for instream projects. Missing values were not measured in that year of sampling for a particular site.

Site Number	Site Name	Year 0	Year 0*	Year 1	Year 3	Year 5	Year 10
02-1444	Little Skookum Valley	0	---	0	0	-0.0210	-0.8623
02-1463	Salmon Creek	0.0474	---	0.0452	0.0039	0.0103	0.0913
02-1515*	Upper Trout Creek	---	---	0.0042	-0.0153	-0.1112	---
02-1561IS*	Edgewater Park	0	---	0	0	0	0
04-1209IS	Chico Creek	-0.2316	0.0007	0.0268	-0.2308	0.5985	---
04-1338	Lower Newaukum	0.0269	---	0.0719	0	-0.0010	0.0726
04-1448	PUD Bar Habitat	0.0050	---	-0.0893	0.0143	0.0106	0.0152
04-1575	Upper Washougal	0.0099	---	0.0095	-0.0849	0.0405	-0.1450
04-1589	Dungeness River	-0.2110	-0.1335	-0.0994	0.0354	-0.1193	---
04-1660IS	Cedar Rapids	-0.0011	-0.0044	0.0008	0.0029	-0.0014	---
05-1533	Doty Edwards	-0.0047	---	-0.0018	-0.0009	-0.0034	0.0012
07-1803	Skookum Reach	-0.0014	---	0.0020	-0.0366	0.0298	---
11-1315	Eagle Island	0.0001	---	0.0621	0.2458	---	---
11-1354*	Lower Dosewallips	-0.0008	-0.0018	---	---	---	---
12-1334*	Elochoman	-0.0114	---	---	---	---	---
12-1657	George Creek	-0.0587	---	-0.0305	-1.6936	---	---
SF-F3 P2BR	SF Asotin Creek Lower 1	0.0250	---	0.1533	0.0449	---	---
SF-F3 P3BR	SF Asotin Creek Lower 2	0.0250	---	0.1533	0.0449	---	---
SF-F4 P1	SF Asotin Creek Upper 1	0.0048	---	-0.0764	-0.2103	0.0033	---
SF-F4 P2	SF Asotin Creek Upper 2	0.0048	---	-0.0764	-0.2103	0.0033	---
Tucannon PA 14	Tucannon PA 14	-0.0708	---	-0.1054	0.1151	---	---
Tucannon PA 26	Tucannon PA 26	0.0397	---	-0.0387	0.0563	---	---
Tucannon PA 3	Tucannon PA 3	0.0806	---	-0.1192	0.0617	---	---

* denotes sites that were not included in analysis.

APPENDIX B: MC-5/6 METRIC DATA

Table B-1. Difference in average vertical pool area (m^2) between impact and control reach for all sampling years for floodplain enhancement projects. Missing values were not measured in that year of sampling for a particular site.

Site Number	Site Name	Year 0	Year 0*	Year 1	Year 2	Year 3	Year 5	Year 10
02-1561CC*	Edgewater Park	0	---	21.7	89.4	---	24.2	11.3
02-1625	SF Skagit Levee Setback	301.4	---	257.4	---	-130.9	340.8	418.8
04-1461	Dryden	-165.9	---	-151.8	-123.5	---	4.0	178.4
04-1563*	Germany Creek	104.8	---	-68.7	-36.7	---	-50.0	---
04-1573	Lower Washougal	-169.3	---	-127.8	-208.2	---	-178.6	-142.6
04-1596	Lower Tolt River	-103.4	-116.3	-24.4	---	29.8	-16.9	---
05-1398	Fenster Levee	10.6	---	175.4	---	-31.9	42.9	---
05-1466	Lower Boise Creek	-4.6	---	6.3	---	2.0	6.6	---
05-1521	Raging River	3.1	---	46.8	---	27.8	-43.9	33.3
05-1546	Gagnon	36.2	---	131.3	133.3	---	15.0	158.1
06-2190*	Riverview Park	-352.5	---	-184.5	-184.3	---	---	---
06-2223	Greenwater River	34.9	---	41.5	---	33.0	22.4	---
06-2239CC*	Fender Mill	-19.9	---	-4.3	-9.4	---	1.1	---
06-2250	Chinook Bend	66.3	---	-163.1	---	95.9	-194.0	---
06-2277*	Upper Klickitat	-23.4	---	6.1	5.0	---	-11.1	---
07-1519*	Reecer Creek	3.3	---	-8.2	---	22.6	16.1	---
07-1691	Lockwood Creek	-17.2	---	13.3	13.1	---	30.3	---
10-1765*	Eschbach Park	-18.1	---	-3.9	---	5.8	---	---
11-1354*	Lower Dosewallips	65.0	151.1	---	---	---	---	---
12-1307*	Billy's Pond	-74.2	---	---	---	-44.8	---	---
12-1438*	Lower Nason	1.8	---	2.3	---	---	---	---
12-1657	George Creek	-6.3	---	9.7	---	5.0	---	---
Tucannon PA 26	Tucannon PA 26	-3.5	---	27.2	---	46.2	---	---

* denotes sites that were not included in the analysis

Table B-2. Difference in mean residual depth (cm) between impact and control reach for all sampling years for floodplain enhancement projects. Missing values were not measured in that year of sampling for a particular site.

Site Number	Site Name	Year 0	Year 0*	Year 1	Year 2	Year 3	Year 5	Year 10
02-1561CC*	Edgewater Park	0	---	6.8	27.9	---	1.6	3.5
02-1625	SF Skagit Levee Setback	57.4	---	55.2	---	-26.2	68.2	83.8
04-1461	Dryden	-33.2	---	3.3	6.3	---	15.3	99.6
04-1563*	Germany Creek	67.6	---	-13.7	-22.9	---	-28.7	---
04-1573	Lower Washougal	-24.1	---	6.7	-19.6	---	-22.1	-17.3
04-1596	Lower Tolt River	-20.7	-23.3	-4.9	---	-35.0	-1.8	---
05-1398	Fenster Levee	5.9	---	97.5	---	-11.6	24.2	---
05-1466	Lower Boise Creek	-3.0	---	1.8	---	1.7	4.5	---
05-1521	Raging River	0.1	---	9.4	---	5.6	-9.0	6.6
05-1546	Gagnon	15.3	---	62.6	64.2	---	87.0	76.0
06-2190*	Riverview Park	-78.3	---	-50.4	-48.4	---	---	---
06-2223	Greenwater River	8.1	---	14.7	---	7.3	5.2	---
06-2239CC*	Fender Mill	-13.3	---	-2.9	-6.3	---	0.7	---
06-2250	Chinook Bend	13.3	---	-32.6	---	-1.2	-35.6	---
06-2277*	Upper Klickitat	-15.6	---	4.0	1.7	---	-7.4	---
07-1519*	Reecer Creek	2.0	---	-6.7	---	13.8	0.1	---
07-1691	Lockwood Creek	-11.5	---	8.8	8.8	---	18.7	---
10-1765*	Eschbach Park	-8.9	---	4.4	---	11.5	---	---
11-1354*	Lower Dosewallips	11.7	24.6	---	---	---	---	---
12-1307*	Billy's Pond	-55.9	---	---	---	-37.0	---	---
12-1438*	Lower Nason	1.2	---	2.1	---	---	---	---
12-1657	George Creek	-2.4	---	7.4	---	4.1	---	---
Tucannon PA 26	Tucannon PA 26	2.3	---	9.6	---	14.0	---	---

* denotes sites that were not included in the analysis

Table B-3. Difference in bank canopy cover (1-17) between impact and control reach for all sampling years for floodplain enhancement projects. Missing values were not measured in that year of sampling for a particular site.

Site Number	Site Name	Year 0	Year 0*	Year 1	Year 2	Year 3	Year 5	Year 10
02-1561CC*	Edgewater Park	0	---	-7	-7	---	-6	-4
02-1625	SF Skagit Levee Setback	1	---	1	---	---	---	-1
04-1461	Dryden	5	---	-5	-6	---	-9	-9
04-1563*	Germany Creek	1	---	2	2	---	1	---
04-1573	Lower Washougal	-6	---	3	4	---	-2	1
04-1596	Lower Tolt River	2	0	---	---	---	1	---
05-1398	Fenster Levee	---	---	---	---	-8	-3	---
05-1466	Lower Boise Creek	---	---	-8	---	-2	-2	---
05-1521	Raging River	---	---	---	---	---	-5	-3
05-1546	Gagnon	4	---	-5	-1	---	-3	-5
06-2190*	Riverview Park	-9	---	-12	-6	---	---	---
06-2223	Greenwater River	---	---	5	---	2	2	---
06-2239CC*	Fender Mill	9	---	3	-2	---	-1	---
06-2250	Chinook Bend	---	---	---	---	---	-5	---
06-2277*	Upper Klickitat	2	---	-2	-1	---	-4	---
07-1519*	Reecer Creek	---	---	-17	---	-5	-8	---
07-1691	Lockwood Creek	-4	---	-3	-4	---	-3	---
10-1765*	Eschbach Park	2	---	1	---	---	---	---
11-1354*	Lower Dosewallips	-3	---	---	---	---	---	---
12-1307*	Billy's Pond	-2	---	---	---	---	---	---
12-1438*	Lower Nason	1	---	---	---	---	---	---
12-1657	George Creek	---	---	---	---	---	---	---
Tucannon PA 26	Tucannon PA 26	---	---	---	---	---	---	---

* denotes sites that were not included in the analysis

Table B-4. Difference in percent riparian vegetation structure (%) between impact and control reach for all sampling years for floodplain enhancement projects. Missing values were not measured in that year of sampling for a particular site.

Site Number	Site Name	Year 0	Year 0*	Year 1	Year 2	Year 3	Year 5	Year 10
02-1561CC*	Edgewater Park	0	---	55	-45	---	59	-5
02-1625	SF Skagit Levee Setback	5	---	9	---	---	---	27
04-1461	Dryden	18	---	-5	-23	---	5	-19
04-1563*	Germany Creek	5	---	5	9	---	-5	---
04-1573	Lower Washougal	-14	---	5	0	---	9	9
04-1596	Lower Tolt River	32	9	---	---	---	18	---
05-1398	Fenster Levee	---	---	---	---	-23	0	---
05-1466	Lower Boise Creek	---	---	-23	---	-41	-9	---
05-1521	Raging River	---	---	---	---	---	-32	-8
05-1546	Gagnon	36	---	-23	9	---	-9	-3
06-2190*	Riverview Park	-45	---	-36	-32	---	---	---
06-2223	Greenwater River	---	---	5	---	5	-4	---
06-2239CC*	Fender Mill	-5	---	18	-4	---	-36	---
06-2250	Chinook Bend	---	---	---	---	---	-5	---
06-2277*	Upper Klickitat	18	---	-9	14	---	18	---
07-1519*	Reecer Creek	---	---	-96	---	-100	-96	---
07-1691	Lockwood Creek	-18	---	-23	-27	---	-14	---
10-1765*	Eschbach Park	-32	---	-32	---	-10	---	---
11-1354*	Lower Dosewallips	-14	---	---	---	---	---	---
12-1307*	Billy's Pond	9	---	---	---	-10	---	---
12-1438*	Lower Nason	18	---	68	---	---	---	---
12-1657	George Creek	-80	---	-80	---	-30	---	---
Tucannon PA 26	Tucannon PA 26	-50	---	0	---	90	---	---

* denotes sites that were not included in the analysis

Table B-5. Difference in average channel capacity (m^2) between impact and control reach for all sampling years for floodplain enhancement projects. Missing values were not measured in that year of sampling for a particular site.

Site Number	Site Name	Year 0	Year 0*	Year 1	Year 2	Year 3	Year 5	Year 10
02-1561CC*	Edgewater Park	---	---	---	---	---	---	13.2
02-1625	SF Skagit Levee Setback	56.0	---	-180.7	---	-334.5	-122.1	15.0
04-1461	Dryden	---	---	---	---	---	---	---
04-1563*	Germany Creek	---	---	---	---	---	-5.2	---
04-1573	Lower Washougal	---	---	---	---	---	---	2.2
04-1596	Lower Tolt River	6.5	36.9	8.8	---	42.7	10.3	---
05-1398	Fenster Levee	-11.8	---	109.7	---	20.3	11.7	---
05-1466	Lower Boise Creek	-0.7	---	8.9	---	2.3	0.6	---
05-1521	Raging River	-1.6	---	42.0	---	13.1	-1.5	5.7
05-1546	Gagnon	---	---	---	---	---	---	---
06-2190*	Riverview Park	---	---	-50.3	-60.5	---	---	---
06-2223	Greenwater River	-6.3	---	6.0	---	6.6	0.5	---
06-2239CC*	Fender Mill	---	---	-1.6	---	---	-0.6	---
06-2250	Chinook Bend	-27.2	---	-50.8	---	137.0	65.4	---
06-2277*	Upper Klickitat	---	---	---	8023.9	---	3.8	---
07-1519*	Reecer Creek	9.0	---	-2.8	---	---	3.5	---
07-1691	Lockwood Creek	---	---	---	---	---	---	---
10-1765*	Eschbach Park	---	---	-1.5	---	-11.6	---	---
11-1354*	Lower Dosewallips	6.8	-1.1	---	---	---	---	---
12-1307*	Billy's Pond	47.5	---	---	---	-31.2	---	---
12-1438*	Lower Nason	-0.3	---	---	---	---	---	---
12-1657	George Creek	-0.9	---	1.5	---	1.8	---	---
Tucannon PA 26	Tucannon PA 26	0.1	---	1.7	---	-0.9	---	---

* denotes sites that were not included in the analysis

Table B-6. Difference in floodprone width (m) between impact and control reach for all sampling years for floodplain enhancement projects. Missing values were not measured in that year of sampling for a particular site.

Site Number	Site Name	Year 0	Year 0*	Year 1	Year 2	Year 3	Year 5	Year 10
02-1561CC*	Edgewater Park	---	---	---	---	---	---	10.4
02-1625	SF Skagit Levee Setback	-22.7	---	95.0	---	106.7	519.7	150.0
04-1461	Dryden	---	---	---	---	---	---	-42.7
04-1563*	Germany Creek	---	---	---	---	---	-12.1	---
04-1573	Lower Washougal	---	---	---	---	---	---	160.0
04-1596	Lower Tolt River	---	-0.7	33.7	---	---	14.1	---
05-1398	Fenster Levee	5.3	---	180.3	---	---	---	---
05-1466	Lower Boise Creek	19.7	---	---	---	8.7	---	---
05-1521	Raging River	2.5	---	60.5	---	42.5	---	64.1
05-1546	Gagnon	---	---	---	---	---	---	-61.0
06-2190*	Riverview Park	---	---	---	---	---	---	---
06-2223	Greenwater River	-33.8	---	---	---	-7.9	19.5	---
06-2239CC*	Fender Mill	---	---	61.7	---	---	---	---
06-2250	Chinook Bend	-7.0	---	18.0	---	---	8.3	---
06-2277*	Upper Klickitat	---	---	---	---	---	960.5	---
07-1519*	Reecer Creek	-2452.0	---	---	---	-12.2	138.5	---
07-1691	Lockwood Creek	---	---	---	---	---	---	---
10-1765*	Eschbach Park	---	---	---	---	---	---	---
11-1354*	Lower Dosewallips	3.9	---	---	---	---	---	---
12-1307*	Billy's Pond	-3.7	---	---	---	---	---	---
12-1438*	Lower Nason	6.3	---	---	---	---	---	---
12-1657	George Creek	---	---	---	---	---	---	---
Tucannon PA 26	Tucannon PA 26	---	---	---	---	---	---	---

* denotes sites that were not included in the analysis

Table B-7. Difference in Chinook Salmon densities (fish/m^2) between impact and control reach for all sampling years for floodplain enhancement projects. Missing values were not measured in that year of sampling for a particular site.

Site Number	Site Name	Year 0	Year 0*	Year 1	Year 2	Year 3	Year 5	Year 10
02-1561CC*	Edgewater Park	0	---	0.0221	0.0066	---	0	0
02-1625	SF Skagit Levee Setback	---	---	---	---	---	---	---
04-1461	Dryden	0	---	-0.0002	-0.0006	---	0.0385	0.0172
04-1563*	Germany Creek	0	---	0	0	---	0	---
04-1573	Lower Washougal	0.3443	---	-0.0001	0	---	-0.0018	-0.0002
04-1596	Lower Tolt River	---	---	---	---	---	---	---
05-1398	Fenster Levee	---	---	---	---	---	---	---
05-1466	Lower Boise Creek	-0.0121	---	0	---	0	0	---
05-1521	Raging River	---	---	---	---	---	---	---
05-1546	Gagnon	-0.0086	---	0	0.1036	---	0.0235	-0.0006
06-2190*	Riverview Park	0	---	0	0	---	---	---
06-2223	Greenwater River	---	---	---	---	---	---	---
06-2239CC*	Fender Mill	-0.0419	---	-0.0334	-0.0272	---	0	---
06-2250	Chinook Bend	---	---	---	---	---	---	---
06-2277*	Upper Klickitat	0	---	0	0	---	0	---
07-1519*	Reecer Creek	---	---	---	---	---	0	---
07-1691	Lockwood Creek	0	---	0	0	---	0	---
10-1765*	Eschbach Park	-0.6117	---	0	---	0	---	---
11-1354*	Lower Dosewallips	0.0002	0.0150	---	---	---	---	---
12-1307*	Billy's Pond	0	---	---	---	0	---	---
12-1438*	Lower Nason	0.1068	---	0	---	---	---	---
12-1657	George Creek	0	---	0	---	0	---	---
Tucannon PA 26	Tucannon PA 26	0.0060	---	0.0113	---	0.0023	---	---

* denotes sites that were not included in the analysis

Table B-8. Difference in Coho Salmon densities (fish/m^2) between impact and control reach for all sampling years for floodplain enhancement projects. Missing values were not measured in that year of sampling for a particular site.

Site Number	Site Name	Year 0	Year 0*	Year 1	Year 2	Year 3	Year 5	Year 10
02-1561CC*	Edgewater Park	0	---	0.0004	0	---	0	0
02-1625	SF Skagit Levee Setback	---	---	---	---	---	---	---
04-1461	Dryden	0	---	0.4876	0.3675	---	0.0555	0.0068
04-1563*	Germany Creek	-0.0402	---	-0.0008	1.8217	---	1.1080	---
04-1573	Lower Washougal	0	---	0	0	---	-0.0050	0
04-1596	Lower Tolt River	---	---	---	---	---	---	---
05-1398	Fenster Levee	---	---	---	---	---	---	---
05-1466	Lower Boise Creek	-0.0165	---	0	---	0.3985	0.8499	---
05-1521	Raging River	---	---	---	---	---	---	---
05-1546	Gagnon	-0.0491	---	0	0.0746	---	-0.0224	0
06-2190*	Riverview Park	0	---	0	0	---	---	---
06-2223	Greenwater River	---	---	---	---	---	---	---
06-2239CC*	Fender Mill	0	---	0	-0.0027	---	0	---
06-2250	Chinook Bend	---	---	---	---	---	---	---
06-2277*	Upper Klickitat	0	---	0	0	---	0	---
07-1519*	Reecer Creek	---	---	---	---	---	0.0018	---
07-1691	Lockwood Creek	-0.0533	---	-0.0097	-0.0725	---	-0.0337	---
10-1765*	Eschbach Park	-0.1171	---	0	---	0	---	---
11-1354*	Lower Dosewallips	0.1436	-0.0299	---	---	---	---	---
12-1307*	Billy's Pond	0	---	---	---	0	---	---
12-1438*	Lower Nason	0	---	0	---	---	---	---
12-1657	George Creek	0	---	0	---	0	---	---
Tucannon PA 26	Tucannon PA 26	0	---	0	---	0	---	---

* denotes sites that were not included in the analysis

Table B-9. Difference in steelhead densities (fish/m^2) between impact and control reach for all sampling years for floodplain enhancement projects. Missing values were not measured in that year of sampling for a particular site.

Site Number	Site Name	Year 0	Year 0*	Year 1	Year 2	Year 3	Year 5	Year 10
02-1561CC*	Edgewater Park	0	---	0	0	---	0	0
02-1625	SF Skagit Levee Setback	---	---	---	---	---	---	---
04-1461	Dryden	-0.0031	---	-0.0011	-0.0024	---	-0.0323	0
04-1563*	Germany Creek	0	---	0	-0.0082	---	-0.0121	---
04-1573	Lower Washougal	0	---	-0.0001	0	---	-0.0017	0
04-1596	Lower Tolt River	---	---	---	---	---	---	---
05-1398	Fenster Levee	---	---	---	---	---	---	---
05-1466	Lower Boise Creek	-0.0009	---	0	---	0.0292	0.0980	---
05-1521	Raging River	---	---	---	---	---	---	---
05-1546	Gagnon	-0.0547	---	-0.0007	-0.0158	---	-0.0334	0
06-2190*	Riverview Park	-0.0021	---	-0.0003	0	---	---	---
06-2223	Greenwater River	---	---	---	---	---	---	---
06-2239CC*	Fender Mill	-0.0011	---	-0.0019	-0.0053	---	-0.0011	---
06-2250	Chinook Bend	---	---	---	---	---	---	---
06-2277*	Upper Klickitat	-0.0658	---	0.1298	0.1236	---	-0.0123	---
07-1519*	Reecer Creek	---	---	---	---	---	0	---
07-1691	Lockwood Creek	-0.0012	---	0.0058	0.0638	---	0.0313	---
10-1765*	Eschbach Park	-0.0070	---	0	---	0	---	---
11-1354*	Lower Dosewallips	-0.0008	-0.0018	---	---	---	---	---
12-1307*	Billy's Pond	0	---	---	---	0	---	---
12-1438*	Lower Nason	0	---	0.3537	---	---	---	---
12-1657	George Creek	-0.0587	---	-0.0305	---	-1.6936	---	---
Tucannon PA 26	Tucannon PA 26	0.0397	---	-0.0387	---	0.0563	---	---

* denotes sites that were not included in the analysis

APPENDIX C: FISH COUNTS FOR MC-2

Table C-1. Chinook Salmon counts in the impact and control reaches for all sampling years for instream projects (MC-2). Missing values were not measured in that year of sampling for a site.

Site	Site Name	Station	Year 0	Year 0*	Year 1	Year 3	Year 5	Year 10
02-1444	Little Skookum Valley	Control	0	---	0	0	0	0
		Impact	0	---	0	0	0	0
02-1463	Salmon Creek	Control	0	---	0	0	2	0
		Impact	9	---	0	0	2	0
02-1515*	Upper Trout Creek	Control	0	---	0	0	0	---
		Impact	---	---	0	0	0	---
02-1561IS*	Edgewater Park	Control	0	---	0	0	0	0
		Impact	0	---	104	0	0	0
04-1209IS	Chico Creek	Control	0	0	0	0	0	---
		Impact	0	0	0	0	0	---
04-1338	Lower Newaukum	Control	8	---	30	95	10	2
		Impact	13	---	0	40	10	1
04-1448	PUB Bar Habitat	Control	0	---	2	1	5	74
		Impact	0	---	0	0	5	21
04-1575	Upper Washougal	Control	0	---	0	0	0	0
		Impact	0	---	0	0	0	0
04-1589	Dungeness River	Control	9	46	5	35	361	---
		Impact	170	70	39	23	149	---
04-1660IS	Cedar Rapids	Control	126	6	0	0	0	---
		Impact	0	5	46	0	0	---
05-1533	Doty Edwards	Control	0	---	0	0	0	1
		Impact	0	---	0	2	1	1
07-1803	Skookum Reach	Control	28	---	27	9	12	---
		Impact	95	---	28	12	24	---
11-1315	Eagle Island	Control	226	---	75	88	---	---
		Impact	336	---	22	11	---	---
11-1354*	Lower Dosewallips	Control	0	0	---	---	---	---
		Impact	3	232	---	---	---	---
12-1334*	Elochoman	Control	55	---	---	---	---	---
		Impact	13	---	---	---	---	---
12-1657	George Creek	Control	0	---	0	0	---	---
		Impact	0	---	0	0	---	---
SF-F3 P2BR	SF Asotin Creek Lower 1	Control	0	---	0	0	---	---
		Impact	0	---	0	0	---	---
SF-F3 P3BR	SF Asotin Creek Lower 2	Control	0	---	0	0	---	---
		Impact	0	---	0	0	---	---
SF-F4 P1	SF Asotin Creek Upper 1	Control	0	---	0	0	---	---
		Impact	0	---	0	0	---	---
SF-F4 P2	SF Asotin Creek Upper 2	Control	0	---	0	0	---	---
		Impact	0	---	0	0	---	---
Tucannon PA 14	Tucannon PA 14	Control	370	---	151	108	---	---
		Impact	238	---	69	383	---	---
Tucannon PA 26	Tucannon PA 26	Control	244	---	40	109	---	---
		Impact	228	---	77	87	---	---
Tucannon PA 3	Tucannon PA 3	Control	368	---	117	64	---	---
		Impact	368	---	50	414	---	---

* denotes sites that were not included in the analysis

Table C-2. Coho Salmon counts in the impact and control reaches for all sampling years for instream projects (MC-2). Missing values were not measured in that year of sampling for a site.

Site	Site Name	Station	Year 0	Year 0*	Year 1	Year 3	Year 5	Year 10
02-1444	Little Skookum Valley	Control	10	---	0	6	0	0
		Impact	7	---	0	0	0	0
02-1463	Salmon Creek	Control	97	---	46	149	44	64
		Impact	590	---	94	299	373	162
02-1515*	Upper Trout Creek	Control	0	---	0	0	0	---
		Impact	---	---	0	0	0	---
02-1561IS*	Edgewater Park	Control	0	---	0	0	0	0
		Impact	0	---	2	0	0	0
04-1209IS	Chico Creek	Control	208	117	1076	68	368	---
		Impact	119	47	912	47	928	---
04-1338	Lower Newaukum	Control	6	---	21	48	173	109
		Impact	19	---	222	181	173	362
04-1448	PUB Bar Habitat	Control	0	---	59	9	149	3
		Impact	0	---	40	1	27	0
04-1575	Upper Washougal	Control	0	---	0	0	0	0
		Impact	0	---	0	0	0	0
04-1589	Dungeness River	Control	1616	2044	652	299	2204	---
		Impact	2296	1791	1344	534	3228	---
04-1660IS	Cedar Rapids	Control	132	172	23	21	226	---
		Impact	0	97	47	0	66	---
05-1533	Doty Edwards	Control	173	---	69	64	163	252
		Impact	529	---	262	234	375	178
07-1803	Skookum Reach	Control	2	---	1	56	92	---
		Impact	0	---	4	21	213	---
11-1315	Eagle Island	Control	14	---	251	610	---	---
		Impact	41	---	391	1079	---	---
11-1354*	Lower Dosewallips	Control	1704	514	---	---	---	---
		Impact	3837	17	---	---	---	---
12-1334*	Elochoman	Control	235	---	---	---	---	---
		Impact	112	---	---	---	---	---
12-1657	George Creek	Control	0	---	0	0	---	---
		Impact	0	---	0	0	---	---
SF-F3 P2BR	SF Asotin Creek Lower 1	Control	0	---	0	0	---	---
		Impact	0	---	0	0	---	---
SF-F3 P3BR	SF Asotin Creek Lower 2	Control	0	---	0	0	---	---
		Impact	0	---	0	0	---	---
SF-F4 P1	SF Asotin Creek Upper 1	Control	0	---	0	0	---	---
		Impact	0	---	0	0	---	---
SF-F4 P2	SF Asotin Creek Upper 2	Control	0	---	0	0	---	---
		Impact	0	---	0	0	---	---
Tucannon PA 14	Tucannon PA 14	Control	0	---	0	0	---	---
		Impact	0	---	0	0	---	---
Tucannon PA 26	Tucannon PA 26	Control	0	---	0	0	---	---
		Impact	0	---	0	0	---	---
Tucannon PA 3	Tucannon PA 3	Control	0	---	0	0	---	---
		Impact	0	---	0	0	---	---

* denotes sites that were not included in the analysis

Table C-3. Steelhead counts in the impact and control reaches for all sampling years for instream projects (MC-2). Missing values were not measured in that year of sampling for a site.

Site	Site Name	Station	Year 0	Year 0*	Year 1	Year 3	Year 5	Year 10
02-1444	Little Skookum Valley	Control	0	---	0	0	3	165
		Impact	0	---	0	0	0	2
02-1463	Salmon Creek	Control	11	---	7	4	1	12
		Impact	64	---	50	11	22	93
02-1515*	Upper Trout Creek	Control	4	---	27	28	124	---
		Impact	---	---	201	111	259	---
02-1561IS*	Edgewater Park	Control	0	---	0	0	0	0
		Impact	0	---	0	0	0	0
04-1209IS	Chico Creek	Control	681	0	568	602	645	---
		Impact	256	1	773	263	1320	---
04-1338	Lower Newaukum	Control	8	---	172	115	266	91
		Impact	62	---	324	179	266	256
04-1448	PUB Bar Habitat	Control	122	---	741	84	20	224
		Impact	133	---	27	318	120	357
04-1575	Upper Washougal	Control	230	---	126	948	623	2361
		Impact	407	---	296	165	1113	1715
04-1589	Dungeness River	Control	4080	1776	1302	2553	1872	---
		Impact	2306	1143	963	1700	1178	---
04-1660IS	Cedar Rapids	Control	29	108	14	46	122	---
		Impact	14	48	27	58	67	---
05-1533	Doty Edwards	Control	21	---	4	10	24	25
		Impact	20	---	1	8	30	29
07-1803	Skookum Reach	Control	58	---	243	1003	246	---
		Impact	44	---	641	980	1536	---
11-1315	Eagle Island	Control	1	---	67	488	---	---
		Impact	1	---	181	848	---	---
11-1354*	Lower Dosewallips	Control	290	283	---	---	---	---
		Impact	258	237	---	---	---	---
12-1334*	Elochoman	Control	94	---	---	---	---	---
		Impact	11	---	---	---	---	---
12-1657	George Creek	Control	200	---	207	1295	---	---
		Impact	128	---	269	43	---	---
SF-F3 P2BR	SF Asotin Creek Lower 1	Control	442	---	585	486	---	---
		Impact	503	---	814	469	---	---
SF-F3 P3BR	SF Asotin Creek Lower 2	Control	442	---	585	486	---	---
		Impact	503	---	814	469	---	---
SF-F4 P1	SF Asotin Creek Upper 1	Control	513	---	756	813	510	---
		Impact	625	---	732	658	599	---
SF-F4 P2	SF Asotin Creek Upper 2	Control	513	---	756	813	510	---
		Impact	625	---	732	658	599	---
Tucannon PA 14	Tucannon PA 14	Control	630	---	562	378	---	---
		Impact	403	---	232	648	---	---
Tucannon PA 26	Tucannon PA 26	Control	599	---	935	1315	---	---
		Impact	676	---	518	1165	---	---
Tucannon PA 3	Tucannon PA 3	Control	439	---	472	66	---	---
		Impact	692	---	194	327	---	---

* denotes sites that were not included in the analysis

APPENDIX D: FISH COUNTS FOR MC-5/6

Table D-1. Chinook Salmon counts in the impact and control reaches for all sampling years for floodplain enhancement projects (MC-5/6). Missing values were not measured in that year of sampling for a site.

Site	Site Name	Station	Year 0	Year 0*	Year 1	Year 2	Year 3	Year 5	Year 10
02-1561CC*	Edgewater Park	Control	0	---	0	0	---	0	0
		Impact	0	---	104	15	---	0	0
02-1625	SF Skagit Levee Setback	Control	---	---	---	---	---	---	---
		Impact	---	---	---	---	---	---	---
04-1461	Dryden	Control	0	---	4	12	---	1	3
		Impact	0	---	0	0	---	76	67
04-1563*	Germany Creek	Control	0	---	0	0	---	0	---
		Impact	0	---	0	0	---	0	---
04-1573	Lower Washougal	Control	2411	---	5	0	---	34	3
		Impact	1666	---	1	0	---	3	0
04-1596	Lower Tolt River	Control	---	---	---	---	---	---	---
		Impact	---	---	---	---	---	---	---
05-1398	Fenster Levee	Control	---	---	---	---	---	---	---
		Impact	---	---	---	---	---	---	---
05-1466	Lower Boise Creek	Control	13	---	0	---	0	0	---
		Impact	1	---	0	---	0	0	---
05-1521	Raging River	Control	---	---	---	---	---	---	---
		Impact	---	---	---	---	---	---	---
05-1546	Gagnon	Control	23	---	0	5	---	1	3
		Impact	0	---	0	144	---	74	1
06-2190*	Riverview Park	Control	0	---	0	0	---	---	---
		Impact	0	---	0	0	---	---	---
06-2223	Greenwater River	Control	---	---	---	---	---	---	---
		Impact	---	---	---	---	---	---	---
06-2239CC*	Fender Mill	Control	37	---	35	41	---	0	---
		Impact	0	---	0	0	---	0	---
06-2250	Chinook Bend	Control	---	---	---	---	---	---	---
		Impact	---	---	---	---	---	---	---
06-2277*	Upper Klickitat	Control	0	---	0	0	---	0	---
		Impact	0	---	0	0	---	0	---
07-1519*	Reecer Creek	Control	---	---	---	---	---	0	---
		Impact	---	---	---	---	---	0	---
07-1691	Lockwood Creek	Control	0	---	0	0	---	0	---
		Impact	0	---	0	0	---	0	---
10-1765*	Eschbach Park	Control	1299	---	0	---	0	---	---
		Impact	879	---	0	---	0	---	---
11-1354*	Lower Dosewallips	Control	0	0	---	---	---	---	---
		Impact	3	232	---	---	---	---	---
12-1307*	Billy's Pond	Control	0	---	---	---	0	---	---
		Impact	0	---	---	---	0	---	---
12-1438*	Lower Nason	Control	0	---	0	---	---	---	---
		Impact	69	---	0	---	---	---	---
12-1657	George Creek	Control	0	---	0	---	0	---	---
		Impact	0	---	0	---	0	---	---
Tucannon PA 26	Tucannon PA 26	Control	244	---	40	---	109	---	---
		Impact	228	---	77	---	87	---	---

* denotes sites that were not included in the analysis

Table D-2. Coho Salmon counts in the impact and control reaches for all sampling years for floodplain enhancement projects (MC-5/6). Missing values were not measured in that year of sampling for a site.

Site	Site Name	Station	Year 0	Year 0*	Year 1	Year 2	Year 3	Year 5	Year 10
02-1561CC*	Edgewater Park	Control	0	---	0	0	---	0	0
		Impact	0	---	2	0	---	0	0
02-1625	SF Skagit Levee Setback	Control	---	---	---	---	---	---	---
		Impact	---	---	---	---	---	---	---
04-1461	Dryden	Control	0	---	4	0	---	74	0
		Impact	0	---	339	260	---	159	25
04-1563*	Germany Creek	Control	36	---	6	344	---	138	---
		Impact	0	---	0	410	---	26	---
04-1573	Lower Washougal	Control	0	---	0	0	---	74	0
		Impact	0	---	0	0	---	2	0
04-1596	Lower Tolt River	Control	---	---	---	---	---	---	---
		Impact	---	---	---	---	---	---	---
05-1398	Fenster Levee	Control	---	---	---	---	---	---	---
		Impact	---	---	---	---	---	---	---
05-1466	Lower Boise Creek	Control	37	---	0	---	288	209	---
		Impact	23	---	0	---	1201	1458	---
05-1521	Raging River	Control	---	---	---	---	---	---	---
		Impact	---	---	---	---	---	---	---
05-1546	Gagnon	Control	132	---	0	0	---	72	0
		Impact	0	---	0	102	---	8	0
06-2190*	Riverview Park	Control	0	---	0	0	---	---	---
		Impact	0	---	0	0	---	---	---
06-2223	Greenwater River	Control	---	---	---	---	---	---	---
		Impact	---	---	---	---	---	---	---
06-2239CC*	Fender Mill	Control	0	---	0	4	---	0	---
		Impact	0	---	0	0	---	0	---
06-2250	Chinook Bend	Control	---	---	---	---	---	---	---
		Impact	---	---	---	---	---	---	---
06-2277*	Upper Klickitat	Control	0	---	0	0	---	0	---
		Impact	0	---	0	0	---	0	---
07-1519*	Reecer Creek	Control	---	---	---	---	---	0	---
		Impact	---	---	---	---	---	4	---
07-1691	Lockwood Creek	Control	44	---	11	149	---	89	---
		Impact	0	---	7	165	---	74	---
10-1765*	Eschbach Park	Control	221	---	0	---	0	---	---
		Impact	104	---	0	---	0	---	---
11-1354*	Lower Dosewallips	Control	1704	514	---	---	---	---	---
		Impact	3837	17	---	---	---	---	---
12-1307*	Billy's Pond	Control	0	---	---	---	0	---	---
		Impact	0	---	---	---	0	---	---
12-1438*	Lower Nason	Control	0	---	0	---	---	---	---
		Impact	0	---	0	---	---	---	---
12-1657	George Creek	Control	0	---	0	---	0	---	---
		Impact	0	---	0	---	0	---	---
Tucannon PA 26	Tucannon PA 26	Control	0	---	0	---	0	---	---
		Impact	0	---	0	---	0	---	---

* denotes sites that were not included in the analysis

Table D-3. Steelhead counts in the impact and control reaches for all sampling years for floodplain enhancement projects (MC-5/6). Missing values were not measured in that year of sampling for a site.

Site	Site Name	Station	Year 0	Year 0*	Year 1	Year 2	Year 3	Year 5	Year 10
02-1561CC*	Edgewater Park	Control	0	---	0	0	---	0	0
		Impact	0	---	0	0	---	0	0
02-1625	SF Skagit Levee Setback	Control	---	---	---	---	---	---	---
		Impact	---	---	---	---	---	---	---
04-1461	Dryden	Control	64	---	22	50	---	96	0
		Impact	0	---	0	0	---	2	0
04-1563*	Germany Creek	Control	0	---	0	20	---	28	---
		Impact	0	---	0	0	---	0	---
04-1573	Lower Washougal	Control	0	---	1	0	---	23	0
		Impact	0	---	0	0	---	0	0
04-1596	Lower Tolt River	Control	---	---	---	---	---	---	---
		Impact	---	---	---	---	---	---	---
05-1398	Fenster Levee	Control	---	---	---	---	---	---	---
		Impact	---	---	---	---	---	---	---
05-1466	Lower Boise Creek	Control	4	---	0	---	93	143	---
		Impact	4	---	0	---	206	326	---
05-1521	Raging River	Control	---	---	---	---	---	---	---
		Impact	---	---	---	---	---	---	---
05-1546	Gagnon	Control	147	---	2	44	---	96	0
		Impact	0	---	0	0	---	0	0
06-2190*	Riverview Park	Control	28	---	3	0	---	---	---
		Impact	0	---	0	0	---	---	---
06-2223	Greenwater River	Control	---	---	---	---	---	---	---
		Impact	---	---	---	---	---	---	---
06-2239CC*	Fender Mill	Control	1	---	2	8	---	1	---
		Impact	0	---	0	0	---	0	---
06-2250	Chinook Bend	Control	---	---	---	---	---	---	---
		Impact	---	---	---	---	---	---	---
06-2277*	Upper Klickitat	Control	40	---	15	3	---	6	---
		Impact	0	---	67	141	---	0	---
07-1519*	Reecer Creek	Control	---	---	---	---	---	0	---
		Impact	---	---	---	---	---	0	---
07-1691	Lockwood Creek	Control	1	---	8	19	---	6	---
		Impact	0	---	15	77	---	23	---
10-1765*	Eschbach Park	Control	52	---	0	---	0	---	---
		Impact	96	---	0	---	0	---	---
11-1354*	Lower Dosewallips	Control	290	283	---	---	---	---	---
		Impact	258	237	---	---	---	---	---
12-1307*	Billy's Pond	Control	0	---	---	---	0	---	---
		Impact	0	---	---	---	0	---	---
12-1438*	Lower Nason	Control	0	---	0	---	---	---	---
		Impact	0	---	47	---	---	---	---
12-1657	George Creek	Control	200	---	207	---	1295	---	---
		Impact	128	---	269	---	43	---	---
Tucannon PA 26	Tucannon PA 26	Control	599	---	935	---	1315	---	---
		Impact	676	---	518	---	1165	---	---

* denotes sites that were not included in the analysis

APPENDIX E: MC-2 SUMMARY METRIC PLOTS

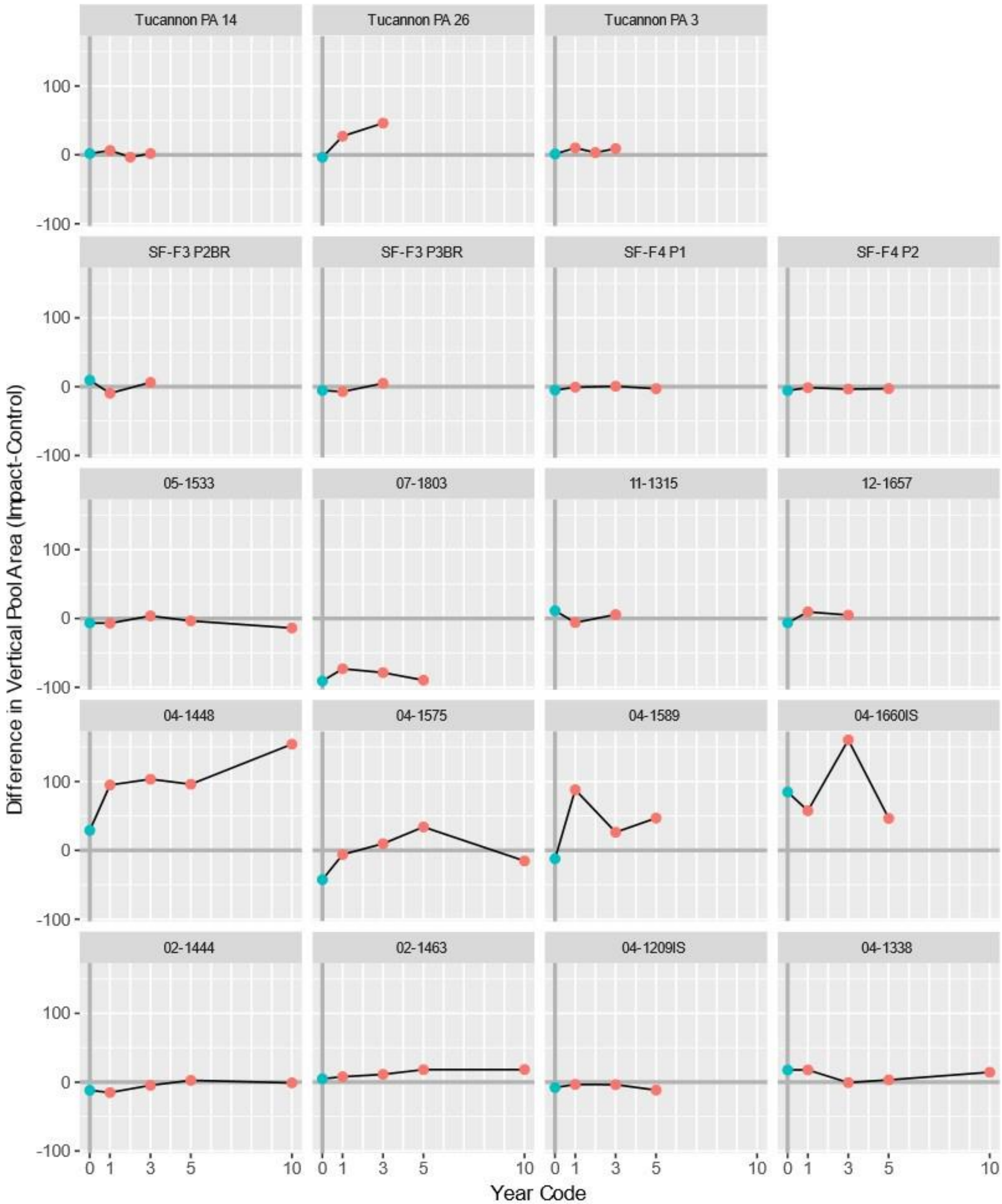

Figure E-1. Difference in average vertical pool area (m^2) between the impact and control reach for each project included in the instream analysis. The blue and red circles represent before (Year 0) and after monitoring data (Year > 0), respectively.

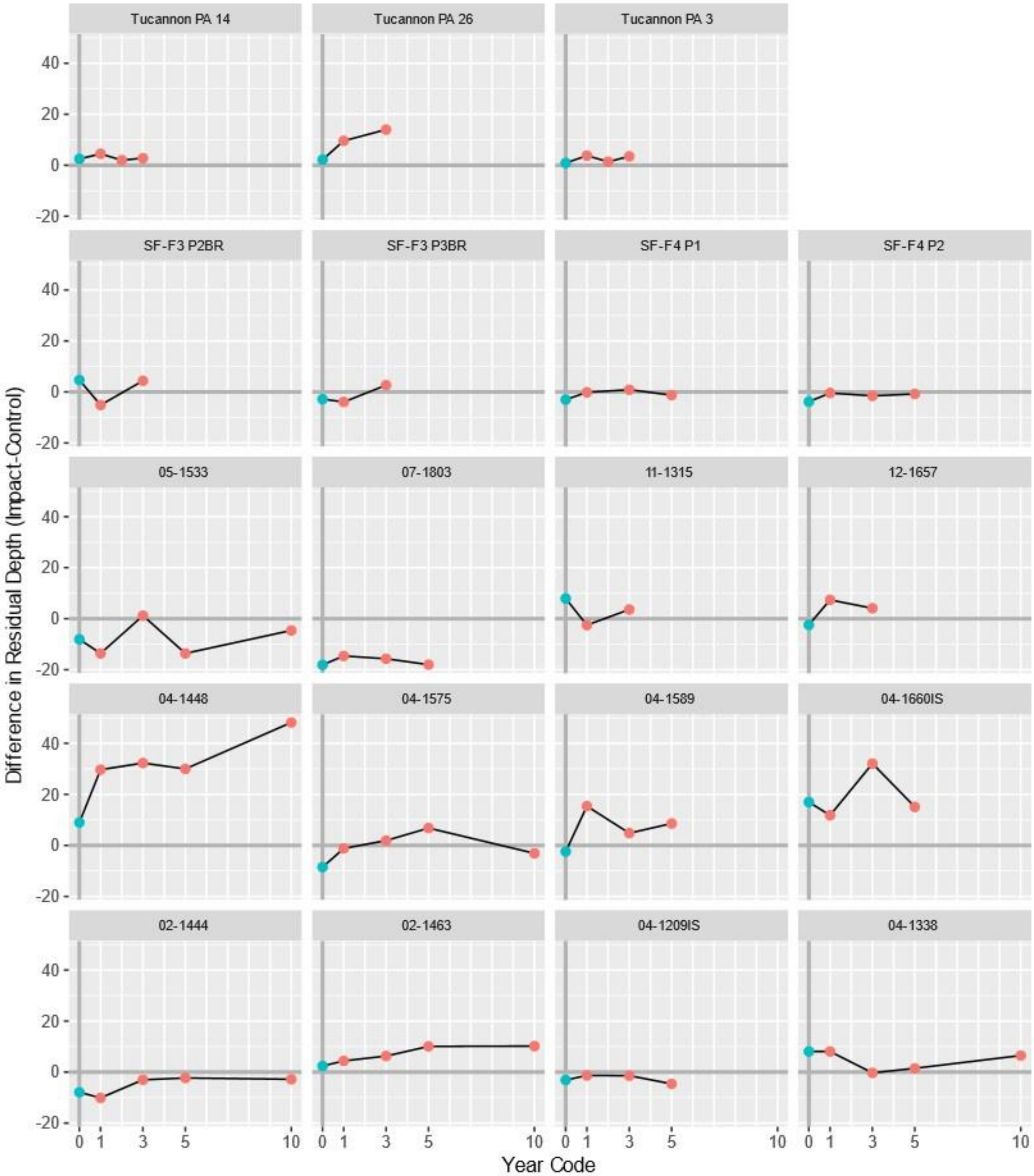

Figure E-2. Difference in mean residual depth (cm) between the impact and control reach for each project included in the instream analysis. The blue and red circles represent before (Year 0) and after monitoring data (Year > 0), respectively.

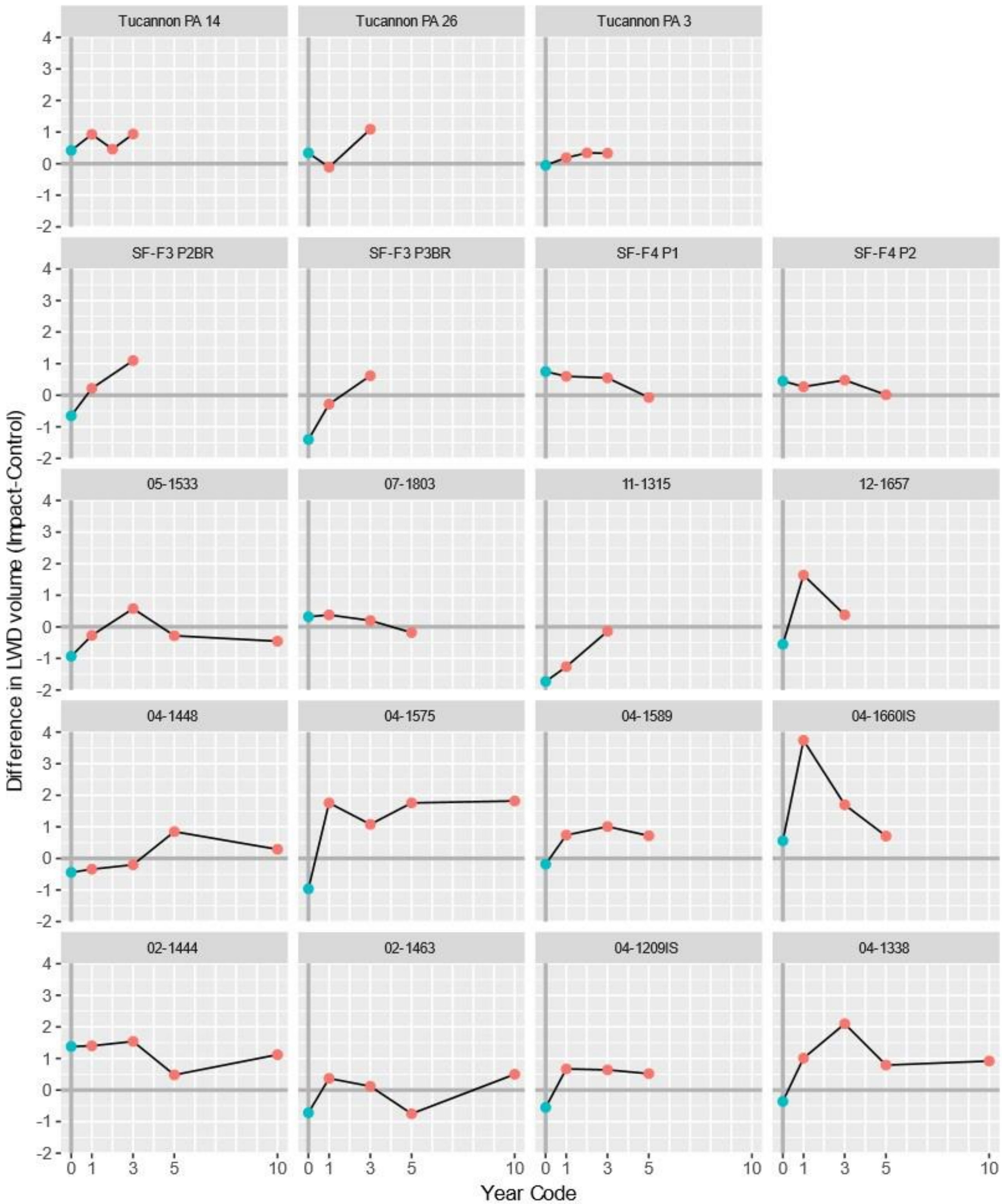

Figure E-3. Difference in $\log_{10}$ LWD volume (m^3) between the impact and control reach for each project included in the instream analysis. The blue and red circles represent before (Year 0) and after monitoring data (Year > 0), respectively.

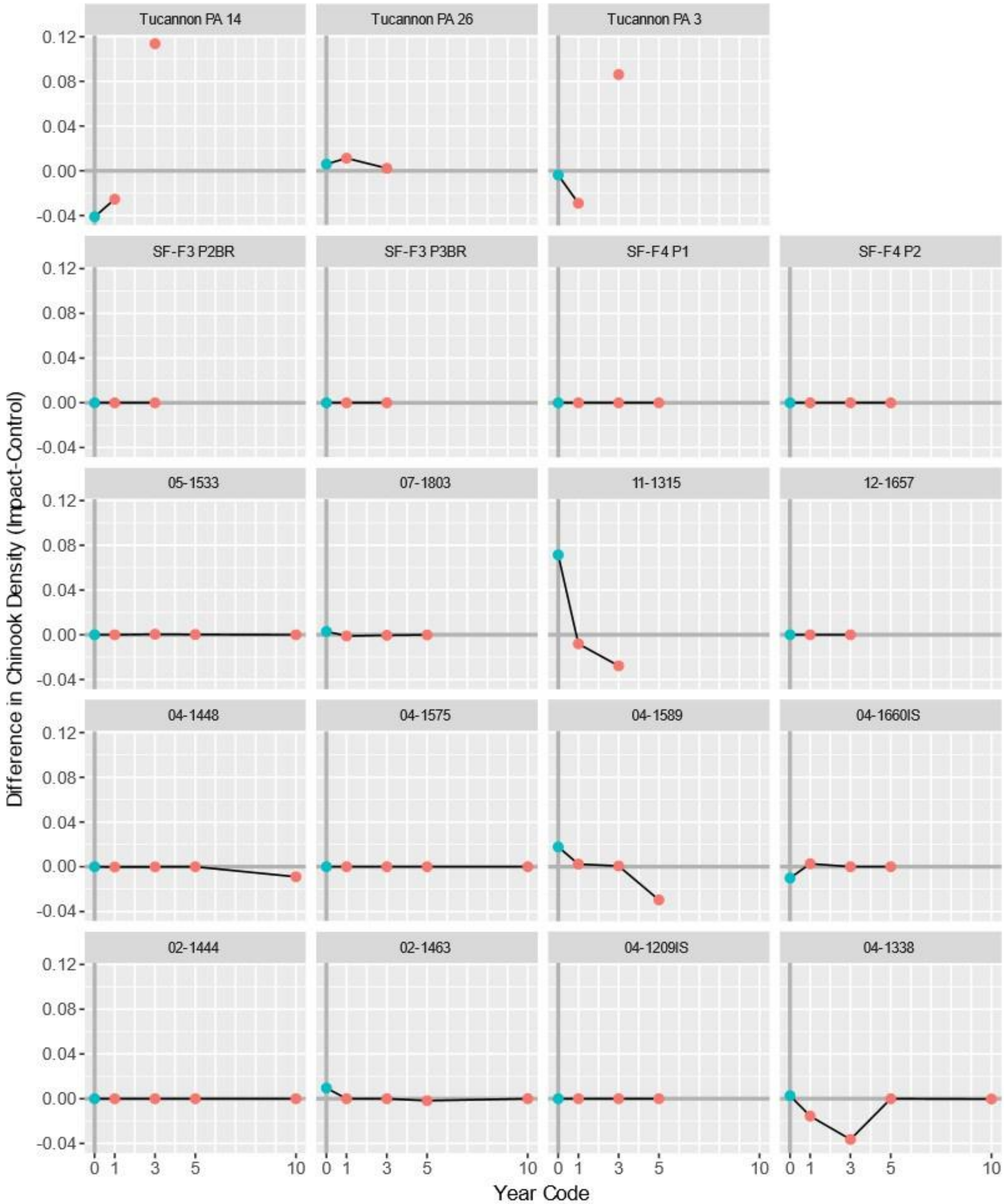

Figure E-4. Difference in Chinook Salmon density (fish/m^2) between the impact and control reach for each project included in the instream analysis. The blue and red circles represent before (Year 0) and after monitoring data (Year > 0), respectively.

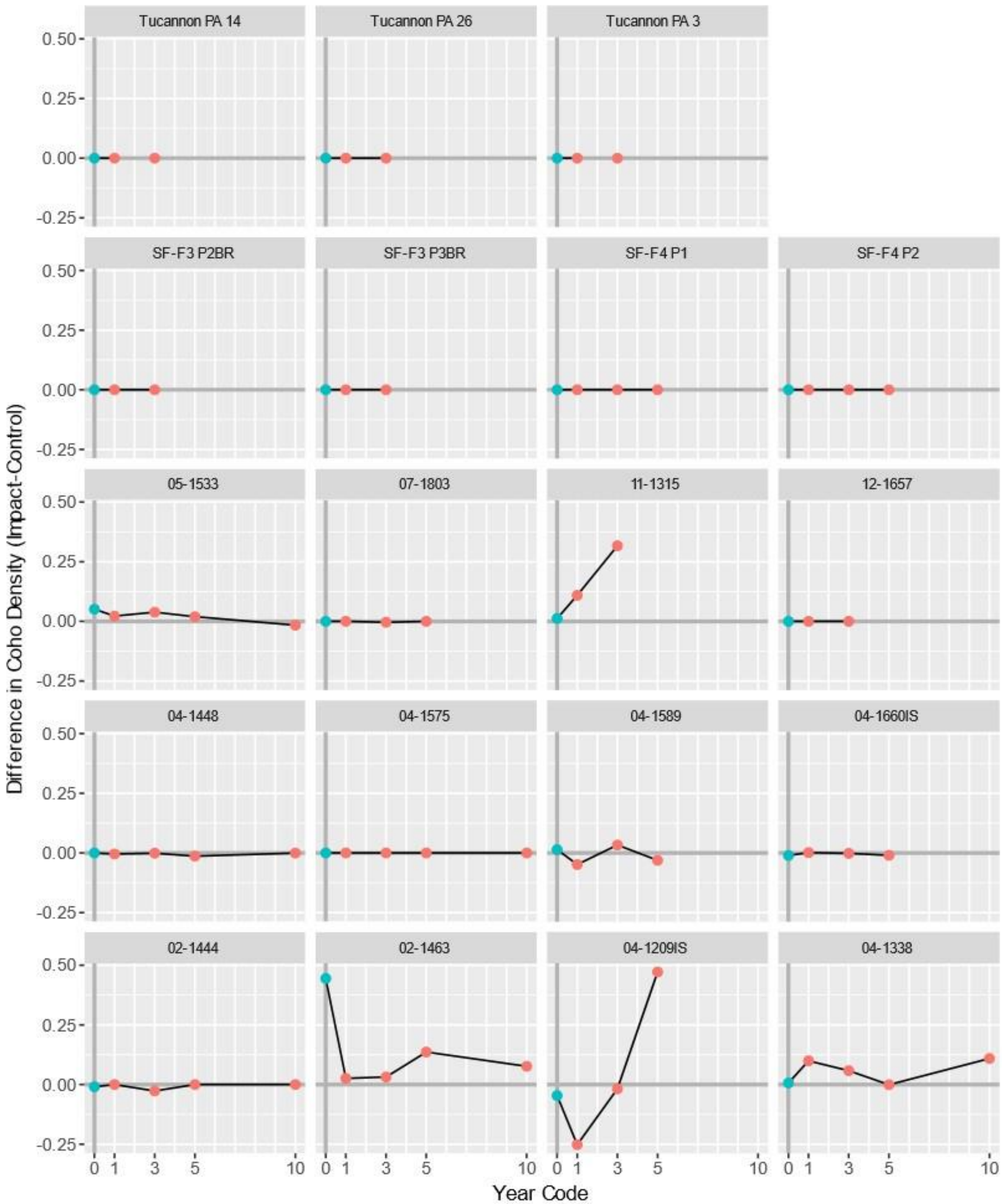

Figure E-5. Difference in Coho Salmon density (fish/m^2) between impact and control reach for each project included in the instream analysis. The blue and red circles represent before (Year 0) and after monitoring data (Year > 0), respectively.

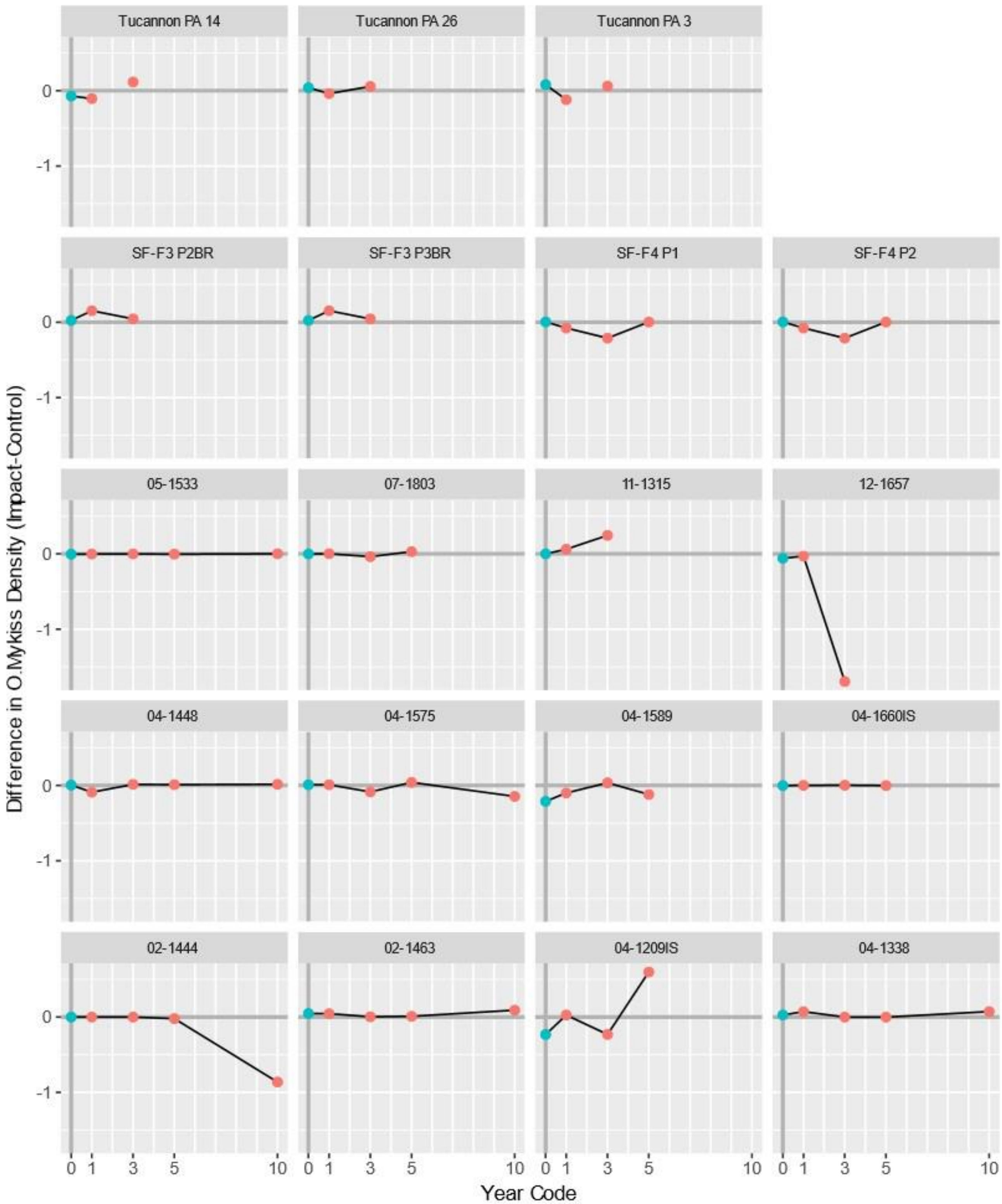

Figure E-6. Difference in steelhead density (fish/m^2) between the impact and control reach for each project included in the instream analysis. The blue and red circles represent before (Year 0) and after monitoring data (Year > 0), respectively.

APPENDIX F: MC-5/6 SUMMARY METRIC PLOTS

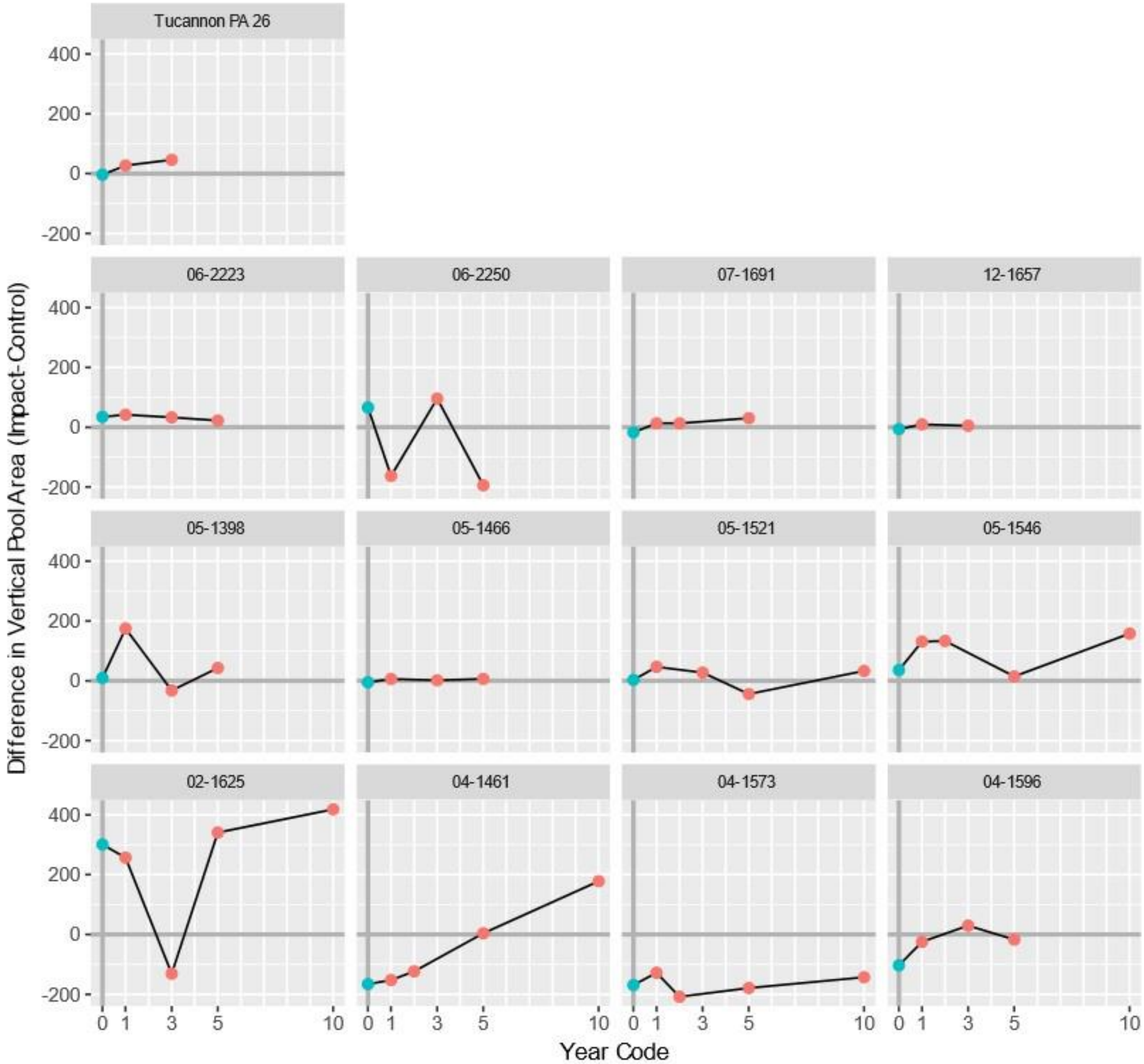

Figure F-1. Difference in vertical pool area (m^2) between the impact and control reach for each project included in the floodplain analysis. The blue and red circles represent before (Year 0) and after monitoring data (Year > 0), respectively.

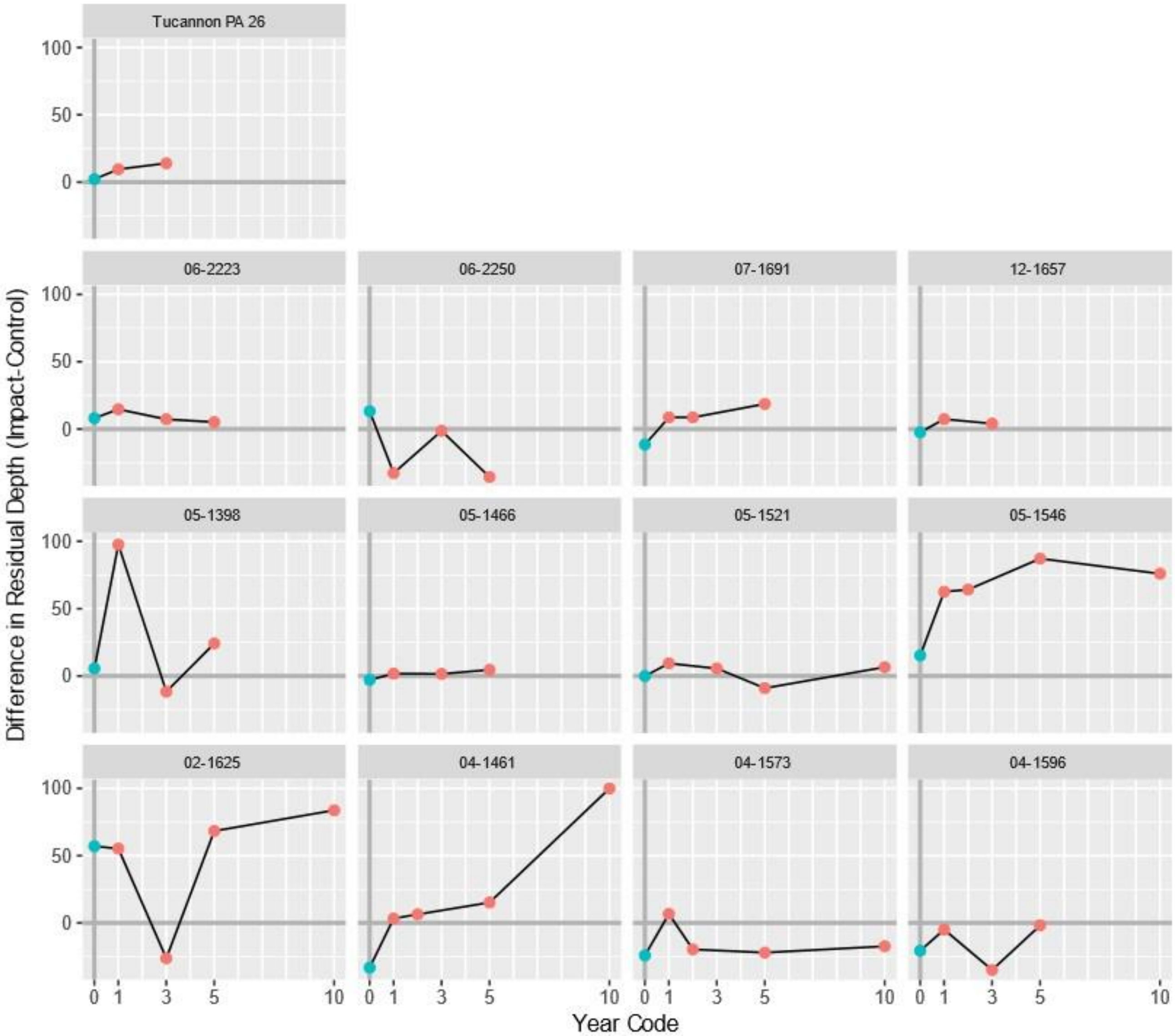

Figure F-2. Difference in mean residual depth (cm) between the impact and control reach for each project included in the floodplain analysis. The blue and red circles represent before (Year 0) and after monitoring data (Year > 0), respectively.

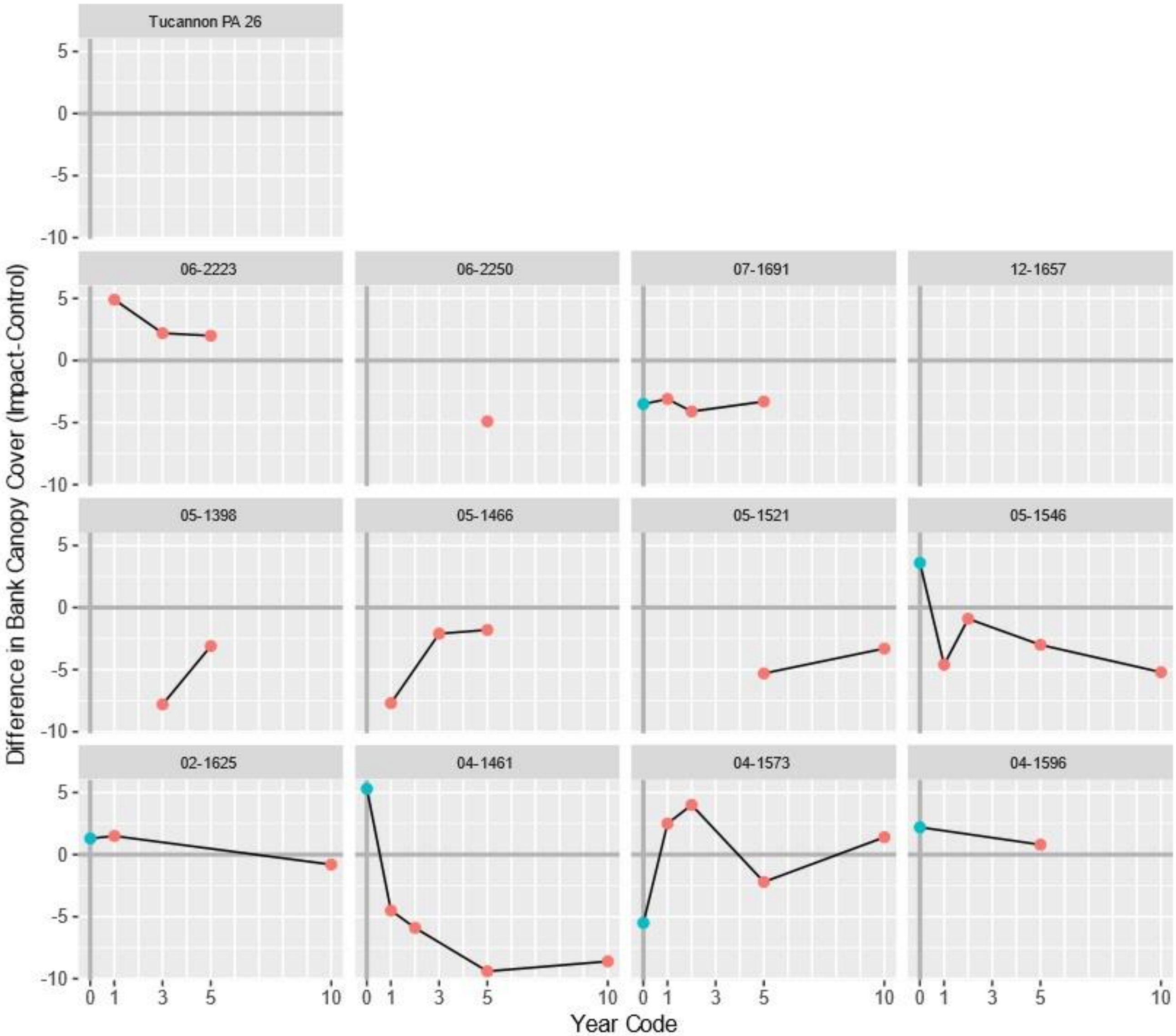

Figure F-3. Difference in bank canopy cover (1-17) between the impact and control reach for each project included in the floodplain analysis. The blue and red circles represent before (Year 0) and after monitoring data (Year > 0), respectively.

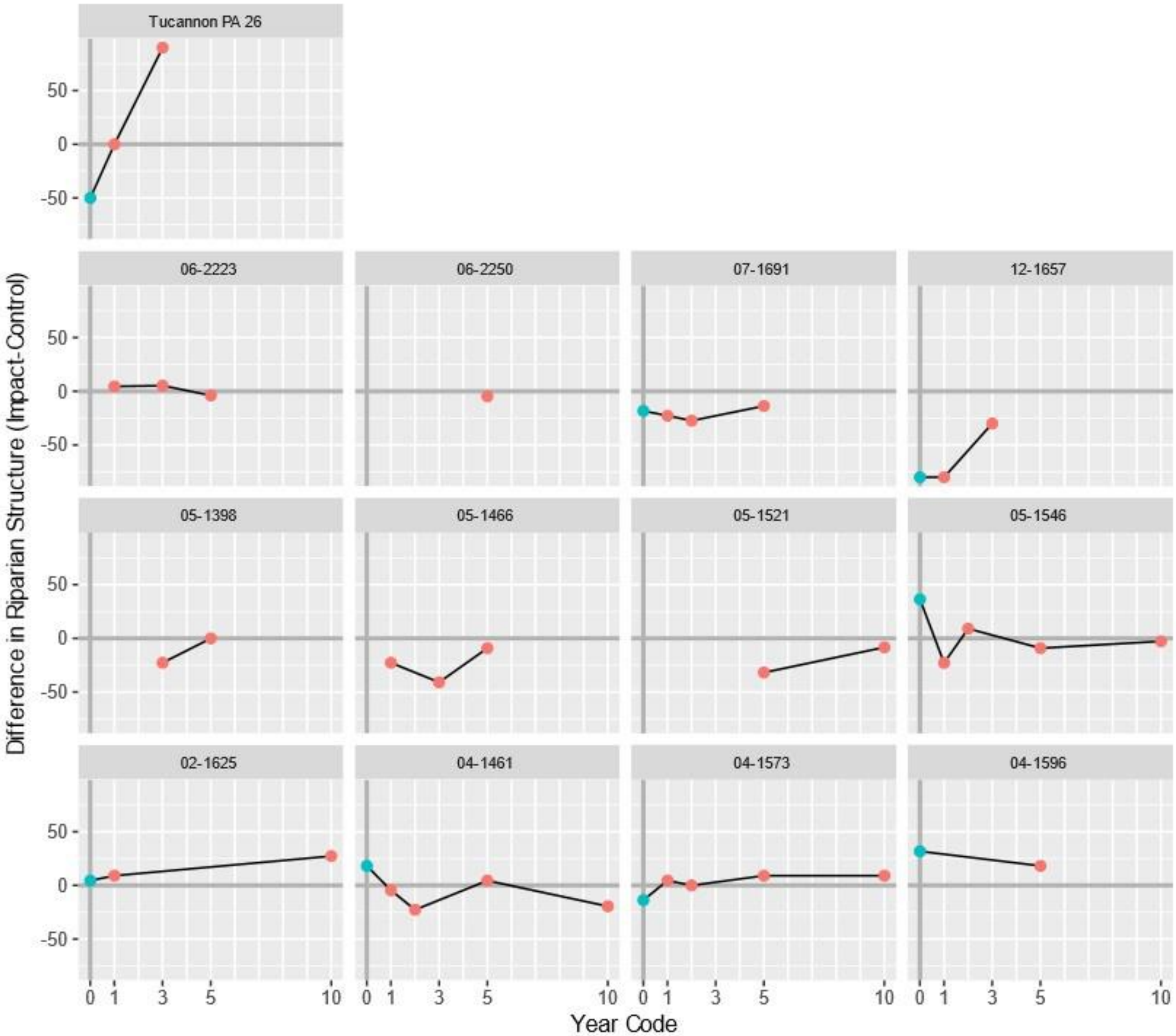

Figure F-4. Difference in riparian vegetation structure (%) between the impact and control reach for each project included in the floodplain analysis. The blue and red circles represent before (Year 0) and after monitoring data (Year > 0), respectively.

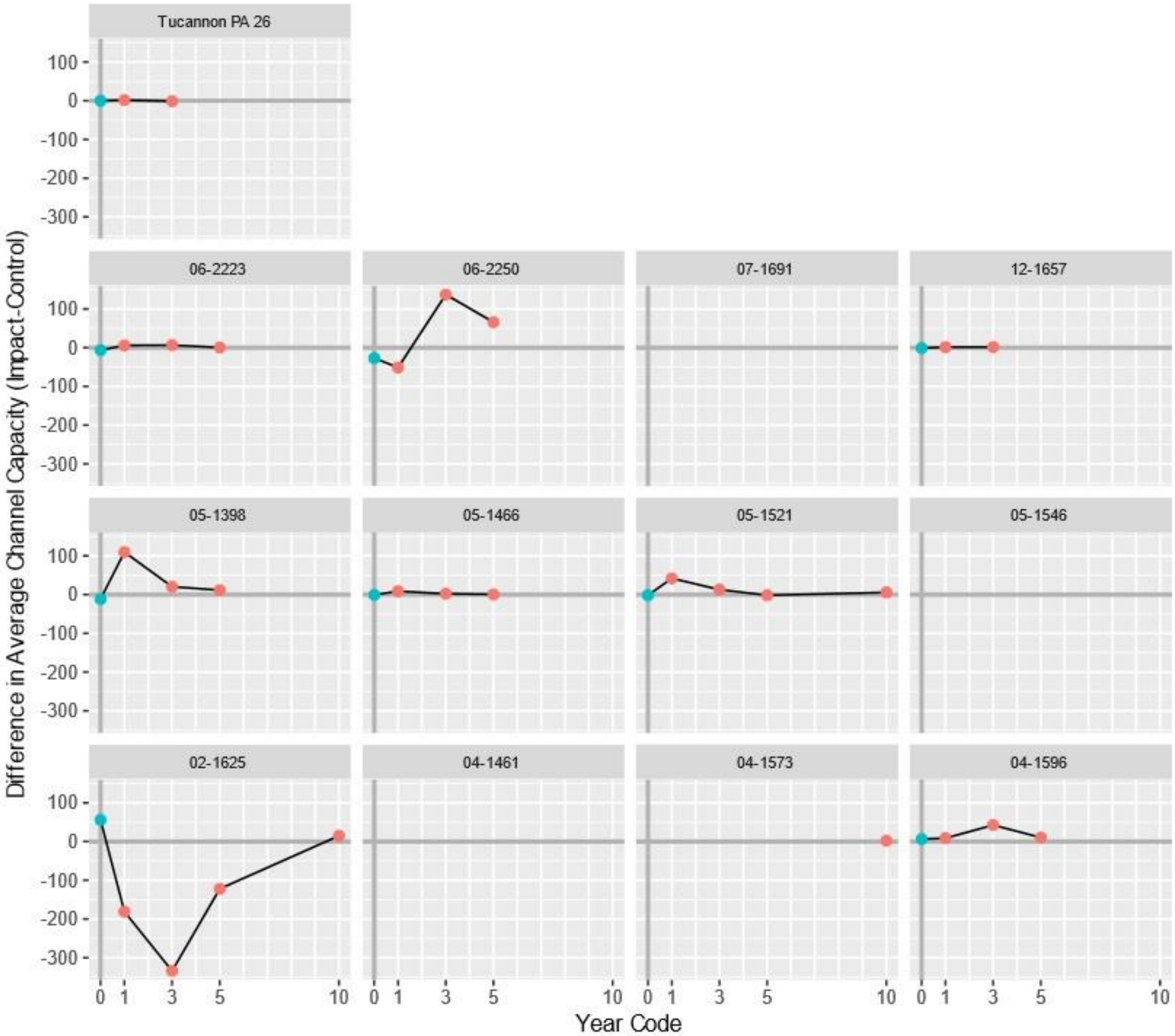

Figure F-5. Difference in average channel capacity (m^2) between the impact and control reach for each project included in the floodplain analysis. The blue and red circles represent before (Year 0) and after monitoring data (Year > 0), respectively.

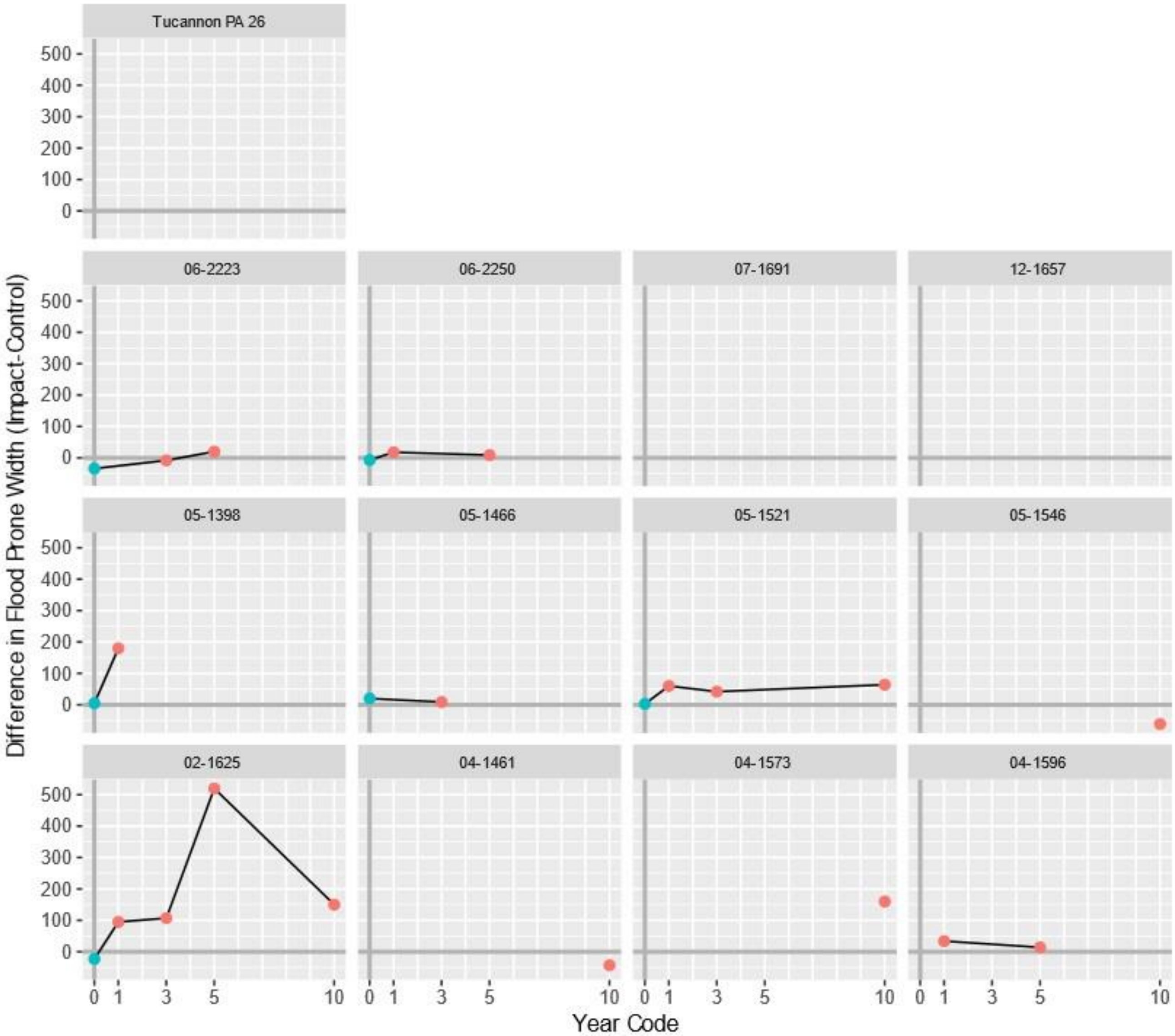

Figure F-6. Difference in floodprone width (m) between the impact and control reach for each project included in the floodplain analysis. The blue and red circles represent before (Year 0) and after monitoring data (Year > 0), respectively.

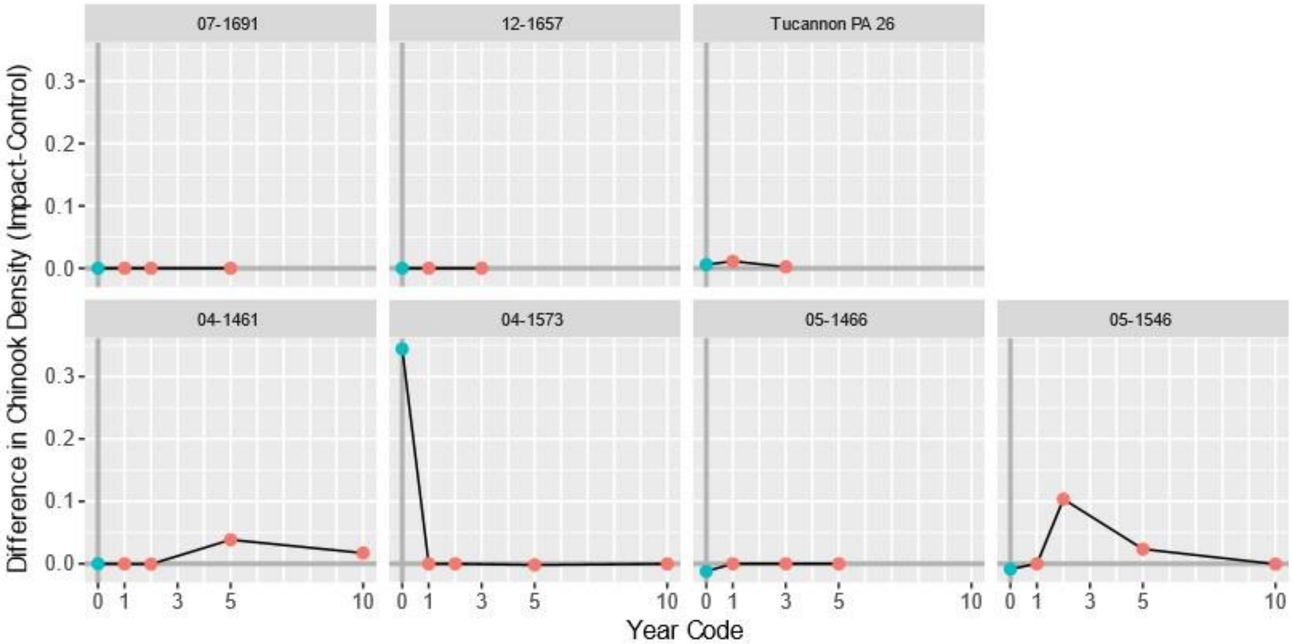

Figure F-7. Difference in Chinook Salmon density (fish/m^2) between the impact and control reach for each project included in the floodplain analysis. The blue and red circles represent before (Year 0) and after monitoring data (Year > 0), respectively.

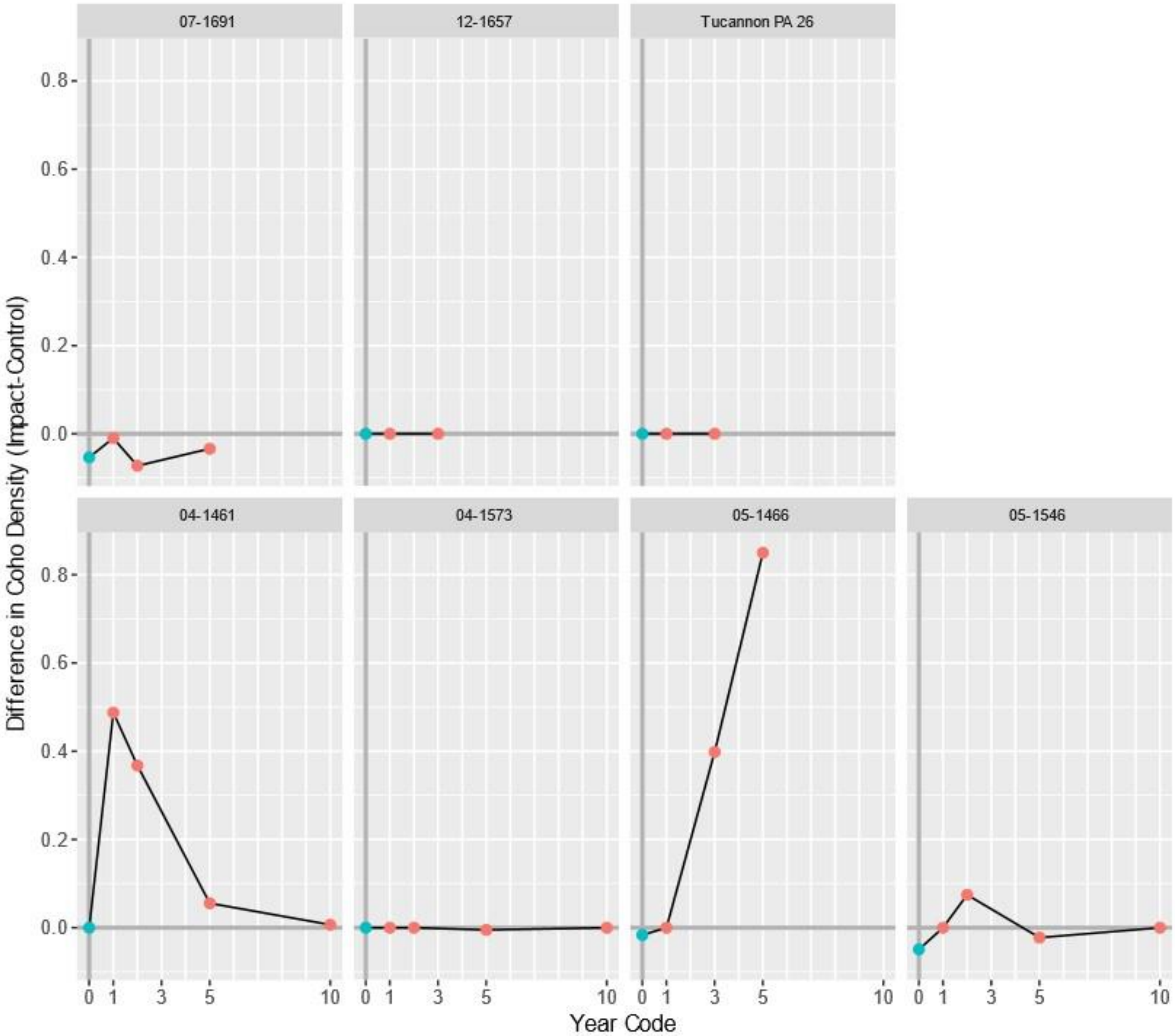

Figure F-8. Difference in Coho Salmon density (fish/m^2) between the impact and control reach for each project included in the floodplain analysis. The blue and red circles represent before (Year 0) and after monitoring data (Year > 0), respectively.

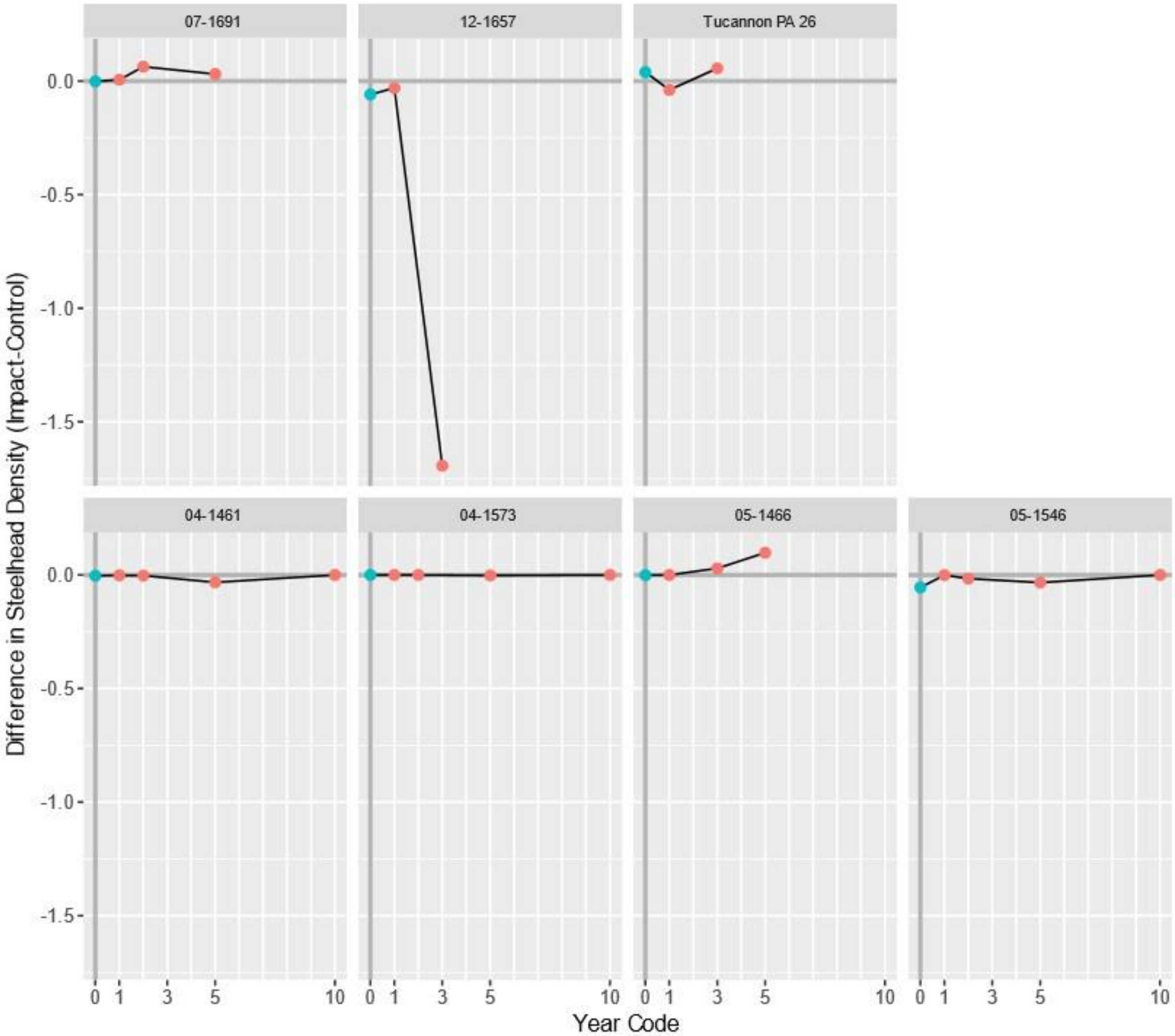

Figure F-9. Difference in steelhead density (fish/m^2) between the impact and control reach for each project included in the floodplain analysis. The blue and red circles represent before (Year 0) and after monitoring data (Year > 0), respectively.