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ARTICLE

Comparing Stream Restoration Project Effectiveness Using a Programmatic Evaluation of Salmonid Habitat and Fish Response

Jennifer S. O'Neal*
Natural Systems Design, 305 Flora Street, Bellingham, Washington 98225, USA

Phil Roni
Cramer Fish Sciences, 25911 Southeast 22nd Place, Sammamish, Washington 98075, USA

Bruce Crawford
Bluefish Company, 210 11th Avenue Southwest, Number 401, Olympia, Washington 98501, USA

Anna Ritchie
Tetra Tech, 19803 North Creek Parkway, Bothell, Washington 98011, USA

Alice Shelly
R2 Resource Consultants, 15250 Northeast 95th Street, Redmond, Washington 98052, USA

Abstract

Hundreds of millions of dollars have been spent on stream restoration projects to benefit salmonids and other aquatic species across the Pacific Northwest, though only a small percentage of these projects are monitored to evaluate effectiveness and far fewer are tracked for more than 1 or 2 years. The Washington State Salmon Recovery Board and the Oregon Watershed Enhancement Board have spent more than US$500 million on salmonid habitat restoration projects since 1999. We used a multiple before-after–control-impact design to programmatically evaluate the reach-scale physical and biological effectiveness of a subset of restoration actions. A total of 65 projects in six project categories (fish passage, instream habitat, riparian planting, livestock exclusion, floodplain enhancement, and habitat protection) were monitored over an 8-year period. We conducted habitat, fish, and macroinvertebrate surveys to calculate the following indicators: longitudinal pool cross section and depth, riparian shade and cover, large woody debris volumes, fish density, macroinvertebrate indices, and upland vegetation condition class. Results indicate that four categories (instream habitat, livestock exclusions, floodplain enhancements, and riparian plantings) have shown significant improvements in physical habitat after 5 years. Abundance of juvenile Coho Salmon *Oncorhynchus kisutch* increased significantly at fish passage projects and floodplain enhancement projects, but significant results were not detected for other fish species. Moreover, the biological response indicators of juvenile salmonid abundance and macroinvertebrate indices showed declines at instream habitat and habitat protection projects, respectively. Our results indicate that a subset of projects can be effectively evaluated programmatically, but power and sample size estimates indicate that two or more years of preproject data are necessary to adequately determine the effectiveness of many project types, particularly for fish. Programmatic evaluations of project effectiveness should include adequate preproject sampling and multiseason monitoring for fish species to address issues of variability that are likely to be encountered in large-scale monitoring programs.

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*Corresponding author: jen@naturaldes.com
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Stream restoration efforts are being conducted throughout the world to enhance or restore function to aquatic systems. In the United States, approximately US$1 billion is spent on stream restoration annually (Bernhardt et al. 2005). Some of the most intensive restoration efforts are occurring in the Pacific Northwest with the goal of improving runs of wild Pacific salmon *Oncorhynchus* spp., many of which are listed under the Endangered Species Act and serve a vital role in the ecology of Pacific Northwest watersheds (Roni et al. 2010). Katz et al. (2007) estimated that more than 23,000 restoration projects were implemented in the Pacific Northwest between 1991 and 2005. With such a significant investment in restoration, there is a need to track the effectiveness of restoration projects and communicate results that can be used to improve future projects. Unfortunately, monitoring and evaluation have not kept pace with rapidly increasing restoration efforts. It is estimated that less than 7% of all restoration projects implemented receive any kind of monitoring and far fewer than that are evaluated for their physical and biological effectiveness (Katz et al. 2007). In fact, numerous authors have called for improved monitoring and evaluation of habitat restoration projects in recent decades (e.g., Reeves and Roelefs 1982; Reeves et al. 1991; Kondolf and Micheli 1995; Roni et al. 2005, 2013a).

The need for more monitoring is recognized and well documented. While there have been a number of published evaluations of restoration, there is a lack of information on monitoring large-scale, long-term project effectiveness across multiple restoration approaches using a consistent sample design and protocols (a programmatic approach). A review of published studies evaluating the physical and biological effectiveness of restoration projects found 345 published studies representing dozens of techniques; however, more than half of these studies focused on instream habitat improvement (Roni et al. 2008). Most studies focused on a specific stream, project, or site (e.g., Cederholm et al. 1997; Reeves et al. 1997; but see Pierce et al. 2013), and many restoration techniques, such as floodplain enhancement, riparian planting, and invasive species removal and even barrier removal, have not been comprehensively monitored (Roni et al. 2008). Some studies have reported on the effectiveness of particular techniques by doing retrospective analysis (e.g., Roni and Quinn 2001; Louhi et al. 2011) rather than analysis of detailed before and after monitoring data. For example, Morley et al. (2005) compared 11 constructed floodplain channels to natural floodplain channels in western Washington. They found that both types of channels supported similar densities of salmonids, but the constructed channels had lower habitat diversity, woody debris, and riparian cover than natural channels. A few meta-analysis studies have compared compendiums of past projects and results from monitoring individual habitat enhancement projects to help determine effectiveness (Avery 2004; Binns 2004; Whiteway et al. 2010), but these studies primarily focused on instream structures, and in some (e.g., Stewart et al. 2009) the results were equivocal. While several agencies fund large state or federal restoration programs, few studies have reported on a comprehensive programmatic evaluation of any large restoration program (e.g., Jones et al. 2014); specifically lacking are studies across a large area, monitoring multiple project types, and using consistent protocols. Many of these agencies have only recently implemented or are currently trying to implement comprehensive monitoring programs on restoration effectiveness so evaluation of this type of work is timely.

The Washington State legislature created the Salmon Recovery Funding Board (SRFB) in 1999 to distribute federal grants for salmonid habitat projects and salmonid recovery activities. Since then, the SRFB has spent more than $500 million on recovery efforts encompassing more than 2,000 projects throughout the state. 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 ranging from required compliance monitoring 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 at the state and federal levels, indicated that a coordinated effectiveness monitoring program was necessary to independently evaluate the success of funded restoration projects. A repeatable, standardized approach for this evaluation would provide accountability for the allocations by the state and federal legislatures to further salmonid recovery, as well as 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 to evaluate a subset of projects from each major category of projects implemented (Table 1). The goals of this monitoring are to provide the following: (1) data on the performance of project categories to help determine their relative effectiveness at addressing habitat problems, (2) feedback to project sponsors on project effectiveness to improve future project design and implementation, and (3) independent accountability for expenditures on restoration at both the state and federal levels. More specifically, the monitoring was designed to determine, for each project category, if there were reach-scale differences attributable to restoration actions in key physical and biological metrics. In this paper, we report the results of this program and provide recommendations for implementation of both restoration efforts and future programmatic monitoring programs.

TABLE 1. Restoration project categories in the Salmon Recovery Funding Board program and the years of monitoring before and after a project, the number of projects in each category that were monitored (sample size), and each specific monitoring schedule. Data have not been collected yet for the 10- and 12-year samples.

Project category	Years of monitoring (before, after)	Sample size (number of projects)	Monitoring schedule
Fish passage	1, 3	9	1 year before; 1, 2, and 5 years after
Instream habitat	1, 4	12	1 year before; 1, 3, 5, and 10 years after
Riparian planting	1, 4	9	1 year before; 1, 3, 5, and 10 years after
Livestock exclusion	1, 4	12	1 year before; 1, 3, 5, and 10 years after
Floodplain enhancement	1, 4	16	1 year before; 1, 3, 5, and 10 years after
Habitat protection	0, 4	7	1, 3, 8, and 12 years after

METHODS

Study sites.—This study occurred at 58 project sites throughout Washington, with 7 additional sites sampled in Oregon (Figure 1). The sites sampled in Washington were funded by the SRFB, and those in Oregon were funded by the Oregon Watershed Enhancement Board (OWEB). Projects in both states were proposed, designed, and implemented by a variety of restoration groups. The length of stream treated by individual projects ranged from 60 to 1,670 m, with most projects treating less than 1,000 m of stream. Project sites were monitored on a range of stream sizes, from smaller streams to larger rivers (1.5–36.0-m bank-full width). Project sites in the study were drawn at random from the total population of funded projects (see Washington State Recreation and Conservation Office 2015) within a given category. A control reach for each project was established on the same stream, in a similar channel type, to allow for paired comparisons. In total, 65 project sites were sampled across six restoration categories with 7 to 16 sites sampled in each category (Figure 1; see Table A.1 in the appendix and Washington State Salmon Recovery Funding Board [2015] for additional project information).

Field methods.—We used a before-after–control-impact design (Stewart-Oaten et al. 1986) to evaluate reach-scale physical and biological changes for each project type. A minimum of 1 year of preproject (before restoration) data was collected at all sites at both control and impact reaches, and the number of years of posttreatment observation (after restoration) was based on estimates for how much time would be needed before detectable results could be measured for a given category (Table 1). For example, fish passage projects were expected to show results soon after project implementation and so were sampled at 1, 2, and 5 years after implementation at both control and impact reaches. Large woody debris installation projects were expected to take longer to show results and so sampling was planned to occur at 1, 3, 5, and 10 years after implementation at both control and impact reaches. This study represents a summary of the data collected during the first 8 years of the monitoring program. Subsequent years of data collection may affect future results. Study reaches were selected to target an area that was most likely to be affected by the project action (impact reach) and one that would not be affected by the project action and would likely remain constant for the life of the study (control reach). We specifically did not select “reference reaches” because in many areas where restoration is needed reference reaches that reflect pristine or ideal habitat conditions were not available. We also worked directly with the project sponsors to determine potential control reach locations that were accessible, not likely to be affected by future restoration, and similar to the treatment reach in geomorphology (channel width, type, gradient), flow, land use, and riparian condition. Control reaches were located on the same stream, generally upstream from the treated (or impact) reach, except for in the case of fish passage projects, where the control reach was located downstream of the barrier in accessible habitat. In side-channel projects in the floodplain enhancement category, a comparable side channel was chosen as a control due to the lack of comparability between main-stem and side-channel habitat.

The reach length sampled at each site was based on 40 times the wetted channel width at the time of the first survey (Peck et al. 2003). This approach was later changed to 20 times the bank-full width to increase repeatability in the surveys due to the variability in wetted widths across years. Wetted width is a much more variable measurement than bank-full width and can change both daily and seasonally. The use of 20 times the bank-full width has been adopted by other statewide monitoring programs, such as

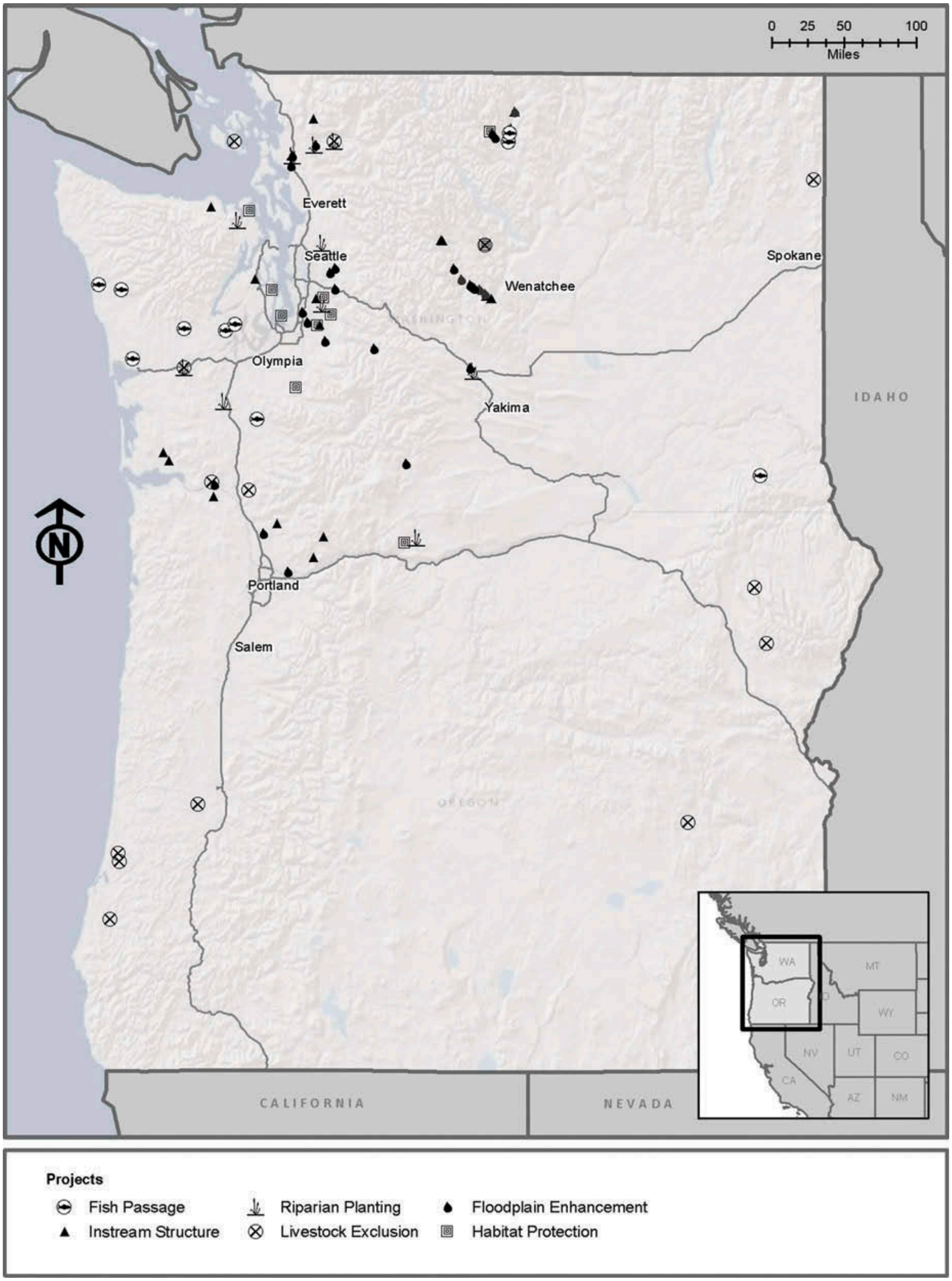

FIGURE 1. Map showing the sample site locations by project type in Washington (WA) and Oregon (OR) that were used in this study to monitor project effectiveness.

those implemented by the Washington Department of Ecology for statewide habitat status and trends (Merritt 2009). Generally, this adjustment resulted in minor changes to the reach lengths and provided a representative sample reach length. Once the reach lengths were established in both the control and impact reaches, they generally remained constant throughout the study.

Each project was monitored using metrics that were directly tied to expected habitat and biological outcomes for a given project category. The metrics selected for monitoring varied by project category, included both physical and biological measurements, and are identified by the protocol in Table 2. Field sampling indicators and techniques were adapted from the U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program (Peck et al. 2003; Crawford 2011a–e) and the Integrated Status and Effectiveness Monitoring Program (ISEMP 2013).

General site layout involved establishing control and impact reaches for each project and sampling the reaches along 11 evenly spaced transects (Peck et al. 2003). Habitat measurements were made at transects and between transects and were selected to match the expected outcomes (responses) for a given restoration project category. For example, thalweg profiles were collected at instream habitat and floodplain enhancement projects because these projects are likely to affect channel form and bed elevation, but they were not collected at riparian planting projects because that category is not expected to affect bed elevation or channel form significantly (Table 2). Data on wetted and bank-full width, riparian condition, substrate, and embeddedness were collected at each transect for specific project categories (Peck et al. 2003). Other habitat metrics included the volume of large woody debris, canopy cover, plant survival, woody species cover, presence of three layers of vegetation, bank erosion, percent fines, and percent embeddedness (Table 2). Floodplain enhancement projects were evaluated using a total station survey and light detection and ranging (also known as LiDAR), where available, to track changes in channel and floodplain topography through time (ISEMP 2013).

We used snorkel surveys to collect juvenile fish densities at both control and impact reaches at most sites (O'Neal 2007; Crawford 2011a, 2011e). One to three divers, depending on stream width, conducted snorkel surveys by moving upstream through the reach, surveying all habitat types and recording fish species, length, and number observed. At one site, where turbidity and insufficient depth made snorkel surveys infeasible, we used three-pass electrofishing to estimate fish abundance. Small numbers of fish were detected, precluding the use of multiple-removal estimates of total abundance. Thus we used the total number of each species captured in all three passes as an index of abundance to compare impact and control densities. Although there are differences between catch efficiency for the two methods (Rodgers et al. 1992), the comparison of the impact and control data sampled using the same method was designed to address this issue. Fish species encountered during snorkeling and electrofishing included several species of Pacific salmon *Oncorhynchus* spp., sculpin *Cottus* sp., and Longnose Dace *Rhinichthys cataractae*, as well as Threespine Stickleback *Gasterosteus aculeatus*, Mountain Whitefish *Prosopium williamsoni*, and Bull Trout *Salvelinus confluentus*. Other species encountered included Redside Shiner *Richardsonius balteatus*, lamprey *Entosphenus* spp., Olympic Mudminnow *Novumbra hubbsi*, Speckled Dace *Rhinichthys osculus*, and sucker *Catostomus* spp. However, we focused our analysis on Coho Salmon *Oncorhynchus kisutch*, steelhead *O. mykiss*, Chinook Salmon *O. tshawytscha*, and all salmonids combined because the purpose of this study was to document changes in salmonid use at project sites.

At fish passage projects, we conducted spawner and redd surveys every 10 d during the spawning season to evaluate adult passage for salmonids. Each project site was assigned a target species for spawning based on project objectives and location. The target species was used to identify the spawning season over which the surveys would be conducted. Surveyors conducted spawner and redd surveys on foot using polarized glasses and noted the number and presence of any spawners within the sample reach. Surveyors tagged and measured carcasses to prevent double counting. Redds were also marked and counted within the sample reach (Crawford 2011a).

Habitat protection projects were sampled as examples of areas protected for conservation but where additional restoration was not planned. Only one sample reach was established for these projects due to the fact that there was no suitable control for protected habitat in these areas—the parcels were unique and hence the need for protection. Fish were enumerated and fish species assemblages were determined using snorkel surveys for salmonids (O'Neal 2007) and quadrat surveys for benthic fish species (Kiffney et al. 2006). Fish assemblage data were processed using the Mebane et al. (2003) index of biological integrity to provide ecological health ratings at each site. Benthic macroinvertebrate samples were collected using a targeted-riffle approach (Peck et al. 2003) and reported using indices for ecological health and community structure at freshwater sites stratified by region in Washington (Wiseman 2003). Measurements of upland vegetation condition were collected for habitat protection projects using methods from Crawford and Arnett (2011) to assess vegetation quality and the level of human disturbance.

Data analysis methods.—Because our objective was to not to determine the effectiveness of each individual project, but to evaluate the effectiveness of different restoration categories (types), we considered each restoration project as one paired sample for a given category. Thus, our unit of analysis in this study was the paired difference between the average value in the treated (impact) reach as compared with the average value for the control reach for each metric within a category. Two statistical metrics were used to detect project-related change: a mean difference metric and a linear trend metric. For the mean difference metric, we compared the preproject mean (paired

TABLE 2. Management decision criteria and statistical criteria for the indicators tested by project category and protocol as established by managers to determine project effectiveness.

Project category and protocol	Indicators tested	Decision criteria
Fish passage (Crawford 2011a)	Juvenile density by species Spawner density by species Redd density by species Engineering specifications of the replacement structure	*t*-test for preproject mean against postproject mean, alpha = 0.10; 20% increase over baseline
Instream habitat projects (Crawford 2011b)	Mean thalweg residual pool vertical profile area Mean residual depth Log_{10} volume of large woody debris Juvenile fish density by species Stability of structure placement	*t*-test for preproject mean against postproject mean, alpha = 0.10; 20% increase over baseline
Riparian planting (Crawford 2011c)	Plant survival (years 1–3) Canopy cover Riparian vegetation structure Bank erosion Woody species cover (years 5 and 10)	*t*-test for preproject mean against postproject mean, alpha = 0.10; 20% increase over baseline
Livestock exclusion (Crawford 2011d)	Canopy cover Riparian vegetation structure Bank erosion Presence of livestock, fence function	*t*-test for preproject mean against postproject mean, alpha = 0.10; 20% increase over baseline
Floodplain enhancement projects (Crawford 2011e)	Mean thalweg residual pool vertical profile area Mean residual depth Bank-full height Bank-full width Flood prone width Proportion of the reach with three-layer riparian vegetation Mean canopy density along the banks Juvenile fish density by species Level of habitat connection	*t*-test for preproject mean against postproject mean, alpha = 0.10; 20% increase over baseline
Habitat protection in freshwater (Crawford and Arnett 2011)	Mean thalweg residual pool vertical profile area Mean residual depth Log_{10} volume of large woody debris Proportion of the reach with three-layer riparian vegetation Mean canopy density along the banks Linear proportion of actively eroding banks Percent fines Percent embeddedness Conifer basal area and stem count Deciduous basal area and stem count Nonnative herbaceous plants Nonnative shrubs Fish assemblage index Macroinvertebrate metric index	Trend line slope for indicator shows improvement in indicator over time; alpha = 0.10

sets of impact minus control values) to the postproject mean of all projects across multiple postproject years (paired sets of impact minus control values) and assessed significance using a paired one-tailed *t*-test (alpha = 0.10). We determined the mean for each indicator across all paired sites for all preproject years combined and all postimplementation years combined:

$(\mathrm{I} - \mathrm{C})_{\mathrm{pre},i}$ = the mean of the annual impact–control differences for site *i* preproject,
$(\mathrm{I} - \mathrm{C})_{\mathrm{post},i}$ = the mean of the annual impact–control differences for site *i* postproject,
$(\mathrm{I} - \mathrm{C})_{\mathrm{post},i} - (\mathrm{I} - \mathrm{C})_{\mathrm{pre},i}$ = the impact metric for site *i*,

where the *t*-test null hypothesis is that the mean of the impact metrics across sites is equal to 0.

If the observed distribution of site metrics differed significantly from a normal distribution (Shapiro–Wilks *P*-value < 0.05), a nonparametric alternative to the *t*-test was used (Wilcoxon test; alpha = 0.10).

We conducted this analysis for five of the six project categories but did not apply it to habitat protection projects because no preproject data were collected for those categories. The mean difference allowed easily identifiable comparisons between the pre- and postproject conditions, indicating the level of change caused by the category. This approach is best suited for indicators that exhibit either stepwise change or change in a dramatic fashion over a short period of time.

For the linear trend metric, we evaluated the slopes of linear trend lines through time for each indicator at each project site to determine if the mean slope was significantly different from 0. This approach was selected for indicators that change slowly through time but are on a distinct trajectory of change. This approach was also applied as the analysis method for habitat protection projects since those projects lacked preproject data. For each site, an estimate was made of the least-squares regression slope of the response (impact minus control for each sampled variable) regressed against time, where time is measured relative to project implementation (Donovan and Flather 2002). Because the projects were not all implemented in the same year, the years were standardized to the project implementation time frame (e.g., year 0, year 1). The first year after project implementation was always labeled year 1, and the year immediately prior to implementation was labeled year 0. The average slope of the regression lines among sites was assessed for a difference from 0 using a *t*-test or nonparametric equivalent (Wilcoxon) test (alpha = 0.10). Trends were not evaluated for variables with data from fewer than three sites or with less than 2 years of data (1 year of preproject and 1 year of postproject data).

In addition to statistical tests, we used an additional approach to examine the minimum standards for project effectiveness set by managers (Crawford 2011a–e; Crawford and Arnett 2011; Table 2). The management decision criteria were based on the objectives established for each monitoring category and included 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 2011a–e, Crawford and Arnett 2011). We used these decision criteria to determine what percentage of projects were meeting the bench marks for effectiveness set by fisheries management.

Power analysis.—A relative statistical power analysis was used to assess how the variance of the mean (impact–control) difference metric varies with increased sampling before and after project implementation. Following Liermann and Roni (2008), the variance for each metric was decomposed among effect sizes into two components—variance among sites (including sampling and temporal variance) and variance within sites. The relative variance for different numbers of sample years before and after implementation was estimated to determine the relative change in variance for different levels of monitoring effort. The relative reduction in variance was represented through the variance multiplier to summarize the relative gain for each additional year of sampling. The multiplier serves as a measure of the level of variance expected under different sampling scenarios and can be used to compare potential reductions in the amount of variance through the addition of sample effort.

RESULTS

Results by project category are presented separately since the performance indicators were designed to detect change at the category rather than the project level. Since specific indicators are tied to each category based on expected outcomes, some indicators can be compared across categories, while others cannot. The range of project actions included in the program was large, and even within a category, there was variability in techniques used, construction approaches, and cost (Table A.1). Fish passage projects included culvert replacements, dam removals, and rock weir replacements. Instream structure projects included both wood and boulder placement, as well as some creation of off-channel habitat. Floodplain enhancement projects included off-channel habitat construction, levee removal, wood placement, side-channel reconnection, and channel relocation. The costs for projects varied widely from $6,000 to $5,083,000, but costs within categories were more comparable (Table A.1).

Fish Passage Results

We observed increases across the nine fish passage projects for juvenile Coho Salmon as well as for all juvenile salmonids combined, but not for other species or for adult spawners or redds (Table 3). Tests using the slope method showed that juvenile Coho Salmon density and the density of all salmonids combined increased ($P = 0.09$, $P = 0.07$, respectively; alpha = 0.10) after barrier projects were implemented (Table 3). The mean difference method also showed

TABLE 3. Results of the statistical analysis for the indicators for fish passage projects using slope and mean difference methods. An asterisk indicates significant results at alpha = 0.10.

Indicator	Sample size	Mean slope or mean difference	Standard error	*P*-value
Slope results				
Chinook Salmon juvenile density (fish/m^2)	9	0.000	0.001	0.26
Coho Salmon juvenile density (fish/m^2)	9	0.012	0.007	0.05[a]*
Steelhead parr density (fish/m^2)	9	0.015	0.011	0.25[a]
All-salmonid density (fish/m^2)	9	0.027	0.016	0.10[a]
All-redd density (redds/km)	9	10.3	11.0	0.22[a]
All-spawner density (spawners/km)	9	95.9	107.0	0.47[a]
Mean difference results				
Chinook Salmon juvenile density (fish/m^2)	9	0.004	0.004	0.20[a]
Coho Salmon juvenile density (fish/m^2)	9	0.020	0.013	0.10[a]
Steelhead parr density (fish/m^2)	9	0.050	0.054	0.29[a]
All-salmonid density (fish/m^2)	9	0.074	0.054	0.08[a]*
All-redd density (redds/km)		32	29	0.28[a]
All-spawner density (spawners/km)		279	303	0.31[a]

[a] Nonparametric test.

that the density of all juvenile salmonids combined increased upstream of the barrier after projects were implemented ($P = 0.10$; Table 3). The changes in densities for other juvenile salmonids, redds, and spawners were not significant.

Instream Habitat Project Results

For the instream habitat projects, improvements in pool area, pool depth, and $\log_{10}$ volume of wood were detected using both the mean difference method ($P < 0.01$, 0.01, 0.01, respectively) and the slope method ($P < 0.01$, 0.02, and 0.01, respectively) (Figure 2). While the habitat indicators showed improvement at these projects, increases in fish numbers were not detected. Juvenile Chinook Salmon and Coho Salmon densities showed slight negative but insignificant trends ($P = 0.36$, $P = 0.68$, respectively), while juvenile steelhead showed a significant negative trend ($P = 0.08$).

For the instream habitat projects that were assessed over 5 years, 90% of the structures placed were still in place by the fifth year. This result met the management criteria for success of retaining 50% of the placed structures. The determination of structure longevity helped to provide context to the effectiveness results with respect to physical and biological outcomes over time in that if structures had not remained in place then there would not be an expectation of habitat changes or fish response to those projects.

Riparian Planting Project Results

Changes were not detected in the riparian vegetation structure (percent of the reach with all three layers of vegetation: ground cover, understory, and canopy cover) using the mean difference ($P = 0.43$) or the slope ($P = 0.51$) method. No differences were detected in the percent of the reach with active bank erosion using the mean difference ($P = 0.90$) or the slope ($P = 0.83$). An increase in the percent of woody species cover was detected at sites monitored at 3 and 5 years after implementation ($P < 0.01$) using the slope. The percent canopy cover did not show change during the 5-year monitoring period using the mean difference ($P = 0.49$) or the slope ($P = 0.99$). Plant survival was not tested for significance since there was not a preproject value for this metric, but the mean was compared with a minimum of 50% survival as designated in the management decision criteria. Across project sites and years, the average survival of projects was 100%, exceeding the minimum survival requirement. One project did not meet the minimum due to a channel avulsion that washed away many of the plantings. Other projects, however, exceeded 100% survival due to the fact that volunteer plantings sprouted, so the number of plants alive in the parcel in later years exceeded the number planted.

Livestock Exclusion Project Results

Livestock exclusion projects resulted in a reduction in bank erosion using both the mean difference ($P < 0.01$) and slope ($P = 0.07$) methods after 5 years of monitoring (Figure 3). Canopy density showed an increase using the slope ($P < 0.01$) but not the mean difference ($P = 0.38$), while no changes were found for riparian vegetation structure (the presence of all three layers of canopy along the reach) using either approach ($P = 0.82$). As with instream habitat projects, livestock exclusion projects were also evaluated for function and durability over time. The management decision criterion was for 80% of projects to remain

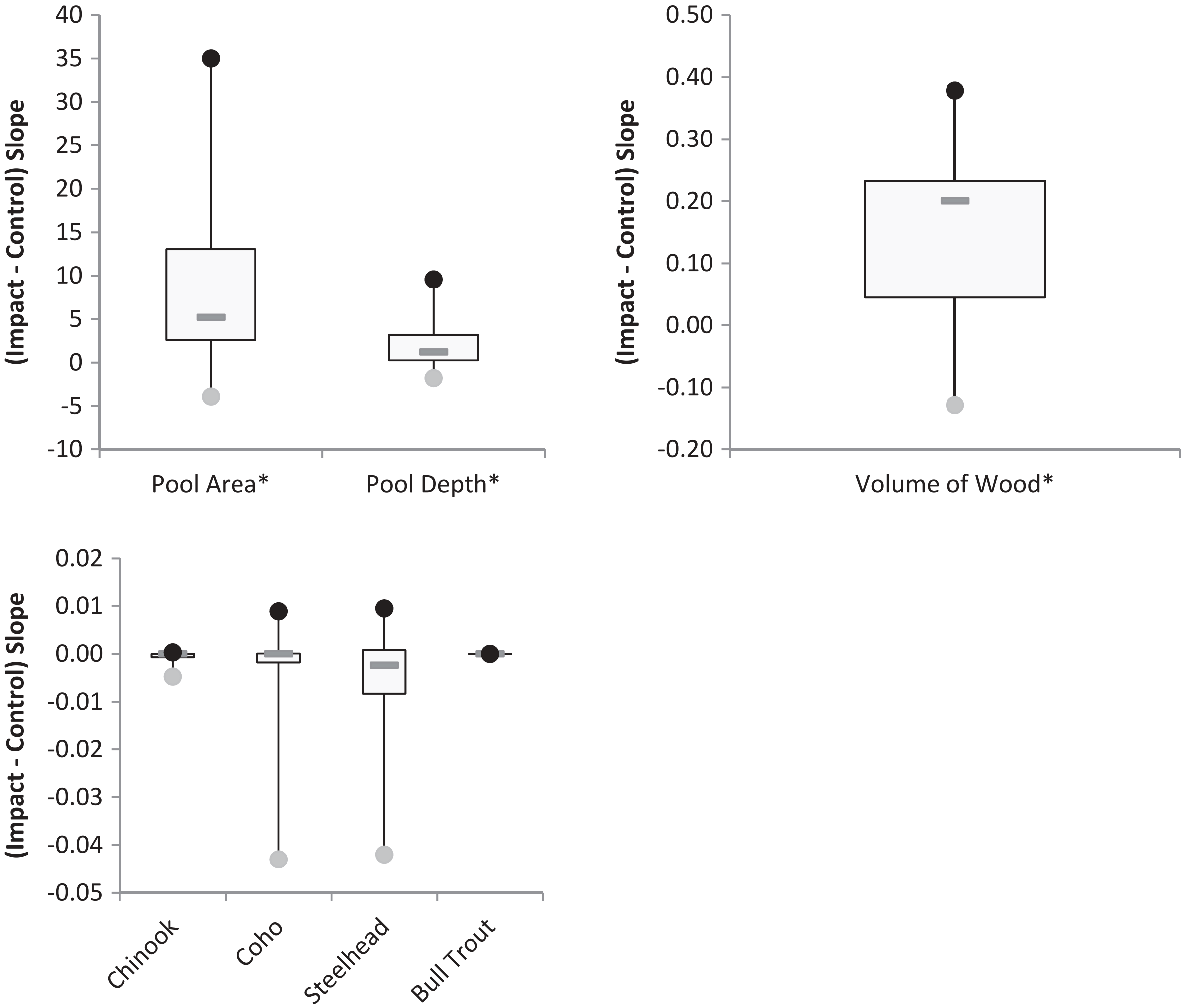

FIGURE 2. Slope box plots showing trends for the instream habitat project variables. The units given are slopes of the regression line for the mean differences between impact and control reaches across sites. The gray bars show the median values, and the box dimensions represent the 25th and 75th percentiles. Gray dots show minimum values, black dots show maximum values, and whiskers show the range of values. An asterisk indicates significance at alpha = 0.10.

functional over 10 years. After 5 years of monitoring, 64% of projects were excluding livestock (Figure 4) but 36% of projects did not remain functional, either due to fence failure or use of the area by livestock.

Floodplain Enhancement Project Results

We found that floodplain enhancement projects showed an increase in bank-full width, flood-prone width, and mean canopy density using the slope method (P = 0.04, 0.10, and 0.06, respectively). Using the mean difference method, flood-prone width (P = 0.08) and juvenile Coho Salmon density (P = 0.02) showed improvement (Table 4). Densities for juvenile Chinook Salmon were very low across most sites, and differences in steelhead parr densities were lower than those of Coho Salmon juvenile densities by an order of magnitude.

Habitat Protection Project Results

Habitat protection projects were evaluated using only the slope method, since no physical project action occurred. Of the seven freshwater projects monitored over an 8-year period, fish community index scores and multimetric index scores for benthic invertebrate samples indicated that the initial health for all sites was good or fair but that ecological health at most sites had declined by the eighth year (P = 0.01 and 0.08, respectively) (Figure 5; Table 5). Coniferous basal area and nonnative herbaceous cover (both relative and absolute cover) showed significant increases over this same time period (P = 0.06 and 0.04, respectively), but no significant changes were detected for the other 16 metrics (Table 5).

Power Analyses

Using a relative power analysis, we were able to assess the relative decrease in variance contributed by additional years of

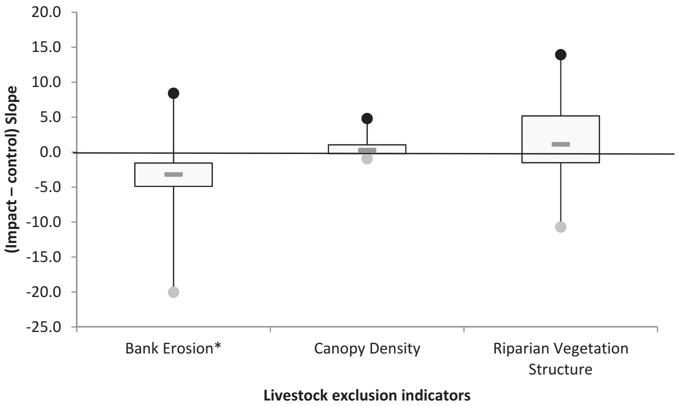

FIGURE 3. Slope box plot showing trends for the livestock exclusion indicators. The gray bars show the mean values, and the box dimensions represent the 25th and 75th percentiles. Gray dots show minimum values, black dots show maximum values, and whiskers show the range of values. An asterisk indicates significance at alpha = 0.10.

monitoring data if there is a stable pre- to postproject change. Comparison of the within-site variance multipliers allows evaluation of the relative contribution of additional years of both postproject and preproject data (Table 6). Reductions in variance are strongly tied to the number of years of preproject data; no amount of after-impact sampling will make up for only having 1 year of preproject data as compared with 2 years. For example, having 2 years of preproject data and 2 years of postproject data will result in a lower within-site variance multiplier than 1 year of preproject data and 100 years of postproject data (1.00 versus 1.01) (Table 6). Also, if one collected 1 year of preproject data and 10 years of postproject data, the variance would be 10% higher than if there had been just 2 years of preproject data and 2 years of postproject data (Table 6). This underscores the need for and value of multiple years of preproject data, as was recommended by Liermann and Roni (2008) in their review of cost-effective sample size management.

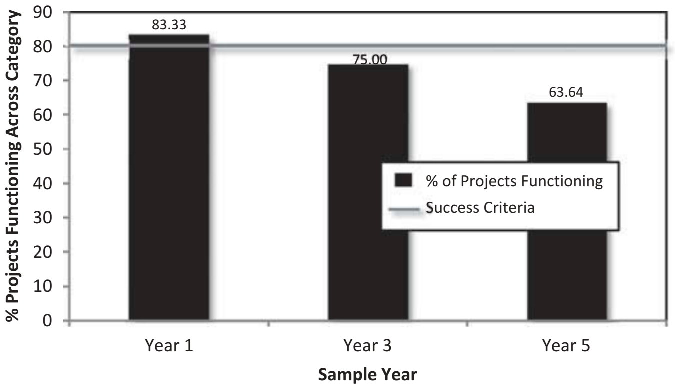

FIGURE 4. Percentage of livestock exclusion projects that were functioning by postproject sample year, showing the success criteria level set for livestock exclusion projects.

Discussion

Our results demonstrate improvements for some project types and metrics (e.g., pool habitat in instream habitat projects, juvenile Coho Salmon at floodplain enhancement projects) but little or no improvement for others (e.g., riparian planting projects, juvenile fish densities at instream structure projects, habitat protection projects). Most other programmatic evaluations of restoration have focused on evaluations of a single type of project, such as instream structures (Roni and Quinn 2001; Avery 2004; Binns 2004), reconnected floodplain habitat (Morley et al. 2005), barriers (Price et al. 2010), or bank protection (Cooperman et al. 2007). Studies of instream structures and floodplain habitat have generally reported positive physical and biological responses, while programmatic evaluations of barrier removal and bank protection have produced mixed results (Cooperman et al. 2007; Price et al. 2010). Our study is unique in that we evaluated several different project categories composed of multiple samples and multiple sites using similar protocols and a consistent sample design. Below we discuss our results for each project category in the context of other studies and provide recommendations for future monitoring and evaluation.

Fish Passage Projects

The fish passage projects we monitored showed significant increases in use by Coho Salmon and all juvenile salmonids combined for areas upstream of barriers addressed by projects. Small increases in density above barriers were found for Chinook Salmon and steelhead, but the overall level of change at these projects was not as dramatic as expected. Project-level results indicated that 44% of projects showed an increase in use upstream of the barrier, 33% of projects showed little to no effect of the project, and 24% of projects showed a negative response. Those projects with a negative response could have been the result of watershed-level reductions in juvenile densities since those projects were all located in the same watershed and reductions in densities were also seen in control reaches. In exploring the potential causes for the lack of effects for fish passage projects, we found that there was a relationship between differences in initial species density before the barriers were fixed and those that were observed upstream after project implementation. A significant relationship was found when initial control reach densities were compared with postproject mean differences between control and impact reaches ($r^2 = 0.93$, $P < 0.013$; Figure 6). From these results we concluded that preproject fish density below barriers is a good predictor of potential increases in use once the barrier is removed or otherwise mitigated.

Other studies of fish passage projects have shown that fish passage restoration projects, when implemented properly, generally have a high probability of beneficial return on monetary investment (Pess et al. 2003, 2005) in reconnecting habitat. Some fish passage projects, however, fail to meet specified

TABLE 4. Results of the statistical analysis for the indicators for floodplain enhancement projects using slope and mean difference methods. An asterisk shows significant results at alpha = 0.10. A negative slope indicates that that indicator was not tested for improvement.

Indicator	Sample size	Mean slope or mean difference	Standard error	*P*-value
Slope results				
Pool area (m^2)	16	2.7	6.4	0.50
Pool depth (cm)	16	2.5	5.1	0.63
Bank-full height (cm)	8	0.038	0.061	0.55
Bank-full width (m)	8	1.80	0.89	0.04*
Flood-prone width (m)	5	38	18	0.10*
Mean canopy density (1–17)	9	–0.77	0.37	0.06*
Riparian vegetation structure (%)	9	–1.00	1.60	0.56
Chinook Salmon juveniles (fish/m^2)	16	0.015	0.018	0.42
Coho Salmon juveniles (fish/m^2)	16	0.120	0.085	0.44
Steelhead parr (fish/m^2)	16	0.004	0.003	0.67
Mean difference results				
Pool area (m^2)	16	3.5	19.0	0.43
Pool depth (cm)	16	7.4	9.0	0.42
Bank-full height (cm)	8	0.17	0.22	0.48
Bank-full width (m)	9	5.2	3.5	0.17
Flood-prone width (m)	5	109	47	0.08*
Mean canopy density (1–17)	9	–2.0	1.7	0.29
Riparian vegetation structure (%)	9	–8.0	6.2	0.24
Chinook Salmon juveniles (fish/m^2)	16	0.000	0.029	0.59
Coho Salmon juveniles (fish/m^2)	16	0.150	0.085	0.02*
Steelhead parr (fish/m^2)	16	0.016	0.012	0.45

design criteria. Price et al. (2010) found that 23 of the 77 fish passage projects they evaluated (approximately 30%) failed to provide basic fish passage and did not comply with Washington Department of Fish and Wildlife design criteria. Since the nine projects we examined met the design criteria, our study suggests that, while fish passage projects are effective at providing increased use for fish species such as Coho Salmon, the failure of specific projects to show increases was not related to design criteria. Our data indicate a relationship between downstream preproject densities and the effectiveness of fish passage projects (Figure 6). Low levels of fish use in downstream reaches prior to project implementation have a lower likelihood of resulting in increased densities upstream after implementation. Downstream fish densities could be used as a biologically based screening criterion to help prioritize barrier projects for funding and implementation to improve the likelihood of selecting successful projects.

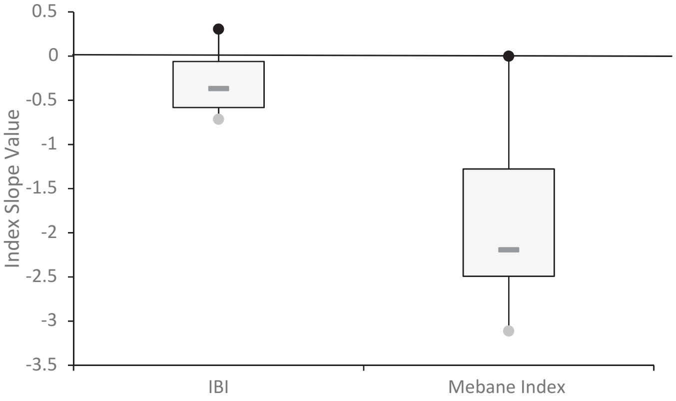

FIGURE 5. Slope box plot for the 8-year sampling period for habitat protection project indicators, showing the average decrease in scores per year for both the index of biotic integrity (IBI) for macroinvertebrates and the Mebane fish community index. The gray bars show the median values, and the box dimensions represent the 25th and 75th percentiles. Gray dots show minimum values, black dots show maximum values, and whiskers show the range of values. Although on an annual basis these changes are small, over time substantial changes in the index values were seen.

Instream Structure Projects

Results for instream habitat projects in our study showed significant increases in pool area, depth, and volume of wood. Structure placement was found to be stable, with 90% of placed elements remaining after 5 years, which is consistent with recent literature on structure stability (Roni et al. 2015). We did not, however, detect significant improvement in fish densities between control and impact reaches. In fact, initial trends over 5 years showed a significant negative trend for juvenile steelhead. This result

TABLE 5. Summary of the statistical results for the freshwater indicators for habitat protection projects. An asterisk indicates significant results at alpha = 0.10.

Indicator	Sample size	Mean slope	Standard error	P-value
Pool depth (cm)	7	0.38	0.42	0.40
Pool area (m^2)	7	1.1	1.2	0.40
Log_{10} of volume of large woody debris (m^3)	7	–0.009	0.060	0.30
Coniferous basal area (ft^2/acre)	9	2.4	1.1	0.06*
Deciduous basal area (ft^2/acre)	9	–1.2	1.2	0.35
Coniferous density (stems/acre)	9	–4.3	1.7	0.04*
Deciduous density (stems/acre)	9	1.5	6.9	0.29
Percent fines (%)	9	–0.56	0.66	0.83
Percent embedded (%)	7	–1.5	1.1	0.16
Bank erosion (%)	9	–0.0076	0.5500	0.99
Mean canopy density (1–17)	9	–0.048	0.049	0.55
Riparian vegetation structure (%)	9	0.83	0.82	0.92
Nonnative herbaceous absolute cover (%)	10	–2.20	0.64	0.01*
Nonnative herbaceous relative cover (%)	10	–0.74	0.39	0.01*
Nonnative shrub absolute cover (%)	10	–1.00	0.89	0.21
Nonnative shrub relative cover (%)	10	–0.016	0.130	0.40
Chinook Salmon juveniles (fish/m^2)	7	0.000	0.000	0.29
Coho Salmon juveniles (fish/m^2)	7	0.003	0.008	0.77
Steelhead parr (fish/m^2)	7	0.014	0.008	0.13
Index of biotic integrity	7	–0.29	0.14	0.08*
Mebane index	7	–1.80	0.40	0.01*

may be due to the smaller size of the projects implemented at some of the sites and the high variance across sites in terms of construction approach. Our project sites were distributed across Washington State and included projects in small streams (mostly single log placements) as well as larger engineered logjams in large rivers, which may have added to the variability and reduced our ability to detect a response from some fish species.

Other studies have also identified mixed results in the fish response to instream habitat projects (e.g., Stewart et al. 2009; Whiteway et al. 2010). Roni and Quinn (2001) studied 30 streams in western Oregon and Washington with placement of large woody debris and found higher densities of juvenile Coho Salmon during the summer and winter and higher densities of age-1 Cutthroat Trout *Oncorhynchus clarkii* and steelhead during the winter. However, the same study found that the response of age-1 steelhead density to treatment during summer was negatively correlated with increases in pool area and that the response of steelhead fry to treatment was negatively correlated with pool area during winter (Roni and Quinn 2001). Nickelson et al. (1992) found comparable densities for Coho Salmon in pools created by spanning structures and in natural pools as well as the increased use of pools with brush added in winter in 21 streams in coastal Oregon. Cederholm et al. (1997) found that winter populations of juvenile Coho Salmon increased significantly in treated reaches, with no significant difference noted during spring and autumn. In that same study, the placement of large woody debris either did not significantly affect steelhead populations or showed a significant decline in the treated reaches compared with the reference location, depending on the season (Cederholm et al. 1997). Thus the results we found for steelhead may be the result of rather limited improvements in physical habitat that occurred at most sites, only sampling during summer, potential differences among age-classes that we did not examine, or a high level of diversity in project approaches. Additional sources of potential decline could include predator effects and seasonal differences in fish habitat use.

Recommendations for future work include stratification into finer project categories for instream habitat projects and additional sampling of fish by season and life stage. Unlike other studies, our work evaluated projects that used several different construction approaches, over a large area (statewide), to achieve varying objectives. Some projects involved the placement of single logs in small streams (<10-m bank-full width), while others included engineered wood and rock structures in larger rivers. The stratification of projects within this group is recommended if a larger sample size can be achieved. Stratification would decrease variance due to project approaches and allow for a more refined assessment of habitat and fish responses to

TABLE 6. Within-site variance multipliers as a function of the number of years of data collected before and after a project based on power and sample size analysis. For example, if 1 year of before-project and 10 years of after-project data were collected, the variance multiplier (based on variance from our data set) would be 1.10. With 2 years of before-project data and just 2 years of after-project data, the variance multiplier would be 1.00 or 10% lower. Note that 2 years of before-project data have a greater effect than 10 years of after-project data.

Number of years of before-project data	Number of years of after-project sampling					
	2	3	4	5	10	100
1	1.50	1.33	1.25	1.20	1.10	1.01
2	1.00	0.83	0.75	0.70	0.60	0.51
3	0.83	0.67	0.58	0.53	0.43	0.34
4	0.75	0.58	0.50	0.45	0.35	0.26
5	0.70	0.53	0.45	0.40	0.30	0.21

specific project actions. As shown by other studies (e.g., Cederholm et al. 1997; Roni and Quinn 2001), differences in use by season and life stage both within and across species can be large and, despite our ability to create expected results in habitat structure, our understanding of how, when, and whether fish are optimally using restoration structures is incomplete. Additional work to better understand how wood placement affects the seasonal and spatial variability of fish is warranted, especially with the continued frequent use of wood placement as a restoration technique.

Riparian Planting Projects

Our study detected significant increases in percent woody cover for riparian planting projects. Reductions in bank erosion and increases in vegetation structure and canopy cover were not significant. The minimum criterion for plant survival were met across the category as a whole, but there were survival issues at a few projects due to poor management (mowing), difficult planting conditions, channel avulsions, and invasive species. These elements were not specifically evaluated in this study; however, the negative effects of invasive species on plant growth at some sites were noted and lower levels of survival were measured at sites with direct mortality (e.g., mowing) and difficult planting conditions (e.g., planting in cobble substrate). For variables in which we did not see significant change, the length of time required for changes in those elements of riparian conditions is likely longer than 8 years, the duration of this study.

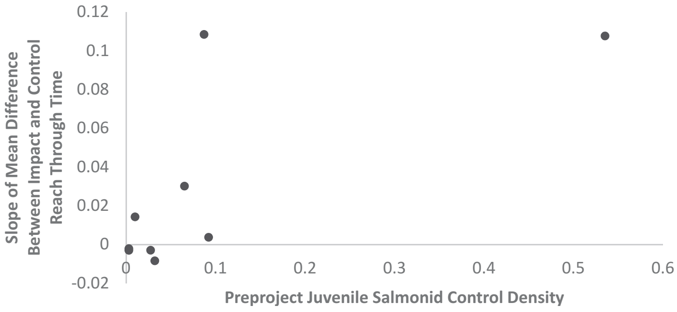

FIGURE 6. Preproject density of juvenile salmonids at control sites as compared with the slope of the mean difference of juvenile salmonid density between paired impact and control reaches through time. A lower density of juvenile salmonids at the control sites shows a lower likelihood of detecting a change in an impact–control comparison (nonparametric correlation = 0.58; nonparametric correlation without outlier = 0.59).

Many factors can influence the success of riparian planting, including soils, water table levels, sun, shade, soil fungi, herbivores, invasive species, soil preparation before planting, and others (Roni et al. 2013b), and other studies have identified a wide variety of approaches for monitoring riparian restoration efforts (Pollock et al. 2005). Several studies are focused on riparian buffers (Parkyn 2004) rather than direct planting efforts along streams and rivers, and most have been implemented over the shorter term (less than 10 years) (Roni et al. 2008). Recent work in King County, Washington, (Hartema et al. 2014) found significant increases for canopy cover and decreases in invasive species at local sites within 2 years after planting.

Our recommendations for additional study on riparian plantings include providing a longer time frame (e.g., 20 years) over which to both assess vegetative changes and document the effectiveness of maintenance measures used at various sites. A study on the relative effectiveness of maintenance efforts to control invasive species and reduce mortality would provide information that would improve the cost effectiveness of project implementation and management success.

Livestock Exclusion Projects

For livestock exclusion projects, we detected significant improvement in bank erosion and canopy density from 12 projects in Washington and Oregon. This result is similar to findings in other studies, which found that removal of livestock and exclusion fencing results in improvements in bank and instream characteristics (Platts 1991; Kauffman et al. 1997; Roni et al. 2002, 2008). In most cases, the project sites in our study did not involve planting within the livestock exclosure, which would likely lead to more rapid changes in canopy cover and other vegetative characteristics. At roughly one-third (36%) of the project sites sampled, evidence of livestock use within the exclosures showed that the projects were not effective at removing livestock. This was generally due to a lack of fence maintenance or to cattle being allowed to pass through the excluded area. Our recommendations for further study include ongoing implementation monitoring by the sponsoring agency for livestock projects to ensure that fences are kept in working order and that the exclusion of livestock from protected areas is being maintained.

Floodplain Enhancement Projects

In this study, floodplain enhancement projects showed an increase in bank-full and flood-prone width and juvenile Coho Salmon density within treated reaches as compared with control reaches. Changes in bank-full and flood-prone width were expected because as the flood-prone width at a site expands the connection with the floodplain increases and there is a greater area engaged during flood flows to provide off-channel habitat and velocity refuge for juvenile fish (Solazzi et al. 2000; Beechie et al. 2006). Increases in juvenile Coho Salmon density are likely due to the increased amount of low-velocity backwater habitat created by these projects. These results are similar to findings from Morley et al. (2005) and Solazzi et al. (2000) in which increased depth and juvenile Coho Salmon density were detected in constructed off-channel habitats. Solazzi et al. (2000) found that new floodplain channels were associated with higher numbers of juvenile Coho Salmon, Cutthroat Trout, and steelhead. Jeffres et al. (2008) found that access to floodplains provided benefits to salmonids by providing additional spawning and rearing habitat.

Significant changes were not detected in pool area, depth, canopy density, or riparian vegetation structure at floodplain enhancement projects. These projects are dependent on flood flows for geomorphic change, and increasing the channel capacity may also decrease the scour effects of flood flows so changes in pool area and depth may be less pronounced. Further, floodplain enhancement projects are often larger restoration efforts, and areas cleared by construction or by natural formation of off-channel habitats will take several years to revegetate completely. Efforts are often made to retain vegetative cover where possible during the construction of off-channel habitat.

Our recommendations for additional study in floodplain restoration include determining the specific responses of Chinook Salmon to floodplain projects in Washington State. Detectable increases in Chinook Salmon use of floodplain projects in the Pacific Northwest have been remarkably absent from published literature except for recent work by Martens and Connolly (2014), who showed higher densities of juvenile Chinook Salmon in side channels than in main-stem and tributary lateral margins. Further monitoring may provide additional insight into species preferences for different habitat conditions. Increasing numbers of these types of projects are being implemented across the region, and additional evaluation of the changes through time for both physical and biological parameters is warranted, especially in the case of levee setbacks, which are more closely tied to the restoration of natural stream processes (e.g., channel migration, sediment transport, and development of off-channel habitat).

Habitat Protection Projects

We found that most habitat protection projects initially protected high-quality aquatic and upland parcels based on multiple ecological indicators (Table 5) and that little change has occurred for most of the metrics examined. The lack of change in many of the metrics tested supports the hypothesis that most of the sites sampled were high-quality habitat that was protected from degradation. Some metrics did show significant changes through time, including vegetation metrics and indices of biological health. Coniferous basal area is expected to increase as the trees at the sites continue to grow, consistent with the hypothesis of high-quality habitat being present at the sites. However, the decrease in the fish and macroinvertebrate index scores through time and the significant increase in nonnative herbaceous cover are signs that the overall condition of the sites preserved for conservation may be at risk. After 8 years, decreases were detected in fish and invertebrate index scores and increases were found in nonnative species absolute and relative cover in the upland vegetation. These results may be due to degradation within the parcel but most likely are due to broader factors outside of the parcel (e.g., continuing issues with fish survival at the watershed scale leading to decreases in fish diversity, changes in water quality or temperature, and increasing spread of invasive species in upland vegetation) that are affecting habitat quality and species diversity. We did not find any other studies that tracked the ecological health of habitat protection projects for salmonids through time. Our recommendations for additional study of habitat protection projects include extending the time between samples to allow for more change at the sites sampled and a more extensive sampling of sites both across the region and within these same watersheds to determine if widespread decreases in ecological health are occurring.

Sample Size and Additional Preproject Monitoring

This study included 1 year of preproject data; however, our relative power analysis showed that 2 years of preproject data would have reduced the variance and increased the power of the statistical tests. More than 2 years of preproject monitoring would be even more beneficial. Many studies have noted a need to increase the level of project effectiveness monitoring for stream restoration projects (Roni and Quinn 2001; Roni et al. 2008). Roni et al. (2005) emphasized the need for multiple years of preproject monitoring in order to distinguish project effects from baseline variability, and we also found this to be important based on a variance analysis of our data.

Summary

The goal of this study was to implement a programmatic approach to monitoring using standardized methods on a statewide level. As such, there is significant variability in sites that are sampled across a large area. We used the categorization of projects to try to hone in on specific restoration practices and provide feedback on the relative effectiveness of common practices. This is a unique approach in terms of trying to capture the performance of projects across a large and diverse spatial extent, and the findings of this study (both cautionary tales and results) can be used to improve future efforts to programmatically monitor restoration projects.

Our results suggest that restoration projects being implemented in Washington and Oregon are in general leading to improvements in physical habitat and, in some cases, fish numbers. However, we also suggest recommendations for improving project planning to help ensure project success (e.g., fish surveys prior to planning barrier removal, clearly identifying specific and measurable project objectives for instream and floodplain enhancement projects) and improving programmatic evaluation of different categories of restoration projects. Specifically, to improve this and other monitoring programs, we recommend collecting at least 2 years of preproject data, stratifying projects based on objective and construction approach, and increasing sample sizes to meet the levels indicated in the power analysis for some project categories, such as floodplain enhancement and instream habitat. For these last two categories, we consider further seasonal analysis of life stage and species-specific use of projects to be warranted to increase the understanding of the differences in summer and winter use by species for project types and construction approaches. Finally, we suggest increasing the study duration while decreasing the sampling frequency for riparian planting and habitat protection projects and completing the study duration of 10 years for instream structure and floodplain enhancement projects. All of these measures would improve program efficiency and provide additional useful metrics to better inform our understanding of the effectiveness of stream restoration projects in the region.

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Appendix: Summary of Project Information

TABLE A.1. Summary information for the projects included in this study. All counties are in Washington State unless otherwise noted. The Environmental Protection Agency (EPA) ecoregions are designated by a name and a number–letter code (given in parentheses following the name of the ecoregion). Abbreviations are as follows: LWD = large woody debris, PUD = Public Utility District, YTAHP = Yakima Tributary Access and Habitat Program, OWEB = Oregon Watershed Enhancement Board, NA = not available, and CMZ = channel migration zone.

Project ID	Project name	Stream	County	EPA ecoregion	Project components	Total cost	Average wetted width
Summary of fish passage project information							
02-1530	Salmon River Tributary 21-0143 Culvert Barrier	Salmon River	Grays Harbor	Low Olympics (1c)	Culvert replacement	$148,300	3.13 m
02-1574	Malaney Creek Fish Passage Project	Malaney Creek	Mason	Central Puget Lowland (2f)	Culvert replacement	$408,672	2.76 m
04-1470	Hiawatha Fish Passage	Hiawatha Creek	Mason	Central Puget Lowland (2f)	Culvert replacement	$548,827	2.68 m
04-1485	Fulton Dam Barrier Removal Project	Chewuch River	Okanogan	Okanogan Valley (10m)	Rock dam removal, roughened channel construction	$523,062	28.68 m
04-1489	Chewuch Dam Barrier Removal Project	Chewuch River	Okanogan	Okanogan Valley (10m)	Dam renovation, roughened channel construction	$272,091	24.26 m
04-1668	Beeville Road Barrier Removal at Milepost 2.09	Peterson Creek	Mason	Central Puget Lowland (2f)	Culvert replacement	$130,000	3.4 m
04-1689	Lucas Creek Barrier Correction Project	Lucas Creek	Lewis	Cowlitz–Newaukum Prairie Floodplains (2i)	Culvert replacement, streambed gravel placement, grade control, LWD placement	$348,361	3.51 m
04-1695	Dekay Road Fish Barrier	Polson Creek	Grays Harbor	Outwash (1e)	Culvert replacement	$538,515	5.79 m
05-1498	Curl Lake Intake Fish Barrier Removal Project	Tucannon River	Columbia	Canyons and Dissected Highlands (11f)	Weir renovation, pool creation, roughened channel construction, LWD placement	$60,602	12.84 m

TABLE A.1. Continued.

Project ID	Project name	Stream	County	EPA ecoregion	Project components	Total cost	Average wetted width
02-1444	Little Skookum Valley Creek, Phase II Riparian	Little Skookum Creek	Mason	Volcanics (1d)	Livestock exclusion fencing, LWD placement, riparian planting	$31,420	1.3 m
02-1463	Salmon Creek 02 Restoration Project	Salmon Creek	Pacific	Willapa Hills (1f)	Off-channel reconnection, LWD placement	$236,946	6.5 m
02-1515	Trout Creek Artificial Instream Structures	Trout Creek	Skamania	Western Cascades Lowlands and Valleys (4a)	Riparian planting, LWD placement	$489,147	12.5 m
02-1561 IS	Edgewater Park Off-Channel Restoration	Skagit River	Skagit	Eastern Puget Riverine Lowlands (2b)	Off-channel construction and restoration, LWD placement, riparian planting	$880,000	6.5 m
04-1209 IS	Chico Creek Instream Habitat Restoration	Chico Creek	Kitsap	Central Puget Lowland (2f)	Weir removal, LWD placement, riparian planting	$925,810	6.5 m
04-1338	Lower Newaukum Restoration	Newaukum Creek	King	Eastern Puget Riverine Lowlands (2b)	Floodplain reconnection and restoration, LWD placement, riparian planting	$769,947	9 m
04-1448	Grays River PUD Bar Habitat Enhancement Project	Grays River	Wahkiakum	Willapa Hills (1f)	Rock structure installation, LWD placement, riparian planting	$316,318	34 m
04-1575	Upper Washougal River LWD Placement Project	Washougal River	Skamania	Western Cascades Lowlands and Valleys (4a)	Rock–log structure installation, LWD placement	$378,405	23 m
04-1589	Dungeness River Railroad Bridge Restoration	Dungeness River	Clallam	Olympic Rainshadow (2d)	LWD placement	$1,023,500	23 m
04-1660 IS	Cedar Rapids Floodplain Restoration	Cedar River	King	Eastern Puget Uplands (2e)	Levee removal, LWD placement, bank armor removal, invasive plant removal, riparian planting	$858,907	28 m
05-1533	Doty Edwards Cedar Creek Restoration Project	Cedar Creek	Clark	Western Cascades Lowlands and Valleys (4a)	Streambed gravel placement, LWD placement, riparian planting, side-channel reconnection	$105,537	14 m

TABLE A.1. Continued.

Project ID	Project name	Stream	County	EPA ecoregion	Project components	Total cost	Average wetted width
07-1803	Skookum Reach Restoration	South Fork Nooksack River	Whatcom	North Cascades Lowland Forests (77a)	Road decommissioning, LWD placement, channel reconstruction, riparian planting	$1,244,891	29 m
Summary of riparian planting project information							
02-1446	Centralia Riparian Restoration Project	Chehalis River	Lewis	Willapa Hills (1f)	Riparian planting	$78,892	55.5 m
02-1561	Edgewater Park Off-Channel Restoration	Skagit River	Skagit	Eastern Puget Riverine Lowlands (2b)	Off-channel construction and restoration, LWD placement, riparian planting	$880,000	7.88 m
02-1623	Snohomish River Confluence Reach Restoration	Snohomish River	Snohomish	Eastern Puget Riverine Lowlands (2b)	Riparian planting, LWD placement, off-channel reconnection	$616,573	5.31 m
04-1649	Salmon–Snow Lower Watershed Restoration	Snow Creek	Jefferson	Olympic Rainshadow (2d)	Riparian planting, tidal channel fill removal, abandoned building removal	$1,021,968	3.09 m
04-1655	Hoy Riparian Restoration Project	Skagit River	Skagit	North Cascades Lowland Forests (77a)	Riparian planting, livestock exclusion fencing	$205,293	159.11 m
04-1660	Cedar Rapids Floodplain Restoration	Cedar River	King	Eastern Puget Uplands (2e)	Levee removal, LWD placement, bank armor removal, invasive plant removal, riparian planting	$858,907	22.76 m
04-1676	YTAHP Wilson Creek Riparian Restoration	Wilson Creek	Kittitas	Pleistocene Lake Basins (10e)	Riparian planting	$26,030	6.9 m
04-1698	Vance Creek Riparian Planting and Fencing	Vance Creek	Chehalis	Willapa Hills (1f)	Riparian planting, livestock exclusion fencing	$29,760	7.99 m
04-1711	Lower Klickitat Riparian Restoration	Klickitat River	Klickitat	Oak–Conifer Foothills (9c)	Riparian planting	$59,772	21.55 m
Summary of Washington livestock exclusion project information							
02-1498	Abernathy Creek Riparian Restoration	Abernathy Creek	Cowlitz	Volcanics (1d)	Invasive plant removal, livestock exclusion fencing, riparian planting	$250,638	10.02 m

TABLE A.1. Continued.

Project ID	Project name	Stream	County	EPA ecoregion	Project components	Total cost	Average wetted width
04-1655 LE	Hoy Riparian Restoration Project	Skagit River	Skagit	North Cascades Lowland Forests (77a)	Livestock exclusion fencing	$205,293	159.11 m
04-1698 LE	Vance Creek Riparian Planting and Fencing	Vance Creek	Chehalis	Willapa Hills (1f)	Riparian planting, livestock exclusion fencing	$29,760	7.99 m
05-1447	Indian Creek Yates Restoration Project	Indian Creek	Pend Oreille	Inland Maritime Foothills and Valleys (15u)	Livestock exclusion fencing, culvert replacement, channel reconstruction, riparian planting	$63,782	5.02 m
05-1547	Rauth Coweeman Tributary Restoration	Coweeman River	Cowlitz	Western Cascades Lowlands and Valleys (4a)	Riparian planting, livestock exclusion fencing, LWD placement, fish barrier removal	$60,500	2.65 m
Summary of Oregon livestock exclusion project information							
205-060 bottle	Bottle Creek Livestock Exclusion Project – OWEB	Bottle Creek	Union (Oregon)	Wallowas–Seven Devils Mountains (11e)	Livestock exclusion fencing	$6,105	NA
205-060 nfclark	North Fork Clark Creek Tributary Exclusion Project – OWEB	North Fork Clark Creek	Union (Oregon)	Mesic Forest Zone (11l)	Livestock exclusion fencing	$6,105	NA
206-072	Gray Creek Livestock Exclusion Project – OWEB	Gray Creek	Coos (Oregon)	Coastal Lowlands (1a)	Livestock exclusion fencing	$39,500	NA
206-095	Jordan Creek Livestock Exclusion Project – OWEB	Jordan Creek	Lane (Oregon)	Valley Foothills (3d)	Invasive plant removal, livestock exclusion fencing, bank sloping, riparian planting	$20,000	NA
206-283 johnson	Johnson Creek Livestock Exclusion Project – OWEB	Johnson Creek	Coos (Oregon)	Mid-Coastal Sedimentary (1g)	Livestock exclusion fencing	$19,836	NA

TABLE A.1. Continued.

Project ID	Project name	Stream	County	EPA ecoregion	Project components	Total cost	Average wetted width
206-283 noble	Noble Creek–Maria Gulch Livestock Exclusion Project – OWEB	Maria Gulch	Coos (Oregon)	Coastal Uplands (1b)	Livestock exclusion fencing, riparian planting	$18,431	NA
206-357	Middle Fork Malheur River Bank Stabilization Project – OWEB	Malheur River	Harney (Oregon)	Owyhee Uplands and Canyons (80f)	Livestock exclusion fencing, bank sloping, riparian planting, rock structure installation	$4,700	NA
				Summary of floodplain enhancement project information			
02-1561	Edgewater Park Off-Channel Restoration	Skagit River	Skagit	Eastern Puget Riverine Lowlands (2b)	Off-channel construction and restoration, LWD placement, riparian planting	$880,000	7.98 m
02-1625	South Fork Skagit Levee Setback and Acquisition	Skagit River	Skagit	Eastern Puget Riverine Lowlands (2b)	Levee setback, off-channel reconnection	$1,067,270	138.43 m
04-1461	Dryden Fish Enhancement Project	Wenatchee River	Chelan	Chiwaukum Hills and Lowlands (77h)	Off-channel construction, LWD placement	$179,750	3.23 m
04-1563	Germany Creek Conservation–Restoration	Germany Creek	Cowlitz	Volcanics (1d)	Off-channel restoration	$768,422	6.39 m
04-1573	Lower Washougal Channel Connectivity and Restoration Project	Washougal River	Clark	Portland–Vancouver Basin (3a)	Rock structure installation, LWD placement, riffle construction, off-channel construction	$264,600	34.91 m
04-1596	Lower Tolt River Floodplain Reconnection	Tolt River	King	Eastern Puget Uplands (2e)	Levee setback, LWD placement, riparian planting	NA	26.25 m
05-1398	Fenster Levee Setback	Green River	King	Eastern Puget Riverine Lowlands (2b)	Levee removal, bank armor removal, floodplain excavation, off-channel reconnection, riparian planting	$811,400	34.58 m
05-1466	Lower Boise Creek Constrained Channel	Boise Creek	King	Eastern Puget Riverine Lowlands (2b)	Channel construction and relocation	$746,600	11 m

TABLE A.1. Continued.

Project ID	Project name	Stream	County	EPA ecoregion	Project components	Total cost	Average wetted width
05-1521	Raging River Preston Reach Restoration	Raging River	King	Eastern Puget Uplands (2e)	Floodplain reconnection	$343,867	17.85 m
05-1546	Gagnon CMZ Off-Channel Project	Wenatchee River	Chelan	Chiwaukum Hills and Lowlands (77h)	Off-channel construction, off-channel reconnection, riparian restoration	$417,937	6.84 m
06-2190	Riverview Park Restoration	Green–Duwamish River	King	Eastern Puget Riverine Lowlands (2b)	Off-channel construction, LWD placement, streambed gravel placement, riparian planting	$102,438	5.4 m
06-2223	Greenwater River Project	Greenwater River	Pierce	Western Cascades Lowlands and Valleys (4a)	Road decommissioning, LWD placement	$570,600	14.3 m
06-2239	Fender Mill Floodplain Restoration–Phase I	Methow River	Okanogan	Okanogan Pine–Fir Hills (77e)	Berm removal, bank armor removal, side-channel reconnection	$75,187	3.6 m
06-2250	Chinook Bend Levee Removal Project	Snoqualmie River	King	Eastern Puget Uplands (2e)	Levee removal	$889,468	88.9 m
06-2277	Upper Klickitat River Enhancement Phase II	Klickitat River	Yakima	Yakima Plateau and Slopes (9a)	Side-channel construction, side-channel reconnection, LWD placement, bank stabilization, pool enhancement, pool construction	$631,980	3.4 m
07-1691	Lockwood Creek Phase 3	Lockwood and Riley Creek	Clark	Portland–Vancouver Basin (3a)	Off-channel construction, LWD placement, riparian planting	$275,105	8.64 m

TABLE A.1. Continued.

Project ID	Project name	Stream	County	EPA ecoregion	Project components	Total cost	Average wetted width
07-2020	Reecer Creek Floodplain Restoration	Reecer Creek	Kittitas	Pleistocene Lake Basins (10e)	Channel construction and relocation, floodplain excavation, off-channel reconnection, dike breaching, riparian planting, LWD placement, rock structure installation	$852,995	11.5 m
Summary of habitat protection project information							
00-1669	Entiat River Habitat Acquisition	Entiat River	Chelan	Chelan Tephra Hills (77f)	Land acquisition	$1,885,163	17.7 m
00-1788	Rock Creek–Ravensdale Retreat Protection Project	Rock Creek	King	Eastern Puget Uplands (2e)	Land acquisition	$583,000	1.44 m
00-1841	Metzler Park Side Channel Acquisition	Green River	King	Eastern Puget Riverine Lowlands (2b)	Land acquisition	$520,454	13.75 m
01-1353	Logging Camp Canyon (Phase 1) Acquisition	Logging Camp Creek	Klickitat	Oak–Conifer Foothills (9c)	Land acquisition, riparian landowner agreement	$464,132	2.2 m
02-1535	WeyCo Mashel Shoreline Acquisition	Mashel River	Pierce	Western Cascades Lowlands and Valleys (4a)	Land acquisition	$632,502	19.5 m
02-1622	Issaquah Creek Log Cabin Reach Acquisition	Issaquah Creek	King	Eastern Puget Uplands (2e)	Land acquisition	$888,045	8.29 m
02-1650	Methow Critical Riparian Habitat Acquisition	Methow River	Okanogan	Okanogan Pine–Fir Hills (77e)	Land acquisition	$5,082,951	32.42 m