SALMON
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Washington State Salmon Recovery Funding Board

# Reach-Scale Effectiveness Monitoring Program

# 2009 Annual Progress Report

April 2010

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# ABSTRACT

Stream restoration activities are being conducted around the world in an effort to restore aquatic habitat function. With more than a billion dollars being spent nationwide on stream restoration each year (Lave 2009), 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 and began a Coordinated Monitoring Program with the Oregon Watershed Enhancement Board (OWEB) in 2006. 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. 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. Monitoring for the Reach-Scale Effectiveness Monitoring Program began in spring 2004 and has continued through 2009. This report, in conjunction with a web-based reporting tool, describes monitoring activities and results for this 6-year monitoring effort. Monitoring for the Coordinated Monitoring Program began in 2006 and continued in 2009, and is also supported by a summary report and a web-based reporting tool.

Monitoring categories included the following: fish passage, in-stream habitat, riparian planting, livestock exclusion, constrained channel, channel connectivity, spawning gravel, diversion screening, and habitat preservation. 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. Seven categories of habitat restoration projects 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.

Initial results indicate that Fish Passage Projects show statistically significant increases in juvenile coho densities upstream of passage structures after project implementation. Improvements for adult coho and redds, Chinook juveniles, and steelhead parr have not been shown to be statistically significant. In-Stream Habitat projects are significantly improving geomorphology by increasing mean vertical pool profile area in the first 3 years after construction. Average increases in volume of wood have not been significant. Livestock Exclusion Projects are effectively decreasing bank erosion in the first 3 years after construction. Significant increases in flood-prone width have been detected at all Constrained Channel Projects monitored. 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.

After 6 years of monitoring, the data that have been collected, along with observations and lessons learned along the way, have led to recommendations regarding the monitoring program. The following recommendations have been made for each project category:

- Fish Passage Projects have been found to be very effective; however, this effect is only detectable when fish population densities below the barrier are reasonably high. It is recommended that the current data be analyzed to determine if there is a detectable density threshold at which differences between control and impact reaches may begin to be detected. Additionally, monitoring of Fish Passage Projects after 2009, except for any needed verification/testing, is not recommended.
- For In-Stream Habitat Projects, structure-scale monitoring of up to 10 additional projects is recommended to detect structure-specific responses of juvenile fish. Monitored projects should also be located within Intensively Monitored Watersheds so that the effects of those projects can be captured in terms of changes at the population level as well. In order to adjust for the additional cost of this fish response monitoring, reach-scale monitoring may be discontinued.

- Riparian Planting Projects have shown that after the second year of monitoring, measuring percent cover of native or desired species is most desirable, as survival of the original plantings is less important and less detectable. This sampling should be repeated in Year 5 and Year 10 post-implementation. Additionally, measurement of canopy density and vegetation structure should be delayed for 10 years until vegetation has had a chance to establish. Qualitative assessment of invasive species should also be included as part of each monitoring event. These recommendations also apply to those Livestock Exclusion Projects that include a planting component.
- It is recommended that Channel Connectivity Projects be combined with Constrained Channel Projects to develop an approach for monitoring the development and maintenance of floodplain habitat. A more successful monitoring model than the current one 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.
- It is recommended that monitoring of Spawning Gravel Projects be suspended until more projects of this type are implemented. With so few projects currently in the monitoring pool, we are collecting case study data, but these data cannot be widely applied due to the small sample size.
- Diversion Screening Projects have been performing as designed. As such, it is recommended that monitoring for implementation of these projects be discontinued. However, long-term success of Diversion Screening Projects depends on continued maintenance, so funding for maintenance and cleaning of diversion screens should be included in the funding for the project.
- It is recommended that the field monitoring for Habitat Protection Projects be delayed for 5 to 10 years. Additionally, remote sensing (aerial photos or satellite images) should be used to assess the value of the parcel to the habitat in the watershed through time.

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# 1 INTRODUCTION

Stream restoration efforts are being conducted throughout the world to enhance or restore function to aquatic systems. In western North America alone, hundreds of millions of dollars are being spent annually on restoration projects with the goal of improving wild Pacific salmon runs (Lave 2009), many of which are listed under the Endangered Species Act (ESA) and serve a vital role in the ecology of the region. 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.

The SRFB approved funding for the Reach-Scale Effectiveness Monitoring Program in 2004. Funding for the Reach-Scale Effectiveness Monitoring Program includes funding from 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. 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.

Successful coordination between Washington and Oregon has been included as a part of this monitoring program. 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 2009 field seasons. It includes a brief description of data collection methods for each monitoring category, data analysis, and recommendations for future monitoring and reporting. In 2009, a web-based component of the report was also developed. 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 clearing house for restoration project data.

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 the Summary and Recommendations Section.

# 2 METHODS

There are currently nine monitoring categories actively being monitored in the program. Descriptions of those categories and the detailed protocols used to monitor them are available in Crawford (2008 a-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.

Of the nine monitoring categories, seven of them follow a Before After Control Impact, or BACI, design. Monitoring was also conducted for Diversion Screening Projects, which are assessed based on a function without a control. Additionally, Habitat Protection Projects do not have a control reach and the monitoring goal is to track changes in ecological health through time. BACI design projects monitored in 2009 included Fish Passage, In-stream Habitat, Riparian Planting, Livestock Exclusion, Constrained Channel, Channel Connectivity, and Spawning Gravel.

# 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 post-implementation data. Table 1 lists the implemented projects in each category 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.

Analyses performed on 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 were composed of two components: 1) decision criteria that are specific to the monitoring category and the type of project design; and 2) an evaluation of the percentage 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 |
|---|---|---|---|
| 02-1530 | Salmon River Tributary 21-0143 Culvert Barrier | Fish Passage | Years 1 and 2 |
| 02-1574 | Malaney Creek Fish Passage Project | Fish Passage | Years 1 and 2 |
| 04-1470 | Hiawatha Fish Passage | Fish Passage | Year 1 and 2 |
| 04-1485 | Fulton Dam Barrier Removal | Fish Passage | Years 1 and 2 |
| 04-1489 | Chewuch Dam Barrier Removal | Fish Passage | Years 1 and 2 |
| 04-1668 | Beeville Road MP 2.09 | Fish Passage | Years 1 and 2 |
| 04-1689 | Lucas Creek Barrier Correction | Fish Passage | Years 1 and 2 |
| 04-1695 | Dekay Road Fish Barrier | Fish Passage | Years 1 and 2 |
| 05-1498 | Curl Lake Intake Barrier Removal | Fish Passage | Years 1 and 2 |
| 02-1444 | Little Skookum Valley, Phase II: Riparian | In-Stream Habitat | Years 1 and 3 |
| 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 | Year 1 |
| 04-1448 | PUD Bar Habitat Enhancement | In-Stream Habitat | Years 1 and 3 |
| 04-1575 | Upper Washougal River LWD Placement | In-Stream Habitat | Years 1 and 3 |
| 04-1589 | Dungeness River Railroad Bridge Restoration | In-Stream Habitat | Year 1 |
| 05-1533 | Doty Edwards Cedar Creek | In-Stream Habitat | Year 1 |
| 04-1660 | Cedar Rapids Floodplain Restoration | In-Stream Habitat | Year 1 |

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

| Project Number | Project Name | Category | Years of Post-Implementation Data |
|---|---|---|---|
| 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 and 3 |
| 04-1649 | Snow Creek Lower Watershed Site 1A | Riparian Plantings | Years 1 and 3 |
| 04-1655 | Hoy Riparian Restoration | Riparian Plantings | Years 1 and 3 |
| 04-1660 | Cedar Rapids Floodplain Restoration | Riparian Plantings | Year 1 |
| 04-1676 | YTAHP Wilson Creek Riparian Restoration | Riparian Plantings | Years 1 and 3 |
| 04-1698 | Vance Creek Riparian Planting and Fencing | Riparian Plantings | Years 1 and 3 |
| 04-1711 | Lower Klickitat Riparian Restoration | Riparian Plantings | Years 1 and 3 |
| 02-1498 | Abernathy Creek Riparian Restoration | Livestock Exclusions | Years 1, 3, and 5 |
| 04-1655 | Hoy Riparian Restoration | Livestock Exclusions | Years 1 and 3 |
| 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 | Year 1 |
| 205-060 | OWEB: Bottle Creek | Livestock Exclusions | Year 1 and 3 |
| 205-060 | OWEB: North Fork Clark | Livestock Exclusions | Year 1 and 3 |
| 02-1625 | SF Skagit Levee Setback Acq & Restoration | Constrained Channel | Years 1, 3, and 5 |
| 04-1596 | Lower Tolt River Floodplain Reconnection | Constrained Channel | Year 1 |
| 05-1398 | Fenster Levee Setback | Constrained Channel | Year 1 |
| 05-1521 | Raging River Preston Reach | Constrained Channel | Years 1 and 3 |
| 06-2250 | Chinook Bend Levee Removal | Constrained Channel | Year 1 |
| 02-1561 | Edgewater Park Off-Channel Restoration | Channel Connectivity | Years 1 and 2 |
| 04-1461 | Dryden Fish Enhancement CMZ Project | 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 |
| 04-1563 | Germany Creek Conservation Restoration | Channel Connectivity | Year 1 |
| 07-1691 | Lockwood Creek Phase 3 | Channel Connectivity | Year 1 |
| 02-1540 | Touchet River Screens Phase 2 | Diversion Screening | Year 1 |
| 02-1543 | Walla Walla Urban Fish Screens & Meters | Diversion Screening | Years 1 and 2 |
| 02-1544 | Tucannon River Screens Phase 2 | Diversion Screening | Years 1 and 2 |
| 02-1656 | Dry/Cabin Creek Fish Passage & Screening | Diversion Screening | Years 1 and 2 |
| 04-1373 | Indian Creek Diversion Screening | Diversion Screening | Years 1 and 2 |
| 04-1373 | Indian Creek Diversion Screening | Diversion Screening | Years 1 and 2 |
| 04-1373 | Indian Creek Diversion Screening | Diversion Screening | Years 1 and 2 |
| 04-1568 | Garfield County Irrigation Screening Pro | Diversion Screening | Years 1 and 2 |
| 00-1669 | Entiat River Habitat Acquisition | Habitat Protection | Years 1 and 3 |
| 00-1788 | Rock Creek/Ravensdale-Retreat | Habitat Protection | Years 1 and 3 |
| 00-1841 | Metzler Park Side Channel Acquisition | Habitat Protection | Years 1 and 3 |
| 01-1353 | Logging Camp Canyon – Phase 1 | Habitat Protection | Years 1 and 3 |
| 02-1485 | Chimacum Creek Estuary Riparian Acquisition | Habitat Protection | Years 1 and 3 |
| 02-1535 | Weyco Mashel Shoreline Acquisition | Habitat Protection | Years 1 and 3 |
| 02-1592 | Curley Creek Estuary Acquisition | Habitat Protection | Years 1 and 3 |
| 02-1622 | Issaquah Cr Log Cabin Reach Acquisition | Habitat Protection | Years 1 and 3 |
| 02-1650 | Methow Critical Riparian Habitat Acquisition | Habitat Protection | Years 1 and 3 |
| 04-1335 | Piner Point on Maury Island | Habitat Protection | Years 1 and 3 |

Regional trends through time, 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 2 years. Because we are using the linear regression slope, this test is most sensitive to a linear increase occurring across the sampled years. Another possible metric to use would be to compare “Year 0” to the average result after implementation. However, the regression slope should be sensitive to any type of monotonic change.

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, or two years prior to Year 1, they are labeled as Year -1. If samples were collected in multiple pre-implementation years, only the most recent year was retained in the analysis because we are not focusing on 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 non-parametric 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 empirical cumulative distribution function is plotted to show the range and variability of slopes (relative to their mean) for the category. 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 based on the magnitude of the starting mean (impact-control) differences. This power analysis was conducted in order 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, since the issue with these variables is a matter of direction rather than variability.

Seven freshwater habitat protection sites have been monitored in 2004 (Year 0) and 2007 (Year 3). Three estuary sites have also been monitored and the upland vegetation data from those sites were included in the analysis for those variables. The habitat protection sites are being monitored for change for 15 variables. For each variable, the null hypothesis is that there is no change or an improvement, and the alternative hypothesis is that there has been an ecological decline. A one-tailed paired t-test with alpha = 0.05 is used to test the hypothesis. If there is evidence of non-normality (Shapiro-Wilks test with alpha = 0.05), a nonparametric Wilcoxon test is used.

**Table 2.** Indicators Tested for Each Monitoring Category

| **Monitoring Category** | **Indicators Tested** |
|---|---|
| Fish Passage Projects | • Juvenile fish density by species<br>• Number of spawners per kilometer or redds per kilometer by species |
| In-stream Habitat Projects | • Mean thalweg residual pool vertical profile area<br>• Mean residual depth<br>• Juvenile fish density by species<br>• $\text{Log}_{10}$ volume of large woody debris (LWD) |
| Riparian Planting Projects | • Linear proportion of actively eroding banks<br>• Mean canopy density along the banks<br>• Proportion of the reach with three-layer riparian vegetation |
| Livestock Exclusion Projects | • Linear proportion of actively eroding banks<br>• Mean canopy density along the banks<br>• Proportion of the reach with three-layer riparian vegetation |
| Channel Connectivity Projects | • Juvenile fish density by species<br>• Mean thalweg residual pool vertical profile area<br>• Mean residual depth<br>• Mean canopy density along the banks<br>• Proportion of the reach with three-layer riparian vegetation |

**Table 2.** Indicators Tested for Each Monitoring Category (continued)

| Monitoring Category | Indicators Tested |
|---|---|
| Habitat Protection | • Mean thalweg residual pool vertical profile area<br>• Mean residual depth<br>• $\text{Log}_{10}$ volume of LWD<br>• Proportion of the reach with three-layer riparian vegetation<br>• Mean canopy density along the banks<br>• Linear proportion of actively eroding banks<br>• Percent fines<br>• Percent embeddedness<br>• Conifer basal area and stem count<br>• Deciduous basal area and stem count |
| Estuarine Indicators | • Non-native herbaceous plants<br>• Non-native shrubs<br>• Fish Assemblage Index<br>• Macroinvertebrate Metric Index<br>• Percent slope from mean high tide to mean low tide or low water<br>• Percent of the length of the intertidal transect with fines<br>• Linear extent of fine sediment along the intertidal transect<br>• Percent of the length of intertidal transect with marine algae<br>• Linear extent of algae along the intertidal transect<br>• Percent of the length of the intertidal transect with vascular plants<br>• Linear extent of vascular plants along the intertidal transect |

## 3.1 FISH PASSAGE PROJECT RESULTS

Based on the data collected for each of the individual projects and the mean change for the Fish Passage Projects as a group, there was a significant increase in density of coho juveniles (Figure 1). Improvements for coho adults and redds, Chinook juveniles, and steelhead parr were not significant. Table 3 shows the results of the statistical analysis of Fish Passage Projects.

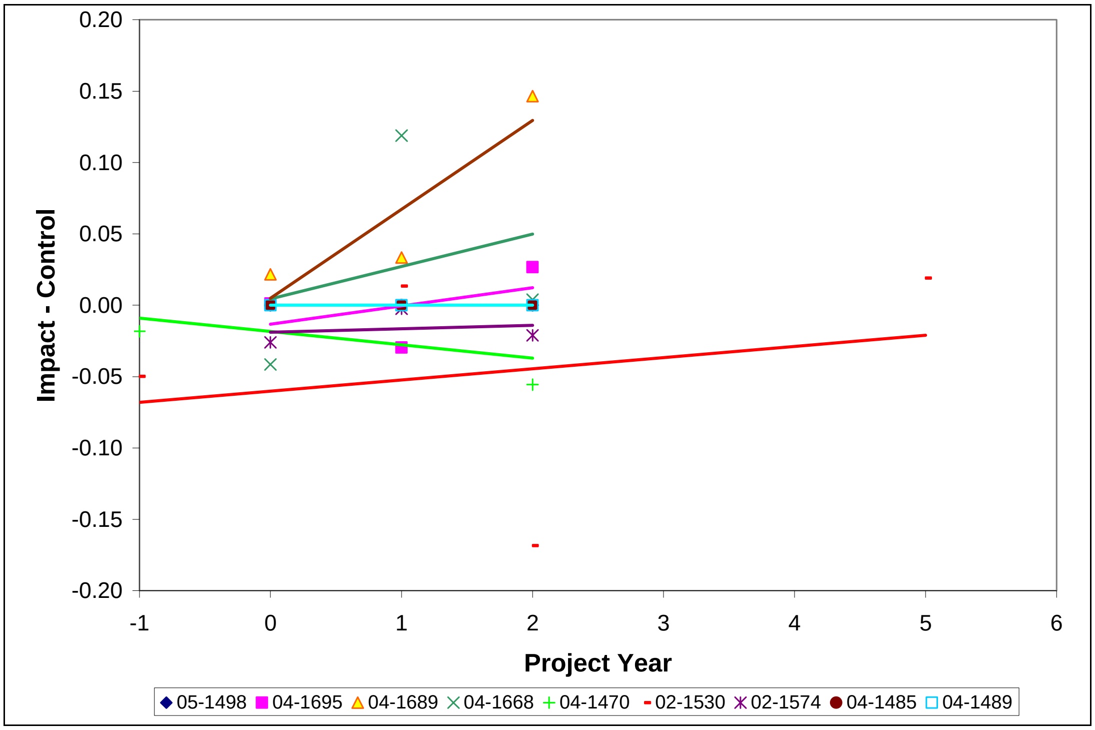

**Figure 1.** Significant Increase in Coho Juveniles Across Sites

**Table 3.** Summary of Results for Fish Passage Projects

| Indicator | Baseline Mean (Impact-Control) | Average Change as Percent of Baseline | | |
|---|---|---|---|---|
| | **Year 0** | **Year 1** | **Year 2** | **Year 5** |
| Chinook Adults (fish/km) | 48 | -37% | -74% | n/a[a] |
| Chinook Redds (redds/km) | 8.3 | -27% | -53% | n/a[a] |
| Coho Adults (fish/km) | -25 | 20% | 39% | 99% |
| Coho Redds (redds/km) | -13 | 14% | 28% | 71% |
| Chinook Juveniles (fish/m$^2$) | -0.0023 | 35% | 69% | 173% |
| Coho Juveniles (fish/m$^2$) | -0.013 | 88% | 175% | 438% |
| Steelhead Parr (fish/m$^2$) | -0.058 | 22% | 45% | 112% |

[a] Chinook spawners and adults have not yet been observed at any sites in Year 5.

For the adult and redd variables analyzed, analyses were hampered by the small sample size (n = 5), due to the need to segregate projects by target (and presence of) species. To provide greater strength in the analyses, a larger number of projects where each of the species is known to be present would need to be sampled. For example, in order to detect a 30 percent change in coho adult densities with 80 percent power, a sample size of approximately 13 projects would be required (Figure 2). Similar challenges were faced in analyzing juvenile densities. For steelhead parr, a sample size of approximately 11 projects would be required to detect 30 percent change with 80 percent statistical power (Figure 3).

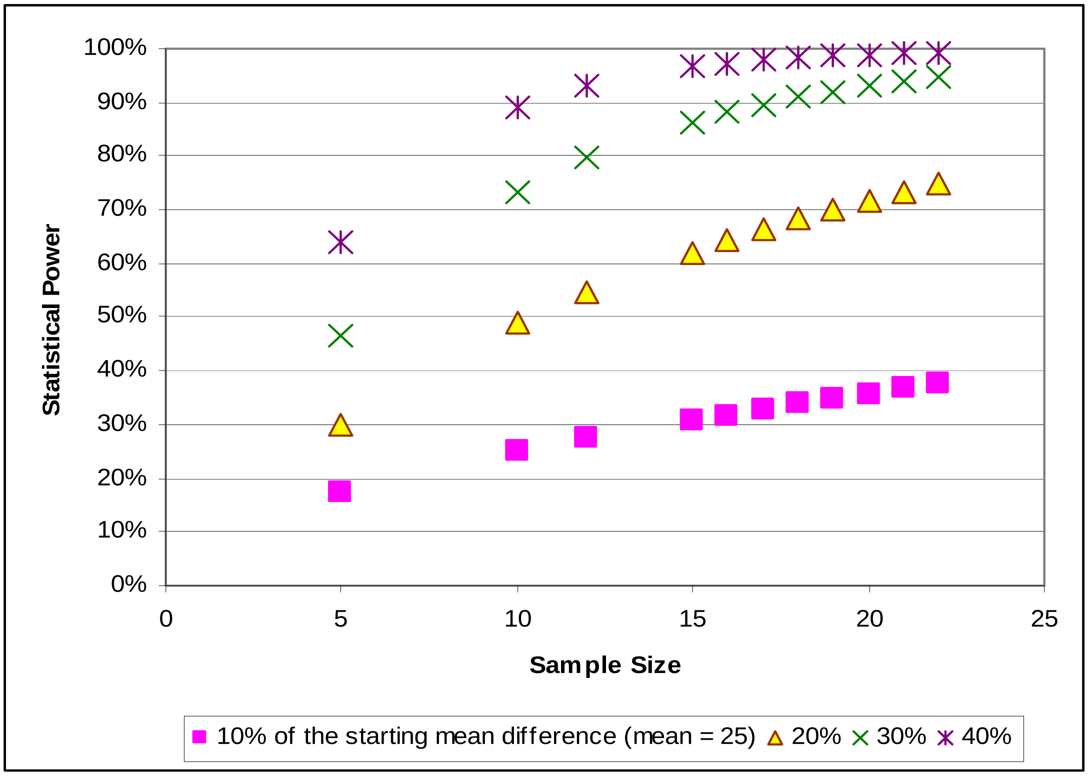

**Figure 2.** Statistical Power for Coho Adults

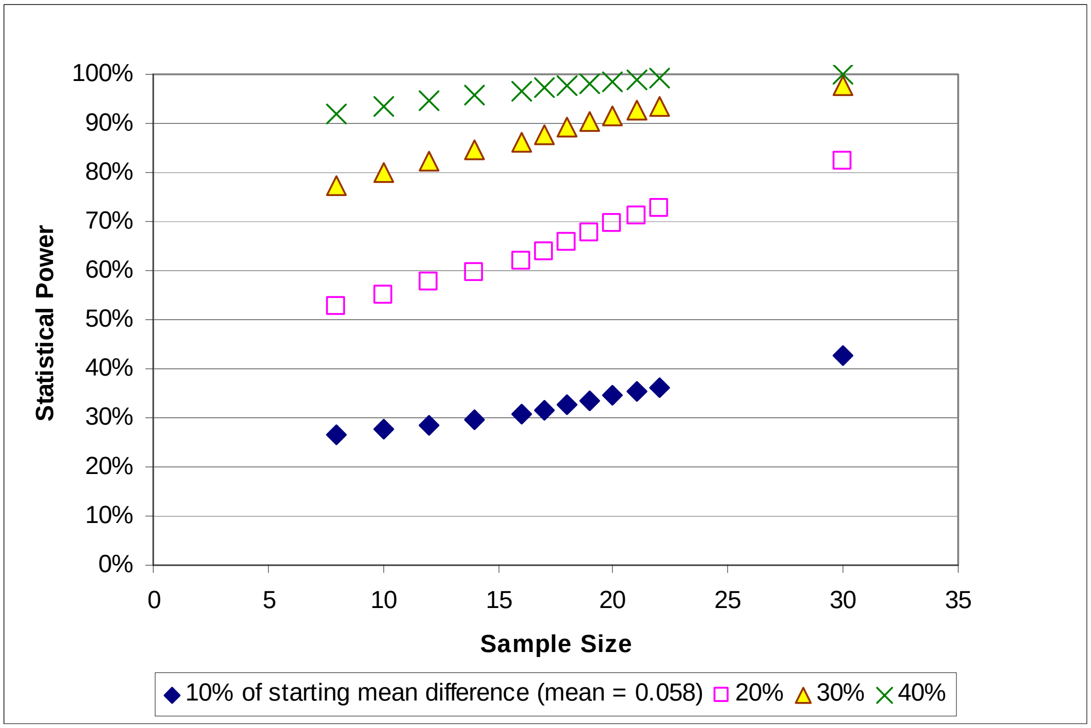

**Figure 3.** Statistical Power for Steelhead Parr

Very small numbers of fish counted for some projects, combined with zero values for other projects, resulted in non-significant findings and require large sample sizes to detect a change. When return timing for each species (e.g., 4 to 6 years for Chinook salmon) is compared with the frequency of sampling for the category (Years 0, 1, 2, and 5), the ability to detect project-caused changes in the relative abundance of adult salmon is difficult to statistically evaluate as the monitoring period is equal to or less than one generation time. However, as the question pertaining to adult salmon and spawning is one related to access to habitat upstream of the barrier, and not an increase in abundance, future evaluations may be more appropriately focused on whether there were any adult fish upstream of the barrier rather than statistical evaluation (i.e., did any adult fish go upstream of the barrier and spawn in all years after project implementation?), and if the decision criteria related to passage design continued to be met in future years (i.e., are the fish passage design criteria being met?). Using this approach, eight out nine projects (88 percent) show that spawners and redds were detected upstream of the barrier, which meets the success criteria of 80 percent of projects as established in the protocols.

Although the sample sizes for juvenile fish are greater than the sample sizes for the adults and redds, these are smaller than the sample size that would increase the ability to detect the current mean difference with 80 percent power. The large range in the sample size for juvenile fish is due to the presence of zero results in some data sets; projects where specific juvenile species have never been observed result in zero values included in the analysis (i.e., the species may not utilize this area of the drainage); and/or the timing of habitat utilization for each species versus surveying timing (i.e., when juvenile salmonids are actually in a drainage versus survey timing in Year 0, 1, 2, and 5). As an example, for west side projects, densities of Chinook salmon juveniles have been an order of magnitude lower than those detected for coho and steelhead. Fish surveys are conducted at low water during the summer to allow for the greatest water clarity and for surveyor safety; however, Chinook are more likely to be using rearing habitat on the west side during the spring, and may not be present during the survey.

As with adult fish, because the monitoring question for Fish Passage Projects is focused on fish accessing the available habitat upstream of the barrier, future evaluations may more appropriately assess the presence of juvenile fish upstream of the barrier and if the decision criteria related to passage design continue to be met in future years. Using this approach, for juvenile fish, eight of nine projects showed that juvenile fish were detected upstream of the barrier, indicating that 88 percent of the projects were effective at allowing juvenile fish passage by Year 3. This approach could be paired with information on the length and quality of habitat upstream of the barrier to determine the habitat value of increasing passage. Using engineering criteria developed to assess whether or not a culvert provides fish passage, 100 percent of the projects evaluated in this category were considered to be fish passable, thus exceeding the 80 percent criteria.

Analyses also suggest that detecting an increase in juvenile fish density above a barrier (impact reach) is dependent on having sufficient juvenile density downstream of the barrier prior (control reach) to project implementation. Without sufficient initial density, the probability that juveniles will move above the barrier and be detected by monitoring is very low. There is likely a threshold where biological response to projects such as these is detectable; however, the limited sample size in our analysis did not allow for detection of that threshold.

## 3.2 IN-STREAM HABITAT PROJECT RESULTS

In-Stream Habitat Projects monitored in this program are currently shown to be significantly increasing the mean vertical pool profile area. Average increase in volume of wood was not found to be significant. Table 4 shows the results of the statistical analysis of In-Stream Habitat Projects.

**Table 4.** Summary of Results for In-Stream Habitat Projects

| Indicator | Baseline Mean (Impact-Control) | Average Change as Percent of Baseline | | |
|---|---|---|---|---|
| | Year 0 | Year 1 | Year 3 | Year 5 |
| Mean Vertical Pool Profile Area ($m^2$) | 2.0 | 542% | 1627% | 2711% |
| Mean Residual Depth (cm) | 2.6 | -13% | -40% | -66% |
| Log10 Volume of Wood ($m^3$) | 0.32 | 18% | 54% | 90% |
| Chinook Juvenile (fish/$m^2$) | 0.0011 | -403% | -1209% | -2015% |
| Coho Juvenile (fish/$m^2$) | 0.063 | -33% | -100% | -167% |
| Steelhead Parr (fish/$m^2$) | 0.0049 | -123% | -370% | -616% |

It can be concluded that In-Stream Habitat Projects are effective at increasing thermal refuge in the first years after project implementation. A statistically significant increase in mean vertical pool profile area has been seen across all sites (Figure 4).

Of the In-Stream Habitat Projects assessed, all of them retained greater than 50 percent of the artificial instream structures (AIS) that were placed at the project site as of Year 3. As a result, the In-Stream Habitat Projects currently exceed the 50 percent criteria for AIS remaining in place.

Figure 5 illustrates the empirical cumulative distribution functions for the regression slopes for In-Stream Habitat Projects. This figure allows all indicators for a category to be viewed simultaneously and shows the cumulative distribution of the ratio of the slope to the mean for a given parameter across all projects. Looking at the x-axis, if most of the line is positive (to the right of the zero value), then most of the slopes for the projects are positive. (See Figure 4 for an example of the slopes for each project.) The closer the line is to vertical, the less variability observed in that indicator. Conversely, the more horizontal distance covered by a line, the higher the observed variability. Using mean vertical pool profile area (AREASUM) as an example, the black line in the figure is predominately on the positive side of the graph and shows relatively low variability; hence, it is the significant result showing an increase in this indicator.

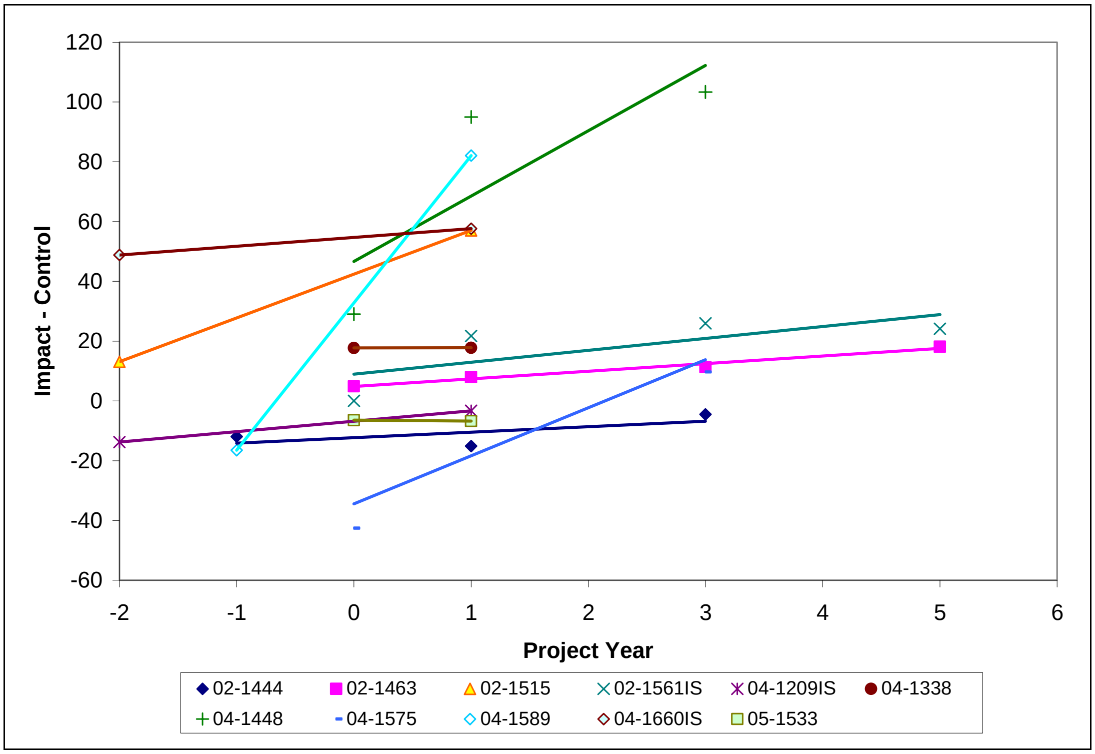

**Figure 4.** Significant Increase in Mean Vertical Pool Profile Area Across Sites

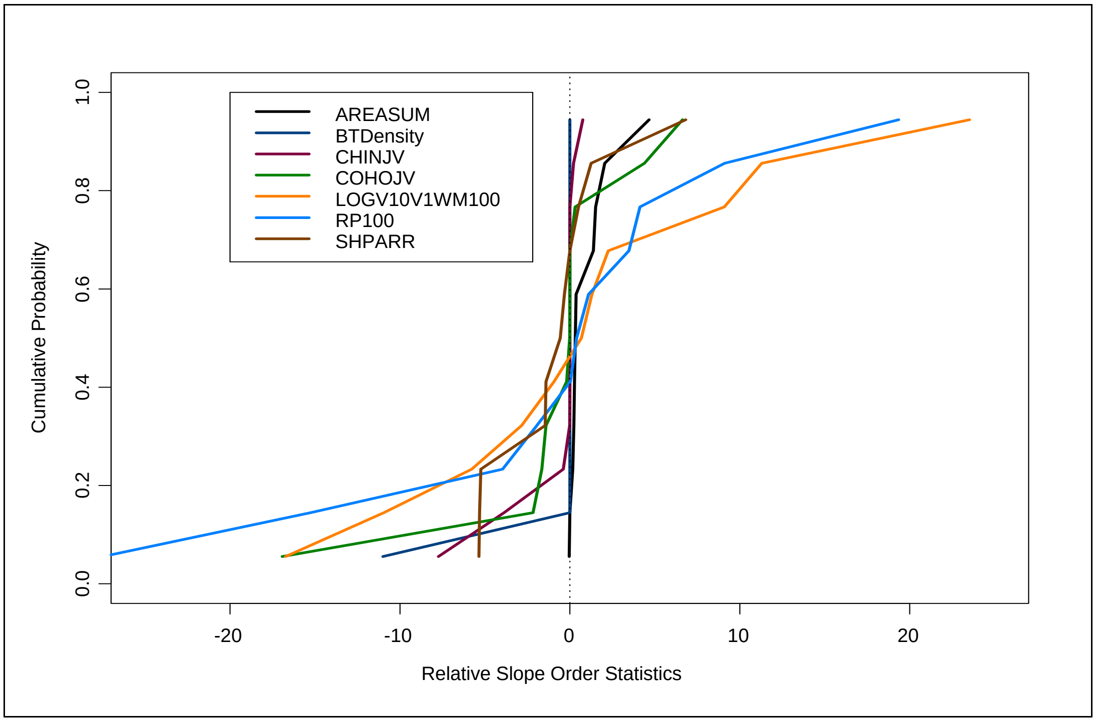

**Figure 5.** Empirical Cumulative Distribution Functions for the Regression Slopes for In-Stream Habitat Projects

## 3.3 RIPARIAN PLANTING PROJECT RESULTS

None of the Riparian Planting variables showed significant results and average improvement for the linear proportion of actively eroding banks was 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 will likely have a greater effect on the riparian cover and streambank conditions. As the plantings become established and mature to mid- to upper-canopy levels, it is expected that riparian vegetation structure and canopy cover along the bank will increase. As the riparian vegetation becomes well established, the linear proportion of actively eroding banks will likely decrease. Table 5 shows the results of the statistical analysis of Riparian Planting Projects.

**Table 5.** Summary of Results for Riparian Planting Projects

| Indicator | Baseline Mean (Impact-Control) | Average Change as Percent of Baseline | | |
|---|---|---|---|---|
| | Year 0 | Year 1 | Year 3 | Year 5 |
| Linear Proportion of Actively Eroding Banks (%) | 9.6 | -10% | -30% | -50% |
| Riparian Vegetation Structure (%) | -34 | -5% | -14% | -24% |
| Mean Canopy Density (1-17) | -2.7 | -1% | -2% | -3% |

Regarding survival of riparian plantings (see Crawford 2008c for decision criteria), in Year 1, 100 percent of the project sites sampled exceeded the 50 percent survival criteria. 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 were presumably due to herbicide drift from an adjacent property that caused high mortality in the riparian plantings at this site.

## 3.4 LIVESTOCK EXCLUSION PROJECT RESULTS

Livestock Exclusion Projects included in this program were effective at significantly reducing bank erosion across all sites (Figure 6). This reduction was more than 20 percent of the baseline. Average improvements in riparian vegetation structure and mean canopy density were not statistically significant. Table 6 shows the results of the statistical analysis of Livestock Exclusion Projects.

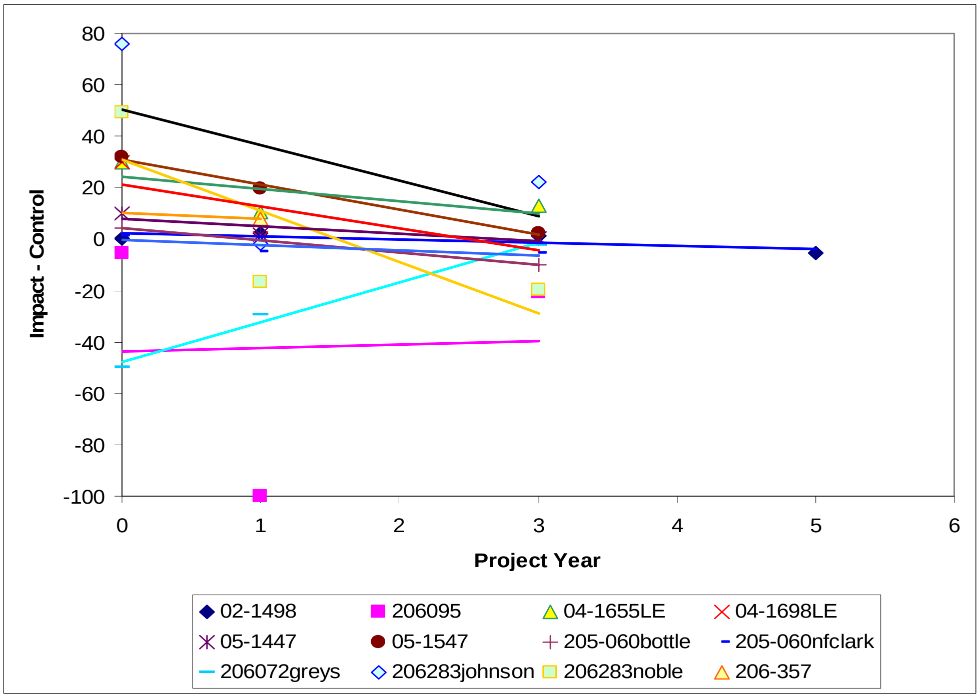

**Figure 6.** Mean Significant Decrease in Bank Erosion Across Sites

**Table 6.** 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 |
|---|---|---|---|---|
| Linear Proportion of Actively Eroding Banks (%) | 16 | -28% | -83% | -138% |
| Riparian Vegetation Structure (%) | -20 | 9% | 26% | 43% |
| Mean Canopy Density (1-17) | -2.7 | 13% | 39% | 65% |

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. Therefore, the Livestock Exclusion Projects, as a category, exceed the 80 percent success criteria for Year 1 and Year 3.

## 3.5 CONSTRAINED CHANNEL PROJECT RESULTS

Constrained Channel Projects monitored as a part of this program were effective at significantly increasing flood-prone width across all sites (Figure 7). Average improvements in bankfull width and mean residual depth are not statistically significant. Table 7 shows the results from indicators where significant differences were detected.

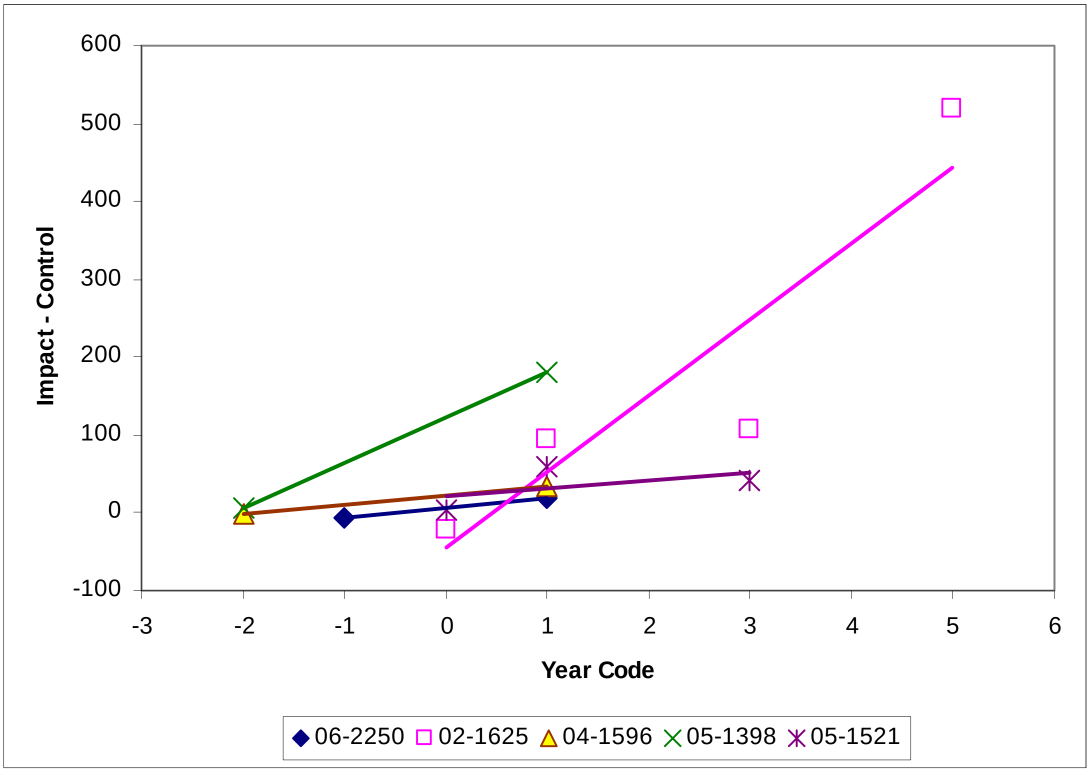

**Figure 7.** Increasing Trend in Flood-Prone Width Was Detected Across All Sites

**Table 7.** Summary of Results for Constrained Channel Projects

| **Indicator** | **Baseline Mean (Impact-Control)** | **Average Change as Percent of Baseline** | | |
|---|---|---|---|---|
| | **Year 0** | **Year 1** | **Year 3** | **Year 5** |
| Bankfull height | 0.061 | 212% | 635% | 1,059% |
| Bankfull width | -2.9 | 41% | 123% | 204% |
| Mean Vertical Pool Profile Area ($m^2$) | 53 | -40% | -119% | -198% |
| Mean Residual Depth (cm) | 11 | 49% | 146% | 244% |
| Channel Capacity | 8.4 | -7% | -21% | -34% |
| Floodprone width | -4.5 | 845% | 2,536% | 4,226% |

## 3.6 CHANNEL CONNECTIVITY PROJECT RESULTS

Table 8 shows the results from indicators for channel connectivity projects. There were no significant improvements shown for this category. Average improvements for coho juveniles were seen, but are not significant. All other variables displayed average declines (Figure 9).

**Table 8.** Summary of Results for Channel Connectivity Projects

| Indicator | Baseline Mean (Impact – Control) | Average Change as Percent of Baseline | | |
|---|---|---|---|---|
| | Year 0 | Year 1 | Year 2 | Year 5 |
| Mean Vertical Pool Profile Area (m$^2$) | -35 | -40% | -79% | -199% |
| Mean Residual Depth (cm) | 2.4 | -136% | -272% | -681% |
| Riparian Vegetation Structure (%) | 4.6 | -64% | -127% | -319% |
| Mean Canopy Density (1-17) | 0.16 | -244% | -489% | -1222% |
| Chinook Juvenile (fish/m$^2$) | 0.056 | -47% | -93% | -233% |
| Coho Juvenile (fish/m$^2$) | -0.024 | 136% | 271% | 679% |
| Steelhead Parr (fish/m$^2$) | -0.010 | -71% | -142% | -354% |

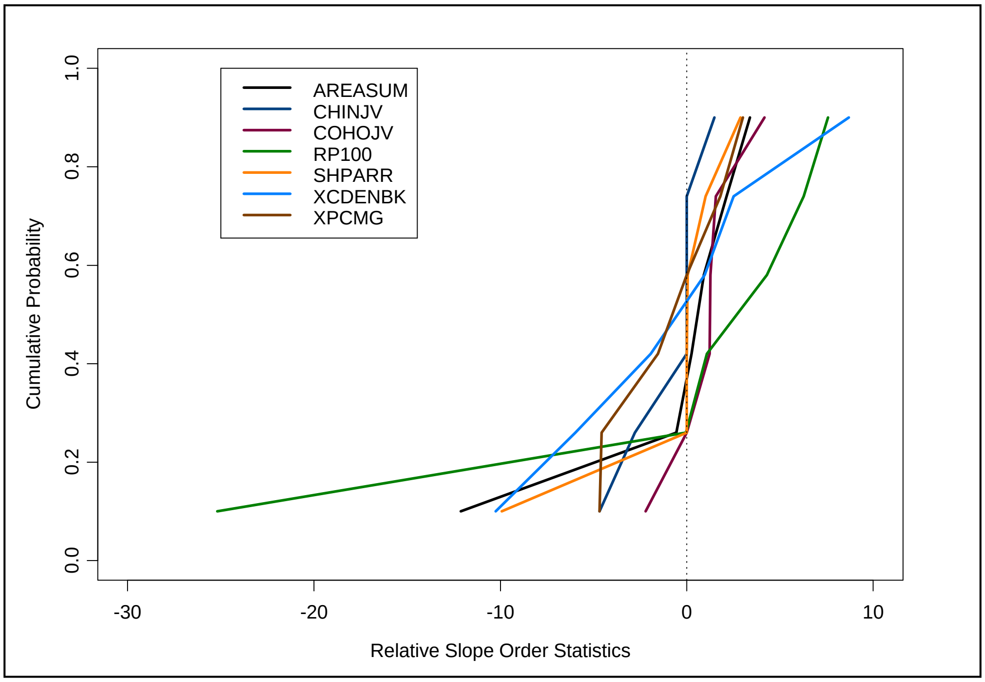

**Figure 8.** Empirical Cumulative Distribution Functions for the Regression Slopes for Channel Connectivity Projects

As shown in Figure 8, there is a large amount of variability in the indicators measured for Channel Connectivity Projects, and many of the indicators show initial decreasing trends (more negative slopes). Coho juvenile density (COHOJV), represented by the purple bold line in this figure, shows the most consistently positive slopes and the least variability of all of the indicators. Additional projects and years of data will be needed to clarify the trends for this category.

## 3.7 DIVERSION SCREENING PROJECT RESULTS

The analysis for this category did not involve statistics and was based on a series of indicators that were measured and compared to standard National Oceanic and Atmospheric Administration

(NOAA) Fisheries guidance. The decision criteria were based on the proportion of the indicators measured that were in compliance with the guidance. Using data from both monitoring years to date, Table 8 identifies the results for the diversion screening monitoring. In both years, the Diversion Screening Projects were in compliance with more than 80 percent of the parameters measured and were determined to be effective (Table 9).

**Table 9.** Summary of Results for Diversion Screening Projects

| Indicators | Year 1 | Year 2 |
|---|---|---|
| Total Number of Indicators in Compliance with NOAA Guidance | 80 | 70 |
| Total Number of Parameters Tested | 89 | 79 |
| **Percent Effective** | **89.89%** | **88.61%** |

## 3.8 HABITAT PROTECTION PROJECT RESULTS

Ten Habitat Protection Projects were included in the analyses for the indicators identified in Table 2. However, for all indicators, other than the upland vegetation indicators, only seven projects were included in the analyses because three of the Habitat Protection Projects are estuarine habitat and, therefore, have a different set of indicators than freshwater projects to establish effectiveness.

Only one upland vegetation indicator, stem count of coniferous trees per acre, showed significant change between the baseline year and Year 3 (Table 10). This indicator was used to assess the health of upland vegetation and was accompanied by increasing trends in coniferous basal area. These indicators were sampled at both estuarine and freshwater sites. Increasing basal area is a positive outcome in terms of maturation of vegetation at the site and the reduced stem count is tied to basal area in that, as the size of the trees increases, the stem count decreases as smaller trees are shaded out. Therefore, the decrease in the stem count of coniferous trees shows maturation of the upland vegetation and improving conditions at the sites. This result was detected in the third year of what is proposed to be a 12-year monitoring program, so these are very early trends. Trends for 6 of 15 indicators point toward improving condition in the habitat, although only one indicator shows significant change (Figure 9). Eight variables showed non-significant declines.

Macroinvertebrate communities were evaluated for the freshwater habitat protection sites using the Multi-Metric Index (MMI) (Wiseman 2003). The MMI provides indices that are specific to eco-regions present in Washington and scoring criteria for each. Figure 10 shows the results from the MMI and Table 11 provides the MMI grading system. Six of the seven sites sampled rated in the “Good” category (Table 11), while one of the sites did not have water in Year 1 and scored in the “Fair” category in Year 3.

**Table 10.** Summary of Results for Habitat Protection Projects

| | Baseline Mean (Impact-Control) | Average Change as Percent of Baseline |
|---|---|---|
| **Indicator** | **Year 1** | **Year 3** |
| Mean Residual Depth (cm) | 16 | 2.1% |
| Log10 Volume of Wood ($m^3$) | 0.68 | -12% |
| Basal area of conifers per acre (square feet/acre) | 98 | 22% |
| Basal area of deciduous trees per acre (square feet/acre) | 114 | -3.6% |
| Stem count of coniferous trees per acre (number/acre) | 140 | -25% |
| Stem count of deciduous trees per acre (number/acre) | 189 | 48% |
| Percent fines (%) | 11 | 38% |
| Percent embeddedness (%) | 44 | 19% |
| Mean Canopy Density (1-17) | 14 | -0.58% |
| Riparian Vegetation Structure (%) | 88 | 3.7% |
| Absolute percent cover of non-native herbaceous plants (%) | 13 | 1200% |
| Absolute percent cover of non-native shrubs (%) | 9.6 | -75% |

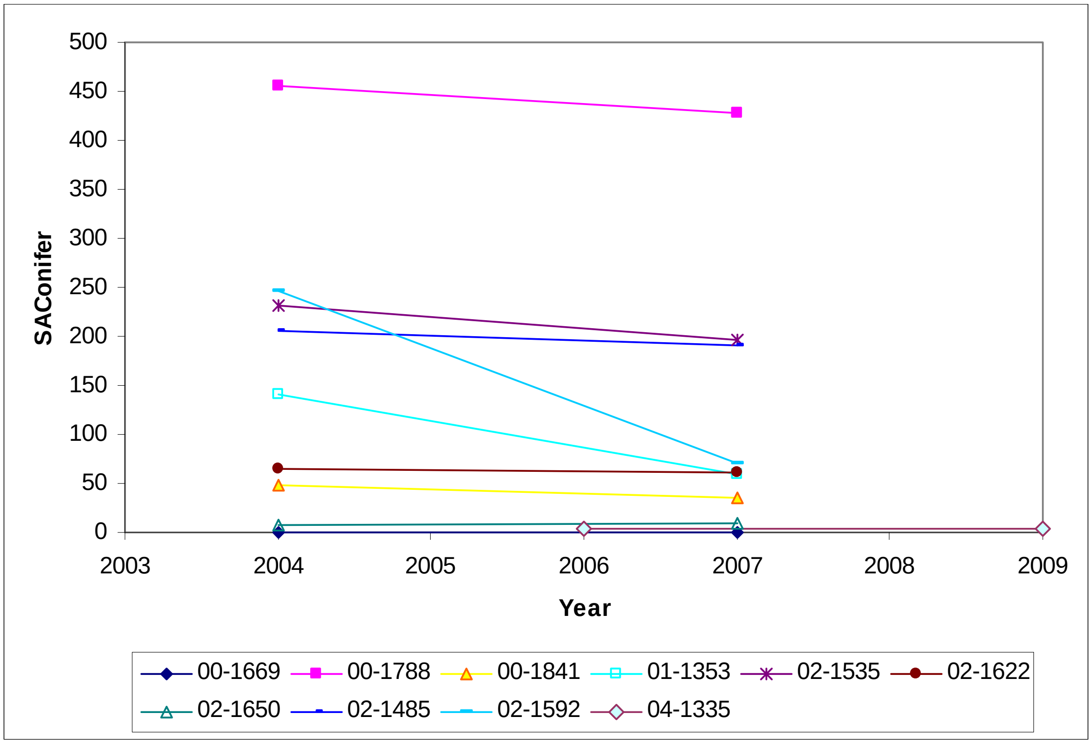

**Figure 9.** Change in Stem Count of Conifers per acre (number/acre) from Year 1 to Year 3 at Seven Acquisition Sites

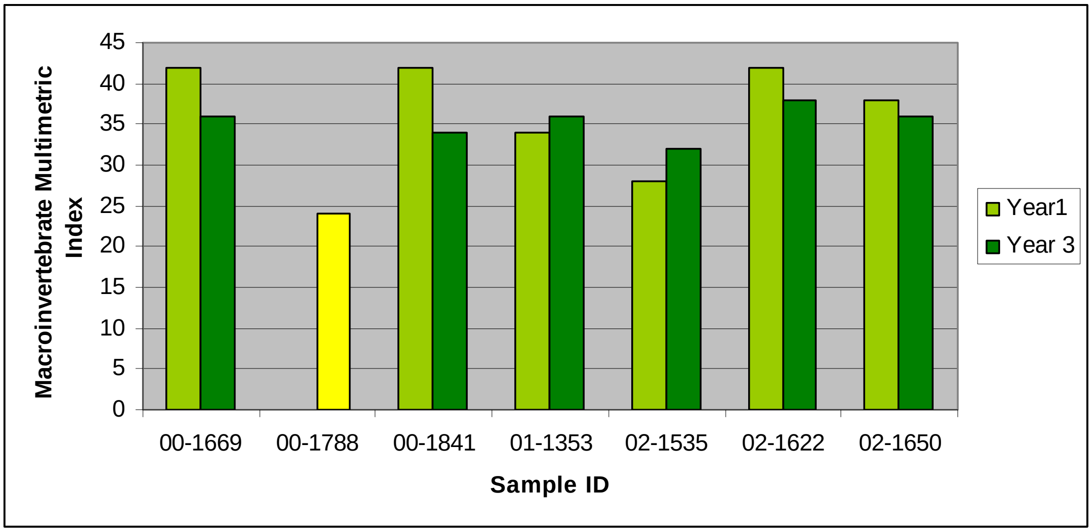

**Figure 10**. Macroinvertebrate Multimetric Index Results.

Note: Green is within the "Good" range. Yellow bars indicate the "Fair" range. See Table 11 for further detail.

**Table 11.** Macroinvertebrate Multimetric Index Grading System

| Narrative Assessment | Puget Lowlands | Cascades | Columbia Plateau |
|---|---|---|---|
| Good | >30 | >28 | ≥ 34 |
| Fair | 20-30 | 23-28 | 23-33 |
| Poor | <20 | <23 | <22 |

Source: Wiseman 2003

Fish assemblage diversity was also assessed using the Mebane Index (Mebane et al. 2003). Figure 11 shows the results from the Fish Species Assemblage Index and Table 12 provides the fish species assemblage grading system that was used. These data show that, for all sites with enough fish to achieve a score, all sites were in the "Good" range in both Year 1 and in Year 3, indicating that these sites support high-quality habitat and that quality is being maintained through time. Site 00-1788 did not have enough fish to calculate an index value.

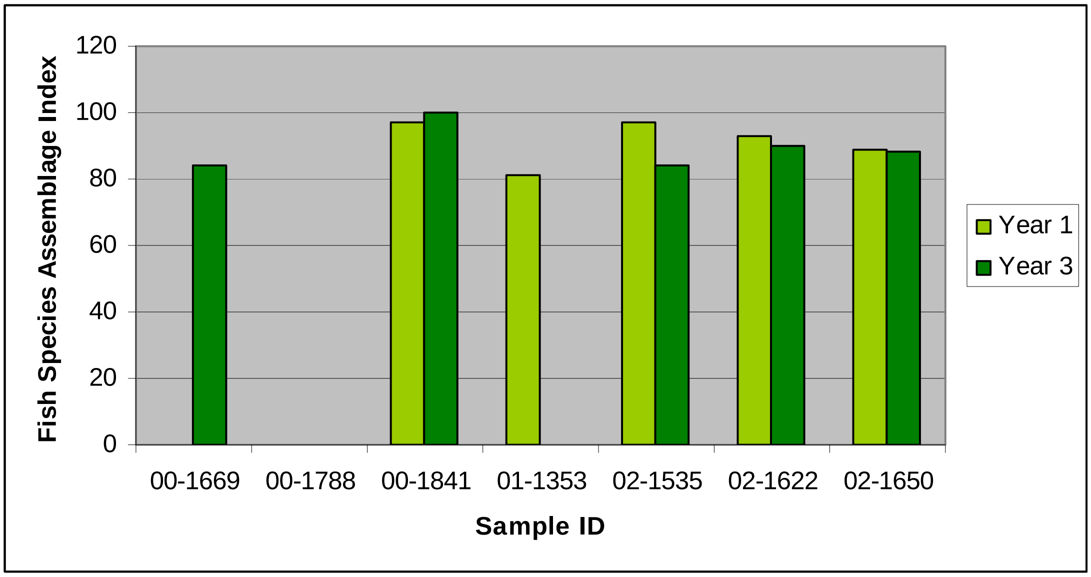

**Figure 11.** Fish Species Assemblage Index Results.

Note: Green is within the "Good" range. See Table 12 for more detail.

**Table 12.** Fish Species Assemblage Grading System

| Score | Rating | Description |
|---|---|---|
| 75-100 | Good | Possessing or approaching biological integrity. Minimal disturbance. Hosts a diverse and abundant assemblage of species. |
| 50-74 | Fair | Somewhat lower quality waters where socially desirable alien species are present, reflecting relatively high-quality physical and chemical habitats. Native and cool water species area dominant, but generally tolerant species occur more frequently. |
| <50 | Poor | Poor-quality habitat. Cold water and sensitive species are rare or absent and generally tolerant species predominate. |

Source: Mebane et al. 2003

# 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 are then evaluated at three levels; however, not all three levels apply to all project categories. Level 1 analysis evaluates the functional criteria of the project as compared to the engineered design. Level 2 analysis considers the effectiveness of the project in respect to habitat indicators. Fish response is captured in the Level 3 analyses.

The data analysis and evaluations conducted to date indicate that some monitoring categories are showing significant changes in the first 1 to 3 years after implementation. Conclusions by category include the following:

- Fish Passage Projects show significant improvement for density of coho juveniles.
- In-Stream Habitat Projects are significantly improving channel morphology by increasing mean vertical pool profile area.
- Livestock Exclusion Projects are effectively decreasing bank erosion.
- Constrained Channel Projects are significantly increasing flood-prone width.

In addition, functional evaluations show the following conclusions:

- Fish Passage structures remain functional.
- In-Stream Habitat Projects are retaining Artificial Instream Structures (AIS).
- Riparian plantings have over 50 percent plant survival.
- Livestock Exclusion Projects remain functional.
- In general, off-channel habitats are maintaining connection with mainstream habitats.
- Diversion Screening Projects have been determined to be effective for over 80 percent of parameters measured.

All of these indicators of effectiveness have been reached before the timeframes established in the objectives for each monitoring category (see protocols). Additional years of monitoring these projects will assist in confirming project effectiveness.

There are factors that may influence the analysis of certain project category data. This discussion will address, by project category, factors affecting the analyses and recommendations to address those factors.

## 4.1 IN-STREAM HABITAT PROJECTS

Juvenile fish sampling for In-Stream Habitat Projects occurs once during the summer in Years 0, 1, 3, 5, and 10. This frequency of sampling affects the observed juvenile densities. Use by Chinook juveniles may often occur in the spring, rather than the summer, which could impact the results of sampling efforts. In addition, each of the In-Stream Habitat Projects has different target species. This results in zero values for species that were not observed during the survey, which increases the variance in the data set.

Adding to these confounding factors in the analysis are the differences between the types of In-Stream Habitat Projects. Specifically, the eight projects included in the analysis for Year 0 versus Year 1 comprise projects targeted for different species, which are intended to perform different functions (e.g., aggrading the channel for sediment storage versus creating scour for localized pool formation), and constructed of varying materials (e.g., wood, boulders) using various construction approaches (e.g. pool construction by machinery, development of pool-riffle sequences). Last, and most important, each of the projects included in this category are located in different geographic, geomorphic, and hydrologic settings. Although increasing the spatial distribution of the sample size likely increases the robustness of the study design, including projects comprising such varying geographic, geologic, and hydrologic characteristics likely confounds interpretation of the results.

To adequately detect increases in fish 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 would likely be adequate [Roni and Quinn 2001]), it would assist in adequately addressing the question of increases in fish density due to In-Stream Habitat Projects. Over time, if the current sample size is maintained and not segregated, the current trend for coho, Chinook, and steelhead parr will likely either continue to decrease or be maintained over time primarily due to the confounding information obtained from surveying these In-Stream Habitat Projects.

## 4.2 FLOODPLAIN RECONNECTION PROJECTS

Floodplain Reconnection Projects consist of the Channel Connectivity and Constrained Channel Projects. Results from the statistical analyses demonstrate that Constrained Channel Projects are significantly increasing floodprone width in the first 3 years after project implementation. However, additional information needs to be collected to establish the effectiveness of this project category. In 2009, habitats created by project actions were mapped using global positioning system (GPS) and aerial photos. Recommendations for improvements to monitoring for floodplain enhancement projects can be found in Hawkins (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 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.

Table 13 summarizes the results of the 2009 analyses for each monitoring category. Included are results from Level 1, 2, and 3 analysis.

# 5 CONCLUSIONS AND RECOMMENDATIONS

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.

Results to date from the SRFB Reach-Scale Effectiveness Monitoring Program indicate that Fish Passage, In-Stream Habitat, Livestock Exclusion, and Constrained Channel 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. Functional evaluations for Fish Passage and Diversion Screening Projects show that effectiveness has been reached before the timeframes established in the objectives for each monitoring category, suggesting that additional monitoring of these categories is not necessary.

The following are summaries and recommendations specific to each monitoring category.

## 5.1 FISH PASSAGE PROJECTS

Fish Passage Projects have been found to be very effective and cost-effective approaches for increasing the density of juvenile and adult salmonids above an impassible barrier. However, this effect is only detectable when fish population densities below the barrier are reasonably high. At lower population densities, the effect of the project cannot be clearly established unless the amount of upstream habitat is greater than downstream habitat. Similarly, determining the effectiveness of barriers to fish migration that are only partial blockages and still have adults and juveniles above the barrier is difficult using the sample size and approach from this study.

**Table 13.** Summary of Analysis Results

| Project Category | Level 1<br>Functional Criteria | Level 2<br>Habitat Indicators | Level 3<br>Fish Response |
|---|---|---|---|
| Fish Passage | • 100 percent of the Fish Passage Projects monitored in Years 1 and 2 met the >80 percent design criteria and were rated as functional. | • No significant results reported | • Fish Passage Projects showed a significant improvement in density of coho juveniles.<br>• Improvements for coho adults and redds, Chinook juveniles, and steelhead parr were not significant. |
| In-Stream Habitat | • 100 percent of the In-Stream Habitat Projects monitored met the criteria of >50 percent of the AIS remaining within the impact reach by Year 3. | • In-Stream Habitat Projects as a group showed a statistically significant increase over baseline in mean vertical pool profile area for both Years 1 and 3 (and >20 percent).<br>• Average improvement in $\text{Log}_{10}$ volume of LWD was not significant. | • N/A |
| Riparian Planting | • 100 percent of the projects monitored demonstrated a percentage of plants living that exceeded the 50 percent survival criteria. | • No significant results reported | • 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. | • Livestock Exclusion Projects as a group showed a statistically significant reduction over baseline in bank erosion for Year 1 and Year 3 (and >20 percent).<br>• Average improvements in canopy density and riparian vegetation structure were not statistically significant. | • N/A |
| Constrained Channel | • Average improvements in bankfull width are not statistically significant. | • There is a significant improvement in floodprone width across all sites tested.<br>• Average improvements in mean residual depth are 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 3, which exceeds the criteria of >80 percent. | • No significant results reported | • Average improvements in coho juvenile densities are not significant. |

**Table 13.** Summary of Analysis Results (continued)

| Project Category | Level 1<br>Functional Criteria | Level 2<br>Habitat Indicators | Level 3<br>Fish Response |
|---|---|---|---|
| Diversion Screening | • >80 percent of the projects monitored were found to be intact, with >80 percent of the parameters tested in compliance with NOAA Guidance in both Years 1 and 2. | • N/A | • N/A |
| Habitat Protection | • N/A | • Habitat Protection Projects as a group showed a statistically significant decrease over baseline in coniferous stem count (>20 percent).<br>• In freshwater projects, no significant results were observed for the other variables.<br>• Estuarine indicators were not tested because there are only two projects with estuarine data. | • All projects received a “Good” rating on the MMI for macroinvertebrate assemblage in Year 3.<br>• For all sites with enough fish to measure, a Mebane Index score in the “Good” range was given in Year 3. |

It is recommended that the current data be analyzed to determine if there is a detectable density threshold at which differences between control and impact reaches may begin to be detected. Additional monitoring of Fish Passage Projects within the current sample set is not likely to yield additional information with the exception of testing to verify density-dependent effects. In order to detect a density threshold, additional samples would need to be added to the sample set. As a result, monitoring of this category after 2009, except for any needed verification/testing, is not recommended.

## 5.2 IN-STREAM HABITAT PROJECTS

The effects of In-Stream Habitat Projects are less clear than those of Fish Passage Projects. This is due to the number of objectives accomplished using this method and the types of approaches that are 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 current sample size is not adequate to detect clear changes in fish responses, although significant changes in habitat are easily detectable using this sample size.

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.

These issues related to effectiveness of In-Stream Habitat Projects, along with some of the challenges faced in monitoring them, need to be addressed. Additional structure-scale monitoring is recommended to detect structure-specific responses of juvenile fish. The current sample size should be augmented with up to ten additional projects that use the design approaches currently represented in the sample set. This would allow projects to be stratified into groups of approaches, enabling evaluation by approach type. Monitored projects should also be located within Intensively Monitored Watersheds so that the effects of those projects can be captured in terms of changes at the population level as well. In order to adjust for the additional cost of this fish response monitoring, reach-scale habitat monitoring may be discontinued.

## 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 due to bank erosion. Additionally, monitoring for survival in the first 2 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 2, measuring percent cover of native or desired species is recommended instead of survival estimates. Measurements of percent cover should be repeated in Year 5 and Year 10.

The Livestock Exclusion Projects showed short-term (1 to 2 years) 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, that invasive species need to be controlled at the project site 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 for 10 years 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 as though those projects that are 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 a system such that natural channel dynamics can occur to develop more complex off-channel habitat (and abandon it) in areas where constraints have been removed. 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 in order 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.

It is recommended that Channel Connectivity Projects be combined with Constrained Channel Projects to develop an approach for monitoring the development and maintenance of floodplain habitat. The documentation of fish use at these projects and the Constrained Channel Projects would help to determine the level of short-term enhancement that is effective in assisting natural processes in developing off-channel and floodplain habitat. Monitoring at these sites and the constrained channel sites should also include aerial photo use and field mapping to measure and identify the new habitat areas created by the projects. Each year of monitoring should include mapping of the habitat to document the extent that the habitat remains connected and/or continues to develop. Measurement of the level of connection (flow levels, number of days of connection) should be included as part of the effectiveness evaluation.

## 5.5 SPAWNING GRAVEL PROJECTS

Spawning Gravel Projects can be very successful at increasing spawning density in controlled environments where spawning habitat is limited (DFO 2010). In Washington, this technique has not been widely used in projects funded through the SRFB. One Spawning Gravel Project that was funded through the SRFB showed increases in use by steelhead 3 years after gravel placement. Assessments should be made to determine if gravel will remain hydraulically stable at high flows and to determine if there are sources of gravel within the natural sediment transport regime of the stream. If these assumptions are violated, the long-term success of Spawning Gravel Projects is doubtful.

It is recommended that monitoring for these projects be suspended until more projects of this type are implemented. With so few projects currently in the monitoring pool, we are collecting case study data, but these data cannot be widely applied due to the small sample size.

## 5.6 DIVERSION SCREENING PROJECTS

The Diversion Screening Projects that were monitored were found to be installed successfully and met the compliance guidelines set by NOAA Fisheries. However, long-term success of Diversion Screening Projects depends on continued maintenance, which should be included in the funding for the project. Another difficulty for diversion screening programs is that most of the screens are installed at the voluntary request of the landowner. For some projects, funds go unspent for lack of willing landowners. Lack of funding for maintenance, which results in clogged screens or extra effort from the landowner, may result in lower levels of voluntary participation by landowners in these programs.

It is recommended that monitoring for the implementation of these projects be discontinued as the projects are performing as designed. It is also recommended that additional project funding be provided to cover the maintenance and cleaning of diversion screens. Additional monitoring will be needed to determine if participation in these programs is matching expected response from landowners to make sure that grant funding is being used in a timely fashion to install new screens.

## 5.7 HABITAT PROTECTION PROJECTS

Determining the effectiveness of Habitat Protection Projects is difficult in the first 5 years of monitoring. More effective monitoring approaches over the long term may include aerial photo analysis and collection of land use data to determine the relative contribution of the parcel to the habitat in the watershed. Additionally, if acquisitions can be made in areas where natural channel processes are currently limited and acquiring and reconnecting the land would create off-channel or floodplain habitat or LWD recruitment, these changes could be monitored through time to document the specific effectiveness of the acquisition to improve habitat.

It is recommended that the field monitoring for these projects be delayed for 5 to 10 years and that remote sensing (aerial photos or satellite images) be used to assess the value of the parcel to the habitat in the watershed through time. For example, as impervious surface in a watershed increases, the value of protected areas – in terms of the percentage of natural habitat that they provide in the watershed – also increases. If it appears as though these habitats are playing a more pivotal role in the protection of natural, functional habitat in the watershed, they will be deemed to be effective in preventing degradation of the habitat that was protected. It is recommended that these sites be revisited every 5 to 10 years to make sure that they are still intact and functioning as natural habitat.

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