WASHINGTON STATE
RECREATION AND CONSERVATION OFFICE
Salmon Recovery
Funding Board

Reach-Scale Effectiveness Monitoring Program

2013 Annual Progress Report

April 2014

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Prepared by

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ABSTRACT

Stream restoration activities are being conducted around the world in an effort to restore aquatic habitat function. With approximately one billion dollars being spent nationwide on stream restoration annually (Roni et al. 2010), there is a need to track the effectiveness of projects implemented under this funding. In 1999, the Washington state Salmon Recovery Funding Board (SRFB) was created by the state legislature to provide grants and loans for salmon habitat projects and salmon recovery activities across the state. Since its inception, the SRFB has funded more than 1,805 projects and spent more than $581 million in state and federal funds toward salmon recovery in 31 counties in Washington state (SRFB 2014). Monitoring is critical for tracking the results of these expenditures in terms of optimizing the limited funds available for restoration across the region.

Regional coordination of monitoring programs is being sought to increase data compatibility, improve management decisions across jurisdictions, and better utilize monitoring funding and resources. While it is not economically feasible to monitor the long-term success of every project, a subset of projects can be monitored effectively, both within Washington and throughout the Pacific Northwest region. Monitoring data on the effectiveness of projects provides information to project sponsors and lead entities that can be used to improve communication regarding restoration approaches and improve future designs. Using this concept, the SRFB established the Reach-Scale Effectiveness Monitoring Program in 2004 to provide programmatic project effectiveness monitoring across the state. This program samples a subset of projects that have been randomly selected from funded projects throughout the state. Using standardized protocols, the program provides feedback on the effectiveness of different types of projects and can be used to improve decisions regarding project implementation, project funding, and future monitoring efforts. The Reach-Scale Effectiveness Monitoring Program began in spring 2004 and has continued through 2013. This report, in conjunction with information provided through the Habitat Work Schedule (HWS 2013), describes monitoring activities and results for this monitoring effort.

Implementation of the SRFB program first included separating all projects into monitoring categories, and then randomly selecting a subset of projects from each of those categories to monitor. There are currently eight monitoring categories in the program (HWS 2013). The following three categories included projects monitored in 2013, and will be the focus of this report:

- Instream Habitat
- Floodplain Enhancement
- Riparian Planting

Statistical analyses conducted to date indicate that Instream Habitat Projects are significantly influencing localized geomorphology by increasing vertical pool profile area and residual depth in the first 5 years after construction. Statistically significant increases in the volume of wood have also been seen for Instream Habitat Projects, indicating that wood placed as part of restoration projects has remained stable, and is likely leading to additional natural wood recruitment in the treatment reaches. Additional analysis in 2013 showed a significant decrease in juvenile Chinook (*Oncorhynchus tshawytscha*) density over baseline in Year 5. However, no correlation was found between the density of juvenile salmonids and the number of large woody debris pieces per reach. When assessing juvenile fish use of various structure types by species, steelhead (*O. mykiss)* demonstrated the greatest preference for lateral jams and for channel-spanning structures. Chinook, however, did not appear to show a strong preference for any type of structure. Floodplain Enhancement Projects showed significant trends toward improvement in bankfull width and flood-prone width. Significant improvements after project implementation were also seen for pool area and juvenile coho (*Oncorhynchus kisutch*) density in this category. Riparian Planting Projects are showing no statistically significant results to date, but some indications of decrease in bank erosion and increase in vegetation structure have been noted.

Indications of change and observed trends need to be viewed both within the context of the project, and the longer-term perspective that will be developed over the life of the monitoring program as additional years of monitoring events are completed. Additionally, references to juvenile steelhead in this document are made using the scientific name *Oncorhynchus mykiss* because it is not possible to differentiate between juvenile resident rainbow trout and juvenile anadromous steelhead during snorkel surveys.

Additional recommendations to improve project implementation and monitoring are also included as part of this report.

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ACRONYMS AND ABBREVITIONS

AIS	artificial instream structures
BACI	Before-After-Control-Impact
CHaMP	Columbia Habitat Monitoring Program
DEM	digital elevation model
HWS	Habitat Work Schedule
I-C	impact minus control
LWD	large woody debris
MDD	minimum detectable difference
MMI	multi-metric index
OWEB	Oregon Watershed Enhancement Board
RBT	River Bathymetry Toolkit
SRFB	Washington State Salmon Recovery Funding Board
UCSRB	Upper Columbia Salmon Recovery Board

1 INTRODUCTION

Stream restoration efforts are being conducted throughout the world to enhance or restore function to aquatic systems. In the United States, approximately one billion dollars are spent on stream restoration annually (Roni et al. 2010), with the goal of improving wild Pacific salmon runs, many of which are listed under the Endangered Species Act and serve a vital role in both the ecology, and the culture, of the Pacific Northwest. Because of this large amount of capital being invested in restoration, there is a need to track and improve the effectiveness of restoration projects and account for funds being allocated.

The Washington State Salmon Recovery Funding Board (SRFB) was created by the Washington State Legislature in 1999 to distribute federal grants for salmon habitat projects and salmon recovery activities. The Washington Comprehensive Monitoring Strategy was written in 2002 to identify monitoring efforts and prioritize monitoring needs across the state, and to develop a strategy to coordinate these efforts through statewide programs. In 2003, the SRFB funded a survey of restoration project sponsors to determine what, if any, monitoring was being done after projects had been implemented. The responses from the survey indicated that project sponsors were implementing a wide variety of monitoring efforts from compliance monitoring, required by the funding agreement, to full-scale monitoring programs that assessed physical habitat and fish response to restoration.

The inconsistency of the ongoing monitoring efforts, coupled with the need for accountability to funding sources, indicated a need for a coordinated effectiveness monitoring program to independently evaluate the success of funded restoration projects. A repeatable, standardized approach for this evaluation was deemed necessary to provide accountability for the allocations by the state and federal legislatures to further salmon recovery, as well as to help determine the cost-effectiveness of different project categories so that future restoration dollars could be more efficiently spent.

As a result, the SRFB approved funding for the Reach-Scale Effectiveness Monitoring Program in 2004. This work is funded in part by the Pacific Coast Salmon Recovery Fund (PCSRF), a federal funding source through the National Oceanic and Atmospheric Administration (NOAA) for salmon recovery in the Pacific Northwest. Expanding coordination of monitoring efforts in the Pacific Northwest will give federal and state legislators needed information for future funding decisions for salmon habitat restoration. Partnerships with the Oregon Watershed Enhancement Board (OWEB); the Bonneville Power Administration's (BPA's) Research, Monitoring, and Evaluation Program (RME); and the Upper Columbia Salmon Recovery Board (UCSRB) in 2013, increased the level of coordination in monitoring across the region; these partnerships are expected to result in more efficient monitoring and cost savings.

Comparable data collected across the region will provide more usable information to aid resource managers in making decisions regarding ESA-listed salmon species, many of which range across state lines, and some across the US border with Canada. In addition, results from the program are shared with project sponsors and lead entities to help improve communication regarding successful restoration approaches, documents the lessons learned, and identify the best ways to improve project designs and implementation.

Project categories included in the SRFB monitoring program are listed below. Italicized categories are not included in this report, as they have either been completed or, there were no projects within a given category monitored in 2013.

- *Fish Passage*
- Instream Habitat
- Riparian Planting
- *Livestock Exclusion*
- Floodplain Enhancement
- *Spawning Gravel*
- *Diversion Screening*
- *Habitat Protection*

This report summarizes monitoring and data analysis efforts during the 2004 through 2013 field seasons for the three project categories monitored in 2013. Monitoring of Fish Passage Projects and Diversion Screening Projects were completed in 2009; therefore, those project categories are no longer actively monitored in the program. The project pool for Spawning Gravel Projects was not of sufficient size to have statistically valid results, so that category was omitted from monitoring in 2013 as well. None of the Livestock Exclusion or Habitat Protection Projects were scheduled for monitoring in 2013, so those project categories are not discussed in this report. The categories monitored in 2013 were Instream Habitat, Floodplain Enhancement, and Riparian Planting. Included in the data analysis for 2013 are instream habitat and floodplain enhancement projects monitored through the UCSRB Project-Scale Effectiveness Monitoring Program. Information on the other project categories can be found in previous annual progress reports, which are available via the Habitat Work Schedule (HWS), a centralized database for restoration project data (HWS 2013), and through the Recreation and Conservation (RCO) website. www.rco.wa.gov.

This report includes a brief description of data collection methods for each monitoring category, data analysis, results, and recommendations for future monitoring and reporting. Initial response trends for the Instream Habitat, Riparian Planting, and Floodplain Enhancement project categories have been detected using up to 5 years of post-project implementation data. As mentioned above the annual summary reports for this program are available online at the HW, including this report which provides information from the 2013 monitoring effort. The HWS (2013) also contains individual reports for each of the active projects in the program, including project-specific data and results for those sites, as well as protocols used in the monitoring program.

2 METHODS

2.1 FIELD MONITORING METHODS

There are currently eight monitoring categories included within the SRFB program. Projects in three of those categories were monitored in 2013, including Instream Habitat, Floodplain Enhancement, and Riparian Planting (Table 1). Field sampling indicators and techniques were adapted from U.S. Environmental Protection Agency's (EPA) Environmental Monitoring and Assessment Program (Peck et al. 2003) and the Columbia Habitat Monitoring Program (CHaMP 2013). All three of the project categories monitored in 2013 were evaluated using a Before-After-Control-Impact (BACI) experimental design (Stewart-Oaten et al. 1986). The detailed protocols used to monitor projects are available in Crawford (2011a,b,c) and can be found on the Washington Habitat Work Schedule (HWS 2013). The monitoring categories and success criteria are described in the documents listed under Monitoring Protocols 2011. The protocols include goals and objectives for each category, detailed field data collection descriptions, functional assessment methods, summary statistics, and data analysis procedures.

Table 1. Projects Monitored in 2013

Project Number	Project Name	Category	Year of Data Collection
02-1515	Upper Trout Creek Restoration	MC-2 Instream Habitat	Year 5
04-1209	Chico Creek Instream Habitat Restoration	MC-2 Instream Habitat	Year 5
04-1660	Cedar Rapids flood plain	MC-2 Instream Habitat	Year 5
04-1660	Cedar Rapids flood plain	MC-3 Riparian Planting	Year 5
04-1596	Lower Tolt River Floodplain reconnection	MC-5/6 Floodplain Enhancement	Year 5
05-1398	Fenster levee setback	MC-5/6 Floodplain Enhancement	Year 5
05-1466	Lower Boise Creek construction	MC-5/6 Floodplain Enhancement	Year 3
06-2223	Greenwater R ELJ & Road Decommissioning	MC-5/6 Floodplain Enhancement	Year 3
07-1519	Reecer Creek Floodplain Restoration	MC-5/6 Floodplain Enhancement	Year 3
06-2250	Chinook Bend Levee Removal	MC-5/6 Floodplain Enhancement	Year 5
04-1563	Germany Creek Conservation Restoration	MC-5/6 Floodplain Enhancement	Year 5
06-2190	Riverview Park	MC-5/6 Floodplain Enhancement	Year 1
07-1691	Lockwood Creek Phase 3	MC-5/6 Floodplain Enhancement	Year 5

The Monitoring Category (MC)-5/6 Floodplain Enhancement Protocol includes a method from the CHaMP Program for conducting a topographic survey in lieu of the thalweg profile and physical habitat survey that has been used at Channel Connectivity (MC-6) and Constrained Channel (MC-5) sites in the past. Using the topographic survey data, a digital elevation model (DEM) is developed and can be used to track the changes in channel and floodplain topography through time.

By comparing DEMs across years, a quantification of changes in available habitat can be completed allowing the level of floodplain reconnection to be measured. The topographic survey also allows the calculation of channel and habitat conditions that can be tracked over time. Under this method, the DEM is uploaded into the River Bathymetry Toolkit (RBT), a software package used to analyze the data, produce summary statistics, and automate calculations of summary statistics from the DEM (Appendix A). The DEM provides a topographic surface of the channel and surrounding floodplain, which allows more flexibility in data analysis and information output. The DEM can also serve as input into various models, such as flood or flow models, to determine channel response under different flow conditions.

In future years of monitoring, the topographic survey will be repeated in order to compare to the digital data layers across years, which will subsequently allow calculation of changes in habitat conditions through time.

The topographic survey method was applied at nine floodplain project sites in 2013. Additionally, floodplain sites located in the Upper Columbia River basin being monitored under a separate program for the UCSRB were surveyed using the same topographic survey method. Partnering with the UCSRB to monitor floodplain projects using the same methods allowed data sharing and resulted in an increased sample size for both programs at no additional cost, thereby enjoying economies of scale.

2.2 DATA ANALYSIS METHODS

Previous annual reports for this program include data analysis methods and results that assessed success of each project category as a unit on a statewide scale. With only one year of additional data for the sites monitored in 2013, the statistical analysis that was completed in 2012 was not repeated this year, because additional years of data will likely provide a better perspective of changes at the category scale. A summary of previously used statistical methods is provided below; however, details regarding those analyses can be found in past annual summary reports on Habitat Work Schedule (2013). In addition to the methods used previously, the following section describes additional data analyses that were conducted in 2013.

2.2.1 Summary of Previous Data Analysis Methods

Effectiveness evaluations for each monitoring category fall under two methods: those that use percent change criteria, and those that use statistical tests. For each indicator being tested, the effectiveness of a project is determined in terms of whether the post-project value is *significantly* different than the pre-project value, statistically. The percent change in the value is also evaluated to determine if the change is greater than 20 percent. This second evaluation is designed to provide a benchmark for biologically meaningful change. Even if a given change is significant statistically, there are cases when the absolute value of the change as compared to the baseline is so small that the change would not be considered biologically meaningful. This second evaluation is intended to answer that question. Decision criteria for each indicator are defined in the protocols for each category (Crawford 2011a,b,c).

Within the statistical analysis for each protocol, there are two different types of tests: trend analysis, and mean difference analysis for pre-data versus post-data. For the trend analysis based on slope, regional trends through time are evaluated. This type of analysis is intended to create a profile summary, summarizing the trend across all sites with a single number. In this case, the regression slope is used as the trend summary. Regional differences from zero for the regression slopes can then be assessed using a t-test or nonparametric equivalent Wilcoxon test. This can be viewed as an extension of the paired t-test, using the slope or average difference rather than the absolute difference between 2 years. Because the linear regression slope is being used, this test is most sensitive to a linear increase occurring across the sampled years.

An estimate was made of the least-squares regression slope of the response (impact minus control for each sampled variable) regressed against time, where time is measured relative to project implementation. Because the projects were not all implemented in the same year, the years were standardized to the project implementation timeframe (e.g., Year 0, Year 1). The first year after project implementation is always labeled Year 1, and the year immediately prior to implementation is Year 0. The average change method evaluates the difference between Year 0 and the average of all post-project years.

For each variable or indicator within each monitoring category, linear slopes were estimated, and the slopes were evaluated for approximate normality. If the slopes differed significantly from a normal distribution (Shapiro-Wilks p-value < 0.05), a one-tailed nonparametric t-test (Wilcoxon test; $\alpha = 0.10$) was used to assess significant trends. Otherwise, a one-tailed t-test was used. The assumptions for the t-test are the following:

- Sites represent an independent random sample from all possible sites.
- Slope estimates are approximately normally distributed.

Trends were not evaluated for variables with data from fewer than three sites. Also, if the average slope was negative (or positive for bank erosion and bankfull height), we know there cannot be a significant improvement regardless of the statistical test used, so there was no test for those variables.

A slope box plot graph was developed showing the average of the trendline slopes for the net difference between the impact and control reaches for each indicator at each project through time. For each variable, the change estimated by linear trend (averaged across sites) as a percent of the baseline (impact – control) mean at Years 1, 3, and 5 was determined. These estimates are based on the assumption of linear increase or decrease through time based on the direction of improvement for a given indicator. This provides an absolute measure to compare to the benchmark of 20-percent change through time. The percent change over baseline was determined for each indicator showing a significant change in Year 5.

For each indicator tested, the average difference method was applied to evaluate average changes in conditions before and after project implementation. The mean for each indicator across all sites was determined for all pre-project years (baseline data) combined and for all post-implementation years combined. The mean pre-project value was then plotted versus the mean post-project value. This type of analysis allows easily identifiable comparisons between the pre- and post-project conditions indicating the level of change caused by the project.

2.2.2 Additional Analyses Conducted in 2013

2.2.2.1 Fish Analysis

Additional analyses were conducted in 2013 to evaluate fish response to projects. Density was evaluated using a BACI analysis, whereby densities for juvenile Chinook, coho, and *O. mykiss* were summed for each project reach, including UCSRB sites, for each sampling year. For each year, impact values were subtracted from control values for each project. An average of impact minus control (I-C) values was calculated across projects for each sampling year and a standard error determined. These values were then plotted for Instream Habitat and Floodplain Enhancement project categories. T-tests were also conducted to determine if any of the results were significant.

Density, while a useful tool for looking at changes in fish use at restoration locations, can be difficult to interpret in situations where surface area changes are part of the restoration action. In order to account for this, raw counts of fish were also evaluated using a BACI analysis and the methods described for density analysis above.

Project data were also examined to assess fish use of projects and structures. Mean length was calculated by taking the sum of each length multiplied by its occurrence during the survey and then dividing the sum by the total number of individuals for the species observed.

Histograms were generated for projects in the two categories monitored in 2013 and habitat associations were explored for data containing habitat association information. As this information was not consistently collected until recent monitoring years, this evaluation is not strictly looking at BACI results, but rather a further exploration of implementation effects for fish across project types.

2.2.2.2 Power Analysis

In 2013, an assessment of the relative decrease in variance contributed by additional years of monitoring data was conducted (Shelly 2013). Comparison of the within-site-variance multiplier allowed evaluation of the relative contribution of additional years of both post-project and pre-project data. Using the spatial and temporal variability from the dataset, which is based on the first 8 years of the monitoring program, a power analysis was conducted to estimate minimum sample sizes needed to detect statistically significant differences for each indicator and action type. The standard formula to estimate the minimum detectable difference (MDD) for a one-sample t-test of effect size mean (see, for example, Zar 1996 p. 109) was used:

$$MDD = \sqrt{\frac{s^2}{n}}\left(t_{\alpha,\nu} + t_{\beta(1),\nu}\right), \qquad (1)$$

where

s^2 is the estimated variance of effect sizes among sites,
n is the number of sites sampled,
ν = (*n*-1),
α is set to one-tailed alpha = 0.10, and
β = 0.20 (1 – desired power = 80%).

Following Liermann and Roni (2008), the variance among effect sizes into two components was decomposed—variance among sites, and variance within sites (labeled variance through time by Liermann and Roni [2008]). The variance in the samples within sites includes sampling variance as well as temporal variance. As in Liermann and Roni (2008), the estimate of the within-site variance was derived by rewriting the equation (1) above as (Liermann 2011, personal communication):

$$\widehat{E_s} = \frac{\sum_{j=1}^{k_a}(x_{sj}+\bar{E})}{k_a} - \frac{\sum_{j=1}^{k_b} x_{sj}}{k_b}. \qquad (2)$$

The differences between the impact and control sites (x_{sj}) were assumed to come from a common normal distribution with mean 0 and variance σ^2_{time}. The overall average effect size, $\bar{E}$, is fixed. The years of sampling after implementation is $k_a$and the years of sampling before implementation is k_b. Therefore, the variance of the observed effect size within each site (variance of equation (2)) is:

$$\frac{1}{k_a^2}\sum_{j=1}^{k_a} Var\left(x_{sj}\right) + \frac{1}{k_b^2}\sum_{j=1}^{k_b} Var\left(x_{sj}\right) = \sigma^2_{within}\left(\frac{k_b+k_a}{k_b k_a}\right). \qquad (3)$$

Note that if $k_a = k_b$, this equation reduces to equation (3) in Liermann and Roni (2008).

The total variance among effect sizes is the sum among site and within site variance components:

$$var_{observed\ between} = \sigma^2_{within}\left(\frac{k_b+k_a}{k_b k_a}\right) + \sigma^2_{between}. \qquad (4)$$

The variance of the mean effect size is therefore:

$$var_{mean\ E} = \frac{\sigma^2_{within}\left(\frac{k_b+k_a}{k_b k_a}\right)+\sigma^2_{between}}{n}, \qquad (5)$$

where *n* is the number of sites.

By examining equation (5), the trade-offs between number of sites and number of years can be seen, as well as the before and after year combinations. The variance of the mean is inversely proportional to the number of sites, so there is a direct reduction in the total variance with each additional site (and also a corresponding increase in degrees of freedom for the *t*-statistic). The effect of the number of years of sampling is less direct because it depends on the relative magnitudes of within versus between site variance, and on the combination of before versus after impact years. If the site variance is the dominant component of variance, the number of years sampled will have very little overall impact. The variance for different combinations of before and after years of sampling was calculated to determine the relative change in variance for different levels of monitoring effort. Projects where results had high variation in the data would require more sites and/or years to detect even large changes, while those project metrics with little variation can detect much smaller changes with fewer sites/years.

3 RESULTS

3.1 INSTREAM HABITAT PROJECT RESULTS

Instream Habitat Projects were evaluated to assess trends in indicator response and the average change between pre-project and post-project conditions using the methods described above. The locations of Instream Habitat Projects included in this analysis are shown in Figure 1. Projects in this category were also evaluated using a functional analysis to determine whether they met functional success criteria individually and as a project category. For Instream Habitat Projects, artificial instream structures (AIS) that are placed as part of the project are tracked over time to determine whether they remain in place and maintain functionality as designed.

Success is met when a project retains 50 percent or more of the AIS placed at the site. As a category, 80 percent of the Instream Habitat Projects must meet this criterion by Year 10 to meet the functional success criteria.

For the Instream Habitat Projects monitored in this program, statistically significant improvements are currently being seen in pool area, pool depth, and $\log_{10}$ volume of wood ($\alpha = 0.10$) (Table 2) using both the slope method and the average difference method. Chinook, (*Oncorhynchus tshawytscha),* coho *(O. kisutch*), bull trout (*Salvelinus confluentus),* and rainbow/steelhead *(O. mykiss)* juvenile densities showed no significant increases in density above Year 0 values using data through 2013; however, a significant decrease ($p<0.1$) was found in Chinook density in Year 3 and Year 5 as compared to baseline levels. The generation time, or the average time between birth of an individual and birth of its offspring, may be a factor in the ability to detect changes in juvenile fish densities by Year 5.

For the salmonid species being monitored, generation time varies by species between 3 and 5 years. Therefore, it may take additional years of monitoring to capture improvements in this indicator. IMW monitoring programs in the region have reported results that multiple generation times (7-10 years) are needed to show significant responses in fish numbers resulting from restoration actions (Bilby et al. 2005). For each of the indicators found to be statistically significant in Year 5, the percent change over baseline was also calculated. Pool area, pool depth, and volume of wood showed large positive increases of greater than 20 percent over baseline in all years monitored. Table 2 summarizes the results of statistical analysis using both the slope method and the average difference method for Instream Habitat Projects.

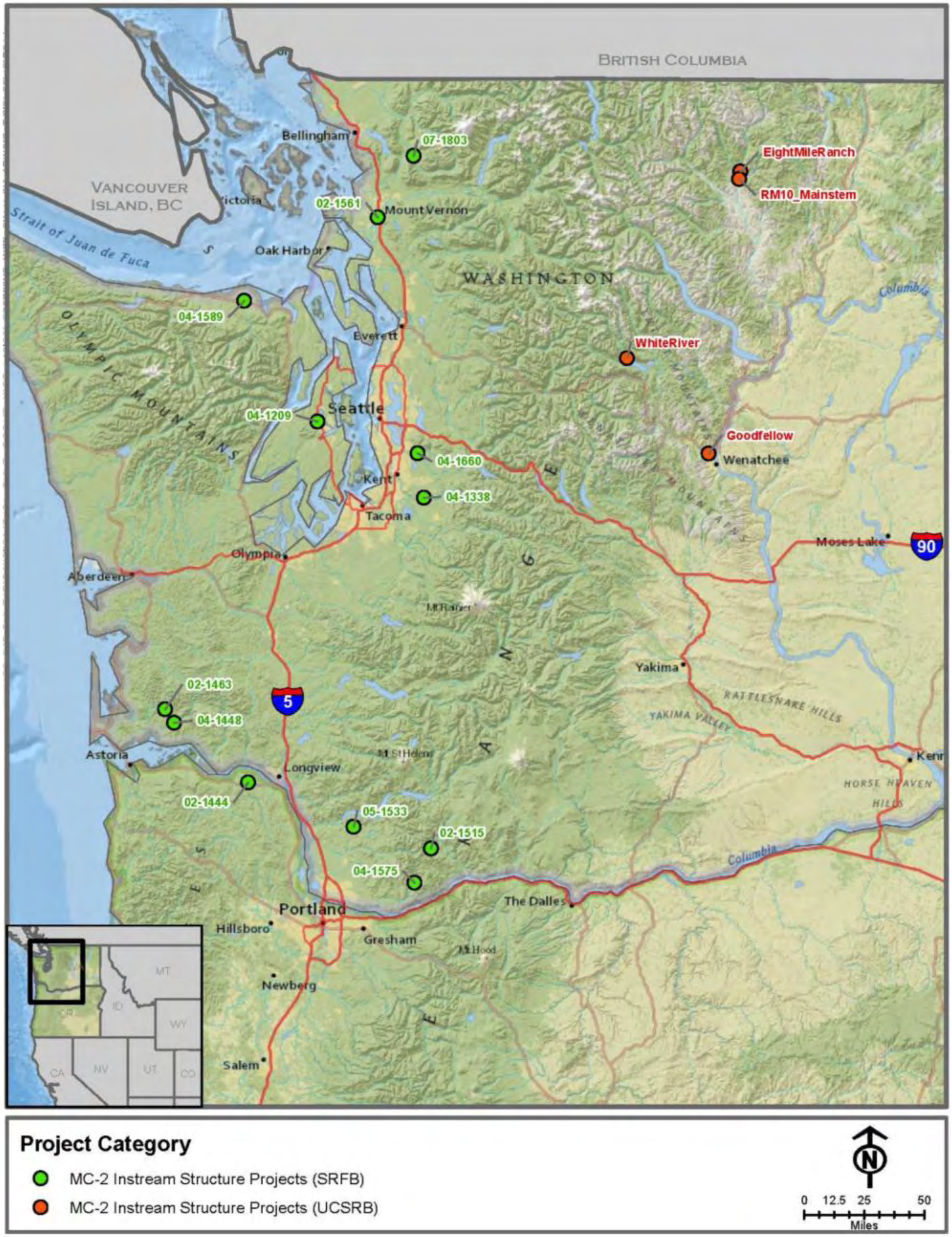

Figure 1. Instream Habitat Project locations

Table 2. Summary of Results for Instream Habitat Projects through 2012

Slope Method				
Indicator	**Test**	**Mean Slope**	**Standard Error of the Mean Slope**	**p-value**
Pool Area (m^2)	one-tailed t-test (positive slope)	8.9	2.7	0.003
Pool Depth (cm)	one-tailed t-test (positive slope)	2.0	0.75	0.010
Log_{10} Volume of Wood (m^3)	one-tailed t-test (positive slope)	0.15	0.041	0.001
Chinook Juveniles (fish/m^2)	N/A	-0.0007	0.0004	N/A
Coho Juveniles (fish/m^2)	N/A	-0.0032	0.0032	N/A
O. mykiss Parr (fish/m^2)	N/A	-0.0060	0.0033	N/A
Bull Trout (fish/m^2)	N/A	-0.000001	0.000002	N/A
Average Difference Method				
Indicator	**Test**	**Mean Difference**	**Standard Error of Mean Difference**	**p-value**
Pool Area (m^2)	one-tailed t-test (positive difference)	29.2	7.1	0.001
Pool Depth (cm)	one-tailed t-test (positive difference)	6.1	1.8	0.003
Log_{10} Volume of Wood (m^3)	one-tailed t-test (positive difference)	0.9	0.21	0.001
Chinook Juveniles (fish/m^2)	N/A	-0.0020	0.0018	N/A
Coho Juveniles (fish/m^2)	N/A	-0.0233	0.0293	N/A
O. mykiss Parr (fish/m^2)	N/A	-0.0112	0.0085	N/A
Bull Trout (fish/m^2)	one-tailed Wilcoxon test (positive difference)	0.000001	0.00001	0.61

Note: Blue highlight indicates statistically significant results.
N/A – negative slope or difference detected

Three Instream Habitat projects were monitored in 2013. The summary fish data from 2012 were updated with the 2013 data, resulting in the charts shown in Figures 2a through 2c. No significant increases in density above Year 0 values were detectable for the Instream Habitat Project category for juvenile Chinook, coho, or *O. mykiss*; using data through 2013; however, a significant decrease ($p<0.1$) was found in Chinook density in Year 3 and Year 5 as compared to baseline levels. The graphs below are plotted with error bars at one standard error (Figures 2a through 2c).

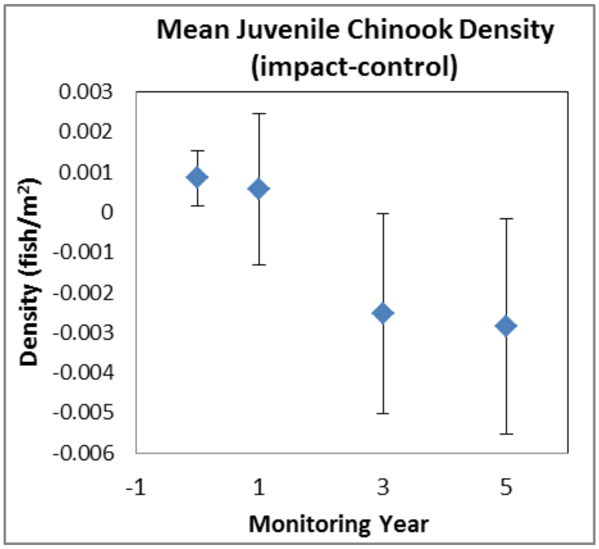

Figure 2a. Mean juvenile Chinook density (I-C)

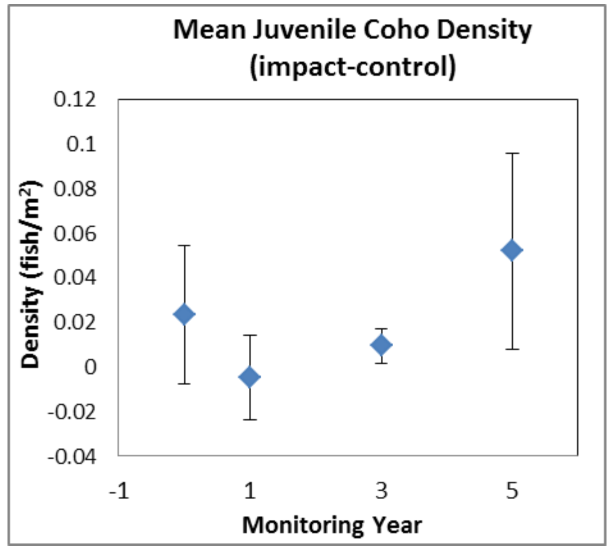

Figure 2b. Mean juvenile coho density (I-C)

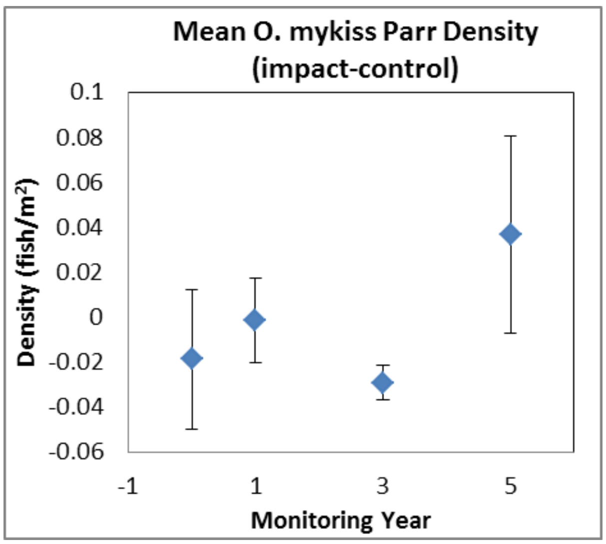

Figure 2c. Mean *O. mykiss* parr density (I-C)

When evaluating differences in raw counts (abundance) before and after project implementation, there is a significant increase in the number of *O. mykiss* using the projects post-implementation. Using a paired t-test, at an alpha = 0.10, the value of impact-control for Year 5 was compared to those for Year 0, with a p = 0.066. Trends in coho abundance, post-implementation, appear to decrease in Years 1 and 3 and increase in Year 5; however, no significant difference from Year 0 is detectable due to variability. Chinook abundance appears to show a downward trend with a minor increase in Year 1; however, no significant difference from Year 0 is detectable due to data variability (Figures 3a through 3c).

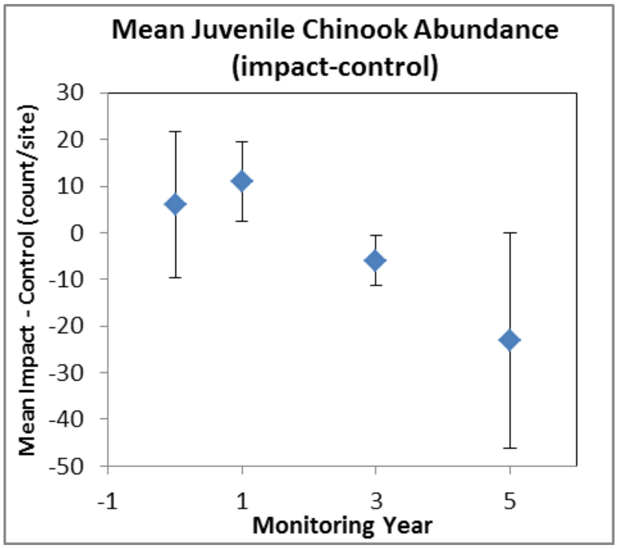

Figure 3a. Mean juvenile Chinook abundance (I-C)

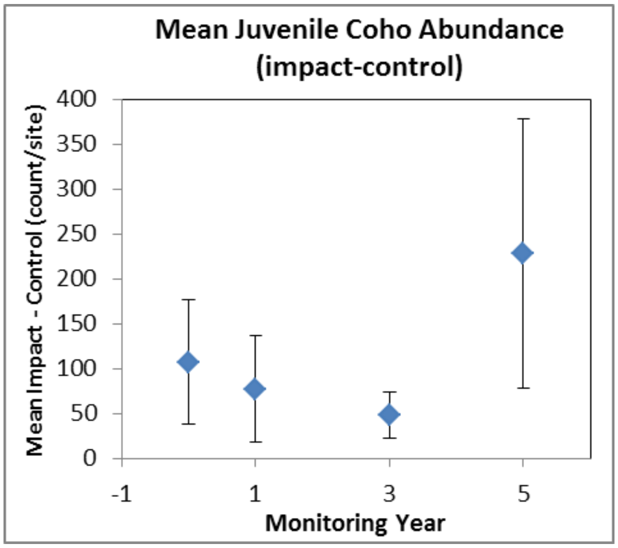

Figure 3b. Mean juvenile coho abundance (I-C)

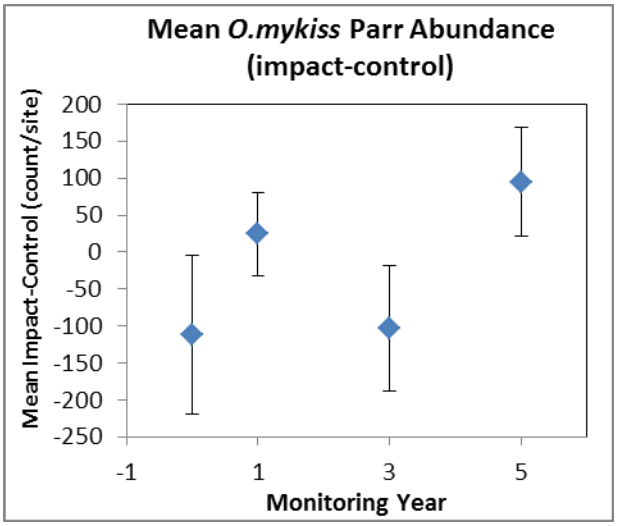

Figure 3c. Mean *O. mykiss* parr abundance (I-C)

A review of the difference between monitoring years for control, and impact reaches separately, shows similar trends in abundances between control and impact reach pairs (Figures 4a through 4c).

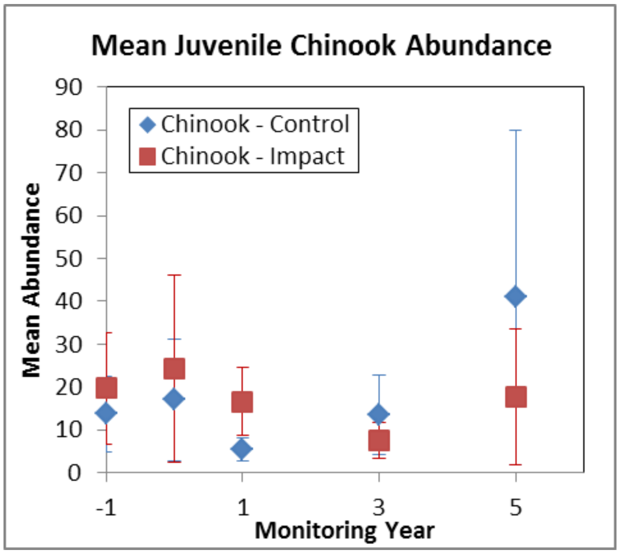

Figure 4a. Mean Chinook abundance by reach

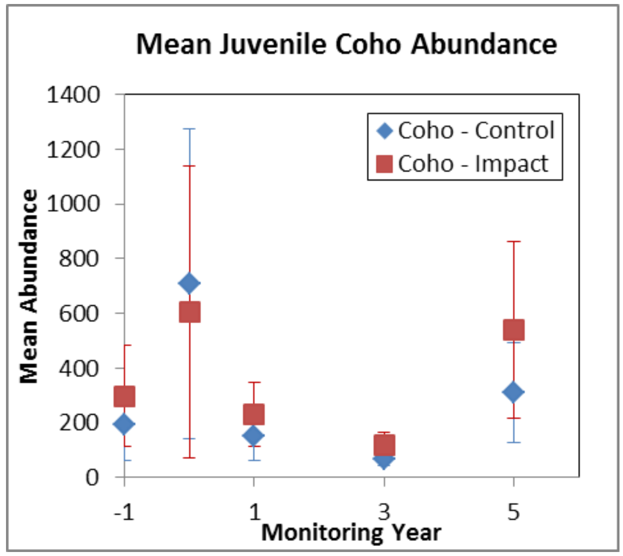

Figure 4b. Mean coho abundance by reach

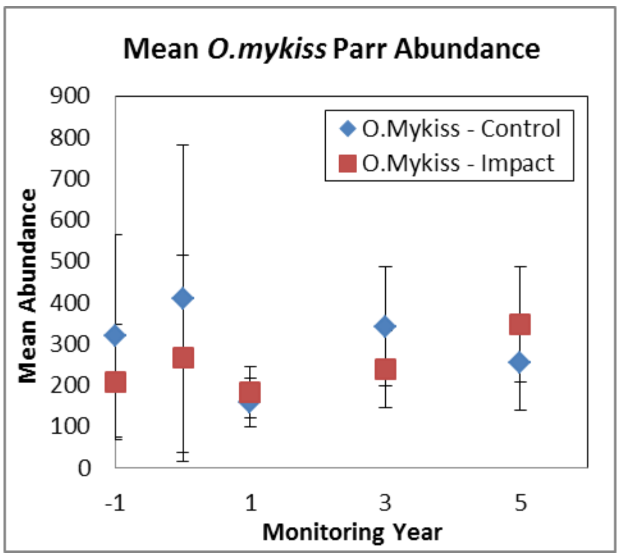

Figure 4c. Mean *O. mykiss* abundance by reach

Additional analyses were conducted by project category to detect variation in fish use of restoration project sites. When assessing salmonid use across all Instream Habitat projects (UCSRB and SRFB) by size class and species, structures were primarily used by Chinook and coho in the size range of 30 millimeters (mm) to 100 mm (Figure 5). *O. mykiss*, however, showed use of structures across all size classes (Figure 5). Fish density and abundance across various types of Instream Habitat projects were also evaluated for Chinook and *O. mykiss* (Figures 6 and 7, respectively). Fish use was analyzed for lateral jams, channel-spanning structures, and mid-channel jams. Lateral jams are built into a bank, channel spanning structures span the channel from bank to bank, and mid-channel jams are free-standing jams in the center of the main channel or a side channel. *O. mykiss* densities were highest for channel-spanning structures, lateral jams, and mid-channel jams, with channel-spanning structures showing the greatest densities (Figure 6). When evaluating structure types by abundance, *O. mykiss* showed the strongest response for mid-channel jams, followed by lateral jams, channel-spanning structures, and sediment storage structures (Figure 7). Chinook densities and abundance, however, were relatively low for all structure types (Figures 6 and 7).

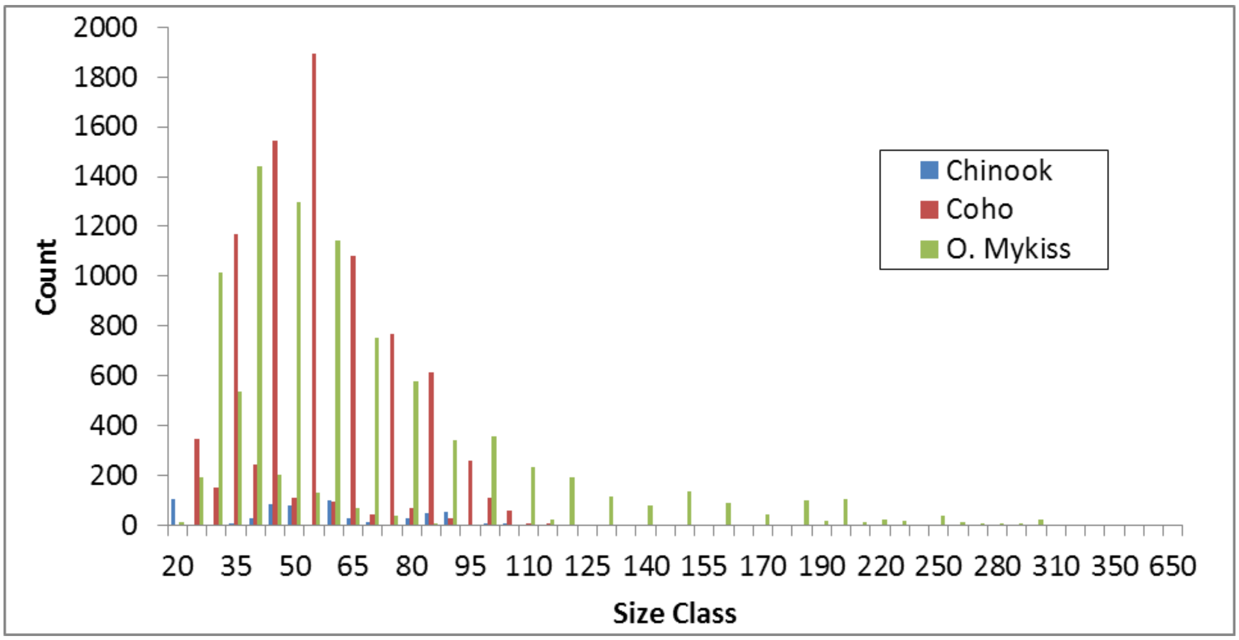

Figure 5. Distribution of salmonid size class and species utilizing Instream Habitat projects

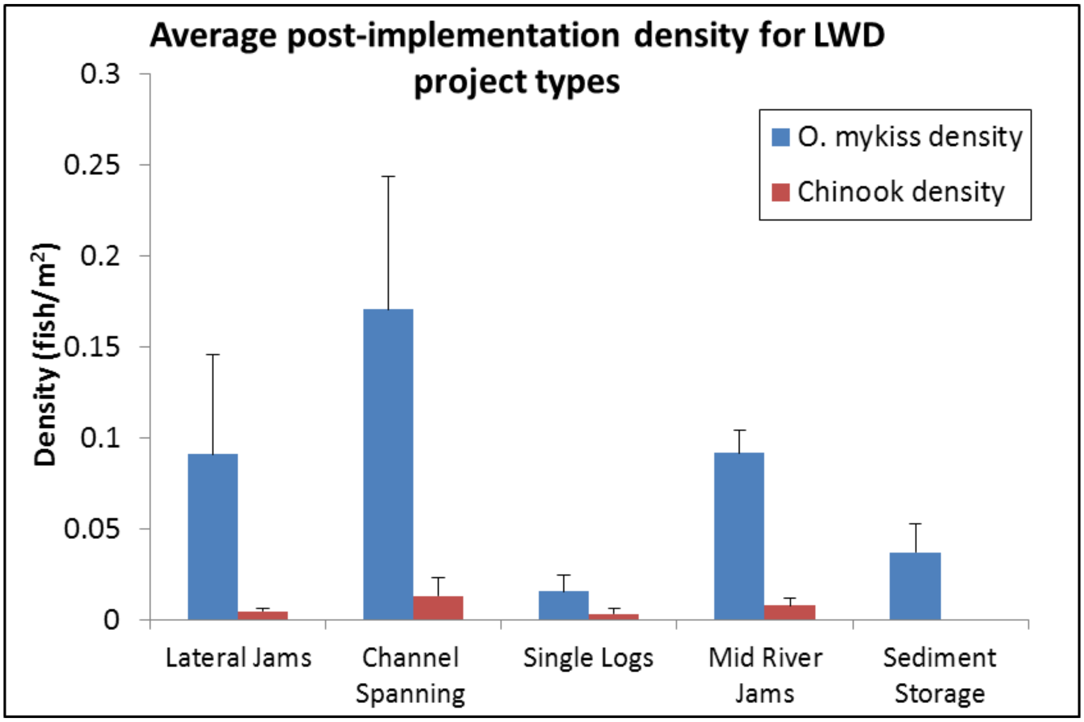

Figure 6. Average post-implementation density for difference Instream Habitat project types

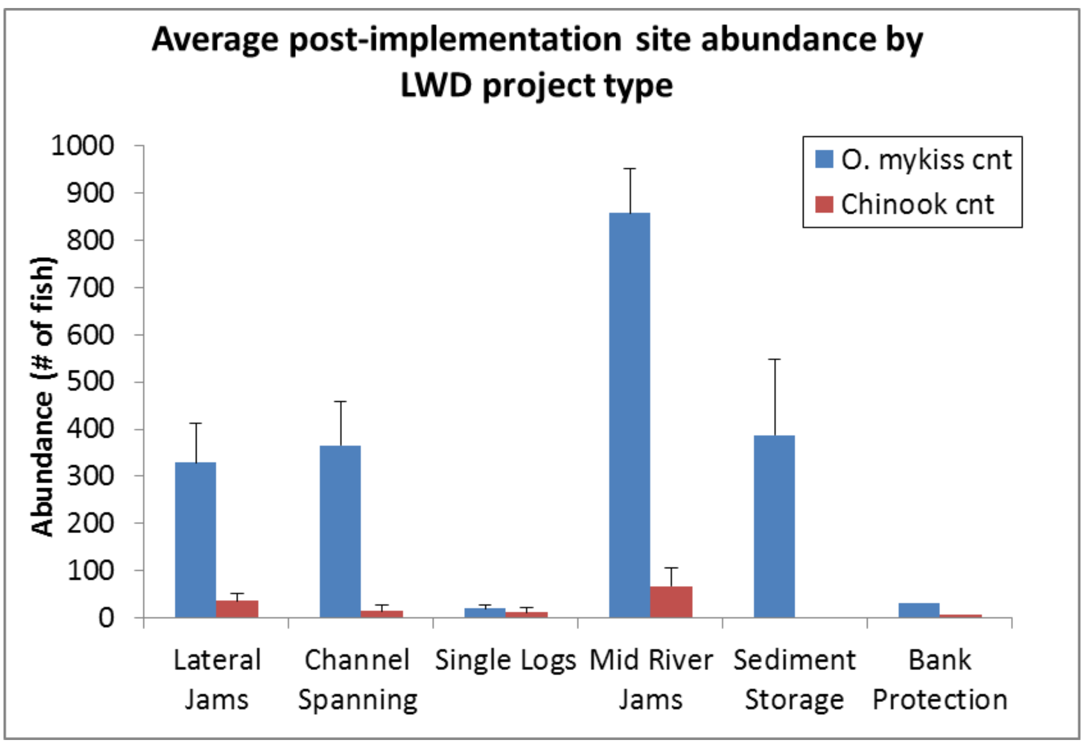

Figure 7. Average post-implementation abundance for difference Instream Habitat project types

Additionally, the relationship between the density of wood placed at a site and the density of juvenile fish was evaluated for *O. mykiss* and coho (Figures 8a and 8b). There was very little discernable trend of fish density as a property of pieces of large woody debris (LWD) per meter.

For the majority of projects, fish density did not appear to increase within transects with more wood.

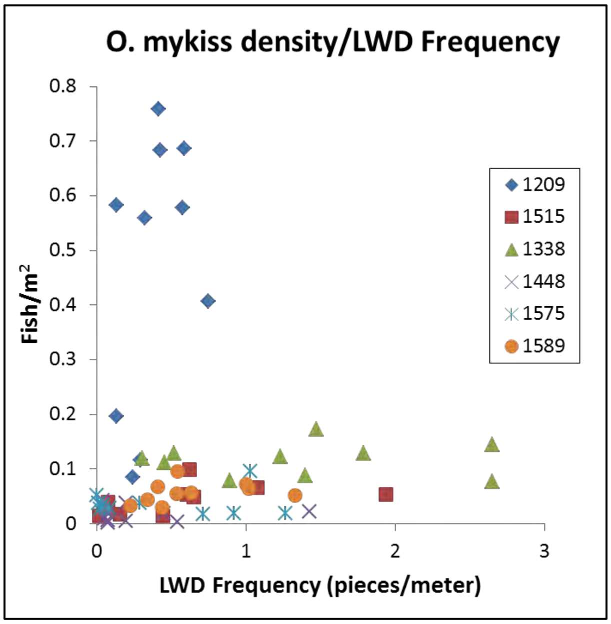

Figure 8a. *O. mykiss* density by LWD frequency

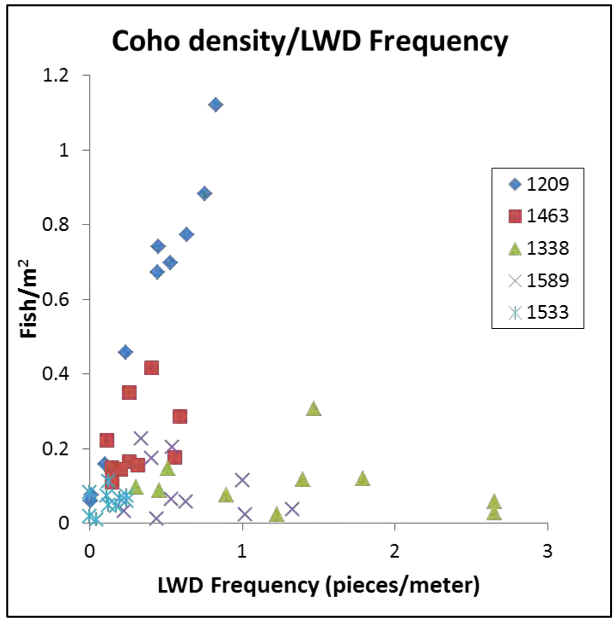

Figure 8b. Coho density by LWD frequency

As a category, 80 percent of Instream Habitat Projects monitored must meet the AIS success criteria of retaining 50 percent of the structures through Year 10 to be considered successful. In 2013, 91 percent (10 out of 11) of the projects monitored in this category met the functional success criteria; therefore, the category as a unit was deemed successful (Figure 9). One project (04-1660) monitored for Year 5 data retained only 10 percent of the AIS initially placed at the site; however, large scale erosion and channel migration events at the site likely contributed to this result. Following project implementation in 2009, the site experienced a large storm-related flow event which caused most of the wood structures to be washed out of the survey reach. In 2010, several new log jams were installed. By Year 5, only 10 percent of the number of logs initially placed at the site could be documented in the impact reach.

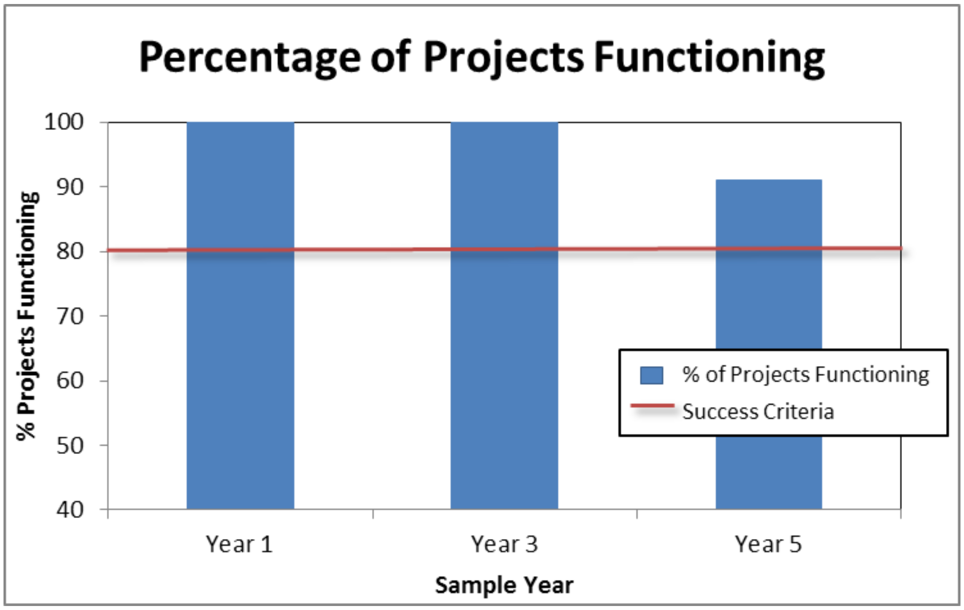

Figure 9. Percentage of projects monitored that meet success criteria for in-stream habitat category

A power analysis of the Instream Habitat data indicates that to detect a significant increase in juvenile Chinook salmon, a change of 400 percent could be detected if there were 25 projects sampled. Two years of pre-project data would increase the ability to detect change more significantly than 19 years of post-project data (Figure 10). The smallest step-change (MDD) in juvenile Chinook density following instream habitat projects that has at least 80% power of being detected with a one-tailed t-test (alpha = 0.10), given the variance among sites and within sites observed for the SRFB project. The MDD is given as a function of number of sites and pattern of temporal sampling. For example, the black line with circle is for 1 year pre-treatment and 3 years post-treatment.

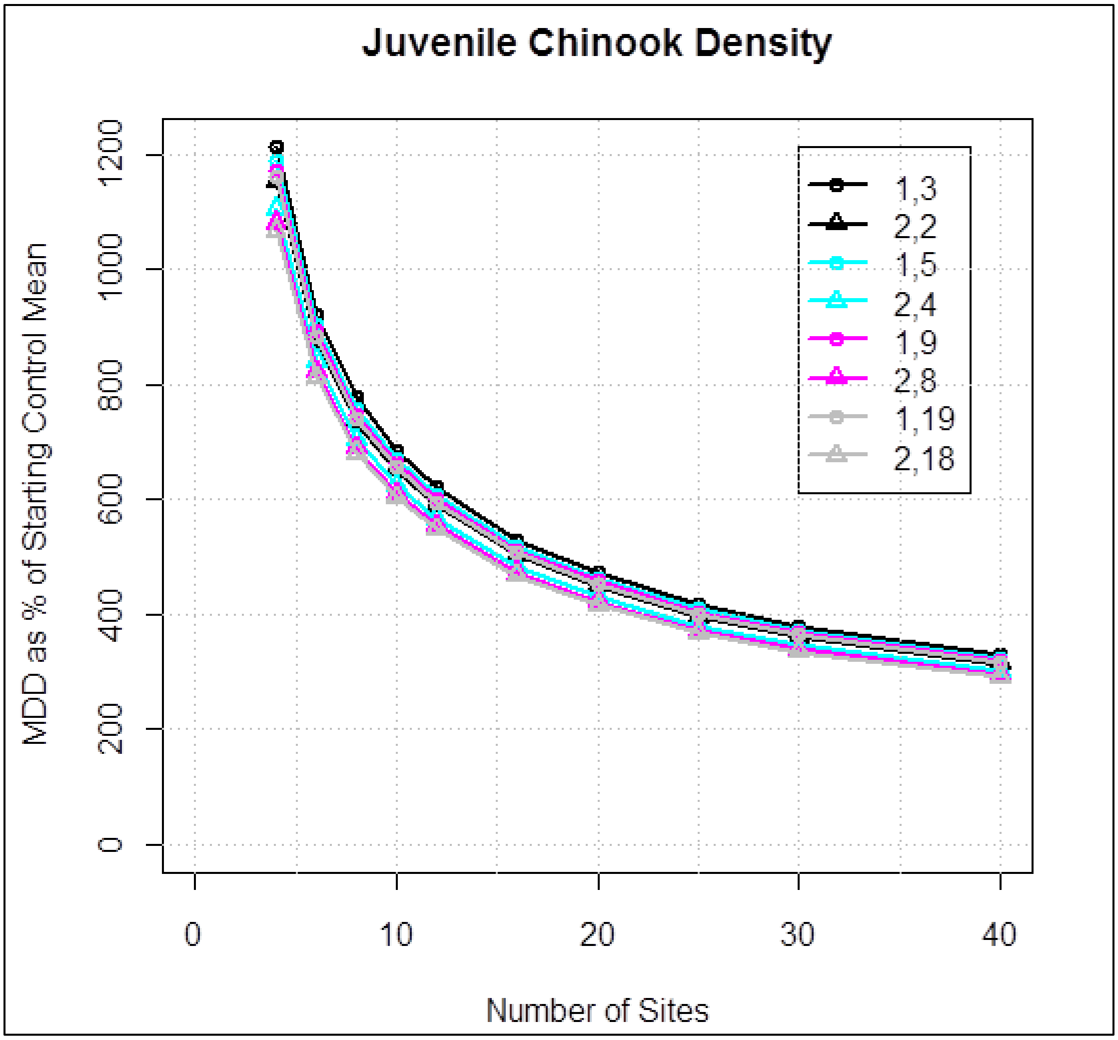

Figure 10. Power analysis results for juvenile Chinook density

3.2 RIPARIAN PLANTING RESULTS

One Riparian Planting Project was monitored in 2013. The locations of all Riparian Planting Projects monitored for the SRFB program are shown in Figure 11. Riparian Planting Projects were evaluated to assess indicator response over time and the average change between pre-project and post-project conditions as shown in Table 3. Survival of plantings is used as functional success criteria for this category in Years 1 and 3 following project implementation. After Year 3, however, monitoring the survival of plantings is not feasible due to the difficulty in locating the original plantings. Therefore, after Year 3, percent woody vegetation cover is used as an indicator for long-term success. To meet success criteria in Years 1 and 3, 50 percent of the plantings at a site must survive. After Year 3, 80 percent cover of woody vegetation by Year 10 must be met to meet the functional success criteria for this category.

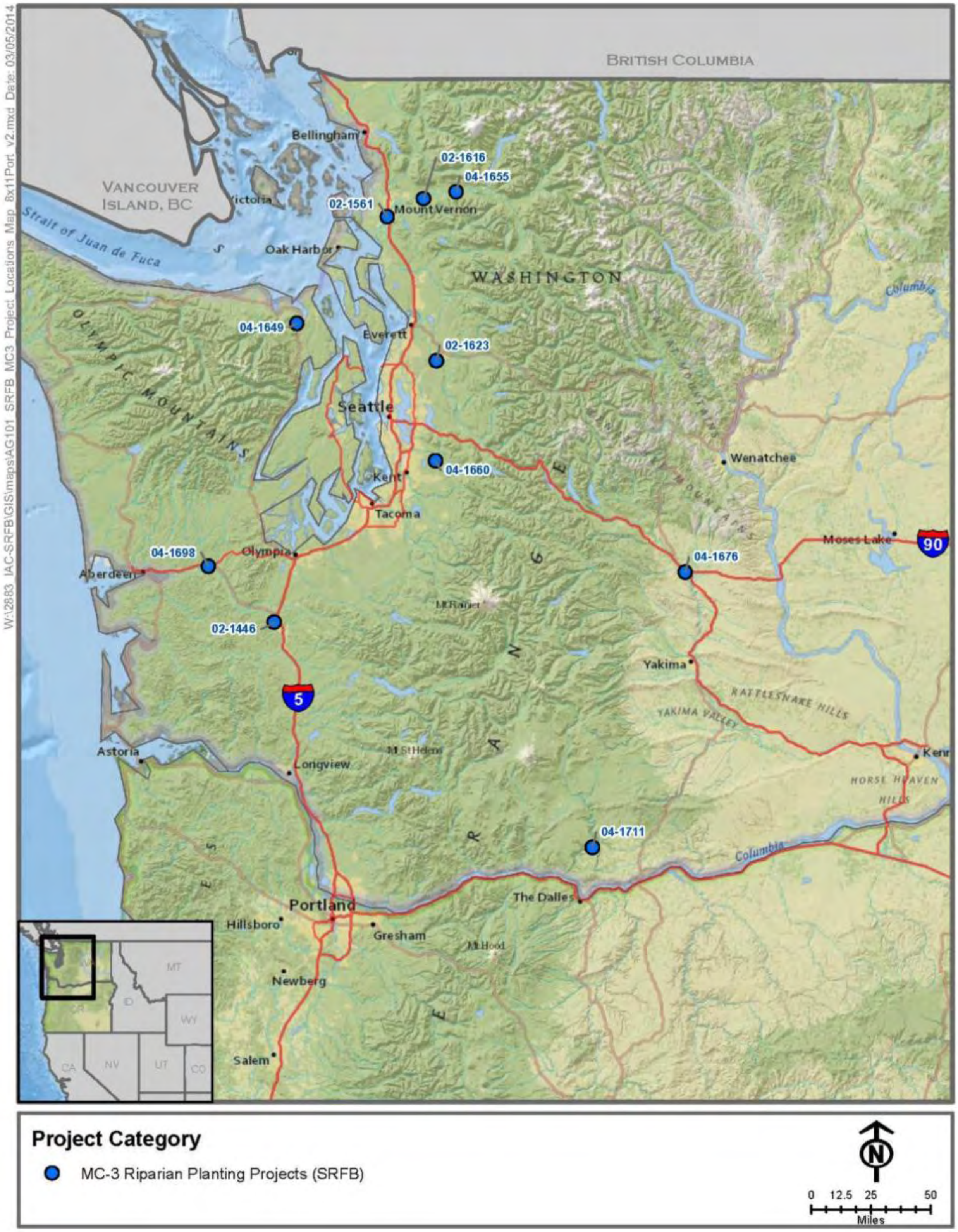

Figure 11. Riparian Planting Project locations

None of the Riparian Planting variables showed significant results, likely due to the short relative time frame for monitoring changes in vegetation indicators. Changes in the linear proportion of actively eroding banks (bank erosion), mean canopy density, and riparian vegetation structure were not statistically significant; however, some indication of improvement has been seen in this category, with bank erosion showing an average decrease following implementation, and riparian vegetation structure showing an average increase. High variability has been noted across sites for riparian vegetation structure, while less variability has been documented for bank erosion and canopy density. Part of the reason for lack of detectable change may be that at some sites, plantings are not located directly along the stream banks, but are instead installed in the floodplain. As a result, these plantings have little effect in the short term on indicators such as stream canopy density, but over time they will likely have a greater effect on the riparian vegetation structure, wood recruitment, and stream bank conditions. As the plantings become established and mature to increase canopy density and stream shade, it is expected that riparian vegetation structure and canopy density indicators will show an increase. As the riparian vegetation becomes well established, bank erosion will likely decrease. Table 3 shows the results of the statistical analysis of Riparian Planting Projects.

Table 3. Summary of Results for Riparian Planting Projects

Slope Method				
Indicator	**Test**	**Mean Slope**	**Standard Error of the Mean Slope**	**p-value**
Linear Proportion of Actively Eroding Banks (%)	one-tailed t-test (negative slope)	-0.39	1.5	0.40
Riparian Vegetation Structure (%)	one-tailed t-test (positive slope)	0.02	0.31	0.48
Mean Canopy Density (1-17)	one-tailed t-test (positive slope)	1.65	2.5	0.26
Average Difference Method				
Indicator	**Test**	**Mean Difference**	**Standard Error of the Mean Difference**	**p-value**
Linear Proportion of Actively Eroding Banks (%)	one-tailed t-test (negative step change)	-0.85	6.5	0.45
Riparian Vegetation Structure (%)	one-tailed t-test (positive step change)	-0.75	1.0	0.76
Mean Canopy Density (1-17)	one-tailed t-test (positive step change)	6.53	7.9	0.22

Note: None of the indicators for Riparian Planting Projects showed statistically significant results.

One Riparian Planting Project was monitored in 2013 to collected Year 5 data. Of the projects monitored for woody vegetation cover each year, none have yet met or exceeded the success criteria of greater than 80 percent woody vegetation cover by Year 10 in any year monitored. This result is expected because the plantings are currently only in Year 5 and the success criteria were designed to be met by Year 10. However, as a category, an increase in the average percentage of woody vegetation coverage has shown improvement over time, indicating a trend toward success (Figure 12).

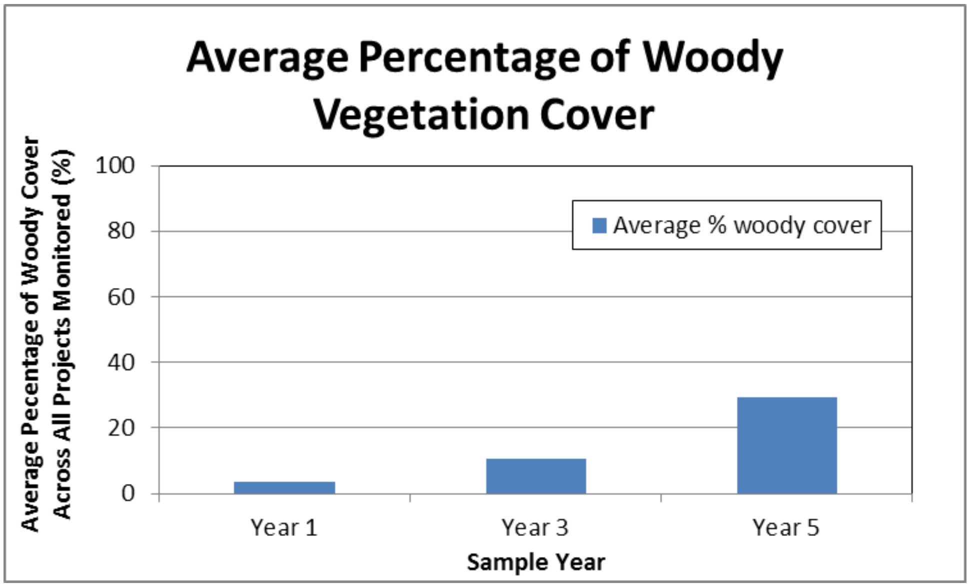

Figure 12. Average percentage of woody vegetation cover for projects monitored in riparian planting category

A power analysis indicated that a small change in shade (20 percent) could be detected with a sample size of about 12 projects under this program. Collecting 2 years of pre-project data rather than just 1 year reduces the needed sample size to 10 projects (Figure 12). We used this data set to evaluate the relative gain from additional data collection events, at various combinations of 4, 6, 10, and 20 years of sampling. Figure 13 shows that 2 years of pre-project data had a similar effect on the ability to detect change as 19 years of post-project data with 1 year of pre-project data. The smallest step-change (MDD) in percent shading at the bank following riparian planting projects that has at least 80% power of being detected with a one-tailed t-test (alpha = 0.10), given the variance among sites and within sites observed for the SRFB project. The MDD is given as a function of number of sites and pattern of temporal sampling. For example, the black line with circle is for 1 year pre-treatment and 3 years post-treatment.

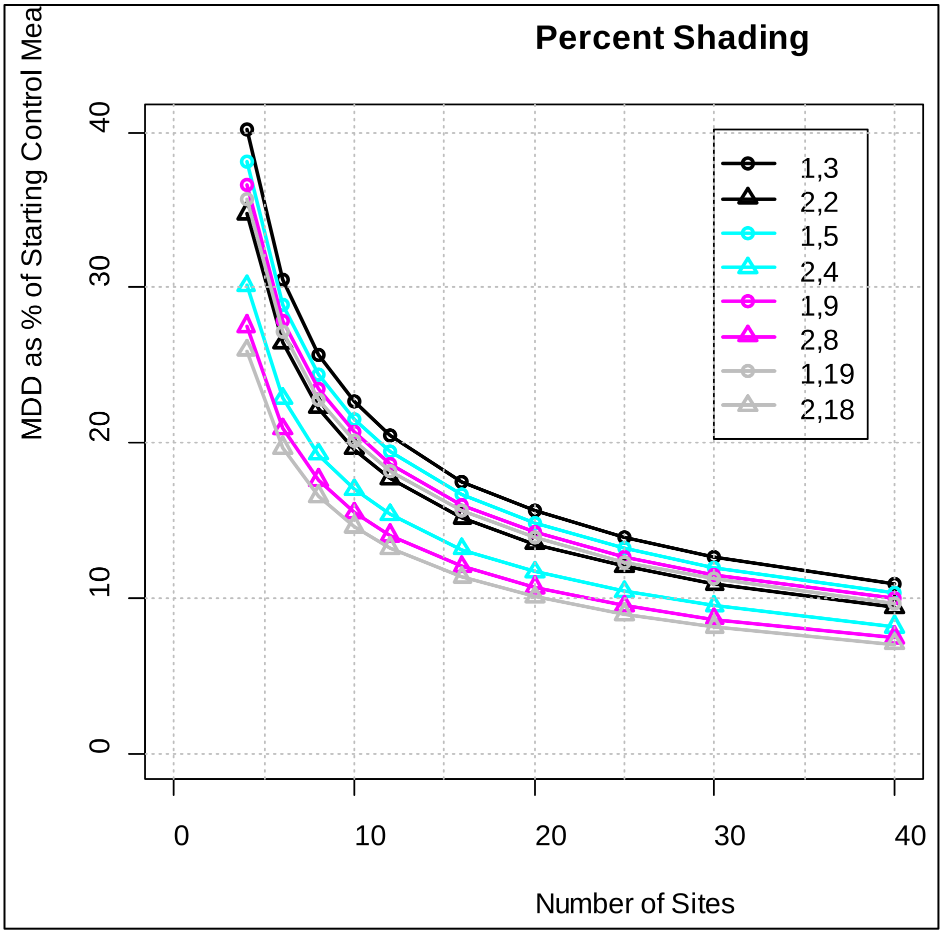

Figure 13. Power analysis results for percent shading

3.3 FLOODPLAIN ENHANCEMENT PROJECT RESULTS

Similar to the Instream Habitat and Riparian Planting categories, Floodplain Enhancement Projects were evaluated to assess trends in indicator response and the average change between pre-project and post project conditions. The Floodplain Enhancement projects included in this analysis are shown in Figure 14. Statistically significant improvements were seen for bankfull width and flood-prone width using the slope method and the average difference method (Table 4). Significant improvements were also noted for pool area and juvenile coho density when tested using the average difference method (Table 4). Although significant improvements in juvenile coho density were detected, changes in juvenile Chinook and *O. mykiss* densities were not significant. Density responses of juveniles should be compared with changes in abundance for project sites, such as floodplain enhancement projects, where the available habitat area increases substantially. In many cases, while the density decreases, the abundance of fish using the site will actually increase, as fish spread out into the newly created habitat. Results for abundance in this study show increases in use by Chinook and *O. mykiss* at floodplain projects through Year 2. Year 5 data are from an incomplete data set and need to be further evaluated.

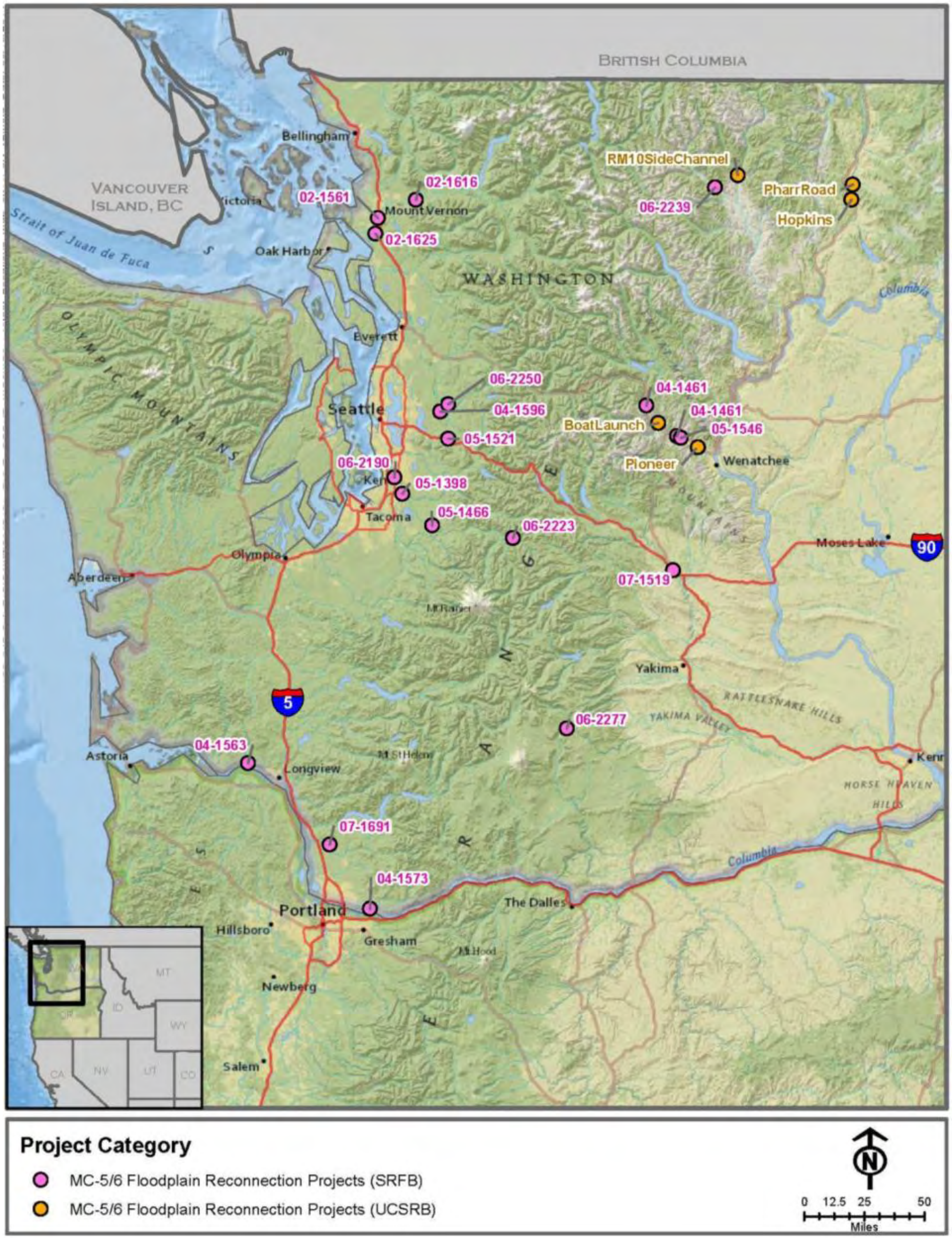

Figure 14. Floodplain Enhancement Project locations

Table 4. Summary of Results for Floodplain Enhancement Projects

Slope Method					
Indicator	**Number of Sites Tested**	**Test**	**Mean Slope**	**Standard Error of the Mean Slope**	**p-value**
Pool Area (m^2)	18	one-tailed Wilcoxon test (positive slope)	4.2	5.8	0.11
Pool Depth (cm)	18	one-tailed Wilcoxon test (positive slope)	2.5	4.5	0.22
Bankfull Height (cm)	6	one-tailed t-test (negative slope)	0.11	0.13	N/A
Bankfull Width (m)	8	one-tailed t-test (positive slope)	1.8	0.89	0.038
Flood-prone Width (m)	5	one-tailed t-test (positive slope)	38	17	0.048
Mean Canopy Density (1-17)	11	one-tailed t-test (positive slope)	-0.94	0.34	N/A
Riparian Vegetation Structure (%)	11	one-tailed t-test (positive slope)	0.16	1.6	0.46
Chinook Juveniles (fish/m^2)	17	one-tailed Wilcoxon test (positive slope)	0.0138	0.0166	0.20
Coho Juveniles (fish/m^2)	17	one-tailed Wilcoxon test (positive slope)	0.1166	0.0802	0.18
O. mykiss Parr (fish/m^2)	17	one-tailed Wilcoxon test (positive slope)	0.0041	0.0030	0.34
Average Difference Method					
Indicator	**Number of Sites Tested**	**Test**	**Mean Difference**	**Standard Error of Mean Difference**	**p-value**
Pool Area (m^2)	18	one-tailed Wilcoxon test (positive difference)	10	18	0.084
Pool Depth (cm)	18	one-tailed Wilcoxon test (positive difference)	9.0	7.9	0.13
Bankfull Height (cm)	6	one-tailed t-test (negative difference)	0.35	0.40	N/A
Bankfull Width (m)	8	one-tailed t-test (positive difference)	4.7	3.3	0.099
Flood-prone Width (m)	5	one-tailed t-test (positive difference)	109	47	0.041
Mean Canopy Density (1-17)	11	one-tailed t-test (positive difference)	-3.0	1.6	N/A
Riparian Vegetation Structure (%)	11	one-tailed t-test (positive difference)	-3.4	6.0	N/A
Chinook Juveniles (fish/m^2)	17	one-tailed Wilcoxon test (positive difference)	0.0008	0.0269	0.20
Coho Juveniles (fish/m^2)	17	one-tailed Wilcoxon test (positive difference)	0.1232	0.0805	0.042
O. mykiss Parr (fish/m^2)	17	one-tailed Wilcoxon test (positive difference)	0.0153	0.0115	0.22

Note: Blue highlight indicates statistically significant results; N/A – negative slope or difference detected

Of the Floodplain Enhancement projects where connectivity of a side channel to the main river or stream is a primary objective, monitoring included an assessment of connection to determine functional success. In order to meet the functional success criteria as a category, 80 percent of the projects must remain connected by Year 5. All projects monitored for connectivity in Years 1 and 2 remained connected and met this criterion, while 87.5 percent (7 out of 8) met the criteria in Year 5.

Table 4 shows a summary of the results from indicators tested in the Floodplain Enhancement Project category. For the Instream Habitat category assessment discussed above, the same number of projects was used to test each parameter. This category, however, is slightly different in that the number of projects used for testing each indicator varied among indicators. Two protocols, MC-5 Constrained Channel and MC-6 Channel Connectivity, were combined and monitored as a single category in 2012; therefore, not all projects in the newly combined category have data for all indicators. However, valuable information can be gathered from all available data, which has been provided below.

Statistically significant results were found for four indicators in this category in Year 5: pool area, bankfull width, flood-prone width, and juvenile coho density. For each of those indicators, the percent change over baseline was calculated to determine if a 20-percent change or more occurred. Pool area increased by greater than 20 percent in Year 1 and Year 5, with decreases detected in Years 2 and 3 (Table 5). Bankfull width decreased in Year 1 and Year 5, but an increase of greater than 20 percent was found in Year 3 (Table 5). Both flood-prone width and juvenile coho density increased by greater than 20 percent over baseline during every year of monitoring (Table 5).

Table 5. Percent Change over Baseline for Floodplain Enhancement Indicators with Statistically Significant Results

Indicator	Percent Change Over Baseline			
	Year 1	**Year 2**	**Year 3**	**Year 5**
Pool Area (m^2)	28	-228	-116	352
Bankfull Width (m)	-164	N/A	142	-432
Flood-prone Width (m)	126	N/A	126	282
Coho Juveniles (fish/m^2)	235	788	N/A	112

N/A – Due to the combined protocol, not all indicators were collected in all years.

A total of nine Floodplain Enhancement projects were monitored in 2013. Not all of these projects are monitored for fish density, however, so not all of these projects were included in the calculations for project effects on salmonid densities. Of the nine projects monitored in 2013, four included fish monitoring. When evaluating juvenile densities across monitoring years (impact minus control), Chinook appear to only slightly increase over time (Figure 15a). While the 2 years following implementation resulted in an increasing trend of impact density over control density for coho, Year 5 values, while still higher than Year 0, are much reduced from the previous two monitoring years (Figure 15b). *O. mykiss* results are variable, but the Year 5 monitoring indicates very similar differences between impact and control as was observed in Year 0 monitoring, and a decreasing trend since Year 1 monitoring post-implementation (Figure 15c). It is worth noting that only five sites have Year 5 data, while there are 16 sites with Year 0 data, 14 sites with Year 1 data, and 11 sites with Year 2 data.

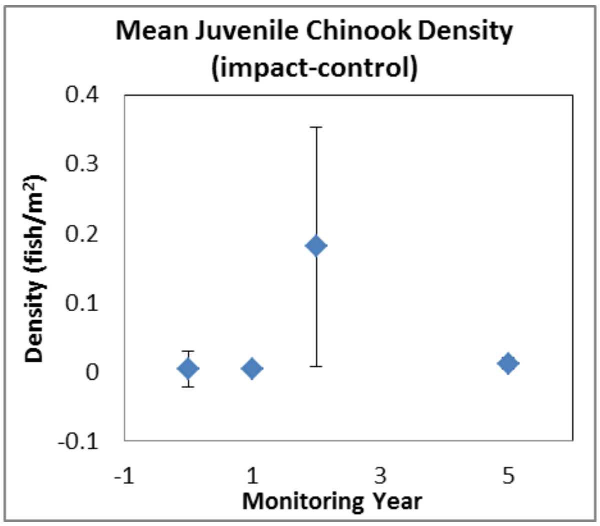

Figure 15a. Mean juvenile Chinook density (I-C)

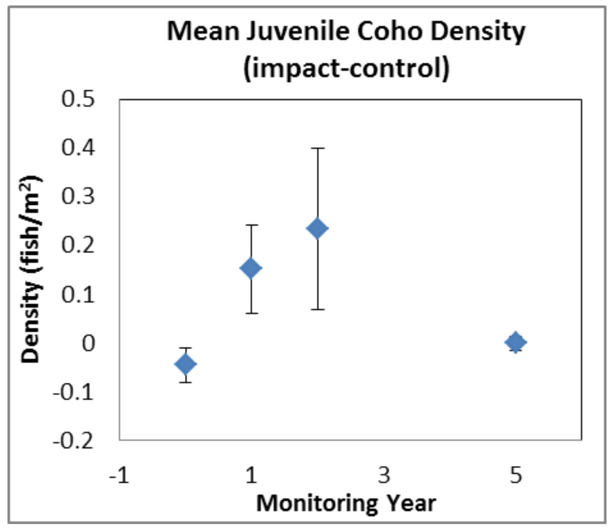

Figure 15b. Mean juvenile coho density (I-C)

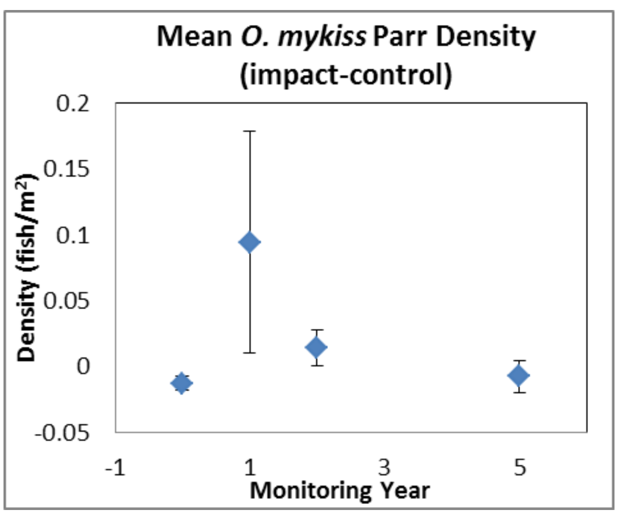

Figure 15c. Mean *O. mykiss* parr density (I-C)

For all Floodplain Enhancement Projects monitored in 2013, there is an apparent decrease in abundance for impact-control results in Year 5 over the previous year (Figures 16a through 16c). It is important to note, however, that only five projects included Year 5 fish monitoring in 2013, so it is an incomplete response assessment relative to Year 0. Trends through Year 2 indicate increases post-implementation for *O. mykiss* and Chinook, but a decrease (though not significant) relative to Year 0 for coho.

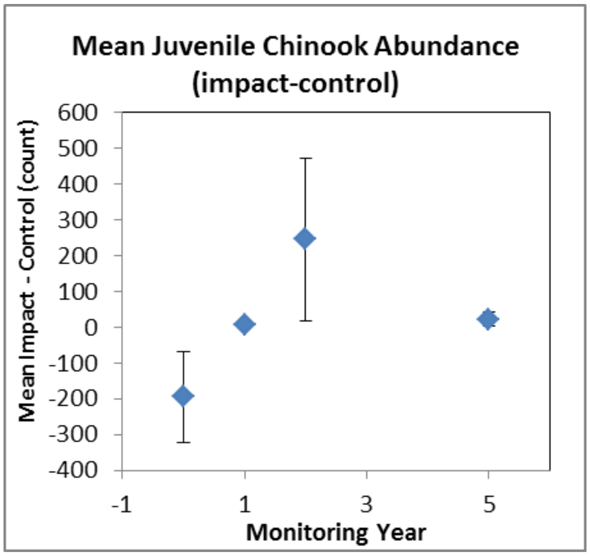

Figure 16a. Mean juvenile Chinook abundance (I-C)

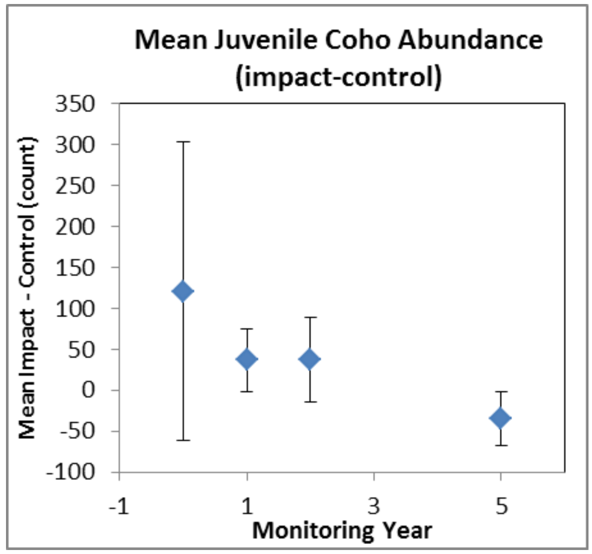

Figure 16b. Mean juvenile coho abundance (I-C)

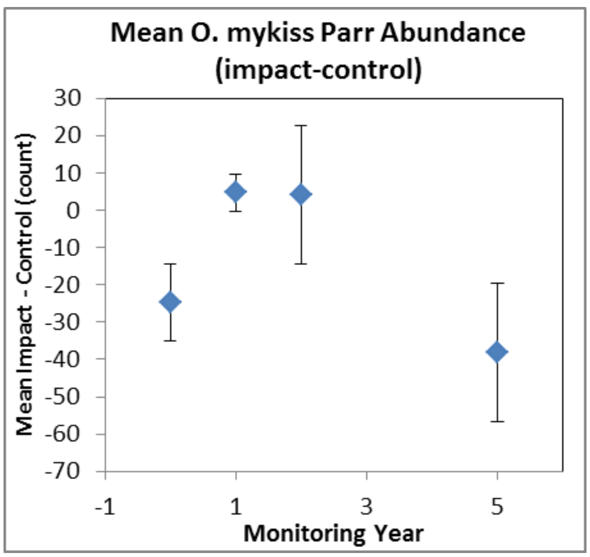

Figure 16c. Mean *O. mykiss* parr abundance (I-C)

A review of the difference between monitoring years for control and impact reaches separately shows an increase in abundance post-project for Chinook, with mixed responses for Coho and *O. mykiss* (Figures 17a through 17c).

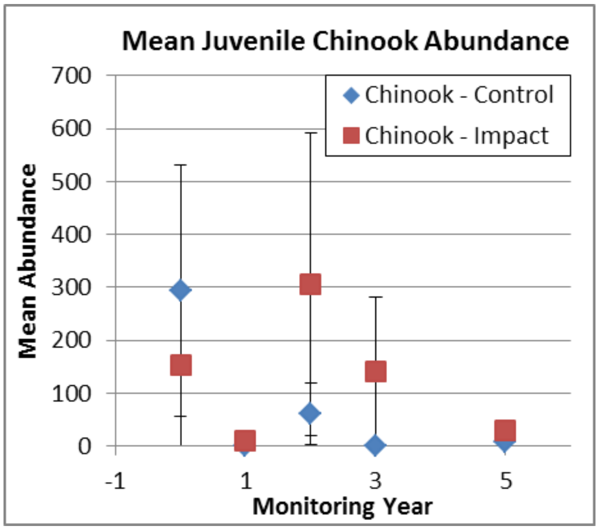

Figure 17a. Mean Chinook abundance by reach

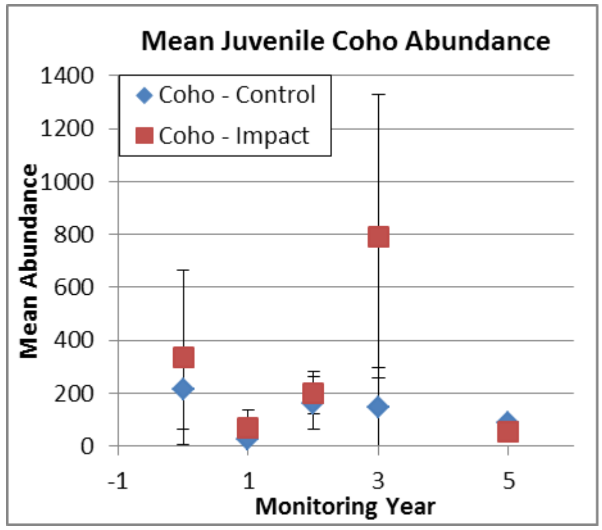

Figure 17b. Mean coho abundance by reach

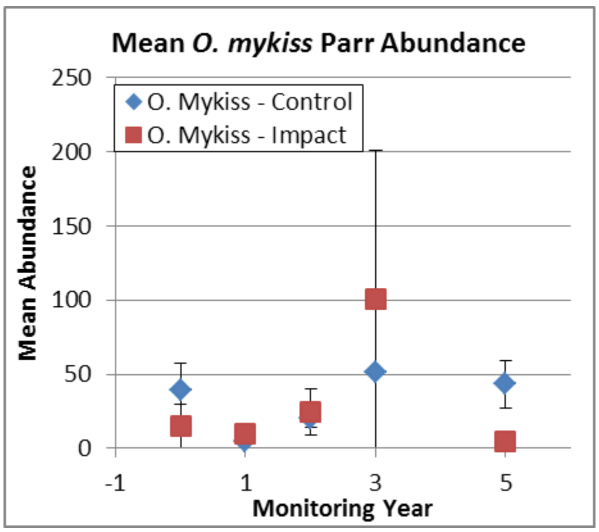

Figure 17c. Mean *O. mykiss* abundance by reach

In 2013, four projects were monitored under the SRFB program for connectivity, all of which were Year 5 monitoring events. All but one of the projects were connected at the time of the survey, thus meeting the functionality criteria. With one project not maintaining connection, the percentage of total project functioning in Year 5 was 87.5 percent (7 out of 8). The project that was deemed non-functional (04-1563) was connected at the downstream end at the time of the survey in early May; however, flows were disconnected at various points along the channel and at the upstream end, resulting in isolated pockets of water. This site experienced a mass wasting event not long after implementation which resulted in a great deal of sediment being deposited into the reach. Monitoring indicated that the site was functional in Years 1 and 3, however, suggesting that additional sediment may have been deposited in the reach by Year 5, or that the site maintains full connection only during higher flows which were not present at the time of monitoring in early May. Although these results meet the success criteria for the category as a whole, this criteria should be monitored closely to determine if connectivity projects maintain their connection by Year 10 (Figure 18).

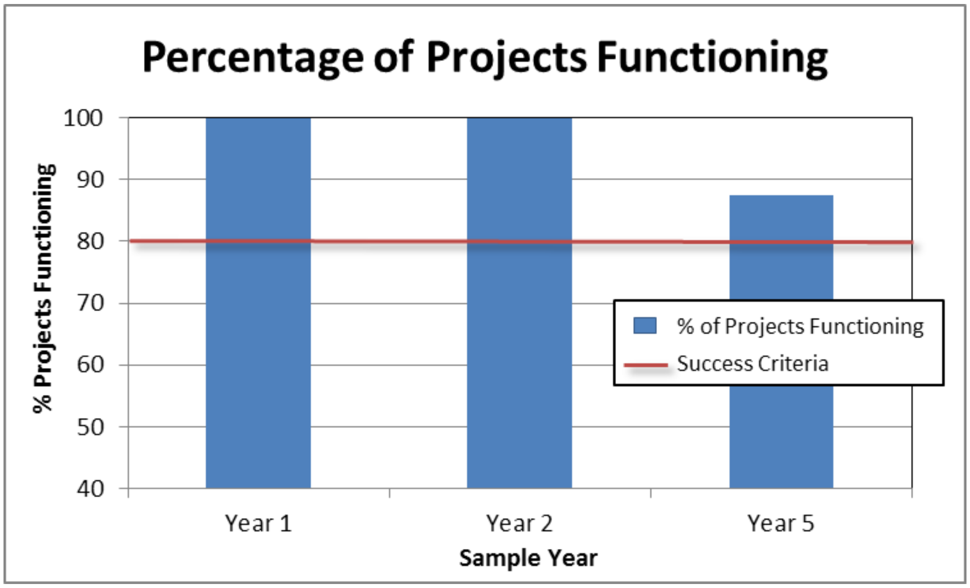

Figure 18. Percentage of projects monitored that meet success criteria for floodplain enhancement category

4 RESULTS SUMMARY AND DISCUSSION

4.1 INSTREAM STRUCTURES

Since the ultimate goal of most large woody debris (LWD) projects is to improve outcomes for resident and anadromous fish populations, existing studies have often focused on the response of fish to restoration projects, and the results have been mixed. In a study of 30 streams in western Oregon and Washington, Roni and Quinn (2001) found that LWD placement can lead to higher densities of juvenile coho during the summer and winter, and higher densities of age 1+ cutthroat and *O. mykiss* during the winter. However, the same study found that age 1+ *O. mykiss* density response to treatment during summer was negatively correlated with increases in pool area, and the response of trout fry to treatment was negatively correlated with pool area during winter (Roni and Quinn 2001). After placement of LWD in a small coastal tributary of the Chehalis River in Washington, winter populations of juvenile coho salmon increased significantly in the treated reaches; however, there was no significant difference during spring and autumn (Cederholm et al. 1997). At the same site, LWD placement either did not significantly affect *O. mykiss* populations, or it showed a significant decline in the treated reaches compared to the reference location, depending on the season (Cederholm et al. 1997). Other studies have found that larger salmonids respond most strongly to instream structures, suggesting that the created habitat is particularly suited to adult salmonids (Whiteway et al. 2010). Improved and more widespread monitoring can help answer remaining questions about fish response to instream structures.

Results for instream habitat projects in our study showed increases in pool area, depth, and volume of wood present, and these results are similar to habitat changes detected by Roni and Quinn (2001); however, we did not detect significant changes in fish use between control and impact reaches. One reason for this result may have been the wide range of project actions included in this category, and a lack of specific project objectives associated with project implementation.

Instream structures include boulder and log placements designed to redirect hydraulics, provide bank stability, promote scour or gravel storage, and provide more complex habitat. Because of the variation in the nature of projects in this category, projects with varied levels of effectiveness likely contributed to a highly varied response by fish. Additionally, specific objectives describing detailed habitat outcomes and expected fish use by life stage and season were often lacking, leading to difficulty in evaluating project effectiveness.

Implications for management from this study include: 1) recommendations to require specific project objectives that detail the expected habitat and biological outcomes from projects, with expectations for fish use by species, lifestage, and season; and 2) stratification of projects within this group by construction method, habitat outcome, ecoregion, and target species. Evaluation of the use of various structure types by fish life stage and season is vital to our understanding of the function and value of these projects. As reported in other studies, differences in use by season and life stage within a species, and across species, can be significant, and our understanding of how, when, and whether fish are optimally using restoration structures is incomplete.

The assumption of “build it and they will come” has not completely been born out in scientific evaluation of instream habitat projects, especially for Chinook salmon juveniles. Our past and current investments in this type of restoration approach are significant, and the effort and expenditure warrant detailed evaluation of the appropriate uses of this technique.

The extent to which installed LWD projects, such as engineered log jams (ELJs), remain in place and functioning after several years has also been inconsistent throughout the Pacific Northwest. In a study of 161 fish habitat structures in 15 streams in southwest Oregon and southwest Washington (Frissell and Nawa 1992), the incidence of functional impairment and outright failure following a flood magnitude that recurs every 2 to 10 years varied widely among streams; the median failure rate was 18.5 percent and the median damage rate (impairment plus failure) was 60 percent. The reasons for failure were many and there was no simple structure-design-to-failure correlation (Frissell and Nawa 1992). Despite the risks of structural failure, few projects in a meta-analysis of 211 stream restoration projects reported on the stability of the evaluated structures, making it difficult to draw conclusions regarding their effectiveness over time (Whiteway et al. 2010).

Under the SRFB monitoring program, one project (04-1660) did not meet the stability criterion established by funding entities and project managers. The project was exposed to high flows in 2010, which resulted in a large scour event and the loss of many of the original structures. Since then, the project has been reconstructed with new structures, which remain in place and appear to be functioning as intended as of an evaluation in 2012. These results demonstrate the need for longer-term evaluations of both structure performance and stability, and fish use of structures.

4.2 RIPARIAN PLANTING

Riparian habitat improvement projects involving the installation of riparian vegetation are common habitat restoration techniques and are often coupled with other restoration actions. They have the potential to create improvements in bank stability, streamside shading, erosion, and other benefits within a moderate length of time (5 to 20 years), but also provide longer-term benefits by helping to establish a functional riparian corridor. Approaches to monitoring riparian restoration have not been standardized (Pollock et al. 2005), although there have been significant efforts to monitor riparian treatments in the shorter term (less than 10 years) (Roni et al. 2008). Issues affecting the success of riparian restoration efforts include grazing by herbivores, and understory and overstory control (Roni et al. 2008). Reducing the effects of invasive species, by removal or chemical treatments, is another element affecting the success of riparian restoration projects in general and projects monitored under the SRFB program in particular.

Under the SRFB program, no significant changes were detected for riparian planting projects; however, 8 years may be an inadequate time frame for new plantings to affect instream habitat (Roni et al. 2008). Project success in our study was affected by invasive species and by river migration that washed away plantings that had been installed in previous years. Implications for management of riparian planting efforts include: 1) management of invasive plants and additional maintenance of planted areas should be included in funding packages for planting projects; and 2) evaluation of river migration potential should be included in the process of siting the planting locations. In terms of monitoring recommendations, based on the power analysis, we recommend extending the sampling duration to 20 years for this project type, and reducing the sampling frequency to 10 years. Similar to previous studies, we also recommend integration of biological survey techniques such as monitoring fish and macroinvertebrate responses into monitoring for riparian restoration (Pollock et al. 2005; Roni et al. 2008).

4.3 FLOODPLAIN ENHANCEMENT

Floodplain restoration has been shown to be an effective technique for increasing rearing habitat for Chinook salmon and other species (Sommer et al. 2005). Common techniques for floodplain restoration and enhancement include levee removal, setback or breaching, removal of floodplain encroachment features or armoring, topographic adjustments in the channel or floodplain, reconnection or enhancement of side-channels and floodplain channels, and creation of new floodplain channels. These types of projects are targeted at increasing off-channel habitat and floodplain connection with mainstem channels, and range in size and scale from smaller side channel projects a few hundred feet in length to floodplain reconnection and levee removal projects several miles long. Techniques to reconnect floodplains are still in development (Pess et al. 2005), and additional study on the effectiveness of this project type is warranted due to highly variable project costs and the potential for large improvements in fish habitat and survival, as well as the potential to help restore natural river processes.

Fish that rear in floodplains have demonstrated significant increases in growth compared to those rearing in mainstem habitats, likely due to favorable velocities, temperatures, and available food resources (Sommer et al. 2001, Sommer et al. 2005, Urabe et al. 2010). Riverine species benefit from having access to floodplains for rearing and spawning and as refuge from high velocities (Jeffres et al. 2008). New floodplain channels were associated with higher numbers of juvenile coho, cutthroat, and steelhead (Solazzi et al. 2000), and groundwater-fed channels have supported increased numbers of chum, coho, pink, and sockeye salmon (Hall et al. 2000 as cited in Pess et al. 2005).

Monitoring under the SRFB program showed floodplain enhancement projects increasing in bankfull and flood-prone width, and in density of coho juveniles in treated reaches as compared to control reaches. These results are similar to findings from Morley et al. (2005) and Solazzi et al. (2000) where increased depth and coho juvenile density were detected in constructed off-channel habitats. As the flood-prone width at a site expands, the connection with the floodplain increases (i.e., there is a greater area engaged during flood flows to provide off-channel habitat and refuge for juvenile fish species). Observed increases in juvenile coho density may be due to the increased amount of low velocity backwater habitat created by these projects. Lower velocity habitat with extensive cover has been linked to higher densities of coho salmon (Bustard and Narver 1975) and Chinook (Sommer et al. 2005).

Implications for management in floodplains from this study include: 1) evaluation of floodplain reconnection projects should include assessment of the geomorphic and topographic changes across large areas that are outside of the active channel; and 2) specific timing and use of habitats by fish should also be evaluated to guide future development of projects and to evaluate their contribution toward recovery efforts.

Baseline information on channel and floodplain form and condition is a critical foundation upon which to evaluate the effects of reconnection and enhancement efforts (Pess et al. 2005). Further monitoring may provide additional insight as to species preferences for different habitat conditions across seasons and ecoregions. We have found an increasing number of these types of projects are being implemented across the region, and additional evaluation of the changes through time for both physical and biological parameters across seasons is warranted, especially in the case of levee setbacks, which are more closely tied to the restoration of natural stream processes.

4.4 SUMMARY

The projects in each monitoring category were assessed based on a set of response indicators that apply to each category. Those response indicators were then evaluated at three levels; however, not all three levels applied to all project categories (Table 6). Level 1 analysis evaluated the functional criteria of the project as compared to the design. Level 2 analysis considered the effectiveness of the project with respect to habitat indicators. Both Level 1 and 2 analyses apply to all project categories tested in 2013. Fish response to changes in habitat was captured in the Level 3 analysis, which was not evaluated for Riparian Planting Projects.

Table 6. Summary of Analysis Results for Year 5 Data

Project Category	Level 1 Functional Criteria	Level 2 Habitat Indicators	Level 3 Fish Response
Instream Habitat	• 100 percent of the Instream Habitat projects met the criteria of >50 percent of the artificial instream structures (AIS) remaining within the impact reach in Years 1 and 3, and 91 percent of the project met the criteria in Year 5.	• Instream Habitat Projects as a group showed a statistically significant increase over baseline in mean vertical pool profile area, mean residual depth, and $\log_{10}$ volume of large woody debris.	• No statistically significant improvements in juvenile fish density were found. Significant decrease in Year 5 over baseline noted for juvenile Chinook.
Riparian Planting	• 100 percent of the projects demonstrated a percentage of plants living that exceeded the 50 percent survival criteria in Year 1 and 89 percent of the projects exceed the survival criteria in Year 3. • None of the projects monitored in Year 5 met the 80 percent cover of woody riparian species criteria; however, this criterion is not required to be met until Year 10.	• No significant results reported.	• N/A
Floodplain Enhancement	• 100 percent of the projects monitored for connectivity had channels that remained connected to the stream in Years 1 and 2, with 87.5 percent of the project meeting the criteria by Year 5. This result still meets the criteria of >80 percent of projects remaining connected.	• Floodplain Enhancement Projects as a group showed statistically significant results for bankfull width and flood-prone width. • A significant improvement was also seen for pool area, but only when comparing average pre- and post-project conditions.	• A significant improvement in juvenile coho density was noted when comparing average pre- and post-project conditions.

5 RECOMMENDATIONS AND CONCLUSIONS

The following are category-specific summaries and recommendations that have been developed as a result of the data collected and observations made through monitoring to date.

5.1 INSTREAM HABITAT PROJECTS

The effects of Instream Habitat Projects are difficult to determine due to the number of objectives accomplished using this method and the types of approaches grouped together under this category. In-stream structures include boulder and log placements designed to redirect hydraulics, provide bank stability, promote scour or gravel storage, and provide more complex habitat. Therefore, due to the variation in the nature of projects in this category, it is beneficial to understand and consider the specific objectives of each project when evaluating for effectiveness. Close coordination with project sponsors, their design teams, and lead entities is needed to accomplish this level of understanding.

The ability to detect fish response to In-Stream Habitat Projects is tied to fish density at the project site, fish abundance at each project site, and the generation time of target species. If the density and abundance of fish populations is low, detecting change in these very low densities is difficult, independent of the effects of the project. Streamflow velocity could be used as a surrogate for the effectiveness of some projects for certain species, specifically coho and Chinook juveniles using larger systems. Beechie et al. (2005) found that the presence of low velocity habitat (less than 0.15 ft/sec) in larger systems (exceeding 25-meter bankfull width) was closely correlated with fish use. Lower velocity habitat, with extensive cover, has been linked to higher densities of coho salmon. Chinook densities have not been significantly linked to this factor, but juvenile Chinook are likely to respond favorably to off-channel or low-velocity rearing areas. Further monitoring may provide additional insight as to species preferences for different habitat conditions.

Generation time for the species of salmonids being monitored may affect the results for juvenile fish densities in this category. Although generation time varies among species, it generally ranges from 3 to 5 years for the fish species being monitored. Therefore, the results of these projects on fish densities may not be captured through monitoring until up to 10 years after project implementation (Bilby et al. 2005).

Sampling during summer low flows may preclude observations of juvenile Chinook. To adequately detect increases in coho and Chinook density due to Instream Habitat Projects, it is likely more appropriate to segregate the projects in this monitoring category based on some basic groupings such as similarities in geography, geology, hydrology, project type, project objectives, and target fish species. Although such segregation will greatly increase the number of projects needed to be sampled within this monitoring category as a whole (around 30 projects would likely be sufficient [Roni and Quinn 2001]), it would assist in adequately addressing the question of increases in juvenile coho, *O. mykiss*, and Chinook density resulting from Instream Habitat Projects. We recommend expanding the study in this category to include more projects and allow for stratification of the project type into groupings such as similarities in geography, geology, hydrology, project type, project objectives, and target fish species.

5.2 FLOODPLAIN ENHANCEMENT PROJECTS

Floodplain Enhancement Projects are typically large-scale projects that are costly to implement, but can be very effective as improving habitat conditions at the landscape level. As a result, it is important that changes are captured at each project site and that conditions can be compared over time. By repeating the topographic survey during each monitoring event, a comparison of the digital data layers can be made that allows calculation of changes in habitat conditions such as pool area and depth, channel capacity, volume of newly created habitat, and floodplain connectivity. Working collaboratively with project partners such as the UCSRB and BPA to monitor floodplain projects using this method has resulted in increased power of analysis and thereby statistical significance.

Similar to Instream Habitat Projects, generation time may be a factor in capturing the effects of Floodplain Enhancement Projects on juvenile fish densities. For the species being monitored, generation times vary from approximately 3 to 5 years. Although some significant improvements were detected for coho, it may take additional years of monitoring to capture changes in Chinook and *O. mykiss* densities. We recommend expanding the study in this category to include more projects and allow for stratification of the project type into groupings such as similarities in geography, geology, hydrology, project type, project objectives, and target fish species.

5.3 RIPARIAN PLANTING PROJECTS

Riparian Planting Projects yielded data that were unexpected for some of the variables measured. For instance, when monitoring for increases in canopy density at the water's edge, it was found at some sites that riparian plantings were not installed at the water's edge, but were installed 5 to 15 meters away from the water to prevent loss of the plants due to bank erosion. Additionally, monitoring for survival in the first 3 years was effective in determining if adequate species were selected and whether the plantings received adequate watering and maintenance. However, after Year 3, measuring percent cover of woody species rather than measuring survival estimates is recommended because of the difficulty in re-locating the original plantings among recruits and other naturally occurring vegetation. Measurements of percent cover of woody species should be repeated in Year 5 and Year 10.

For Riparian Planting Projects, it is recommended that the measurement of canopy density and vegetation structure be delayed until vegetation has had a chance to establish. If plantings are not included as part of the project, the response of the canopy density and vegetation structure indicators is likely to take more time. The success of the projects depends on adequate control of invasive species. Therefore, qualitative assessment of invasive species should be included as part of each monitoring event and as a follow-up to project implementation.

5.4 CONCLUSIONS

Results to date from the SRFB Reach-Scale Effectiveness Monitoring Program indicate that Instream Habitat Projects are showing significant changes in physical habitat within the first 5 years following implementation. Floodplain Enhancement Projects are showing significant trends toward improvement in several geomorphic variables and juvenile coho density within the first 5 years of monitoring. The results from the UCSRB monitoring program were combined with the SRFB projects and contributed to this significant finding. Riparian Planting Projects are not showing significant changes in any of the variables tested; however, they are showing average increases in several indicators, and additional monitoring is expected to reveal significant improvements in this category.

The Reach-Scale Effectiveness Monitoring Program provides numerous benefits that support funding entities, project sponsors, and lead entities. Data collected as part of this program allows project results to be compared within a category because a consistent set of protocols are used for all projects monitored in that category. Communication on the results from the programs helps to distribute information regarding the effectiveness of approaches to restoration that are being used across the region. Dissemination of this information helps project sponsors and lead entities learn about approaches that are working in other areas, which allows for improved future project designs and implementation of more successful salmon recovery efforts. By sharing project information through annual reports and the Habitat Work Schedule (2013), project sponsors and other planning entities can share what has already been done across the region and adapt their efforts toward success.

A partnership with UCSRB was established to monitor Instream Habitat and Floodplain Enhancement Projects within the Upper Columbia Basin. Four of the UCSRB sites were monitored in 2013, and the data from those sites were included in the analyses for those project categories under the SRFB program. Additional partnerships are being developed with BPA through their Action Effectiveness Monitoring Program, Native American Tribes, and other entities across the Columbia Basin.

By working with entities such as the UCSRB, BPA, and others to monitor projects using standardized protocols, data can be shared. As a result, the sample size for these categories has increased, thus improving the power of analysis and statistical significance at no additional cost to either entity. Continued development of this partnership and others will improve the program over the long term.

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