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Washington State Salmon Recovery Funding Board

Reach-Scale Effectiveness Monitoring Program

2010 Annual Progress Report

March 2011





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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 a 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. The SRFB has funded more than 1,307 projects and spent more than $404 million in state and federal funds toward salmon recovery. Additionally, regional coordination across monitoring programs is sought to increase data compatibility, improve management decisions across jurisdictions, and better utilize monitoring resources. While it is not economically feasible to monitor the long-term success of every project, a subset of projects can be effectively monitored, both within a state and across the region. Monitoring data on the effectiveness of projects provides information to project sponsors that can be used to improve communication about restoration approaches and improve future designs. Using this concept, the SRFB funded the Reach-Scale Effectiveness Monitoring Program in 2004 to programmatically provide project effectiveness monitoring across the state. Monitoring for the Reach-Scale Effectiveness Monitoring Program began in spring 2004 and has continued through 2010.

Implementation of the SRFB program included first separating all projects into nine monitoring categories, and then selecting a subset of projects from each of these categories to monitor. In 2010, monitoring categories included the following:

- In-stream Habitat
- Riparian Planting
- Livestock Exclusion
- Channel Connectivity

Monitoring of Fish Passage and Diversion Screening Projects was completed in 2009; therefore, those project categories were not monitored in 2010. The project pool for Spawning Gravel Projects is not currently of sufficient size to have statistically valid results, so that category was omitted from monitoring in 2010 as well. None of the Habitat Protection Projects or Constrained Channel Projects were scheduled for monitoring this year, so those project categories are not discussed in this report.

The SRFB invested in the Coordinated Monitoring Program for Livestock Exclusions with the Oregon Watershed Enhancement Board in 2006. The Coordinated Monitoring Program is currently focused on one of the categories, Livestock Exclusion Projects, in both Oregon and Washington. The results from both programs provide information about the probable

effectiveness of other projects in the same category and the relative effectiveness between categories.

This report, in conjunction with a web-based reporting tool, describes monitoring activities and results for this 7-year monitoring effort. Monitoring for the Coordinated Monitoring Program began in 2006 and continued in 2010, and is also supported by a summary report and a web-based reporting tool.

The intent of the monitoring was to test whether habitat targeted for restoration had been improved or preserved, and for some categories, whether localized salmon and steelhead abundance had increased. Where structures were part of habitat improvement, engineering specifications were also tested for effectiveness in meeting design criteria over time. This effort served as implementation (compliance) monitoring for these projects.

Field sampling indicators and techniques were adapted from U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program (Peck et al. 2003). Specific protocols were developed to detect changes in habitat, fish populations, or ecological status expected to result from project implementation. Of the four project categories monitored in 2010, all of them were evaluated using a Before After Control Impact (BACI) experimental design (Stewart-Oaten et al. 1986). Each project is monitored before implementation and after implementation on a rotating schedule, depending on project type. Monitoring duration for each category ranges from 5 years post-implementation to 12 years post-implementation.

Several changes have been made to the protocols over the past year. The MC-5 protocol for Constrained Channel and the MC-6 protocol for Channel Connectivity have been combined into a joint protocol for Floodplain Reconnection Projects. This change allows for monitoring of the development and maintenance of floodplain habitat over time. In an effort to coordinate more closely with other monitoring programs in the region and enhance our ability to share data, some minor changes to the field protocols are being made. These changes will help increase the compatibility between the SRFB data and data collected by the U.S. Forest Service and projects funded through the Bonneville Power Administration.

Results from the 2010 analysis indicate that In-Stream Habitat Projects are significantly improving geomorphology by increasing mean vertical pool profile area, or pool area, and mean residual depth, or pool depth, in the first 5 years after construction. These projects also resulted in statistically significant improvements in steelhead densities within the first 5 years. Significant regional improvement in volume of wood has also been seen for In-Stream Habitat Projects, indicating that wood placed as part of restoration projects has remained stable and is likely leading to more natural wood recruitment in the treatment reaches. Significant trends were not found for any of the Riparian Planting metrics; however, while not statistically significant, average improvements for bank erosion and mean canopy density have been reported. Livestock Exclusion Projects are effectively decreasing bank erosion in the first 5 years after construction. While no significant improvements were found for Channel Connectivity Projects, increasing trends were seen in both geomorphology and juvenile fish metrics. Indications of change and observed trends are preliminary and 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 the full list of projects in each category is implemented. Additional recommendations to improve project implementation and monitoring are also included as part of this report.

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1 INTRODUCTION

Stream restoration efforts are being conducted throughout the world to enhance or restore function to aquatic systems. In the United States, approximately a billion dollars is 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 the ecology of the Pacific Northwest. With so much money being spent on 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 needs that were occurring in the state and to develop a strategy to coordinate these efforts through state-wide 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 necessary to provide accountability for the expenditures of 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 most 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, a federal funding source 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 and the Bonneville Power Administration’s Research, Monitoring, and Evaluation Program in 2010 have increased the level of coordination in monitoring across the region and will result in more efficient monitoring and cost savings. Comparable data collected across the region will provide better information to aid resource managers in making decisions regarding listed salmon species, many of which range across state lines. In addition, results from the program are shared with project sponsors to help improve communication about successful restoration approaches, lessons learned, and the best ways to approach project design.

Project categories included in the SRFB monitoring program are the following:

- Fish Passage
- In-stream Habitat
- Riparian Planting
- Livestock Exclusion
- Constrained Channel
- Channel Connectivity
- Spawning Gravel
- Diversion Screening
- Habitat Protection

For one of the monitoring categories, Livestock Exclusion Projects, the projects monitored occurred in both Oregon and Washington, and the funding for monitoring and reporting was provided jointly by both states. These data have been combined for analysis in this report, resulting in a regional representation of the effectiveness of this project type. This coordination has resulted in a larger sample size, allowing for more robust data analysis at a reduced cost to both states.

This report summarizes monitoring and data analysis efforts during the 2004 through 2010 field seasons for the project categories monitored in 2010. Monitoring of Fish Passage and Diversion Screening Projects was completed in 2009; therefore, those project categories were not monitored in 2010. The project pool for Spawning Gravel Projects is not currently of sufficient size to have statistically valid results, so that category was omitted from monitoring in 2010 as well. None of the Habitat Protection Projects or Constrained Channel Projects were scheduled for monitoring this year, so those project categories are not discussed in this report.

The categories monitored in 2010 were In-stream Habitat, Riparian Planting, Livestock Exclusion, and Channel Connectivity. These categories are the units of analysis for work under this program. This report includes a brief description of data collection methods for each monitoring category, data analysis, and recommendations for future monitoring and reporting. The web-based component of the report that was developed in 2009 has been updated to include information from the 2010 monitoring effort. It contains individual reports for each of the active projects in the program, as well as project-specific data and results for those sites. The web-based information can be viewed at http://206.127.112.131/FishPass/fishmanager_WMP.html, and will also be made available through Washington's Habitat Work Schedule, a centralized database for restoration project data. Additional information project categories other than those monitored in 2010 can be viewed on the Washington State Recreation and Conservation Office website, under Project Effectiveness Monitoring, at http://www.rco.wa.gov/doc_pages/other_pubs.shtml#monitoring.

Initial response trends for some projects have been detected using up to 5 years of post-project implementation data, but for other projects it will take longer to detect changes. Recommendations for improving effectiveness monitoring efforts are included in Section 5, Recommendations and Conclusions.

2 METHODS

There are currently nine monitoring categories included within the SRFB program. Field sampling indicators and techniques were adapted from U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program (Peck et al. 2003). Of the four project categories monitored in 2010, all of them were evaluated using a Before After Control Impact (BACI) experimental design (Stewart-Oaten et al. 1986). Each project is monitored before implementation and after implementation on a rotating schedule, depending on project type. The detailed protocols used to monitor them are available in Crawford (2008a-h) and Crawford and Arnett (2008), and can be found on the Washington Recreation and Conservation Office website at www.rco.wa.gov/monitoring/protocols.shtml. The monitoring categories and success criteria are described in the documents listed under Reach-Scale Effectiveness Monitoring Protocols (Revised 2008). The protocols include goals and objectives for each category, detailed field collection descriptions, summary statistics, and data analysis procedures.

In 2010, monitoring for Fish Passage Projects and Diversion Screening Projects was completed because those categories were shown to be effective and additional evaluation was not necessary. Monitoring of Spawning Gravel Projects was discontinued due to the small number of projects in the sample pool. Therefore, of the nine monitoring categories in the program, only six of them are currently active, and projects in four of those categories were monitored in 2010. Project categories monitored in 2010 included In-stream Habitat, Riparian Planting, Livestock Exclusion, and Channel Connectivity.

3 DATA ANALYSIS AND RESULTS

Analysis of a monitoring category is contingent upon the category containing at least two projects that have been implemented and having at least one year of pre-implementation and post-implementation data. The goal of this data analysis is to evaluate the success of these projects as a unit. Table 1 lists the projects in each category monitored in 2010 and the number of years for which post-implementation data have been collected. The table includes projects that were funded through the Oregon Watershed Enhancement Board (OWEB) and are part of the data analysis for Livestock Exclusion Projects through the Coordinated Monitoring Program. This report evaluates regional trends through time including all of the post-implementation data.

Analyses performed for each monitoring category fall under two methods: those that use decision criteria and those that use statistical tests. Decision criteria were applied to the projects in Table 1 to determine project effectiveness for each monitoring category using several indicators (Table 2). The decision criteria were based on the objectives established for each monitoring category and comprised two components: 1) decision criteria that are specific to the monitoring category and the type of project design; and 2) an evaluation of the percent change in the mean difference between impact reaches and control reaches for each indicator in a category. Decision criteria for each indicator were defined in the protocols used to monitor each category Crawford (2008 a-h) and Crawford and Arnett (2008).

Table 1. Projects Included in the Data Analyses

Project Number	Project Name	Category	Years of Post-Implementation Data
02-1444	Little Skookum Valley, Phase II: Riparian	In-Stream Habitat	Years 1, 3, and 5
02-1463	Salmon Creek	In-Stream Habitat	Years 1, 3, and 5
02-1515	Upper Trout Creek Restoration	In-Stream Habitat	Year 1
02-1561	Edgewater Park Off-Channel Restoration	In-Stream Habitat	Years 1, 3, and 5
04-1209	Chico Creek Instream Habitat Restoration	In-Stream Habitat	Year 1
04-1338	Lower Newaukum Restoration	In-Stream Habitat	Years 1 and 3
04-1448	PUD Bar Habitat Enhancement	In-Stream Habitat	Years 1, 3, and 5
04-1575	Upper Washougal River LWD Placement	In-Stream Habitat	Years 1, 3, and 5
04-1589	Dungeness River Railroad Bridge Restoration	In-Stream Habitat	Year 1 and 3
04-1660	Cedar Rapids Floodplain Restoration	In-Stream Habitat	Year 1
05-1533	Doty Edwards Cedar Creek	In-Stream Habitat	Years 1 and 3
07-1803	Skookum Reach Restoration	In-Stream Habitat	Year 1
02-1446	Centralia Riparian Restoration Project	Riparian Plantings	Years 1, 3, and 5
02-1561	Edgewater Park Off-Channel Restoration	Riparian Plantings	Years 1, 3, and 5
02-1623	Snohomish River Confluence Reach Restoration	Riparian Plantings	Years 1, 3, and 5
04-1649	Snow Creek Lower Watershed Site 1A	Riparian Plantings	Years 1, 3, and 5
04-1655	Hoy Riparian Restoration	Riparian Plantings	Years 1, 3, and 5
04-1660	Cedar Rapids Floodplain Restoration	Riparian Plantings	Year 1
04-1676	YTAHP Wilson Creek Riparian Restoration	Riparian Plantings	Years 1, 3, and 5
04-1698	Vance Creek Riparian Planting and Fencing	Riparian Plantings	Years 1 and 3
04-1711	Lower Klickitat Riparian Restoration	Riparian Plantings	Years 1, 3, and 5
02-1498	Abernathy Creek Riparian Restoration	Livestock Exclusions	Years 1, 3, and 5
04-1655	Hoy Riparian Restoration	Livestock Exclusions	Years 1, 3, and 5
04-1698	Vance Creek Riparian Planting and Fencing	Livestock Exclusions	Year 1 and 3
05-1447	Indian Creek Yates Restoration	Livestock Exclusions	Year 1 and 3
05-1547	Rauth: Coweeman Tributary Restoration	Livestock Exclusions	Year 1 and 3
206-095	OWEB: Jordan Creek	Livestock Exclusions	Year 1 and 3
206-072	OWEB: Grays Creek	Livestock Exclusions	Year 1 and 3
206-283	OWEB: Noble Creek	Livestock Exclusions	Year 1 and 3
206-283	OWEB: Johnson Creek	Livestock Exclusions	Year 1 and 3
206-357	OWEB: Malheur	Livestock Exclusions	Years 1 and 3
205-060	OWEB: Bottle Creek	Livestock Exclusions	Year 1 and 3

Table 1. Projects Included in the Data Analyses (continued)

Project Number	Project Name	Category	Years of Post-Implementation Data
205-060	OWEB: North Fork Clark	Livestock Exclusions	Year 1 and 3
02-1561	Edgewater Park Off-Channel Restoration	Channel Connectivity	Years 1, 2 and 5
04-1461	Dryden Fish Enhancement CMZ Project	Channel Connectivity	Years 1 and 2
04-1563	Germany Creek Conservation Restoration	Channel Connectivity	Years 1 and 2
04-1573	Lower Washougal Restoration-Phase 1	Channel Connectivity	Years 1 and 2
05-1546	Gagnon CMZ Off-Channel Habitat Project	Channel Connectivity	Years 1 and 2
06-2239	Fender Mill Floodplain Restoration	Channel Connectivity	Year 1
07-1691	Lockwood Creek Phase 3	Channel Connectivity	Years 1 and 2

Table 2. Indicators Tested for Each Monitoring Category Evaluated in 2010

Monitoring Category	Indicators Tested
In-stream Habitat Projects	• Mean thalweg residual pool vertical profile area • Mean residual depth • Juvenile fish density by species • Log_{10} volume of large woody debris • Juvenile fish density by species
Riparian Planting Projects	• Linear proportion of actively eroding banks • Proportion of the reach with three-layer riparian vegetation • Mean canopy density along the banks
Livestock Exclusion Projects	• Linear proportion of actively eroding banks • Proportion of the reach with three-layer riparian vegetation • Mean canopy density along the banks
Channel Connectivity Projects	• Mean thalweg residual pool vertical profile area • Mean residual depth • Proportion of the reach with three-layer riparian vegetation • Mean canopy density along the banks • Juvenile fish density by species

Regional trends through time for the project categories monitored in 2010, including all of the post-implementation data, are evaluated in this report. This type of trend, a longitudinal analysis, is intended to create a profile summary, summarizing the trend across all sites with a single number. In this case, we use the regression slope as our trend summary. Regional differences from zero for the regression slopes can then be assessed using a t-test or nonparametric equivalent test. This can be viewed as an extension of the paired t-test, using the slope rather than the absolute difference between two years. Because we are using the linear regression slope, this test is most sensitive to a linear increase occurring across the sampled years.

We have estimated 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, we standardized the years to the project implementation timeframe. The first year after project implementation is always labeled Year 1, and the year immediately prior to implementation is Year 0. Year 1 was always sampled, but Year 0 was not. For example, if samples were collected the year previous to Year 0, they are labeled as Year -1, for example. If samples were collected in multiple pre-implementation years, only the most recent year was retained in the analysis, because we are not evaluating trends prior to implementation.

For each variable within each monitoring category, the years were reset, 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 can not be a significant improvement regardless of the statistical test used, so there is no test for those variables.

For each variable, the change estimated by linear trend (averaged across sites) as a percent of the baseline (impact – control) mean at Year 1, 3, and 5 was determined. This provides an absolute measure to compare to the benchmark of 20 percent change through time. The Year 1 estimate is the most reliable estimate because all current sites have been observed in Year 1. The Year 5 estimate is an extrapolation because most sites have not yet been observed for Year 5. Also note that these estimates are based on the assumption of linear increase or decrease through time.

For each monitoring category, the relative slopes are displayed in a boxplot by endpoint, or variable. The relative slopes are the slopes divided by the absolute value of the baseline (impact – control) mean. Variables with statistically significant improving regional trends are plotted within each monitoring category. For variables with average improving trends that were not statistically significant, the observed variance was used to estimate statistical power for minimum detectable differences in average slope using a t-test. The minimum detectable difference was reported as a proportion or multiple of the starting mean (impact – control) differences. This power analysis was conducted to evaluate the effectiveness of current sample sizes to detect future trends. It is not to be used to evaluate the strength of the significance tests already conducted. It was not conducted on variables with declining (i.e., not improving) average trends, because the issue with these variables is a matter of direction rather than variability. The results given in this report are for monitoring variables for which 2010 data have been collected only.

3.1 IN-STREAM HABITAT PROJECT RESULTS

For the In-Stream Habitat Projects monitored in this program, there are currently significant regional improvements being seen in pool area, pool depth, log_{10} volume of wood, and density of steelhead parr (Table 3). Chinook and coho juveniles showed average declines; however, those results were not significant (Table 3).

Table 3. Summary of Results for In-Stream Habitat Projects

Indicator	Baseline Mean (Impact – Control)	Average Change as Percent of Baseline (Regression Line)			Statistically Significant Results
	Year 0	Year 1	Year 3	Year 5	
Pool Area (m^2)	-5.7	121%	362%	604%	X
Pool Depth (cm)	-1.1	125%	374%	624%	X
Log_{10} Volume of Wood (m^3)	-0.15	203%	608%	1013%	X
Chinook Juvenile (fish/m^2)	0.0013	-88%	-265%	-441%	
Coho Juvenile (fish/m^2)	0.028	-19%	-57%	-94%	
Steelhead Parr (fish/m^2)	-0.0039	95%	285%	474%	X

It can be concluded that In-Stream Habitat Projects are effective at increasing refuge in the first years after project implementation for steelhead. A statistically significant increase in pool area has been seen across all sites except for one (Figure 1).

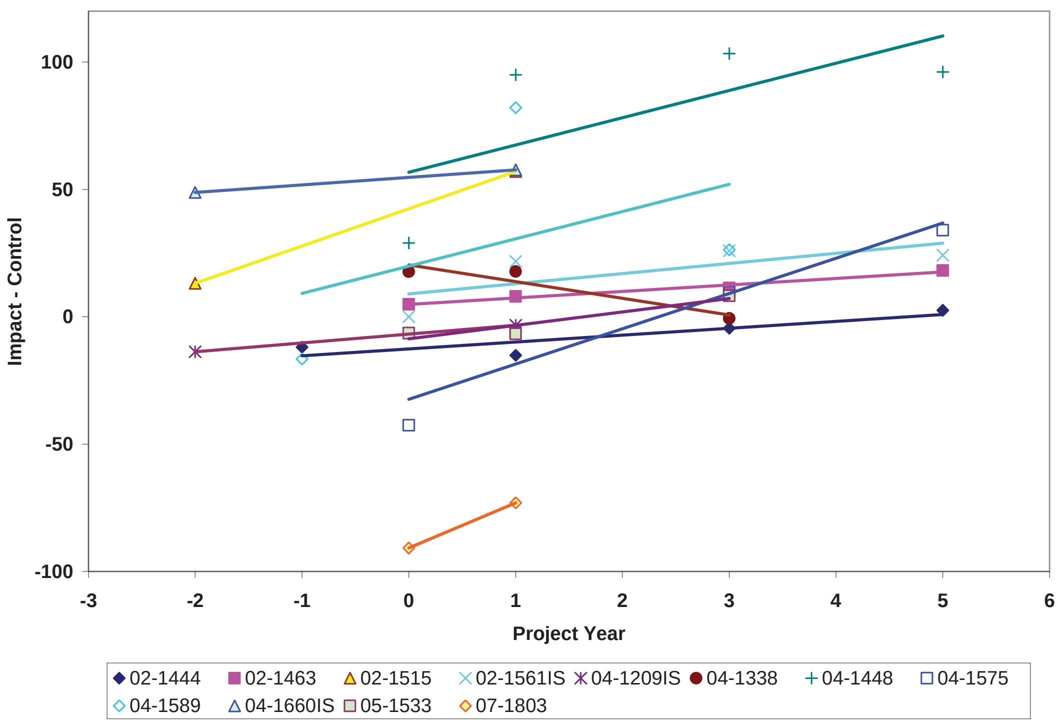

Figure 1. Significant Increase in Mean Vertical Pool Profile Area Across Sites

Of the In-Stream Habitat Projects assessed, all of them retained more than 50 percent of the artificial in-stream structures (AIS) that were placed at the project site as of Year 5. As a result, the In-Stream Habitat Projects currently exceed the 50 percent goal for AIS remaining in place and are meeting the success criteria established for this category.

Figure 2 is a boxplot displaying the range of relative slopes of trendlines by variable for In-stream Habitat Projects. Relative slopes are slopes divided by the absolute value of the baseline (impact – control) mean. The middle line is the median slope, and the box encloses the interquartile range (1st to 3rd quartile). The boxplot illustrates the variance and mean for each parameter analyzed. While results were statistically significant for pool area, the boxplot shows very little variance from the mean. Pool depth also showed statistically significant improvements; however, Figure 2 shows larger variability for that indicator. The extremely high and low points shown on the graph in Figure 2 are considered anomalies.

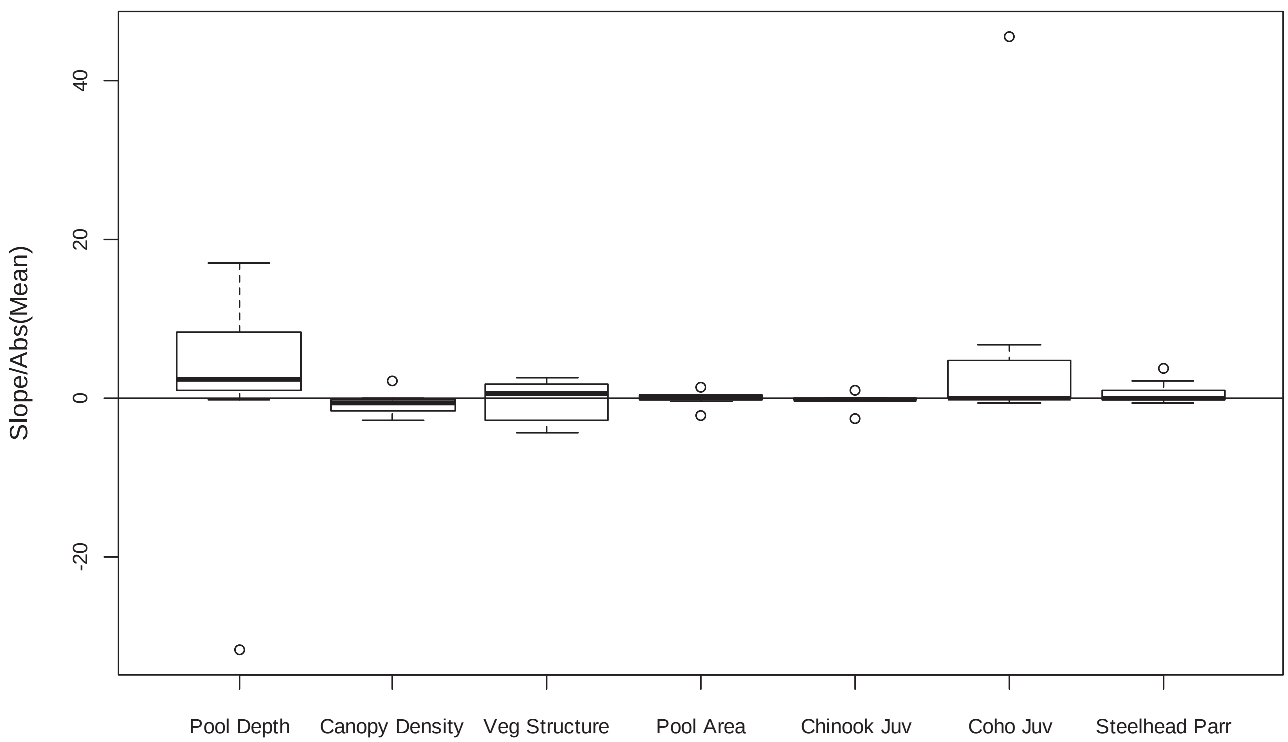

Figure 2. Boxplot Displaying Range of Relative Slopes of Trendlines by Variable for In-Stream Habitat Projects

3.2 RIPARIAN PLANTING PROJECT RESULTS

None of the Riparian Planting variables showed significant results, likely due to the short relative time frame for monitoring changes in vegetation. Average improvements for the linear proportion of actively eroding banks and mean canopy density and average decline in riparian vegetation structure were not statistically significant. Many of the plantings at each of the riparian planting sites are not located directly along the streambanks but instead in the floodplain. As a result, these plantings have little effect in the short term on indicators such as stream canopy cover, but over time they will likely have a greater effect on the riparian cover and streambank conditions. As the plantings become established and mature to provide canopy cover and stream shade, it is expected that riparian vegetation structure and canopy cover indicators will show an increase. As the riparian vegetation becomes well-established, the linear proportion of actively eroding banks will likely decrease. Table 4 shows the results of the statistical analysis of Riparian Planting Projects.

Table 4. Summary of Results for Riparian Planting Projects

Indicator	Baseline Mean (Impact – Control)	Average Change as Percent of Baseline (Regression Line)			Statistically Significant Results*
	Year 0	Year 1	Year 3	Year 5	
Linear Proportion of Actively Eroding Banks (%)	9.6	-14%	-42%	-69%	
Riparian Vegetation Structure (%)	-34	-3.1%	-9.4%	-16%	
Mean Canopy Density (1-17)	-2.7	1.70%	5.20%	8.60%	

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

Regarding survival of riparian plantings (see Crawford 2008c for decision criteria), in Year 1, 100 percent of the project sites sampled exceeded the goal of 50 percent survival for the category. Survival of planted species declined between Year 1 and Year 3; and one site did not reach the 50 percent survival criteria in Year 3. For the Year 3 data, 8 out of 9, or 89 percent of projects, met the 50 percent survival criteria. The high mortality observed among the riparian plantings in the project that did not meet the survival criteria was presumably due to herbicide drift from an adjacent property. After Year 3, 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.

Figure 3 illustrates the power curves generated using the data from Riparian Planting Projects. These curves can be used to determine the relationship between sample size, desired power, and minimum detectable difference for Riparian Planting Projects. To detect a 30 percent change at an 80 percent statistical power, approximately 11 projects would be required.

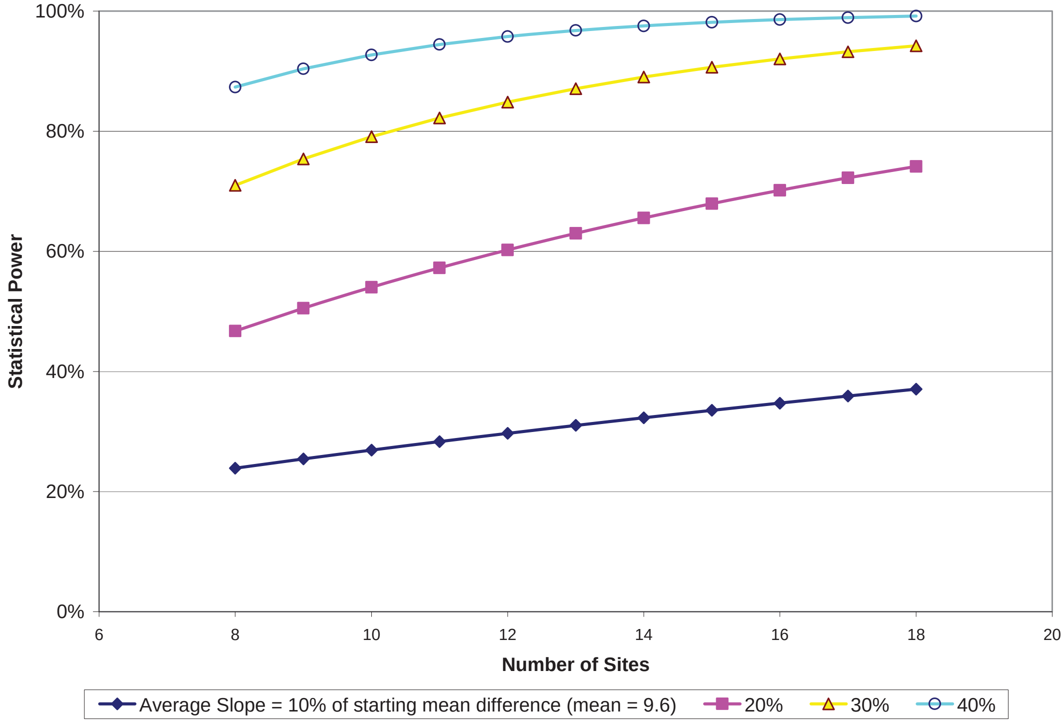

Figure 3. Statistical Power Needed to Detect Significant Change in Bank Erosion.

3.3 LIVESTOCK EXCLUSION PROJECT RESULTS

Livestock Exclusion Projects included in this program were effective at significantly reducing bank erosion (Figure 4). Figure 4 shows the trendlines for each individual project monitored in the Coordinated Monitoring Program for Livestock Exclusions. All projects except for one indicate negative trends in the amount of bank erosion over 3 years of monitoring. This reduction was more than 20 percent of the baseline value; applying the success criteria represents meaningful improvements in bank erosion. Average improvements in riparian vegetation structure and mean canopy density were not statistically significant. Table 5 shows the results of the statistical analysis of Livestock Exclusion Projects.

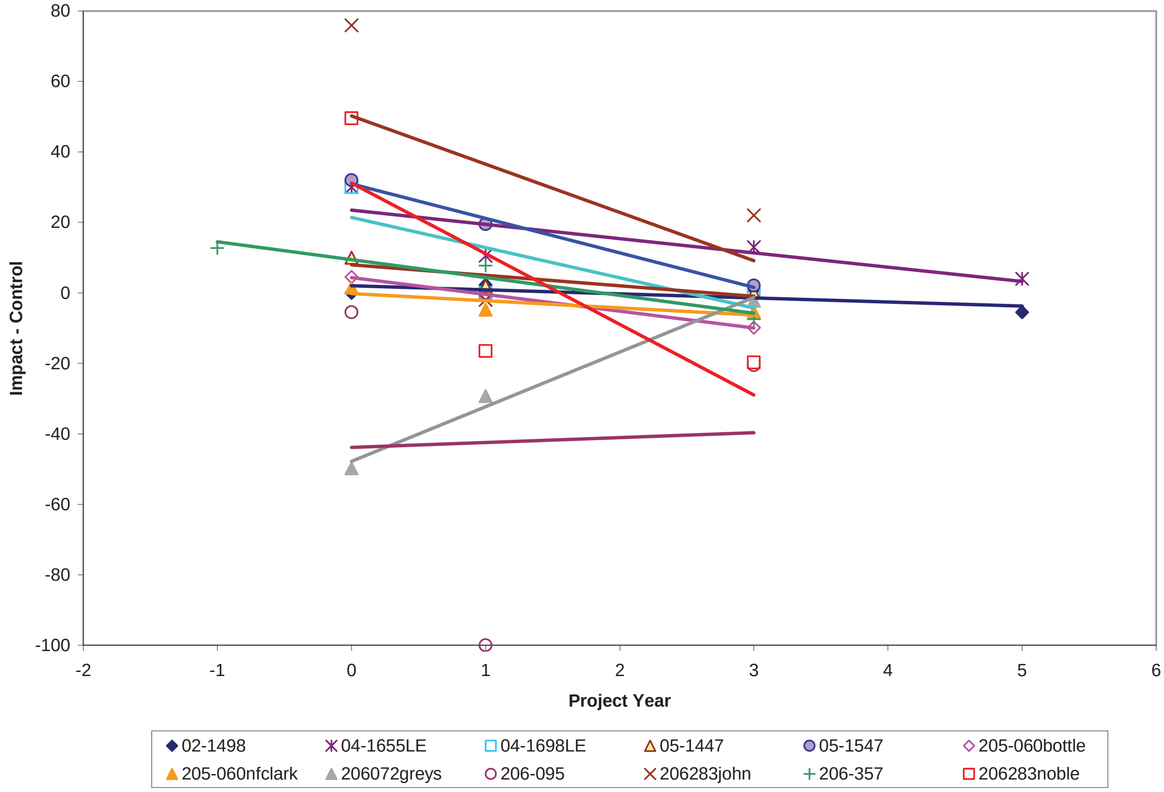

Figure 4. Significant Decrease in Bank Erosion through Time

Table 5. Summary of Results for Livestock Exclusion Projects

Indicator	Baseline Mean (Impact – Control) Year 0	Average Change as Percent of Baseline Year 1	Year 3	Year 5	Statistically Significant Results
Linear Proportion of Actively Eroding Banks (%)	16	-29%	-87%	-145%	X
Riparian Vegetation Structure (%)	-20	8.5%	25%	42%	
Mean Canopy Density (1-17)	-2.7	24%	72%	120%	

Evaluation of livestock projects includes an assessment of exclusion function. This assessment evaluates whether the fencing structure is fully intact and is successfully excluding livestock from the fenced area. Observations of animal droppings, wildlife grazing or browsing, and other indicators are documented as well. Of the projects included in the analysis for Year 1, 83.3 percent of them were evaluated as functional. For Year 3, 81.8 percent of the projects included in the analysis were considered functioning. In 2010, only one Livestock Exclusion Project was monitored and it was found to be functional. Therefore, the Livestock Exclusion Projects, as a category, continue to exceed the 80 percent success criteria for intact and functioning fencing as well as excluding livestock.

3.4 CHANNEL CONNECTIVITY PROJECT RESULTS

Table 6 shows the results from indicators for Channel Connectivity Projects. No statistically significant improvements were shown for this category, likely due to the smaller sample size and higher variability of responses to these projects. Average improvements for pool area, pool depth, coho juvenile density, and steelhead parr density were seen, but are not significant (Figure 5). All other variables showed average declines, which are not significant either.

Table 6. Summary of Results for Channel Connectivity Projects

Indicator	Baseline Mean (Impact – Control)	Average Change as Percent of Baseline			Statistically Significant Results*
	Year 0	Year 1	Year 2	Year 5	
Pool Area (m^2)	-33	2.9%	5.8%	15%	
Pool Depth (cm)	0.12	1201%	2402%	6005%	
Riparian Vegetation Structure (%)	3.2	-34%	-68%	-169%	
Mean Canopy Density (1-17)	1.5	-55%	-111%	-277%	
Chinook Juvenile (fish/m^2)	0.048	-24%	-48%	-119%	
Coho Juvenile (fish/m^2)	-0.02	787%	1574%	3936%	
Steelhead Parr (fish/m^2)	-0.0084	81%	161%	403%	

*None of the indicators for Channel Connectivity Projects showed statistically significant results.

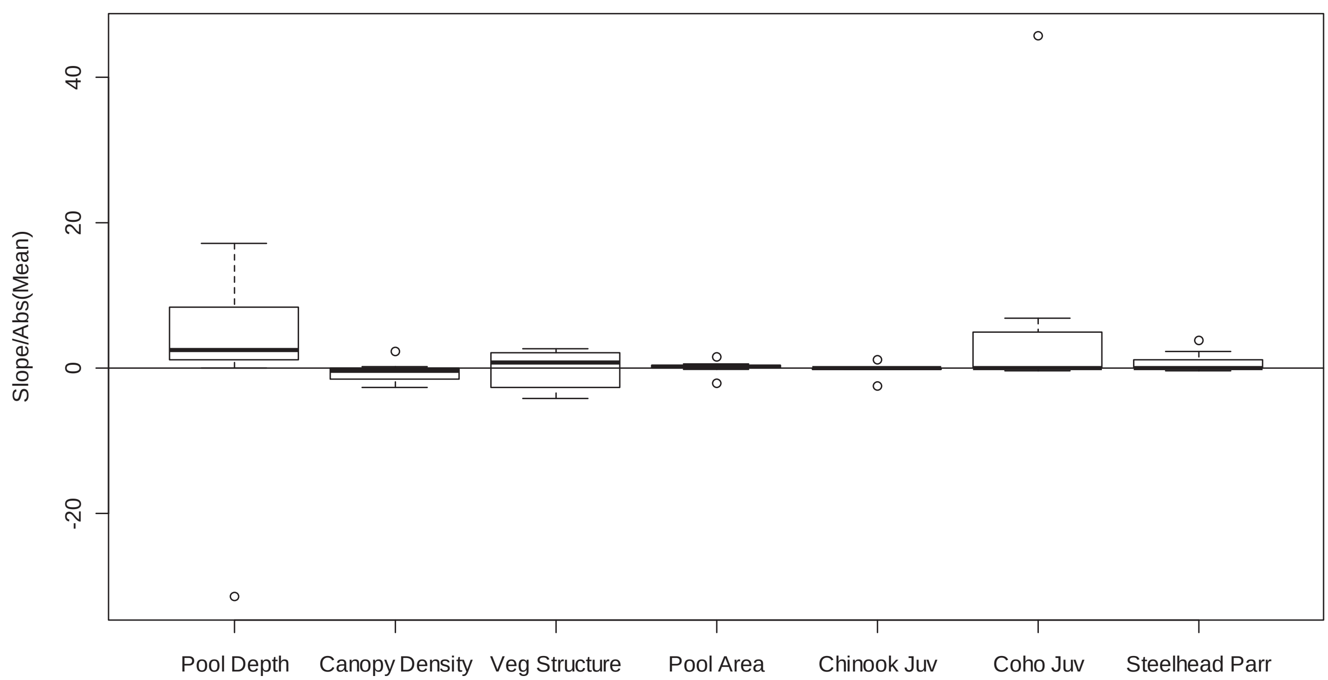

Figure 5. Boxplot Displaying Range of Relative Slopes of Trendlines by Variable for Channel Connectivity Projects

Figure 5 is a boxplot displaying the range of relative slopes of trendlines by variable for Channel Connectivity Projects. Relative slopes are slopes divided by absolute value of baseline (impact – control) mean. As shown in the figure, the baseline mean for pool depth is very small, resulting in distortion to the boxplot, so the mean slope was used as a relative correction in this case. The middle line is the median slope, and the box encloses the interquartile range (1st to 3rd quartile). The strongest trends are currently seen for pool depth and juvenile coho density. With additional projects and years of data, we would expect to detect significant change for these indicators.

4 RESULTS SUMMARY AND DISCUSSION

The projects in each monitoring category were assessed based on a set of response indicators that apply to each project type. Those response indicators were then evaluated at three levels; however, not all three levels applied to all project categories. Level 1 analysis evaluated the functional criteria of the project as compared to the engineered design. Level 2 analysis considered the effectiveness of the project in respect to habitat indicators. Fish response was captured in the Level 3 analysis.

The data analysis and evaluations conducted to date indicate that some monitoring categories are showing significant changes in the first 1 to 5 years after implementation. Conclusions by category include the following:

- In-Stream Habitat Projects are significantly improving channel morphology and habitat by increasing mean vertical pool profile area, mean residual depth, and $\log_{10}$ volume of wood. Steelhead parr density is also showing significant improvement at these sites. Both Chinook and coho juveniles showed average declines; however, these results were not statistically significant. Additional investigation into Chinook juvenile responses to large woody debris projects is warranted. Coho responses to these projects have been established in other studies (Roni et al. 2010).
- Riparian Planting Projects are not showing significant trends in any of the indicators tested, likely due to the short time frame for monitoring compared to that for vegetative change. Average improvements in bank erosion and canopy density have been seen, as well as an average decline in riparian vegetation structure; however, none of those results are statistically significant. Decreases in vegetation structure may be due to removal of invasive shrubs and forbs prior to installation.
- Livestock Exclusion Projects are significantly decreasing bank erosion. While not statistically significant, average improvements are also being seen for canopy density and riparian vegetation structure in this category. Additional time is required to detect significant change in vegetation.

- Channel Connectivity Projects are not showing significant improvements in any of the variables tested. Average improvements are being seen in geomorphic variables, including mean vertical pool profile area and mean residual depth, and in juvenile coho and steelhead parr densities. All other variables showed average, but nonsignificant, declines. A greater sample size and further years of monitoring are expected to solidify trends in indicators for these projects.

In addition, functional evaluations show the following conclusions for each category:

- In-Stream Habitat Projects are sufficiently retaining AIS.
- Riparian Planting Projects are successfully exceeding the 50 percent plant survival criterion.
- Livestock Exclusion Projects remain functional.
- Off-channel habitats are generally maintaining connection with mainstem habitats.

Table 7 summarizes the results of the 2010 analyses for each monitoring category. The table includes results from Level 1, 2, and 3 analyses.

Table 7. Summary of Analysis Results for 2010

Project Category	Level 1 Functional Criteria	Level 2 Habitat Indicators	Level 3 Fish Response
In-Stream Habitat	• 100 percent of the In-Stream Habitat Projects monitored met the criteria of >50 percent of the artificial in-stream structures (AIS) remaining within the impact reach by Year 5.	• In-Stream 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 (LWD).	• Significant improvements in steelhead parr were seen. • Average declines for Chinook and coho juvenile densities were not significant.
Riparian Planting	• 89 percent of the projects monitored in Years 1 and 3 demonstrated a percentage of plants living that exceeded the 50 percent survival criteria.	• No significant results reported • Average improvements for bank erosion and canopy density were not significant.	• N/A
Livestock Exclusion	• 83.3 percent in Year 1 and 81.8 percent in Year 3 of the projects monitored were found to be functional, thus exceeding the >80 percent criteria. 100 percent of the projects monitored in 2010 were functional.	• Livestock Exclusion Projects as a group showed a statistically significant reduction over baseline in bank erosion. • Average improvements in canopy density and riparian vegetation structure were not statistically significant.	• N/A
Channel Connectivity	• 100 percent of the projects monitored had channels that remained connected to the stream in Years 1 and 2, which exceeds the criteria of >80 percent.	• No significant results reported. • Average improvements in mean vertical pool profile area and mean residual depth were not significant.	• Average improvements in coho juvenile and steelhead parr densities were not significant.

5 RECOMMENDATIONS AND CONCLUSIONS

The following are general and project 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 GENERAL RECOMMENDATIONS

The following recommendations are being made as a result of lessons learned through monitoring over the past 7 years. Several of them are general suggestions that apply to all project categories and others are specific to certain types of projects. Additional discussion related to the projects categories monitored in 2010 can be found below.

- Biological factors such as predation and population potential should be considered when designing a project or choosing a project implementation location, as they can influence the success of a project.
- Biological response to projects is dependent on many factors and may take longer to stabilize for some project categories than others. Monitoring periods for each category should be planned to capture biological responses.
- Habitat structures should be sized appropriately for the drainage basins in which they are installed so they can withstand peak flows and function as intended.
- Information about habitat and watershed conditions surrounding the project area, which may affect project performance, would be helpful prior to project design and implementation. This should be considered and discussed in funding applications.
- Pre-project fish density data should be collected to assess the potential for colonization and use of newly created or available habitat by salmonids. If fish densities are not sufficient prior to the project, substantial increases in fish numbers may not be detectable following project implementation.
- Funding for maintenance of Riparian Planting and Livestock Exclusion Projects should be included in the project plan to ensure control of invasive species and success of plantings.
- Hydraulic analysis for Floodplain Reconnection Projects would confirm whether flows are adequate to maintain connection and guide the design process towards success. This would allow project designers to determine if a channel reconnection or a side channel creation project is most suitable at the project location and would provide the best opportunity for increasing available habitat for salmonids over the long term.

- Channel creation projects should be paired with floodplain restoration efforts whenever possible to maximize both short- and long-term response.
- Initial assessment of habitat conditions should be conducted for Habitat Protection Projects prior to purchase, using existing protocols. This assessment will help determine if existing habitat is of sufficient quality to provide benefit to salmonids.

5.2 IN-STREAM HABITAT PROJECTS

The effects of In-Stream 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.

The effectiveness of this project category may also be tied to fish density at the project site. If the density of fish populations is low, detecting change in these very low densities could be difficult, independent of the effects of the project. Additionally, velocity could be used as a surrogate for the effectiveness of some projects for certain species, specifically coho and Chinook juveniles. 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.

Sampling during summer low flows may preclude observations of juvenile Chinook. To adequately detect increases in coho and Chinook density due to In-Stream 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, and target fish species. Although this 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 and Chinook density due to In-Stream Habitat Projects

5.3 RIPARIAN PLANTING AND LIVESTOCK EXCLUSION PROJECTS

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

The Livestock Exclusion Projects showed short-term (1 to 2 year) significant reductions in bank erosion due to the installation of fencing along streams in areas grazed by livestock. Results were stronger in areas that were planted as well as having fencing installed. It was also noted that at sites where plantings were installed, invasive species need to be controlled as part of the effort or the success of the plantings is at risk.

For both Livestock Exclusion and 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. Especially for Riparian Planting Projects, 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.

5.4 FLOODPLAIN RECONNECTION PROJECTS (CHANNEL CONNECTIVITY AND CONSTRAINED CHANNEL)

From the data collected over the last 5 years at Channel Connectivity Project sites, it appears that those projects designed to only be connected to the main flow at high water have a lower chance of remaining connected and supporting fish habitat over the long term. Those channels that have a larger range of flows during which they are connected, or which are always connected, are more likely to maintain that connection and not fill in with fine sediments. Results show that channel designs must ensure that adequate velocity is maintained in the off-channel area or the risk of deposition and disconnection from the main channel due to aggradation is increased. Off-channel habitat in river systems is dynamic by nature, and those designs that allow for dynamic processes in the creation (and re-creation) of off-channel habitat are more likely to be successful in the long term.

Constrained Channel Projects have shown a high probability of long-term success and detection of effect if they are linked together. In unconfined river systems, natural channel dynamics often cause off-channel habitat to develop (and be abandoned) through time. Small, isolated projects are unlikely to encourage natural channel development processes in a river system, so a holistic watershed approach should be taken when identifying and selecting these projects for funding.

In general, Channel Connectivity Projects can be closely linked with Constrained Channel Projects. A more successful monitoring model would be to implement a floodplain reconnection project over a large area and then enhance or augment natural off-channel habitat development processes in areas where these habitats are likely to be maintained. Creation of habitat can help to jump-start the development of off-channel rearing habitat, a component that is a limiting factor in many systems in Washington State. Over the long term, however, these channels are likely to be abandoned as the river develops and shifts course within the valley. In areas where off-channel habitat is lacking as compared to historical conditions, the valley is generally wide enough and unconfined enough to support such habitat. As a result, the course of a natural river system within an unconfined broad valley is likely to change and adjust through time, which helps to create new habitat. It is only when these rivers are restricted through the confinement of levees and revetments that the off-channel habitat that was originally part of the system is lost. Creation of this type of habitat may help in the short term but, to be maintained, the natural river processes must be allowed to work to transform and adjust the hydraulic interaction with the floodplain as needed.

Acquisition of areas along river systems where natural channel formation can occur is critical to the success of these restoration efforts. Acquisition of areas and removal of channel constraints, combined with active efforts to create off-channel habitat to jump-start the process in key areas would result in longer-term sustainable floodplain restoration and habitat improvement. At the watershed scale, for this approach to be successful, it would need to be applied along the majority of the unconstrained floodplain within a system.

In 2009, it was recommended that Channel Connectivity Projects be combined with Constrained Channel Projects to develop an approach for monitoring the development and maintenance of floodplain habitat. Since then, monitoring at these sites has included the use of aerial photos and field mapping to measure and identify the new habitat areas created by the projects. This allows documentation of the extent that the habitat remains connected and/or continues to develop during each year of monitoring. Recommendations for improvements to monitoring for Floodplain Reconnection Projects, including the use of remote sensing, can be found in Hawkins and O'Neal (2010). These recommendations include establishing topographic layers for the floodplains as well as channel form or bathymetry layers for each project. These data layers could be used to track landscape changes through time. They could also serve as input to hydraulic models, which could be used to predict the amount of habitat available for given flood flows. The estimate of the amount of available habitat could be combined with estimates of fish species density from monitoring other areas with existing floodplain habitat or the literature to evaluate the potential use by fish in the project area. Additional fish metrics may be needed to correctly evaluate this type of project, such as an estimate of juvenile fish survival during extreme events. These data could be summarized in a habitat quality index, which could be used as a comparative metric for any floodplain enhancement project, and would allow for both effectiveness evaluation and for comparison of projects across the region.

5.5 CONCLUSIONS

Both the Reach-Scale Effectiveness Monitoring Program and the Coordinated Monitoring Program provide numerous benefits that support project sponsors. Data collected as part of the programs allow project results to be compared because a consistent set of protocols are used for all projects monitored. Communication about the results from the programs helps to spread information about approaches to restoration that are being used across the region. Dissemination of this information helps project sponsors learn what approaches 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 web-based reporting tools, project sponsors and other planning entities can learn from what has already been done across the region and adapt their efforts toward success.

In 2010, several modifications to the monitoring protocols were made to address multiple needs across the region. Coordination with the U.S. Forest Service and Bonneville Power Administration, as well as input from the Governor's Forum on Monitoring, led to changes that were incorporated into the protocols, including the addition of various metrics to the protocols for In-stream Habitat Projects, Riparian Planting Projects, Livestock Exclusion Projects, Floodplain Reconnection Projects, and Habitat Protection Projects. In an effort to improve data sharing capabilities across the region, additional minor changes were made to the protocols that will allow closer coordination with large-scale programs such as the Integrated Status and Effectiveness Monitoring Program (ISEMP), the Aquatic and Riparian Effectiveness Monitoring Plan (AREMP), the PACFISH/INFISH Biological Opinion Effectiveness Monitoring Program (PIBO), and Columbia Habitat Monitoring Program (CHaMP).

Results to date from the SRFB Reach-Scale Effectiveness Monitoring Program indicate that In-Stream Habitat and Livestock Exclusion Projects are showing significant changes in some variables within the first 1 to 5 years following implementation. The remaining variables will likely require additional time and more projects to identify significant change. As more years of data are collected, it will be possible to determine the presence of trends through time for variables in each monitoring category. Riparian Planting and Channel Connectivity Projects are not showing significant changes in any of the variable tested; however, they are showing average increases in several indicators. Additional monitoring is expected to reveal significant improvements in these categories.

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