OWEB-SRFB Coordinated Monitoring Program for Livestock Exclusion Projects

2017 Final Report

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OWEB-SRFB COORDINATED MONITORING PROGRAM FOR LIVESTOCK EXCLUSION PROJECTS

2017 FINAL REPORT

Prepared for:

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Applied Research in Fisheries, Restoration, Ecology, and Aquatic Genetics.

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EXECUTIVE SUMMARY

The Oregon Watershed Enhancement Board (OWEB) in partnership with the Washington Salmon Recovery Funding Board (SRFB) developed the coordinated monitoring program for livestock exclusions in 2006 to combine monitoring efforts across state jurisdictions. Under the coordinated program, the intent of the monitoring efforts was to determine whether habitat targeted for restoration had been improved. This partnership leverages the investment of both states to increase the sample size of livestock exclusion projects evaluated, while at the same time reducing costs for each agency. This report summarizes the 10th year of monitoring and the final results of the coordinated program. A before-after control-impact (BACI) experimental design was used to evaluate livestock exclusion projects one year before livestock exclusion and 1, 3, 5, and 10 years post-treatment (impact). Field sampling indicators and techniques were adapted from the U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program.

Specific protocols were developed by the SRFB to examine changes in riparian structure, shade (bank canopy cover), bank erosion, and instream fine sediment (pool tail fines) from livestock exclusion. A total of 12 projects were monitored over the course of the study, eight of which were sampled in 2017. We collected the final year of data (Year 10) in 2017, while selection of study sites and all prior years of data collection were completed by a previous contractor. We used a combination of paired *t*-tests, regression analysis, and mixed-effects ANOVA models to analyze data. Results indicate that livestock exclusion projects significantly reduced bank erosion and improved riparian structure by Year 10, but we found no significant effects of livestock exclusion on bank canopy cover or pool tail fines. However, the mean percentage of pool tail fines was lower in all impact reaches. The reduction in bank erosion is consistent with previous studies on livestock exclusions, which have generally shown decreases in bank erosion and increases in riparian vegetation structure and shade. It is possible that canopy cover may continue to improve in impact reaches with continued livestock exclusion. However, the lack of change in canopy cover and fine sediment are likely the results of several factors including: evidence of livestock grazing in many impact reaches, livestock exclusion in control reaches, limitations of the riparian sampling protocols, and additional noise due to some control reaches that were not well matched with impact reaches.

Many projects had intact fencing, but there were several instances where gates were left open, the fence was in the lay down position, or cattle were accessing the reach from upstream or downstream of the project location. Future efforts monitoring livestock exclusion projects should focus on implementation (compliance) monitoring to ensure livestock are excluded, more rigorous selection of control reaches, and improved riparian and instream sampling that more accurately measures changes in vegetation structure, shade, and channel conditions. Finally, there is fairly extensive documentation of improvement in riparian vegetation and instream habitat conditions if livestock are properly excluded, but limited information on effects of livestock exclusion on fish and other aquatic biota. Therefore, future effectiveness monitoring of livestock exclusion projects should also be designed to evaluate the response of fish, macroinvertebrates, and other aquatic biota.

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INTRODUCTION

Livestock grazing near streams has led to the degradation of riparian and stream habitats throughout the world (Platts 1991; Belsky et al. 1999; Medina et al. 2005). Livestock grazing directly affects riparian zones by decreasing riparian vegetation through trampling and consumption, leading to increased bank erosion and fine sediment, degraded stream habitats, and impaired riparian and stream processes (Platts 1991; Belsky et al. 1999; Roni et al. 2002). Reduced shade, cover, pool area and depth, and increasing water temperatures and fine-sediment deposition from riparian grazing negatively impact salmonids and other fishes (Platts 1991; Sievers et al. 2017). Complete exclosures that are properly constructed and maintained can be effective at protecting banks and riparian vegetation from livestock grazing and other activities, leading to passive short- and long-term riparian habitat recovery and improved riparian vegetation conditions as well as reduced bank erosion, channel width, and fine sediment levels (Medina et al. 2005; Ranganath et al. 2009; Roni et al. 2014; Batchelor et al. 2015). Increased riparian vegetation, density, and structure within an exclosure provide several advantages. First, more riparian vegetation and overhanging banks are associated with a decrease in width:depth ratio (Magilligan and McDowell 1997; Clary 1999; Bayley and Li 2008). These conditions favor age-0 trout (Moore and Gregory 1988) and these improvements to water quality and bank stabilization are strongly associated with salmonid habitat quality (Walling and Webb 1992; Quinn 2005). Second, there is improved physical habitat which can provide protection from predators (Bayley and Li 2008). Finally, exclosures increase feeding opportunities due to invertebrate production in developed vegetated, undercut banks (Rhodes and Hubert 1991; Baxter et al. 2005), and increases in terrestrial invertebrate drift biomass input (Edwards and Huryn 1996). Improved riparian conditions also benefit terrestrial communities through terrestrial-aquatic linkages (e.g., Nakano et al. 1999), and benefit water quality by reducing the influx of sediment (Waters 1995).

Stream restoration efforts are conducted throughout the world to enhance or restore function of aquatic and riparian ecosystems. In the United States, more than a billion dollars is spent on stream restoration annually (Bernhardt et al. 2005), with the goal of many projects being the recovery of Pacific salmon listed as threatened or endangered under the Endangered Species Act (NOAA 2015). Restoration of streams affected by livestock access often includes installation of riparian fencing to construct exclosures and achieve maximum protection within grazed landscapes (Medina et al. 2005). Investments in the construction and maintenance of exclosures have been made to improve watershed health within Oregon, Washington, and across the western United States (Platts et al. 1991; Batchelor et al. 2015). Given the level of investment in salmon and trout habitat restoration, there is a need to track and assess the effectiveness of livestock exclusion projects to help guide future restoration and allocation of funds. Effectiveness monitoring of these restoration projects is critical to evaluate project performance and provide information to better inform future project designs through adaptive management (Rinne 1999; Medina et al. 2005).

The Oregon Watershed Enhancement Board (OWEB) and Washington Salmon Recovery Funding Board (SRFB) are both responsible for funding watershed and salmon habitat restoration projects in their respective states. The OWEB strives to conserve and restore crucial elements of natural systems that support fish, wildlife, and people, with an emphasis on restoring salmon and trout throughout the state (OCSRI 1997; OWEB 2003). This comprehensive program works to benefit watershed health and wildlife, including threatened and endangered salmonids, by implementing livestock exclusion projects that improve riparian vegetation. The SRFB provides funding for elements necessary to achieve overall salmon recovery, including habitat projects and other activities that result in sustainable and measurable benefits for salmon and other fish species (https://www.rco.wa.gov/).

The Monitoring Strategy for the Oregon Plan for Salmon and Watersheds and the Washington Comprehensive Monitoring Strategy Monitoring Oversight Committee both outline goals and objectives for monitoring aquatic habitat and the biological effects of restoration (OWEB 2003; Monitoring Oversight Committee 2002). Both states have developed comprehensive, long-term monitoring strategies to identify monitoring needs for restoration actions. A coordinated monitoring approach increases the efficiency of monitoring and results in cost savings. Comparable data collected across a region provides better information to aid resource managers in making decisions regarding listed salmon species, many of which range across state lines. With that in mind, OWEB and SRFB developed the OWEB-SRFB Coordinated Monitoring Program for Livestock Exclusion Projects in 2006 to combine efforts across state jurisdictions and produce coordinated data from a regional perspective.

The OWEB-SRFB Coordinated Monitoring Program for Livestock Exclusions focused on livestock exclusion projects in both Oregon and Washington. Livestock exclusion projects were selected for the Coordinated Monitoring Program because: 1) there was a need to increase the sample size of livestock exclusion projects monitored to improve the design and analysis; 2) there was a need in Oregon to monitor a sub-sample of the large number of livestock exclusion projects implemented; and 3) there has been significant investment by both states in livestock exclusion projects for the benefit of salmonids. Livestock exclusion projects were monitored in both Oregon and Washington, and 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.

The primary goal of livestock exclusion projects is to exclude livestock from riparian areas where the animals can cause significant damage to the stream (e.g., by breaking down streambanks, increasing sedimentation, and damaging shade-producing trees and shrubs), and to allow or enhance recovery where damage has occurred. By excluding livestock, adverse impacts can be avoided and natural recovery of vegetation can take place (Crawford 2011). The monitoring goal is to determine the effectiveness of livestock exclusions at improving riparian conditions along fish bearing streams by addressing: 1) are livestock excluded from the riparian area; 2) has treatment led to improvements in riparian condition including cover, shade, and structure; 3) has bank erosion been reduced in the treatment (impact) reach; and 4) are fine sediment levels reduced in the treated reach?

METHODS

Monitoring Design and Replication

The details of the methods and monitoring design are provided in Crawford (2011). Here we provide a summary of the design but refer readers to Crawford for details. Livestock exclusion projects were evaluated using a before-after control-impact (BACI) experimental design (Green 1979; Stewart-Oaten et al. 1986). Each project (impact) and control sites were monitored before (Year 0) and after implementation on a rotating schedule (Years 1, 3, 5, and 10). The site selection and data collection for Years 0 to 5 for all projects and in Year 10 for 04-1655 Hoy and 02-1498 Abernathy were conducted by a previous contractor (Tetra Tech). Cramer Fish Sciences was contracted to collect data in Year 10 and complete the final report for the program.

Projects were selected from those that had been funded by OWEB or SRFB but had not yet been implemented for the given baseline sampling year (Figure 1). Study sites ranged in wetted width from 2 m to 60 m and in elevation from 9 m to 1,463 m. Annual precipitation was highly variable among sites and dominant geology was either volcanic or sedimentary (Table 1). An impact reach was selected within the project area where change was expected to result from the project (e.g., the exclosure area). With assistance from grantees and project sponsors, a control reach was selected upstream and, when possible, in close proximity to the impact reach. These reaches were often on adjacent properties and permission to access both the impact and control reaches over time was gained prior to sampling. Potential control sites were examined and it was determined in the field if they were suitable (similar to the impact reach prior to livestock exclusion). Selection of adequate controls is critical to account for natural variability in riparian and stream habitat that is occurring throughout a stream and not the result of livestock exclusion. Details of site selection and identification of impact and control reaches can be found in Tetra Tech (2009).

Once the control and impact reaches were established, each reach was monitored for one year before implementation (Year 0) to collect baseline data that reflect pre-existing conditions. Following project implementation, those same reaches were surveyed on a rotating schedule (Year 1, 3, 5, and 10) to assess changes that result from the project.

Field Methods

The OWEB-SRFB Coordinated Monitoring Program for Livestock Exclusion Projects uses field sampling indicators and techniques that were adapted from the U.S. Environmental Protection Agency's Environmental Monitoring and Assessment Program (Lazorchak et al. 1998; Peck et al. 2003) and from Oregon Department of Fish and Wildlife's Methods for Stream Habitat Surveys (Moore et al. 2008). The detailed Crawford (2011) protocol used to monitor livestock exclusion projects can be found at http://hws.ekosystem.us/content/MC-4_Protocol_for_Effectiveness_Monitoring_of_Livestock_Exclusion_Projects_2011.pdf. The protocol includes goals and objectives for the monitoring category, success criteria, detailed field data collection descriptions, functional assessment methods, summary statistics, and data analysis procedures.

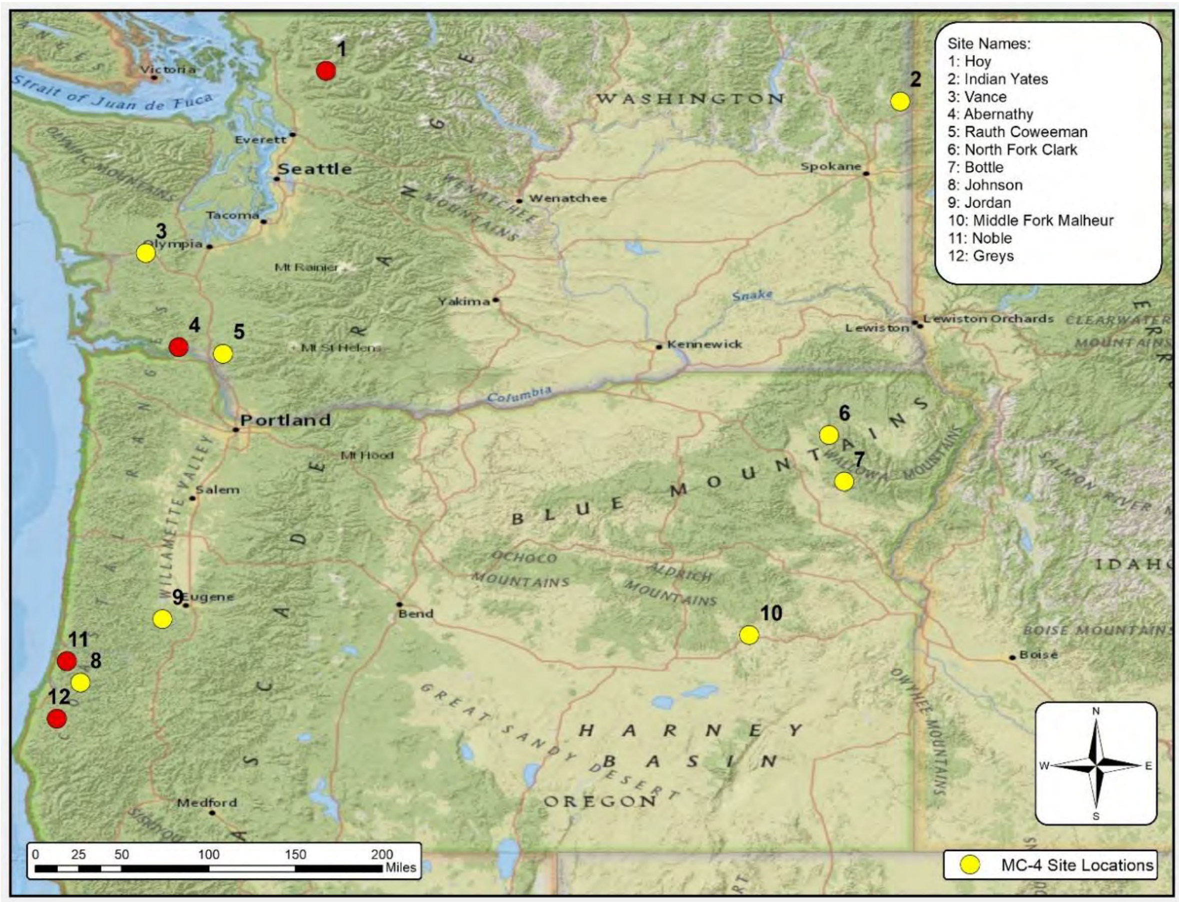


Figure 1. Livestock exclusion project locations monitored throughout Oregon and Washington. 04-1655 Hoy, 02-1498 Abernathy, 206-283b Noble, and 206-072 Greys were not sampled in 2017 (red) and all other sites were sampled in 2017 (yellow).

Site Layout

Once impact and control reaches were selected, the total reach length was calculated using bankfull measurements in the impact reach (Crawford 2011). Five bankfull measurements were recorded and averaged around the center of the reach (X-site). The total reach length was calculated by multiplying the mean bankfull width by twenty (minimum of 150 m and maximum of 500 m). This same reach length was then used for the control reach and was to remain the same for each year of monitoring. Once a site length was calculated, the reach layout was completed by locating Transects A-K (Figure 2). Transects were placed at a distance of one-tenth the average bankfull widths (i.e., if a reach length was 150 m, the distance between transects was 15 m).

Bank Erosion

The lineal distance that was actively eroding along each bank was estimated between Transects A-K (Crawford 2011). Active erosion was defined as actively eroding or collapsing banks. The percent bank erosion between each transect on both banks was then averaged across the reach.

Table 1. Physical characteristics of livestock exclusion study sites. Geology is dominant geology (unpublished Washington State Department of Ecology) where Sed. = sedimentary and Vol. = volcanic. Yearly precipitation was obtained from the USGS StreamStats Program. Wetted width (WW) is the average of the wetted width measurements over all sampling years.

Site ID	Site Name	County (State)	Basin	First Year Sampled	Geology	Site Elev. (m)	Precip. (cm/yr)	WW (m)	Site Length (m)
02-1498	SRFB: Abernathy	Cowlitz (WA)	Abernathy	2004	Vol.	27	201.9	6.0	240
04-1655	SRFB: Hoy Riparian	Skagit (WA)	Skagit	2005	Sed.	34	266.7	60.0	210
04-1698	SRFB: Vance	Grays Harbor (WA)	Chehalis	2006	Sed.	12	167.9	5.0	150
05-1447	SRFB: Indian Creek-Yates	Pend Oreille (WA)	Indian	2006	Sed.	744	92.7	5.3	160
05-1547	SRFB: Rauth Coweeman	Cowlitz (WA)	Coweeman	2006	Vol.	73	150.6	2.7	150
205-060a	OWEB: Bottle	Union (OR)	Grande Ronde	2006	Vol.	1,463	88.9	4.0	150
205-060b	OWEB: NF Clark	Union (OR)	Grande Ronde	2006	Vol.	1,387	85.9	2.0	150
206-072	OWEB: Greys	Coos (OR)	Coquille	2006	Sed.	9	159.8	3.3	150
206-095	OWEB: Jordan	Lane (OR)	Long Tom	2006	Sed.	143	132.3	2.8	150
206-283a	OWEB: Johnson	Coos (OR)	Johnson	2006	Sed.	21	193.0	4.5	150
206-283b	OWEB: Noble	Coos (OR)	Tenmile Lakes	2006	Sed.	24	194.3	2.0	150
206-357	OWEB: MF Malheur	Harney (OR)	Malheur	2006	Sed.	1,073	53.8	8.0	375

Riparian Vegetation Structure

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

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

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

Riparian vegetation structure was then summarized for analysis as the proportion of each reach containing all three layers of riparian vegetation (canopy, understory, and ground cover) (Crawford 2011). A layer was counted as containing riparian vegetation if either of the two vegetation types (canopy: small or large trees; understory/ground: woody and non-woody vegetation) were present (greater than 0%). The percentage of the 22 possible locations (right and left bank at Transects A-K) in the reach that had each of the three layers of riparian vegetation present was then calculated. If any layer at a measurement location was absent, this location did not contribute to the percentage of riparian vegetation structure within the reach.

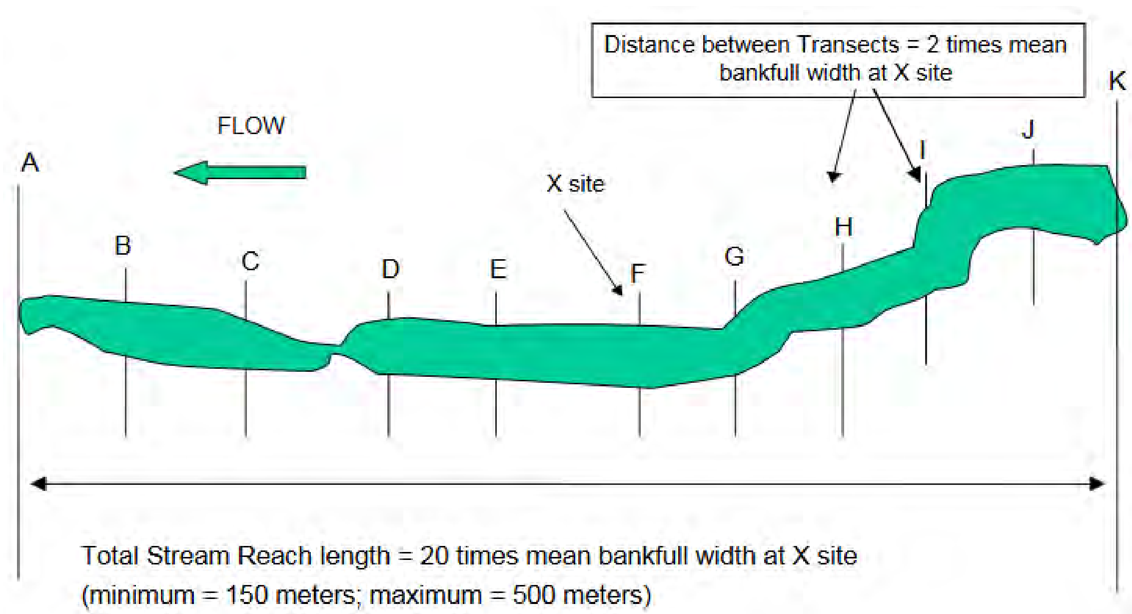


Figure 2. Project reach layout as adopted from Crawford (2011).

Canopy Cover Density

Canopy cover was determined at each Transect A-K using a convex spherical densiometer. The densiometer was taped so that there was a "V" at the bottom and there were 17 visible grid intersections (Mulvey et al. 1992; Figure 3). Six measurements were taken at each transect: four from mid-channel (facing upstream, river left, downstream, and river right) and one at each wetted edge facing away from the main channel (Crawford 2011). The densiometer was held level at 0.3 m above the water level with the recorder's face just below the apex of the taped "V". The number of grid intersection points that were covered by a tree, leaf, high branch, or any other shade-providing feature (i.e., reed canary grass *Phalaris arundinacea*, river bank, bridge or other fixed structure) was counted. The value (0-17) was then recorded. For each project and within each reach, canopy cover density was averaged across all transects, for measurements taken on the right and left banks only, to get a mean value for each monitoring year. The mean canopy cover density from each year of monitoring was then used in the statistical analysis.

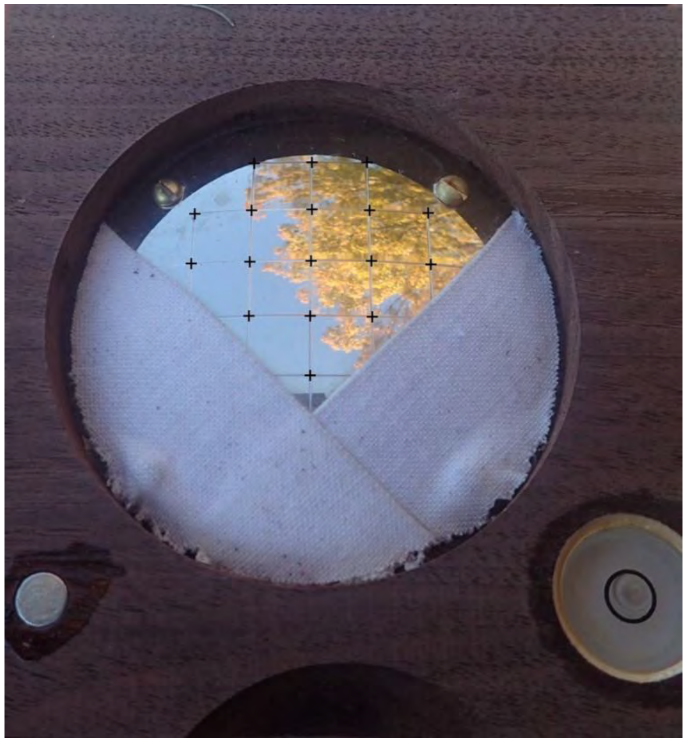


Figure 3. Image of modified densiometer and the remaining 17 grid intersections. In this example, 12 of the 17 intersections show canopy cover, giving a densiometer reading of 12.

Pool Tail Fines

In Year 10 monitoring, measurements for percentage of fine sediment in the pool tail were taken in the first ten scour and plunge pools of each reach. If ten qualifying pools were not in the reach, the total number of qualifying pools was sampled. Pools considered for measurement had to meet the following criteria: 1) main channel pool, not a backwater or side channel; 2) span at least 50% of the wetted channel width at any one point; and 3) maximum pool depth is at least 1.5 times the pool tail depth (Crawford 2011). It should be noted that while pool tail fines are part of the protocol for livestock exclusion projects described by Crawford (2011), they were not collected prior to 2017 at any of the sites.

A 35-cm x 35-cm grid with 49 evenly distributed intersections, with the top right corner included for a total of 50 intersections, was used to measure pool tail surface fines (Crawford 2011). The grid was placed at 25, 50, and 75% of the distance across the wetted channel and upstream from the pool tail crest at a distance equal to 10% of the pool's length or one meter (Figure 4). The grid was placed following the shape of the pool tail crest, which in small streams grid placements could overlap. At each grid placement, the number of intersections that were underlain with sediment less than 2 mm in diameter and less than 6mm diameter were recorded. The number of grid intersections with sediments less than 2 mm in diameter could not exceed those with intersections less than 6 mm in diameter. Percentage of pool tail fines were summarized for analysis by averaging all pool tail fines collected in each pool across the entire reach.

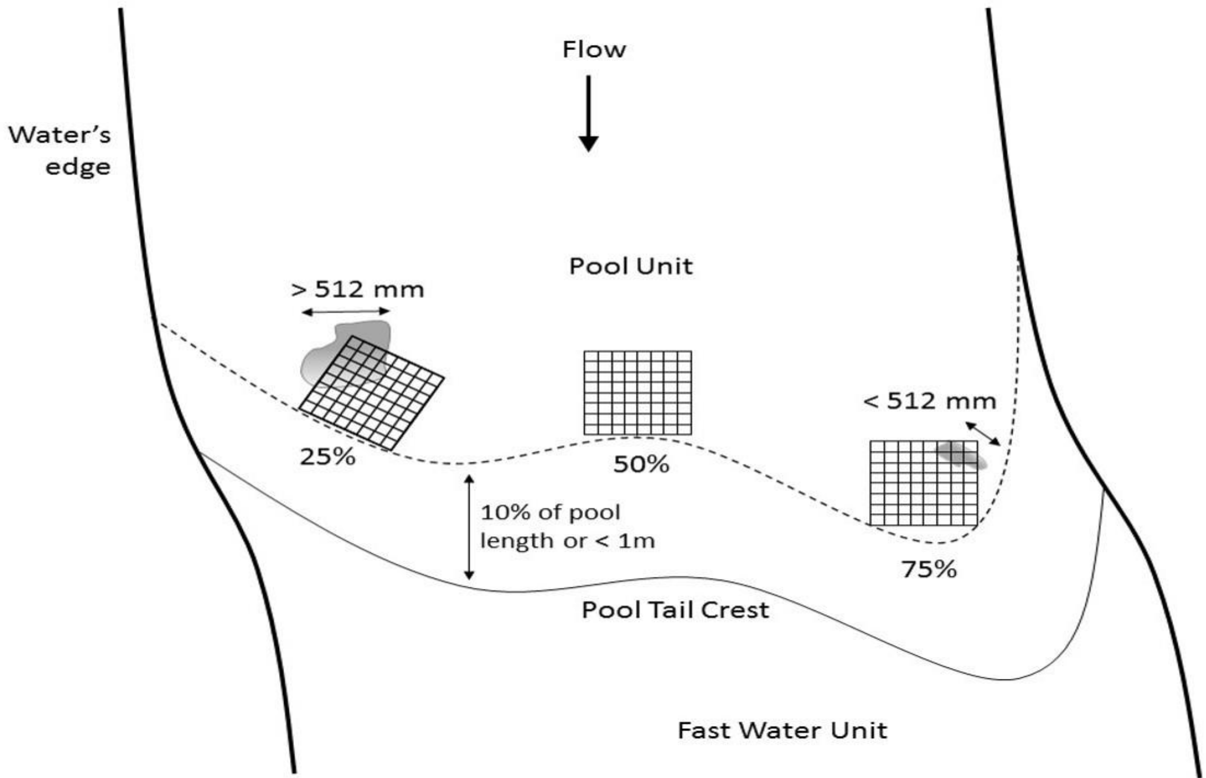


Figure 4. Orientation and location of grid placement for pool tail fines measurements as adapted from Crawford (2011).

Livestock Presence and Fencing Assessment

Monitoring data collected at each site also included a functional assessment of the exclusion, including noting signs of livestock presence within the exclusion zone and damage to the exclusion itself. A fence could be intact with no holes or portions knocked down and could still not be functioning if a portion of the fence was not properly set-up (e.g., gates open, in the lay down position). The length of the exclusion was walked to assess for any breaks in the fence or evidence of livestock getting through the fencing. If there were signs of livestock within the exclusion, we estimated the length of the site with evidence of livestock presence and reported this as a proportion of the total site length.

Data Analysis Methods

All projects were evaluated together as a category to assess trends in indicator response from year to year, and the change between pre-project (Year 0) and post-project (Year 1, 3, 5, and 10) conditions. Statistical analysis was not conducted on individual projects; however, data for each project with monitoring completed in 2017 is provided in the site-specific report pages in Appendix A.

Sites with data collected in all years following project implementation and two projects (206-072 Gray and 206-283b Noble) with only two or three years of after data were included in the analysis (Table 2). Sampling at the two unfinished sites did not take place because access was denied.

Table 2. Livestock exclusion projects and sampling years included in data analysis.

Project Number	Project Name	Year 0 Sampling	Years included in analysis
02-1498	SRFB: Abernathy	2004	Year 1, 3, 5, and 10
04-1655	SRFB: Hoy Riparian	2005	Year 1, 3, 5, and 10
04-1698	SRFB: Vance Creek	2005	Year 1, 3, 5, and 10
05-1447	SRFB: Indian Creek-Yates	2006	Year 1, 3, 5, and 10
05-1547	SRFB: Rauth Coweeman	2006	Year 1, 3, 5, and 10
205-060a	OWEB: Bottle	2006	Year 1, 3, 5, and 10
205-060b	OWEB: NF Clark	2006	Year 1, 3, 5, and 10
206-072	OWEB: Greys	2006	Year 1, 3, and 5
206-095	OWEB: Jordan	2006	Year 1, 3, 5, and 10
206-283a	OWEB: Johnson	2006	Year 1, 3, 5, and 10
206-283b	OWEB: Noble	2006	Year 1 and 3
206-357	OWEB: MF Malheur	2006	Year 1, 3, 5, and 10

Bank Erosion, Riparian Structure, and Canopy Cover

We conducted both basic analyses described by Crawford (2011), previous annual reports (Tetra Tech 2016), and required under our contract, as well as additional analyses used for analyzing BACI data. The required analyses included a mean difference analysis and a trend analysis to test whether projects were effective each monitoring year and remained effective through Year 10 (Crawford 2011). For the mean difference method, the pre-project values were compared to each year of post-project data using a paired one-sided *t*-test with $\alpha = 0.10$. If the data was not normally distributed, a paired one-sided nonparametric *t*-test (Wilcoxon) with $\alpha = 0.10$ was used. For each response variable, our unit of analysis was the paired difference between the impact reach compared to the control reach for each sample year. The null hypothesis is that the mean of the impact metrics across sites is equal to 0. This analysis was conducted on riparian vegetation structure, bank canopy cover, and bank erosion—which were collected in all sampling years. It should be noted that, for Site 04-1655 Hoy which is located on the Skagit River, measurements were only taken on the left bank for all metrics and canopy cover was not recorded in Year 10 (2015) by the previous contractor.

For the second method, the slopes of linear trend lines through time (Year 0 to Year 10) for each indicator at each project site were estimated. Then, using these slopes, a *t*-test or nonparametric equivalent (Wilcoxon) test ($\alpha = 0.10$) was used to test if the average of the slopes differed from 0 for each metric (Crawford 2011; Tetra Tech 2016; O’Neal et al. 2016).

Additional Analysis – Mixed-Effect BACI Model

In addition to the required analysis (Crawford 2011), we ran a more robust BACI style analysis where we fit multiple linear mixed-effect models with α = 0.05 to test the effect of cattle exclusion on bank erosion, riparian structure, and bank canopy cover. The model analyzed was:

$$Response\ Metric \sim CI + BA + (BA * CI) + Random(Site) + Random(Year)$$

Where the fixed effects included in the model were reach type (control or impact), time of measurement (before or after impact), and the BACI interaction term (*BA* * *CI*). The random effects included in the model were Site and calendar Year sampled to allow for site-to-site variation as well as year-to-year variation. To meet assumptions of normality, a square root transformation was applied to the right-skewed bank erosion data. Riparian structure data did not need to be transformed. Bank canopy cover data was not normally distributed and could not be transformed to meet model assumptions for normal distribution of the model residuals (Shapiro-Wilks test, α = 0.05). Therefore, results for bank canopy cover are not reported in the BACI analysis results.

Pool Tail Fines

To test whether the mean percent fines (<2 mm and <6 mm) were significantly different between the control and impact reaches, we conducted an extensive post-treatment analysis of a paired two-sided *t*-test with α = 0.05 for pool tail fines data collected in 2017. Sites were excluded from the analysis if either the control or impact reach of paired site did not have a pool to collect percent fines (Table 3), thus leaving five projects included in the analysis.

Table 3. Livestock exclusion projects sampled in 2017 for percent pool tail fine sediments.

		Number of Plunge and/or Scour Pools	
Project Number	**Project Name**	**Impact**	**Control**
04-1698*	SRFB: Vance Creek	0	0
05-1447*	SRFB: Indian Creek-Yates	0	0
05-1547	SRFB: Rauth Coweeman	1	2
205-060a	OWEB: Bottle	10	1
205-060b	OWEB: NF Clark	1	1
206-095*	OWEB: Jordan	0	1
206-283a	OWEB: Johnson	6	7
206-357	OWEB: MF Malheur	1	1

*Excluded from the analysis due to lack of sampled plunge and/or scour pools in the control and impact reaches.

RESULTS

Bank Erosion, Riparian Structure, and Canopy Cover

There was a significant reduction in bank erosion each year following project implementation when comparing the difference between the control and impact reaches pre- and post-implementation (Table 4; Figure 5). Within the impact reaches, each project either had a decrease of bank erosion or bank erosion remained about the same when comparing Year 0 to

Year 10 (Figure 6). The trend analysis also found bank erosion to decrease significantly over time (P < 0.01).

Mean percent riparian structure remained relatively stable across the years (Figure 5) and was significantly different in Year 10 when compared to Year 0 (Table 4). The trend analysis also found a significant increase in riparian structure over time (P = 0.03). Of the ten projects analyzed, only one project (05-1547 Rauth) had a decrease in percent riparian structure in the impact reach from Year 0 compared to Year 10 relative to differences found in the control reach, while three projects had no change. Project (206-357 MF Malheur) had no riparian cover in Year 0 through Year 10 (Figure 6).

Finally, mean bank canopy cover fluctuated over the years of sampling (Figure 5). However, only Year 5 was significantly different when compared to Year 0 (Table 4). The trend analysis found no significant increase in bank canopy cover over time (P = 0.31). Only three projects out of ten (205-060a Bottle, 206-095 Jordan, and 206-283a Johnson) had increases in bank canopy cover in the impact reaches when comparing Year 0 to Year 10 (Figure 6). Overall, there was a general positive trend in bank canopy cover.

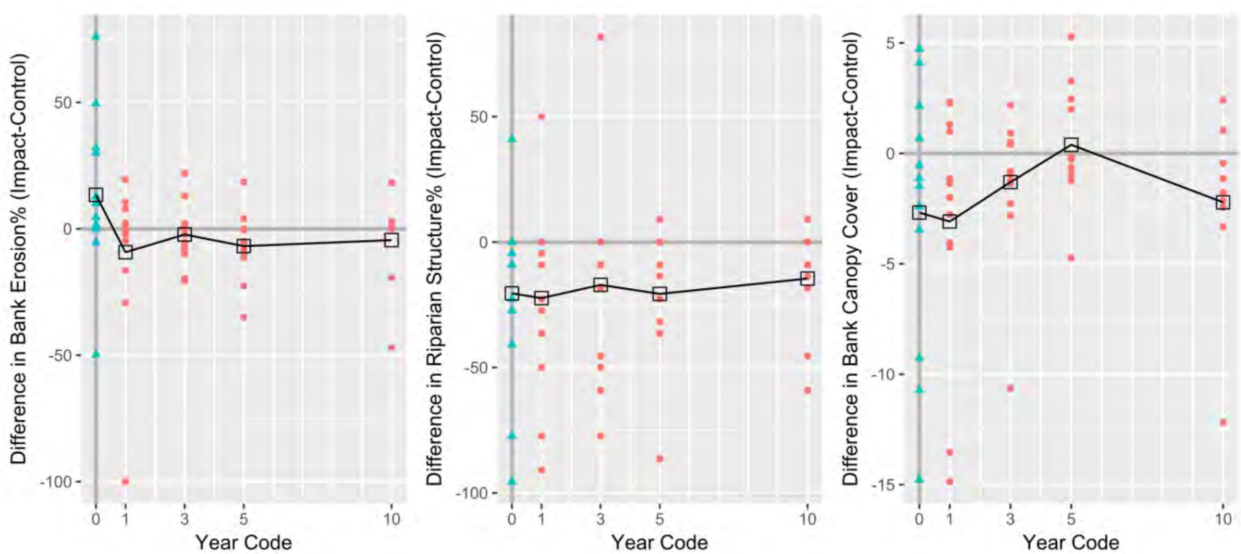


Figure 5. Mean difference for the three measured variables between the control and impact reaches for livestock exclusion projects. The blue triangles represent pre-treatment monitoring data (Year 0) while the red circles represent post-treatment monitoring data (Year > 0).

Table 4. Summary results for paired one-tailed *t*-test of the difference between the impact and control reaches for livestock exclusion projects. Bolded P-values indicate statistical significance at a 0.10 level.

Metric	Years Compared	Test	P-value
Bank Erosion (%)	0↔1	Paired Wilcoxon	**0.02**
	0↔3	Paired *t*-test	**0.04**
	0↔5	Paired *t*-test	**0.03**
	0↔10	Paired Wilcoxon	**0.01**

Metric	Years Compared	Test	P-value
Riparian Vegetation Structure (%)	0↔1	Paired *t*-test	0.81
	0↔3	Paired *t*-test	0.28
	0↔5	Paired Wilcoxon	0.82
	0↔10	Paired Wilcoxon	**0.04**
Bank Canopy Cover	0↔1	Paired Wilcoxon	0.81
	0↔3	Paired Wilcoxon	0.45
	0↔5	Paired *t*-test	**0.03**
	0↔10	Paired Wilcoxon	0.50

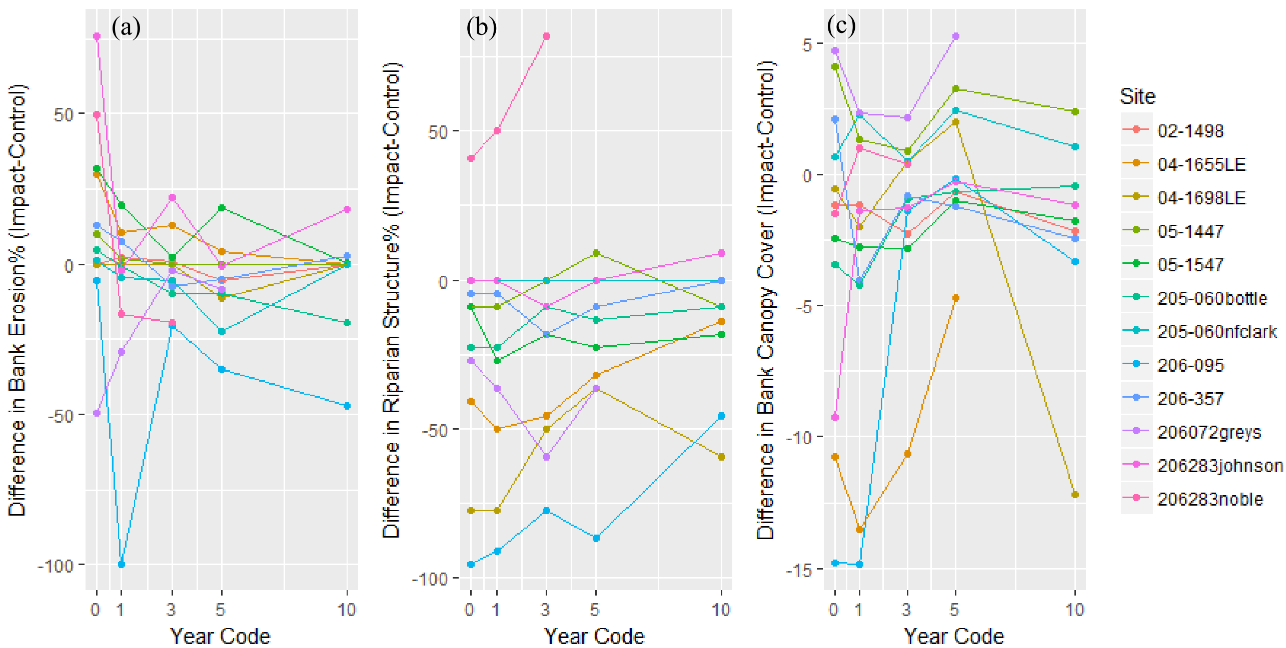


Figure 6. Difference between impact and control sites for bank erosion (a), canopy cover (b), and riparian structure (c) across all years sampled for each project.

Pool Tail Fines

In 2017, the percentage of fine sediment in the pool tails of the impact and control reaches was not significantly different for sediments less than 2 mm (P = 0.06; Figure 7) and for sediments less than 6 mm (P = 0.054; Figure 7). However, the mean percentage of pool tail fines was lower in all impact reaches than in control reaches.

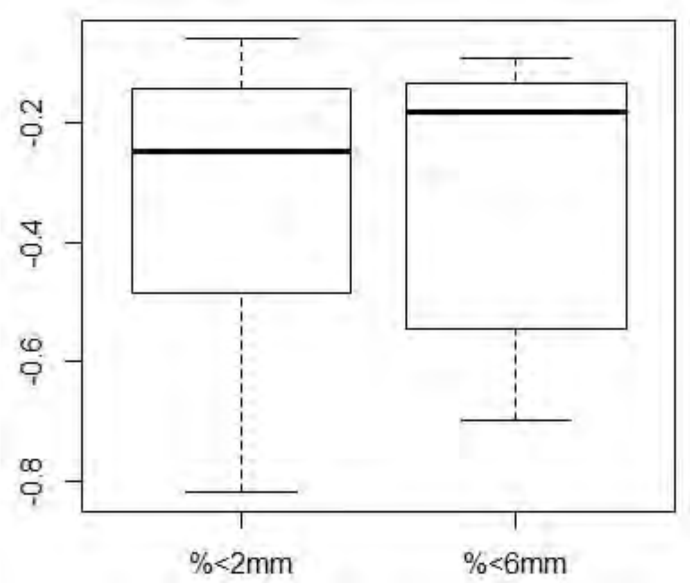


Figure 7. Difference in percent pool tail fines between the impact and control reaches in year 10 for sediments less than 2mm (left) and sediments less than 6mm (right) across all projects analyzed.

Additional Analysis – Mixed Effects BACI Model

Results from the linear mixed-effect model for bank erosion show a significant BACI interaction (P = 0.03; Table 5), with good model fit (Figure 8). These results indicate that there was a significant difference in bank erosion at impact sites after implementation of the exclusion fencing.

Results from the linear mixed-effect model for riparian structure do not show a significant BACI interaction (P = 0.29; Table 6), with good model fit (Figure 9). These results indicate that there was a significant difference between treatments and controls (P < 0.01), but no difference before or after implementation of livestock exclusion.

The mixed-effects model for bank canopy cover could not be assessed because the data was not normally distributed. No standard transformations of the response variable produced a model with normally distributed residuals.

Table 5. Fixed effect results from the BACI analysis on bank erosion. Bolded P-values indicate statistical significance.

Parameter	Estimate	Std. Error	DF	T-value	P-value
(Intercept)	2.9775	0.9271	14.3600	3.212	**0.01**
CI:i	-0.5276	0.4779	72.1900	-1.104	0.27
BA:b	-0.2796	1.1169	48.0500	-0.250	0.80
CI:i*BA:a	2.3561	1.0290	72.1900	2.290	**0.03**

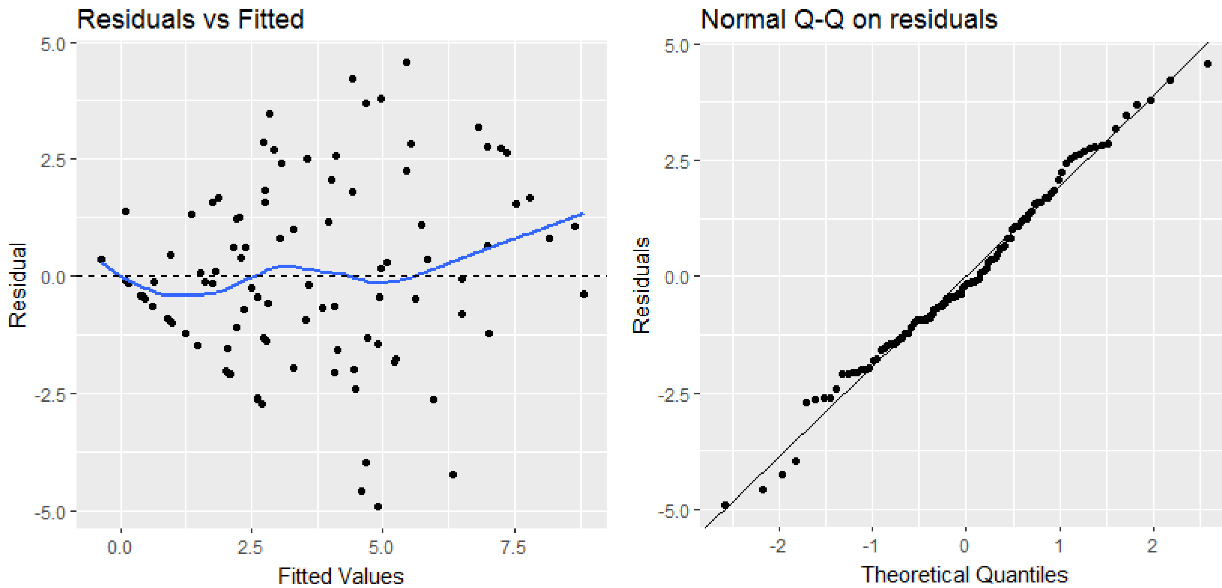


Figure 8. Residual and normal quantile plots for the mixed effect BACI model for bank erosion.

Table 6. Fixed effect results from the BACI analysis on riparian structure. Bolded P-values indicate statistical significance.

Parameter	Estimate	Std. Error	DF	T-value	P-value
(Intercept)	76.247	11.800	9.68	6.461	< **0.01**
CI:i	-21.138	4.087	88.99	-5.172	< **0.01**
BA:b	1.115	6.239	89.01	0.179	0.86
CI:i*BA:a	-9.444	8.800	99.99	-1.073	0.29

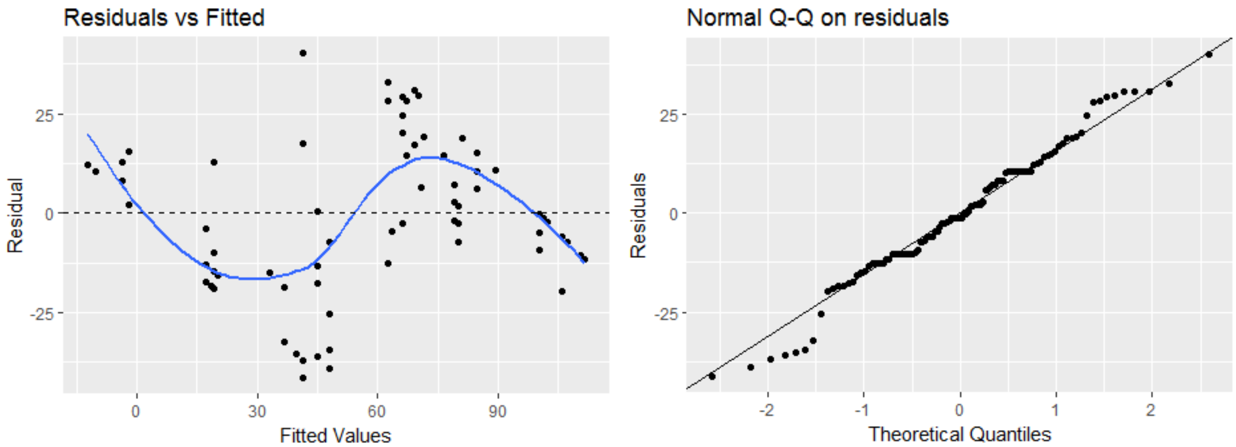


Figure 9. Residual and normal quantile plots for the mixed effect BACI model for riparian structure.

Livestock Fencing and Fencing Assessment

In each year, except for Year 0, there was at least one project with fencing that was not intact and/or functioning. Projects could have intact fencing and not be functioning if there was a gate open or if fences were in the lay down position, as was seen at several project locations. Over the ten years of post-implementation monitoring, there were several projects that had problems with fencing and showed signs of cattle present within the exclusion area (Table 7).

Table 7. Number of projects out of ten projects monitored through Year 10 with fencing not functioning as intended and signs of livestock.

Exclusion Assessment	Year 1	Year 3	Year 5	Year 10
Fencing Not Intact and/or Not Functioning as Intended	0	1	4	4
Signs of Livestock	1	3	4	4

In Year 5, two of the four non-functioning project exclusions were due to fence failure; a tree had fallen on a portion of the fence (205-060a Bottle) and a part of the fence was washed away by an eroding bank (206-357 MF Malheur). The other two projects had either an open gate (206-283a Johnson) or the project was not completed because the landowner had no livestock on the property (02-1498 Abernathy). Though some sites had what looked like intact and functioning fences, there were still signs of cattle within the exclusion area (Table 8). This was seen in Year 3 of monitoring, which had more sites with signs of livestock than non-functioning fencing. It was concluded that livestock were likely entering the site from upstream of the exclosures. Projects 206-095 Jordan and 206-283a Johnson also had fencing found in the control reach, which therefore excluded cattle from the stream.

Table 8. Percent of total reach length where evidence of cattle presence was observed.

		Percent of reach	
Site ID	Site Name	Impact	Control
05-1447	Indian Yates	0.0	0.0
205-060a	NF Clark	18.2	45.5
205-060b	Bottle	72.7	54.5
206-283a	Johnson	0.0	0.0
206-095	Jordan	63.6	0.0
05-1547	Rauth Coweeman	0.0	0.0
04-1698	Vance	0.0	0.0
206-357	Malheur	0.0	16.6

DISCUSSION

A total of ten livestock exclusion projects were sampled over the entire post-project monitoring schedule. Results suggest projects are successfully reducing bank erosion and increasing riparian structure by Year 10. However, projects are not improving canopy cover or reducing fine sediments. Our results for bank stability and riparian structure are consistent with previous studies on the recovery of physical habitat following livestock exclusion. In the Pacific Northwest and beyond, livestock exclusion has been shown to increase bank stability (Platts

1991; Kauffman et al. 1997; Medina et al. 2005; Roni et al. 2008; O'Neal et al. 2016), and also to increase riparian vegetation (Sarr 2002; Archibald 2015; Batchelor et al. 2015). Additionally, bank erosion for OWEB-SRFB livestock exclusion projects decreased and riparian structure increased, on average, by more than 20% from Year 0 to Year 10. Thus, based on the Crawford (2011) management targets, livestock exclusion projects were meeting minimum management success targets for bank erosion and riparian structure, but not for any other metrics.

Though several studies demonstrate that livestock exclusion allows for riparian conditions to recover relatively rapidly (Platts 1991; Roni et al. 2002; Sarr 2002; Archibald 2015), we detected no significant change in canopy cover, except for in Year 5. There was an overall positive trend in canopy cover, suggesting that, with time and continued livestock exclusion, this metric may recover and the probability of detecting a statistically significant difference could increase. Our results may have differed from other studies due to natural environmental variables such as soil compaction (Kauffman et al. 1997), connection to a seed source (Katz et al. 2007), and channel incision (Sarr 2002), but could also be related to design issues including: limitations of sampling methods, selection of poorly matched control and impact reaches, inadequate stratification across ecoregions, or failure to adequately exclude livestock. Percent riparian structure had a gradual response, with statistical significance only in Year 10 with the mean difference analysis, though no significant difference was detected with the more robust mixed effects model.

The inconsistent response in riparian structure may have been due to some limitations of the monitoring protocol. Riparian structure used in OWEB-SRFB monitoring differed from other studies monitoring the response of riparian vegetation to cattle exclusion. Other studies focused on densities of all plant species, plant height, leaf litter accumulation, amounts of bare substrate, and compositional changes (Sarr 2002). Though ground cover (one of the three layers of riparian structure measured in this study) was evaluated in this monitoring program, the riparian structure metric requires improvement in all riparian levels (canopy >5 m, understory 0.5-5 m, and ground cover <0.5 m) to be successful. Natural climatic and other environmental conditions may preclude the growth of vegetation in certain levels (e.g., canopy level), which would result in a conclusion of no riparian improvement even if the riparian area returned to a more natural state. Riparian vegetation structure may not have had a rapid response or improvement may not even be possible at some sites as vegetation must first establish and then grow into all the riparian levels. For example, site 206-357 MF Malheur in eastern Oregon will likely not grow a dense upper canopy level (>5 m) due to the deeply incised channel, geographic area, and arid climate. Rather, studies that focused on bare soil and overall riparian area at any height measured significant changes in vegetation and plant community development following livestock exclusion (Schulz and Leininger 1990; Robertson and Rowling 2000; Sarr 2002; Hosten and Whitridge 2007; Ranganath et al. 2009). Additionally, if livestock exclusion projects were paired with planting within the design exclosure, one may expect to see more rapid changes in canopy cover, riparian structure, and percent fines than expected with passive riparian habitat recovery.

Similar to our fine sediment results, Ranganath et al. (2009) found no significant difference in the percent fines between grazed and exclusion reaches. However, other studies have found grazed sites to have high amounts fine sediments when compared to ungrazed sites (Platts 1991; Herbst et al. 2012). Even with decreased bank erosion, instream habitat may be confounded by site location within a watershed, upstream processes, underlying geology, and hydrology that can affect sediment supply (Medina et al. 2005; Allan and Castillo 2007; Roni et al. 2008; Roni et al.

2013a). Fine sediment data was collected only in Year 10 of monitoring and only five sites were included in the analysis due to the low frequency of qualifying pools in both impact and control reaches. Thus, we may not have detected a difference due to low sample size, lack of pre-project data, or control and impact reach inconsistencies. Results may improve with more years of data collection and as banks continue to stabilize with time. However, it would be worth revisiting the protocol for measuring fine sediment and other in-channel features before conducting additional monitoring. Livestock exclusion leads to reduced fine sediments, typically through reduced bank erosion, but also decreased bankfull width, increased depth, and other channel features which should be part of any livestock exclusion effectiveness monitoring.

Using a BACI monitoring approach helps to account for environmental variability and temporal trends found in both impact and control reaches to better discern livestock exclusion effects from natural variability (Underwood 1992; Roni et al. 2005). However, selection of appropriate controls is critical to increase the probability of detecting a restoration response if one exists (Roni et al. 2013a). Finding sites with similar grazing strategies and physical features to serve as control reaches can be quite difficult (Medina et al. 2005). If control and impact reaches are not selected properly and variation is not accounted for in monitoring, there is a risk that the impact (livestock exclusion) might be masked by underlying natural variation (Underwood 1992; Downes et al. 2002; Roni et al. 2005). A control reach should be selected to be as similar as possible in all respects to the impact reach and considered beyond the influence of the treatment (Downes et al. 2002). The underlying assumption is that the impact reach would have behaved approximately the same as the control reach in the absence of the exclusion (Underwood 1992). There were several OWEB-SRFB sites that had issues regarding the control reach selection, which could have ultimately masked significant results. There were two sites (206-095 Jordan and 206-283a Johnson) where the control reach had fencing to exclude livestock, and there were several impact and control reaches that were not impacted by livestock prior to the start of monitoring. This also suggested the need to ensure that control reaches are not treated and remain control reaches throughout the monitoring period. Additionally, control reaches for two sites (04-1655 Hoy and 206-095 Jordan) were selected in a forested area, while the impact reach was not forested. While the BACI design accounts for some of these differences, the inconsistencies among controls and treatments may have increased variability among sites and reduced the ability to detect changes due to livestock exclusion.

To assess environmental responses to livestock exclusions, the exclusions must be present and functioning. Implementation monitoring should be included in future design and monitoring programs and executed alongside any effectiveness monitoring efforts. At 40% of the projects sampled in Year 10, there was evidence of livestock within the exclosure area, suggesting projects were not effective at excluding livestock. Many projects had intact fencing, but there were several instances where gates were left open, the fence was in the lay down position, or cattle were accessing the reach from upstream or downstream of the project location. This was also apparent and reported in previous years (Tetra Tech 2012). Maintenance and repair of damaged fencing is important to continue to exclude livestock (Medina et al. 2005; Roni et al. 2013b), though it appears in several instances it is just the general function of the fencing that needs to be assessed and properly used following project implementation. In absence of detailed effectiveness monitoring of riparian and instream habitat, simple implementation monitoring may be more appropriate for many livestock exclusions projects.

Stratifying sites by geographic or climatic region, channel size, or other factors may help account for differences among livestock exclusion sites. The geographic extent of sites in this program extended from northern Washington to Central Oregon and east and west of the Cascade Mountains, where mean annual rainfall varied from 86 to 267 cm/yr. Vegetation type, growing season characteristics, and regional weather patterns varied across this extent and could influence site-specific results. Similarly, land use at the sites varied considerably. For example, site 206-283a Johnson was historically grazed by a herd of cattle, but site 05-1547 Rauth had a couple of horses that periodically grazed the area. These differences in site use could also influence results through the level of impact the practices had on the site over time. Stratifying by eco-region or site use could help alleviate some of the influences these factors may have on the results and our understanding of the effectiveness of livestock exclusions. Stratifying sites would, however, require a larger sample size and we were not able to stratify sites post-hoc given the small number of sites and broad geographic extent.

We analyzed livestock exclusion data using three different statistical methods including: 1) a mean difference using paired *t*-tests or a non-parametric equivalent (Wilcoxon test), 2) a trend analysis using a *t*-test on the slopes of individual sites 3) a mixed-effects BACI model. The first two tests were required as part of the livestock exclusion protocol while the mixed-effects BACI model is a more standard approach for analyzing BACI data. All three of these analyses produced similar, but not necessarily identical results and all have strengths and weakness (Table 9). However, in the future, it would be more straightforward to use one statistical test. The paired *t*-test looks only at individual years post-treatment (1, 3, 5, and 10) compared to Year 0.

Table 9. Summary results for the three analysis methods (mean difference, trend, and BACI analyses) for livestock exclusion projects. Bolded P-values indicate statistical significance at a 0.10 level. n/a = metric not run through analysis.

Metric	Mean Difference (Year 10)	Trend	BACI
Bank Erosion (%)	**0.01**	**0.003**	**0.03**
Riparian Vegetation Structure (%)	**0.04**	**0.03**	0.29
Bank Canopy Cover	0.5	0.31	n/a

The analysis is structured in this way largely because there is only one year of pre-project data and the response to restoration (livestock exclusion) is expected to change over time. Additionally, taking an average of all post-years and comparing it to Year 0 would mask temporal changes (improvements with time). The trend analysis seems attractive because it can provide insight into temporal changes. However, with only one year of pre-project data it is highly dependent upon that one year of data for setting the trend. Moreover, while calculating the slope of each individual project and then running a *t*-test on the slopes is not incorrect, it is an unorthodox approach for examining trends in data that we have not seen used before. The mixed-effects BACI model would appear to be the ideal approach, except that there was only one year of pre-project data. This model works best with a more balanced design and would be most appropriate if there were at least two years of pre-project data (Smokorowski and Randall 2017). Given the design used by the SRFB and OWEB, we have the most confidence in the paired *t*-test analysis. The *t*-test is a simple analysis, easily understood by managers, and robust to minor violations of assumptions of normality (Zar 2009). Moreover, we feel *t*-tests are the most appropriate given that there is only one year of pre-project data. Thus, the final analysis for the monitoring design used should focus on examining the response in Year 10 compared to Year 0, using a simple paired *t*-test.

The lack of significant differences between the impact and control reaches in this study does not mean that livestock exclusion has not yielded benefits. The exclusion has been effective at decreasing active bank erosion, which overall can yield benefits to instream habitat and to the establishment and growth of riparian vegetation. Overall trends were positive for riparian structure and canopy cover, which may continue to increase with time and continued exclusion. Moving forward, it is important that fencing is maintained and properly used to allow the riparian area and stream habitat to fully recover. Furthermore, our completion of the final year of data collection and analysis of all years of data suggests several recommendations for future effectiveness monitoring of livestock exclusions projects. These include: 1) more rigorous selection of impact and control reaches, 2) improved methods for monitoring riparian vegetation and shade, 3) stratification of sites by ecoregion, and 4) monitoring additional instream morphological and biological metrics. Most studies on livestock exclusions show rapid recovery if livestock are actually excluded (Dobkin et al. 1999; Platts and Nelson 1985). This suggests that long-term implementation monitoring is needed for livestock sites to ensure fencing is functioning properly. Finally, the pressing need for livestock exclusion effectiveness monitoring is data on fish and other aquatic biota, as few livestock exclusion studies have shown a direct connection and positive response for fish, macroinvertebrates, and other aquatic biota (Rinne 1999; Medina et al. 2005; Roni et al. 2014).

REFERENCES

Allan, J. D., and M. M. Castillo. 2007. Stream ecology: structure and function of running waters, 2nd edition. Springer, Netherlands.

Archibald, M. 2015. The effectiveness of livestock exclosures in the restoration of steelhead (*Oncorhynchus mykiss*) habitat and populations in the John Day River basin of eastern Oregon. Master's Thesis. Utah State University, Logan.

Batchelor, J. L., W. J. Ripple, T. M. Wilson, and L. E. Painter. 2015. Restoration of riparian areas following the removal of cattle in the northwestern Great Basin. Environmental Management 55(4):930–942.

Baxter, C. V., K. D. Fausch, and W. K. Saunders. 2005. Tangled webs: reciprocal flows of invertebrate prey link streams and riparian zones. Freshwater Biology 50:201–220.

Bayley, P., and H. Li. 2008. Stream fish responses to grazing exclosures. North American Journal of Fisheries Management 28:135–147.

Belsky, A. J., A. Matzke, and S. Uselman. 1999. Survey of livestock influences on stream and riparian ecosystems in the western United States. Journal of Soil and Water Conservation 54:419–431.

Bernhardt, E. S., M. A. Palmer, J. D. Allan, G. Alexander, K. Barnas, S. Brooks, J. Carr, S. Clayton, C. Dahm, J. Follstad-Shah, D. Galat, S. Gloss, P. Goodwin, D. Hart, B. Hassett, R. Jenkinson, S. Katz, G. M. Kondolf, P. S. Lake, R. Lave, J. L. Meyer, T. K. O'Donnell, L. Pagano, B. Powell, and E. Sudduth. 2005. Synthesizing U.S. river restoration efforts. Science (Washington) 308(5722):636–637.

Clary, W. P. 1999. Stream channel and vegetation responses to late spring cattle grazing. Journal of Range Management 52:218–227.

Crawford, B.A. 2011. Protocol for monitoring the effectiveness of livestock exclusion projects. Washington Salmon Recovery Funding Board. Olympia, WA. Available at URL: http://hws.ekosystem.us/content/MC-4_Protocol_for_Effectiveness_Monitoring_of_Livestock_Exclusion_Projects_2011.pdf.

Dobkin, D. S., A. C. Rich, and W. H. Pyle. 1999. Habitat and avifaunal recovery from livestock grazing in a riparian meadow system of the northwestern great basin. Conservation Biology 12:209–221.

Downes, B. J., L. A. Barmuta, P. G. Fairweather, D. P. Faith, M. J. Keough, P. S. Lake, B. D. Mapstone, and G. P. Quinn. 2002. Monitoring ecological impacts: concepts and practice in flowing waters. Cambridge University Press, Cambridge, UK.

Edwards, E. D., and A. D. Huryn. 1996. Effect of riparian land use on contributions of terrestrial invertebrates to streams. Hydrobiologia 337:151–159.

Green, R. H. 1979. Sampling design and statistical methods for environmental biologists. John-Wiley, New York.

Herbst, D. B., M. T. Bogan, S. K. Roll, and H. D. Safford. 2012. Effects of livestock exclusion on in-stream habitat and benthic invertebrate assemblages in montane streams. Freshwater Biology 57:204–217.

Hosten, P. E., and H. Whitridge. 2007. Vegetation changes associated with livestock exclusion from riparian areas on the Dead Indian Plateau of southwestern Oregon. U.S. Department of the Interior, Bureau of Land Management, Medford District.

Katz, S. L., K. Barnas, R. Hicks, J. Cowen, and R. Jenkinson. 2007. Freshwater habitat restoration actions in the Pacific Northwest: a decade's investment in habitat improvement. Restoration Ecology 15:494–505.

Kauffman, J. B., R. L. Beschta, N. Orting, and D. Lytjen. 1997. An ecological perspective of riparian and stream restoration in the western United States. Fisheries 22(5):12–24.

Lazorchak, J. M., D. J. Klemm, and D. V. Peck, editors. 1998. Environmental monitoring and assessment program – surface waters: field operations and methods for measuring the ecological condition of wadeable streams. EPA/620/R-94/004F. U.S. Environmental Protection Agency, Washington, D.C.

Magilligan, F. J., and P. F. McDowell. 1997. Stream channel adjustments following elimination of cattle grazing. Journal of the American Water Resources Association 33:867–878.

Medina, A. L., J. N. Rinne, and P. Roni. 2005. Riparian restoration through grazing management: considerations for monitoring project effectiveness. Pages 97–126 *in* P. Roni, editor. Monitoring stream and watershed restoration. American Fisheries Society, Bethesda, Maryland.

Monitoring Oversight Committee. 2002. The Washington comprehensive monitoring strategy and action plan for watershed health and salmon recovery – Volume 2. Available at URL: https://www.rco.wa.gov/documents/monitoring/Comprehensive_Strategy_Vol_2.pdf.

Moore, K. M. S., and S. V. Gregory. 1988. Summer habitat utilization and ecology of cutthroat trout fry (*Salmo clarki*) in Cascade Mountain streams. Canadian Journal of Fisheries and Aquatic Sciences 45:1921–1930.

Moore, K., K. Jones, and J. Dambacher. 2008. Methods for stream habitat surveys: aquatic inventories project. Information Report 2007-01. Oregon Department of Fish and Wildlife, Corvallis.

Mulvey, M., L. Caton, and R. Hafele. 1992. Oregon nonpoint source monitoring protocols and stream bioassessments field manual for macroinvertebrates and habitat assessment. Oregon Department of Environmental Quality, Laboratory Biomonitoring Section, Portland.

NOAA. 2015. Pacific Coastal Salmon Recovery Fund FY2000-2013 Report to Congress. National Marine Fisheries Service, Portland, Oregon.

Nakano, S., H. Miyasaka, and N. Kuhara. 1999. Terrestrial aquatic linkages: riparian arthropod inputs alter trophic cascades in a stream food web. Ecology 80:2435–2441.

OCSRI (Oregon Coastal Salmon Restoration Initiative). 1997. The Oregon plan: restoring an Oregon legacy through cooperative efforts. Submitted to National Marine Fisheries Service. Available at URL: http://ir.library.oregonstate.edu/concern/defaults/tm70n0754.

OWEB (Oregon Watershed Enhancement Board). 2003. Monitoring strategy: Oregon plan for salmon and watersheds. Salem, Oregon. Available at URL: http://www.oregon.gov/OWEB/docs/pubs/monitoringstrategy.pdf.

O'Neal, J. S., P. Roni, B. Crawford, A. Ritchie, and A. Shelly. 2016. Comparing stream restoration project effectiveness using a programmatic evaluation of salmonid habitat and fish response. North American Journal of Fisheries Management 36:681–703.

Peck, D. V., J. M. Lazorchak, and D. J. Klemm. 2003. Environmental monitoring and assessment program – surface waters: Western pilot study operations manual for wadeable streams. U.S. Environmental Protection Agency, Corvallis, Oregon.

Platts, W. 1991. Livestock grazing. Pages 389–423 *in* W. R. Meehan, editor. The influence of forest and rangeland management on salmonids and their habitat. American Fisheries Society, Special Publication 19, Bethesda, Maryland.

Platts, W. S., and R. F. Nelson. 1985. Stream habitat and fisheries response to livestock grazing and instream improvement structures, Big Creek, Utah. Journal of Soil and Water Conservation 40:374–379.

Quinn, T. P. 2005. The behavior and ecology of Pacific salmon and trout. American Fisheries Society, Bethesda, Maryland.

Ranganath, S. C., W. C. Hession, and T. M. Wynn. 2009. Livestock exclusion influences on riparian vegetation, channel morphology, and benthic macroinvertebrate assemblages. Journal of Soil and Water Conservation 64:33–42.

Rhodes, H. A., and W. A. Hubert. 1991. Submerged undercut banks as macroinvertebrate habitat in a subalpine meadow stream. Hydrobiologia 213:149–153.

Rinne, J. N. 1999. Fish and grazing relationships: the facts and some pleas. Fisheries 24(8):12–21.

Robertson, A. I., and R. W. Rowling. 2000. Effects of livestock on riparian zone vegetation in an Australian dryland river. Regulated Rivers: Research & Management 16:527–541.

Roni, P., T. J. Beechie, R. E. Bilby, F. E. Leonetti, M. M. Pollock, and G. R. Pess. 2002. A review of stream restoration techniques and a hierarchical strategy for prioritizing restoration in Pacific Northwest watersheds. North American Journal of Fisheries Management 22:1–20.

Roni, P., T. Beechie, G. Pess and K. Hanson. 2014. Fish-habitat relationships and effectiveness of habitat restoration. NOAA Technical Memorandum NMFS-NWFSC-127.

Roni, P., K. Hanson, and T. J. Beechie. 2008. Global review of the physical and biological effectiveness of stream habitat restoration techniques. North American Journal of Fisheries Management 28:856–890.

Roni, P., M. C. Liermann, C. Jordan, and E. A. Steel. 2005. Steps for designing a monitoring and evaluation program for aquatic restoration. Pages 13-34 *in* P. Roni, editor. Monitoring stream and watershed restoration. American Fisheries Society, Bethesda, Maryland.

Roni, P., M. Liermann, S. Muhar, and S. Schmutz. 2013a. Monitoring and evaluation of restoration actions. Pages 254-279 *in* P. Roni and T. Beechie, editors. Stream and watershed restoration: a guide to restoring riverine processes and habitats. Wiley-Blackwell, Oxford, UK.

Roni, P., G. Pess, K. Hanson, and M. Pearsons. 2013b. Selecting appropriate stream and watershed restoration techniques. Pages 144-188 *in* P. Roni and T. Beechie, editors. Stream and watershed restoration: a guide to restoring riverine processes and habitats. Wiley-Blackwell, Oxford, UK.

Sarr, D. A. 2002. Riparian livestock exclosure research in the western United States: a critique and some recommendations. Environmental Management 30:516–526.

Schulz, T. T., and W. C. Leininger. 1990. Differences in riparian vegetation structure between grazed areas and exclosures. Journal of Range Management 43:295–299.

Sievers, M., R. Hale, and J. R. Morrongiello. 2017. Do trout respond to riparian change? A meta-analysis with implications for restoration management. Freshwater Biology 62:445–457.

Smokorowski, K., and R. Randall. 2017. Cautions on using the Before-After-Control-Impact design in environmental effects monitoring programs. FACETS 2(1):212-232.

Stewart-Oaten, A., W. W. Murdoch, and K. R. Parker. 1986. Environmental impact assessment: "pseudo-replication in time?" Ecology 67:929–940.

Tetra Tech. 2012. OWEB-SRFB coordinated monitoring program for livestock exclusion projects: 2012 Annual Progress Report. Bothell, Washington. Available at URL: http://www.oregon.gov/OWEB/MONITOR/docs/LivestockExclusion2012AnnualReport.pdf.

Tetra Tech. 2016. 2015 annual monitoring report: project effectiveness monitoring program. Bothell, Washington. Available at URL: http://www.rco.wa.gov/documents/monitoring/2015AnnualProgressReport.pdf.

Underwood, A. J. 1992. Beyond BACI: experimental designs for detecting human environmental impacts on temporal variations in natural populations. Journal of Experimental Marine Biology and Ecology 161:145–178.

Walling, D. E., and B. W. Webb. 1992. Water quality I. Physical characteristics. Volume 1. Pages 48-72 *in* P. Calow and G. E. Petts, editors. The rivers handbook: hydrological and ecological principles. Blackwell Scientific Publications, Oxford, UK.

Waters, T. F. 1995. Sediment in streams: sources, biological effects, and control. American Fisheries Society, Bethesda, Maryland.

Zar, J. H. 2009. Biostatistical analysis. Prentice Hall, Upper Saddle River, New Jersey.

APPENDIX A: PROJECT SPECIFIC SUMMARIES

In the following pages, we provide project specific summaries for each of the sites sampled in 2017. These are updates of summaries provided for Year 5 reporting and include an overview of each site (introduction), summary of sampling methods, results, and discussion. Also included are: a table summarizing data for all years, photos of treatments and controls, and other relevant photos. Because there are limited data for each project, results are a description of trends and a qualitative interpretation of results rather than statistical analyses. Details on the sampling protocols and design of the larger study are provided in Crawford (2011).

04-1698 Vance Creek Riparian Planting and Fencing – SRFB

Introduction

Vance Creek supports Cutthroat Trout *Oncorhynchus clarki*, Coho Salmon *O. kisutch*, and possibly Chum Salmon *O. keta*, as well as other aquatic life. The creek was historically manipulated to accommodate agriculture, mining, and residential development. Despite these actions, Coho Salmon and Cutthroat Trout continue to use the stream in limited numbers. Two primary limiting factors affecting the habitat are high sediment input and lack of riparian cover. With over half of the length of the stream used for salmonid spawning and rearing, the objectives of the project were to protect and restore natural streamside vegetation, improve stream temperature, reduce erosion, improve filtration, and recruit large woody debris.

Methods

The project is located on Vance Creek (WRIA 22) in Grays Harbor County, near the city of Elma, Washington in the Washington Coastal Salmon Recovery Region. Both the impact and control reaches measured 150 meters in length. Lonnie Crumley is the primary contact, while the Chehalis Basin Fisheries Task Force sponsored this project. The Vance Creek Riparian Planting and Fencing Project was monitored according to the Washington Salmon Recovery Funding Board Protocol for Monitoring the Effectiveness of Livestock Exclusion Projects (Crawford 2011). Baseline monitoring of livestock exclusion projects was conducted in Year 0, prior to implementation of the project, to capture pre-existing conditions at both the control and impact reaches. Following implementation, the same sites were surveyed in Years 1, 3, 5, and 10 to assess changes that result from the project. Use of a control reach helps discern between changes resulting from project actions and changes due to natural causes. At the control and impact reaches, riparian conditions were assessed for vegetation structure, canopy cover density, and percent of actively eroding banks. During 2017 surveys, the relative quantity of fine sediments in pool tails were assessed for the first 10 plunge or scour pools encountered in the channel. The fencing in the impact reach was evaluated each year to determine if it was intact (not fallen over, no holes, etc.) and functioning (closed gates, etc.) to exclude livestock from the stream.

Results

Canopy cover density in the impact reach was similar to the control reach and even surpassed it in Years 3 and 5. However, there was a large decrease in canopy cover density in Year 10. Bank erosion was reduced to zero percent in both reaches and remained at zero in Year 10. Riparian structure stayed relatively constant in the control reach; both reaches experienced a decrease in structure at Year 5 but then increased again during Year 10. There were no pools to record fines in during Year 10. Fencing remained intact and functioning throughout all ten years of monitoring.

Discussion

Both the impact and control reaches were influenced by beaver activity, creating dam pool habitat and slow water flow through the entire 150 m reaches. There was a beaver dam constructed just downstream of the impact reach and another about 45 m upstream of the bottom of the impact reach. Upstream of the beaver dam in the impact reach, there was channel braiding and thick grass vegetation, creating difficult survey conditions. These changing channel conditions could impact the location that riparian structure and canopy cover density were being measured from year to year, leading to the decrease in density in Year 10 of the impact reach. Overall, the project has been effective at excluding livestock from the channel. However, the growth of reed canary grass is affecting the riparian vegetation and overall success of the project.

Table A-1. Summary statistics for pre- and post-implementation monitoring at 04-1698 Vance Creek. Con = control reach; Imp = impact reach; PTF = pool tail fines.

	Year 0 10/4/06		Year 1 9/11/07		Year 3 6/15/09		Year 5 6/7/11		Year 10 6/12/17	
Variable	**Con**	**Imp**	**Con**	**Imp**	**Con**	**Imp**	**Con**	**Imp**	**Con**	**Imp**
Canopy Cover (1-17)	16.7	15.9	15.7	13.7	16.5	17.0	13.1	15.1	16.0	3.8
Riparian Structure (%)	96	18	86	9	96	46	64	27	91	32
Bank Erosion (%)	40	70	0	0	0	0	11	0	0	0
PTF <2 mm (%)	---	---	---	---	---	---	---	---	N/A	N/A
PTF <6 mm (%)	---	---	---	---	---	---	---	---	N/A	N/A
Fencing Intact	N/A	N/A	N/A	Yes	N/A	Yes	N/A	Yes	N/A	Yes


Control reach during Year 10 of monitoring.


Impact reach during Year 10 of monitoring.


Fencing, looking downstream to upstream on river right in Year 10 of monitoring.


Beaver dam within the impact reach during Year 10 of monitoring.

05-1447 Indian Creek Yates Restoration Project – SRFB

Introduction

The Indian Creek Yates Restoration Project addresses protection of high priority habitats in WRIA 62 where Bull Trout *Salvelinus confluentus* observations have occurred in recent years. Fish habitat in the project reach has been impacted by an impassable culvert and livestock grazing. Historically, at the upstream end of the barrier, splash boards were placed to create a small pond. Silt deposited and filled the channel for approximately 60 m upstream of the culvert. The riparian area was used for grazing horses, which trampled the stream banks and riparian area, limiting the recruitment of riparian shrubs. The Indian Creek Yates Restoration Project was designed to address these issues and improve fish habitat and connectivity within approximately 965 m of the creek. This project replaced an undersized culvert with a small bridge, dredged the upstream channel section and stabilized the silt deposits by seeding, and constructed a riparian fence to promote bank stabilization and re-vegetation. Implementation of this project was intended to restore connectivity throughout Indian Creek, as no other barriers are known to exist.

Methods

The project area is located on Indian Creek, a tributary to the Pend Oreille River, near the community of Furport, Washington in Pend Oreille County (WRIA 62) in the Northeast Washington Salmon Recovery Region. The impact reach was 150 m in length, while the control reach was 205 m long. The project was sponsored by the Kalispel Indian Tribe. The Indian Creek Yates Restoration Project was monitored according to the Washington Salmon Recovery Funding Board Protocol for Monitoring the Effectiveness of Livestock Exclusion Projects (Crawford 2011). Baseline monitoring of livestock exclusion projects was conducted in Year 0, prior to implementation of the project, to capture pre-existing conditions at both the control and impact reaches. Following implementation, the same sites were surveyed in Years 1, 3, 5, and 10 to assess changes that result from the project. Use of a control reach helps discern between changes resulting from project actions and changes due to natural causes. At the control and impact reaches, riparian conditions were assessed for vegetation structure, canopy cover density, and percent of actively eroding banks. During 2017 surveys, the relative quantity of fine sediments in pool tails were assessed for the first 10 plunge or scour pools encountered in the channel. The fencing in the impact reach was evaluated each year to determine if it was intact (not fallen over, no holes, etc.) and functioning (closed gates, etc.) to exclude livestock from the stream.

Results

Throughout the monitoring process all variables remained relatively stable. There was very little erosion measured in the impact reach prior to project implementation and no erosion in the control reach throughout the ten years of sampling. Riparian vegetation structure remained high throughout all years of sampling and canopy cover density was relatively stable over the years. There was no scour or plunge pools in either reach to record pool tail fines in Year 10. Fencing remained intact and functioning throughout all ten years of monitoring.

Discussion

Monitoring for this project was completed in 2017. The fencing in the impact reach excluded horses from the reach and there were no signs of cattle or other livestock within the exclosure during any years of monitoring. Canopy cover density and riparian structure were high in both reaches at the beginning of the surveys and remained that way throughout the surveys. Because values were already high in both reaches in Year 0, it was likely difficult to detect a change over the years. Bank erosion was reduced to zero in the impact reach, equal to erosion levels of the control. Areas in the impact reach that had been impacted by cattle or horses now seem to be recovering.

Table A-2. Summary statistics for pre- and post-implementation monitoring at 05-1447 Indian Creek Yates. Con = control reach; Imp = impact reach; PTF = pool tail fines.

	Year 0 5/30/06		**Year 1 8/20/07**		**Year 3 5/28/09**		**Year 5 6/1/11**		**Year 10 5/31/17**	
Variable	**Con**	**Imp**	**Con**	**Imp**	**Con**	**Imp**	**Con**	**Imp**	**Con**	**Imp**
Canopy Cover (1-17)	12.0	16.1	15.5	16.8	16.1	17.0	12.0	15.2	12.6	15.1
Riparian Structure (%)	100	91	100	91	100	100	86	96	100	91
Bank Erosion (%)	0	10	0	2	0	0	0	0	0	0
PTF <2 mm (%)	---	---	---	---	---	---	---	---	N/A	N/A
PTF <6 mm (%)	---	---	---	---	---	---	---	---	N/A	N/A
Fencing Intact	N/A	N/A	N/A	Yes	N/A	Yes	N/A	Yes	N/A	Yes

Control reach during Year 10 of monitoring.

Impact reach during Year 10 of monitoring.

River left bank in the impact reach viewed from mid-channel during Year 10 of monitoring.

River left bank in the control reach viewed from mid-channel during Year 0 of monitoring.

05-1547 Rauth Coweeman Tributary Restoration – SRFB

Introduction

The Coweeman River was identified as one of the most significant areas for salmon recovery among the Washington Cascade strata subbasins, based on fish population significance and realistic prospects for restoration. The Rauth Coweeman Tributary Restoration Project was intended to provide benefits to all life stages of Chinook Salmon *Oncorhynchus tshawytscha*, Coho Salmon *O. kisutch*, Steelhead Trout *O. mykiss*, Chum Salmon *O. keta*, and sea-run Cutthroat Trout *O. clarki*. This project encompassed the lower 600 m of an unnamed tributary to the Coweeman River. The project objectives were to restore natural streamside vegetation, improve stream temperature, reduce erosion, increase natural filtration, and recruit large woody debris.

With the help of the landowner and Toutle High School students, approximately 140 m of stream was fenced on the Rauth property to protect riparian plantings and stream banks from livestock. In addition to the livestock fencing, this project was designed to improve fish passage through barrier removal and provide access to 2.5 miles of habitat, restore channel cross-section, improve pool and riffle habitat through installation of large woody debris, and restore 2.25 acres of riparian habitat.

Methods

The project area is in Cowlitz County Washington within the Cowlitz River subbasin (WRIA 26). The project is located near the city of Kelso in the Lower Columbia Salmon Recovery Region. Both the impact and control reach were 146 m long. The Cowlitz Conservation District sponsored this project. The Rauth Coweeman Tributary Restoration Project was monitored according to the Washington Salmon Recovery Funding Board Protocol for Monitoring the Effectiveness of Livestock Exclusion Projects (Crawford 2011). Baseline monitoring of livestock exclusion projects was conducted in Year 0, prior to implementation of the project, to capture pre-existing conditions at both the control and impact reaches. Following implementation, the same sites are surveyed in Years 1, 3, 5, and 10 to assess changes that result from the project. Use of a control reach helps discern between changes resulting from project actions and changes due to natural causes. At the control and impact reaches, riparian conditions were assessed for vegetation structure, canopy cover density, and percent of actively eroding banks. During 2017 surveys, the relative quantity of fine sediments in pool tails were assessed for the first 10 plunge or scour pools encountered in the channel. The fencing in the impact reach was evaluated each year to determine if it was intact (not fallen over, no holes, etc.) and functioning (closed gates, etc.) to exclude livestock from the stream.

Results

Canopy cover density and riparian structure fluctuated slightly in each reach over the ten years of monitoring. Erosion in the control reach increased each year, but remained low. Erosion in the impact reach fluctuated between 19 and 33% over the years, but was ultimately less in Year 10 than Year 0. In both reaches, there was a low percentage of fine sediment, with less in the impact reach compared to the control. Fencing remained intact and functioning throughout the whole monitoring process.

Table A-3. Summary statistics for pre- and post-implementation monitoring at 05-1547 Rauth Coweeman. Con = control reach; Imp = impact reach; PTF = pool tail fines.

	Year 0 5/19/06		Year 1 10/12/07		Year 3 5/5/09		Year 5 5/3/11		Year 10 6/6/17	
Variable	**Con**	**Imp**	**Con**	**Imp**	**Con**	**Imp**	**Con**	**Imp**	**Con**	**Imp**
Canopy Cover (1-17)	17.0	14.6	16.6	13.9	16.6	13.8	16.5	15.5	16.1	14.4
Riparian Structure (%)	100	91	100	73	100	82	100	77	100	82
Bank Erosion (%)	1	33	2	21	5	7	12	30	18	19
PTF <2 mm (%)	---	---	---	---	---	---	---	---	14	0
PTF <6 mm (%)	---	---	---	---	---	---	---	---	19	6
Fencing Intact	N/A	N/A	N/A	Yes	N/A	Yes	N/A	Yes	N/A	Yes

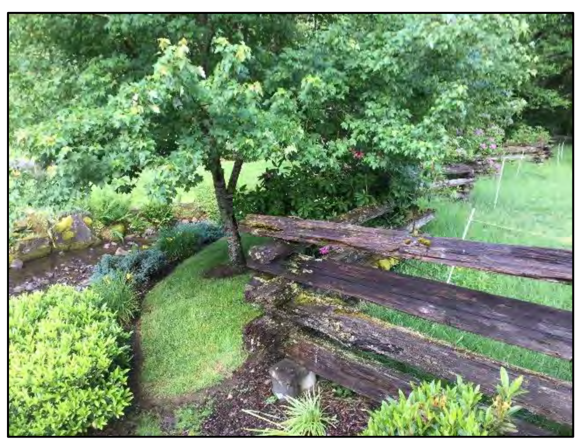
Manicured impact reach in Year 10 of monitoring.

Densely forested control reach during Year 10 of monitoring.

Discussion

Monitoring for this project was completed in 2017. The control reach selected was more of a reference reach with dense forest conditions, while the impact reach was in a mostly open area, much of which was heavily landscaped. Additionally, the control reach did not seem to have any livestock impacts throughout the extent of the monitoring. Erosion in the control reach is likely due to hydrologic changes over the years rather than livestock. Low percentages of eroding banks in both reaches could be responsible for the low percentage of fine sediments in the pools.

Horses excluded from the impact reach in Year 10.



Portion of the exclusion fencing in Year 10.

205-060a Bottle Creek Livestock Exclusion Project – OWEB

Introduction

The Bottle Creek project site is associated with past timber harvest and land management practices that allowed easy access to the stream by cattle for approximately 80 years. The Bottle Creek Project was sponsored by the Union Soil and Water Conservation District in response to the need for improvements in riparian condition along the banks of the creek.

This project was intended to benefit Steelhead Trout *Oncorhynchus mykiss* and resident Redband Rainbow Trout *O. mykiss gairdnerii* by replacing an existing, temporary electric fence with a permanent, four-strand, barbed wire lay down fence to exclude livestock from approximately 610 m of Bottle Creek. The lay down fence is laid down in the winter to prevent significant damage to the fence from snow. The objective of this project was to exclude cows from the riparian area so that deciduous riparian vegetation could be protected and enhanced, providing additional shading to the stream. In addition, this project was designed to improve streambank stability, resulting in decreased sedimentation into the stream.

Methods

The project area is located on U.S. Forest Service land on Bottle Creek, within the Upper Grande Ronde Watershed, in Union County Oregon. The impact and control reaches are located near the town of Union, Oregon and were each 150 m. The Bottle Creek Livestock Exclusion Project was monitored according to the Washington Salmon Recovery Funding Board Protocol for Monitoring the Effectiveness of Livestock Exclusion Projects (Crawford 2011). Baseline monitoring of livestock exclusion projects was conducted in Year 0, prior to implementation of the project, to capture pre-existing conditions at both the control and impact reaches. Following implementation, the same sites were surveyed in Years 1, 3, 5, and 10 to assess changes that result from the project. Use of a control reach helps discern between changes resulting from project actions and changes due to natural causes. At the control and impact reaches, riparian conditions were assessed for vegetation structure, canopy cover density, and percent of actively eroding banks. During 2017 surveys, the relative quantity of fine sediments in pool tails were assessed for the first 10 plunge or scour pools encountered in the channel. The fencing in the impact reach was evaluated each year to determine if it was intact (not fallen over, no holes, etc.) and functioning (closed gates, etc.) to exclude livestock from the stream.

Results

Canopy cover density in both reaches fluctuated over the years of monitoring, which both peaked during Year 3 of monitoring and then decreased in Years 5 and 10. Riparian structure started high in both reaches (over 75% cover) and remained high by the end of sampling (over 80%). Bank erosion initially decreased in Year 1 of both reaches after project implementation but then began to increase every year of monitoring after. Pools in the control reach had a higher percentage of fine sediment compared to pools in impact reach.

In Year 5 of monitoring, the exclusion fence was not functioning properly because a tree had recently fallen onto the fence. There were signs of cattle use within the excluded area in Year 10, with prints and feces throughout.

In Year 10, the monitoring occurred on June 3 and the fence was found in the lay down position. Upon returning to the site in September, to take additional photos, the fence was installed properly and functioning. However, there were signs of cattle use within the excluded area in Year 10, with prints and feces throughout.

Table A-4. Summary statistics for pre- and post-implementation monitoring 205-060a Bottle Creek. Con = control reach; Imp = impact reach; PTF = pool tail fines. Note that in Year 10 the fence was in the lay down position during monitoring.

	Year 0 6/19/06		Year 1 6/14/07		Year 3 6/9/09		Year 5 9/14/11		Year 10 6/3/17	
Variable	**Con**	**Imp**	**Con**	**Imp**	**Con**	**Imp**	**Con**	**Imp**	**Con**	**Imp**
Canopy Cover (1-17)	14.7	11.2	15.1	10.9	15.5	14.6	15.0	14.3	13.2	12.7
Riparian Structure (%)	100	77	100	77	96	86	100	86	91	82
Bank Erosion (%)	7	11	2	1	12	3	15	5	31	12
PTF <2 mm (%)	---	---	---	---	---	---	---	---	76	26
PTF <6 mm (%)	---	---	---	---	---	---	---	---	93	38
Fencing Intact	N/A	N/A	N/A	Yes	N/A	Yes	N/A	No	N/A	No

Impact reach during Year 10 of monitoring.

Control reach during Year 10 of monitoring.

Discussion

All variables in the control reach degraded slightly, likely caused by cattle within the stream area. Banks in the control reach were trampled and littered with cow feces leading to the increase in bank erosion over the years and the high percentage of fine sediment in the pools of the control reach. In comparison, canopy cover density and riparian structure in the impact reach only slightly fluctuated over the ten years of monitoring. Bank erosion in the impact reach seemed to decrease when cattle were excluded and the fencing was intact; however, in years when evidence of cattle presence was observed inside the treatment reach (Years 5 and 10) there was an increase in erosion and decrease in canopy cover density. This illustrates the importance of properly functioning livestock fencing, which prevents banks and vegetation from being trampled.


Cattle prints within the impact reach during Year 10 of monitoring (June 2017).


Exclusion fence in lay down position in the impact reach during Year 10 of monitoring (June 2017).


Exclusion fence in the up position in the impact reach during Year 10 (September 2017).


Control reach during Year 10 (September 2017).

205-060b North Fork Clark Creek Tributary Livestock Exclusion Project – OWEB

Introduction

The North Fork Clark Creek Tributary project site is in an area historically used for timber harvest. Additionally, land-use management has allowed livestock access to the stream for 25 to 30 years, resulting in deteriorated conditions along the riparian corridor. The Union Soil and Water Conservation District sponsored this project to address the need for improvements in riparian condition along the banks of the creek.

This project was intended to benefit Steelhead Trout *Oncorhynchus mykiss* and resident Redband Rainbow Trout *O. mykiss gairdnerii* by replacing the previously existing, temporary electric fence with a permanent, four-strand, barbed wire lay down fence to exclude livestock from approximately 730 m of North Fork Clark Creek. The objective of this project was to exclude livestock from the riparian area so deciduous riparian vegetation could be protected and enhanced, providing additional shading to the stream. In addition, this project was designed to improve streambank stability, resulting in decreased sedimentation into the creek.

Methods

The project area is located on North Fork Clark Creek near the town of Elgin, within the Upper Grande Ronde Watershed, in Union County, Oregon. The impact and control reaches are located on U.S. Forest Service land and were each 150 m long. The North Fork Clark Creek Tributary Exclusion Project was monitored according to the Washington Salmon Recovery Funding Board Protocol for Monitoring the Effectiveness of Livestock Exclusion Projects (Crawford 2011). Baseline monitoring of livestock exclusion projects was conducted in Year 0, prior to implementation of the project, to capture pre-existing conditions at both the control and impact reaches. Following implementation, the same sites were surveyed in Years 1, 3, 5, and 10 to assess changes that result from the project. Use of a control reach helps discern between changes resulting from project actions and changes due to natural causes. At the control and impact reaches, riparian conditions were assessed for vegetation structure, canopy cover density, and percent of actively eroding banks. During 2017 surveys, the relative quantity of fine sediments in pool tails were assessed for the first 10 plunge or scour pools encountered in the channel. The fencing in the impact reach was evaluated each year to determine if it was intact (not fallen over, no holes, etc.) and functioning (closed gates, etc.) to exclude livestock from the stream.

Results

After Year 10 of monitoring, canopy cover density was lower than pre-project conditions in both the control and impact reaches. The impact reach experienced a slight increase in canopy cover density after project implementation, but then decreased each subsequent year. Riparian structure started at 100% for both reaches and did not change throughout the monitoring process. Bank erosion decreased to zero in both reaches by Year 10. In Years 3 and 10, monitoring occurred in June and the exclusion fence in the impact reach was observed in the lay down position. Upon returning in September of Year 10 the fence was observed to be installed properly, however, evidence of livestock presence was observed inside the exclusion zone. The impact reach had less pool tail fine sediments than the control reach, which was measured to be 100% in the pool tail. No signs of cattle were seen within the exclusion area in Year 3 when the fence was down, though prints were seen in Year 10.

Table A-5. Summary statistics for pre- and post-implementation monitoring 205-060b NF Clark Creek. Con = control reach; Imp = impact reach; PTF = pool tail fines. Note that in Year 10 the fence was in the lay down position during monitoring.

	Year 0 6/20/06		Year 1 6/15/07		Year 3 6/10/09		Year 5 9/13/11		Year 10 6/2/17	
Variable	**Con**	**Imp**	**Con**	**Imp**	**Con**	**Imp**	**Con**	**Imp**	**Con**	**Imp**
Canopy Cover (1-17)	14.1	14.8	13.1	15.4	14.3	14.8	11.6	14.1	10.0	11.0
Riparian Structure (%)	100	100	100	100	100	100	100	100	100	100
Bank Erosion (%)	37	39	5	0	8	2	32	9	0	0
PTF <2 mm (%)	---	---	---	---	---	---	---	---	100	18
PTF <6 mm (%)	---	---	---	---	---	---	---	---	100	30
Fencing Intact	N/A	N/A	N/A	Yes	N/A	No	N/A	Yes	N/A	No


Impact reach during Year 10 of monitoring.


Control reach during Year 10 of monitoring.

Discussion

Monitoring for this project was completed in 2017. Since implementation, bank erosion in the impact reach was reduced to zero even with some signs of cattle being observed in the treatment reach. In comparison, canopy cover density in the impact reach only slightly fluctuated over the ten years of monitoring. The initial increase seen in canopy cover density in the impact reach may have been due to the exclusion fencing functioning properly, which then decreased in subsequent years when evidence of cattle was observed inside the treatment reach either because fence was not functioning or was not upright throughout entire grazing period. This illustrates the importance of properly functioning livestock fencing, which prevents banks and vegetation from being trampled.

Cattle prints and feces within the control reach during Year 10 of monitoring (June 2017).

Exclusion fence in the lay down position in the impact reach during Year 10 of monitoring (June 2017).

Cattle prints and feces within the control reach during Year 10 (September 2017).

Exclusion fence in the up position in the impact reach during Year 10 (September 2017).

206-095 Jordan Creek Livestock Exclusion Project – OWEB

Introduction

The Jordan Creek Project is in an area that has been used in agricultural production, resulting in impacted habitat conditions within the creek and adjacent riparian areas. The project was to benefit Cutthroat Trout *Oncorhynchus clarki* and other cold-water species. The project included: 1) the installation of woven wire fencing to exclude use of the creek by livestock; 2) the establishment of off-channel watering facilities for livestock use; 3) sloping of the bank in areas where it was too steep for planting; and 4) planting of trees and shrubs in areas adjacent to the creek. Riparian zone restoration included the removal and long-term control of blackberry, followed by re-vegetation with native trees. Historically, neither the control nor the impact reach were fenced and both were actively used by horses.

The objectives of the Jordan Creek Project included a reduction in bank erosion, the eradication and control of blackberry and other invasive and non-native vegetation, and an increase in native tree and shrub cover to 80 percent within the riparian area. By providing shade to the channel, a reduction in summer stream temperatures in Jordan Creek by an average of 2°C was anticipated. Additional goals of the project included increasing large wood, pool frequency, and channel sinuosity within the creek.

Methods

Jordan Creek is in Lane County near the town of Hadleyville, Oregon. The site is located within the Long Tom Watershed of the Upper Willamette River Basin. The impact and control reach were both 150 m long. This project was sponsored by the Long Tom Watershed Council. The Jordan Creek Livestock Exclusion Project was monitored according to the Washington Salmon Recovery Funding Board Protocol for Monitoring the Effectiveness of Livestock Exclusion Projects (Crawford 2011). Baseline monitoring of livestock exclusion projects was conducted in Year 0, prior to implementation of the project, to capture pre-existing conditions at both the control and impact reaches. Following implementation, the same sites were surveyed in Years 1, 3, 5, and 10 to assess changes that result from the project. Use of a control reach helps discern between changes resulting from project actions and changes due to natural causes. At the control and impact reaches, riparian conditions were assessed for vegetation structure, canopy cover density, and percent of actively eroding banks. During 2017 surveys, the relative quantity of fine sediments in pool tails were assessed for the first 10 plunge or scour pools encountered in the channel. The fencing in the impact reach was evaluated each year to determine if it was intact (not fallen over, no holes, etc.) and functioning (closed gates, etc.) to exclude livestock from the stream.

Results

All variables in the impact reach experienced large changes over the ten years of monitoring. Canopy cover density in the impact reach increased from Year 1 to Year 5, with a slight drop in Year 10 of sampling, though still higher than pre-project. In contrast, canopy cover density in the control reach remained relatively stable across the ten years of monitoring. Riparian structure in the impact reach has increased since Year 0, while the control reach remained constant in each year of sampling except for a slight drop during Year 10. Pre-project implementation, bank erosion in both reaches was above 95%. In the impact reach, bank erosion dropped to zero following implementation and remained below 15% in the following years of sampling. The control reach had a 73% decrease in bank erosion in Year 3 of sampling, which gradually increased in the subsequent sampling years. Only the control reach had a pool to measure fine sediments and the impact reach did not have a scour or plunge pool to take this measurement. Fencing was intact throughout all years of monitoring, though there were signs of cattle present in the impact reach in monitoring Years 3, 5, and 10. There was fencing observed in the control reach during Years 3, 5, and 10 as well, which indicates the control reach was treated sometime between years 0 and 3.

Table A-6. Summary statistics for pre- and post-implementation monitoring 206-095 Jordan Creek. Con = control reach; Imp = impact reach; PTF = pool tail fines.

	Year 0 8/14/06		Year 1 9/13/07		Year 3 6/18/09		Year 5 7/14/11		Year 10 6/6/17	
Variable	**Con**	**Imp**	**Con**	**Imp**	**Con**	**Imp**	**Con**	**Imp**	**Con**	**Imp**
Canopy Cover (1-17)	16.8	2.1	16.6	1.8	17.0	15.6	17.0	16.8	14.9	11.5
Riparian Structure (%)	100	5	100	9	100	23	100	14	86	41
Bank Erosion (%)	100	95	100	0	27	6	47	12	59	12
PTF <2 mm (%)	---	---	---	---	---	---	---	---	67	N/A
PTF <6 mm (%)	---	---	---	---	---	---	---	---	67	N/A
Fencing Intact	N/A	N/A	N/A	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Impact reach during Year 10 of monitoring.

Control reach during Year 10 of monitoring.

Discussion

All measured variables in the impact reach experienced positive changes, indicating that the exclusion fence functioned properly and has allowed the stream to recover. This project has been successful at reducing bank erosion and increasing riparian structure. The largest changes were seen in the decrease of bank erosion and the increase in canopy cover density. Much of the reach had grasses growing along the banks, which led to the increase in canopy cover density compared to the control reach that was forested. More time post-project implementation will allow for shrubs and trees, such as willows, to mature and continue to naturally enhance the stream reach by increasing canopy cover density and riparian complexity. It is worth noting that during Years 3, 5, and 10 of monitoring, exclusion fencing was also found in the control reach. Fencing the control reach confounds the analysis and results as we are unable to attribute responses in bank erosion or riparian structure to livestock grazing (or the lack of livestock grazing). The fencing likely led to the decrease in bank erosion measured in the control reach, though other natural factors not controlled for could have been responsible.

206-283a Johnson Creek Livestock Exclusion Project – OWEB

Introduction

The Johnson Creek Project is located on private land that has been managed for agriculture since the late 1920s. Riparian zone functions and bank stability in Johnson Creek have been greatly reduced. Actively eroding banks along Johnson Creek and other creeks within the basin have contributed to a 10-fold increase in the amount of sediment delivered to Tenmile Lakes. This increase in sedimentation has led to effects on salmon habitat and water quality. The Tenmile Lakes Basin Partnership sponsored the Johnson Creek Project in an effort to address this issue and improve conditions within Johnson Creek and, ultimately, within Tenmile Lakes.

The objective of this project was to improve the riparian condition and reduce sediment input by installing fencing along the creek and excluding livestock from using the area. This effort is expected to result in benefits to the watershed over the long term through increases in ground water storage, stream complexity and shading of the channel, and a reduction in non-point source run-off.

Methods

The project area is located along Johnson Creek, in the Tenmile Lakes Watershed, near the town of Templeton, Oregon in Coos County. The impact and control reach were both 150 m long. The Johnson Creek Livestock Exclusion Project was monitored according to the Washington Salmon Recovery Funding Board Protocol for Monitoring the Effectiveness of Livestock Exclusion Projects (Crawford 2011). Baseline monitoring of livestock exclusion projects was conducted in Year 0, prior to implementation of the project, to capture pre-existing conditions at both the control and impact reaches. Following implementation, the same sites were surveyed in Years 1, 3, 5, and 10 to assess changes that result from the project. Use of a control reach helps discern between changes resulting from project actions and changes due to natural causes. At the control and impact reaches, riparian conditions were assessed for vegetation structure, canopy cover density, and percent of actively eroding banks. During 2017 surveys, the relative quantity of fine sediments in pool tails were assessed for the first 10 plunge or scour pools encountered in the channel. The fencing in the impact reach was evaluated each year to determine if it was intact (not fallen over, no holes, etc.) and functioning (closed gates, etc.) to exclude livestock from the stream.

Results

After ten years of monitoring, all variables in the impact reach have shown positive results. Canopy cover density in the impact reach is higher than pre-project implementation while that of the control reach was slightly lower. The two reaches mirrored one another over the years, following project implementation. Riparian structure remained low in both reaches throughout the ten years of sampling. Bank erosion in the impact reach decreased by over 40% by Year 10, while we saw a 16% increase in the control reach. Pools tails within both the impact and control reaches had moderate to high levels of fine sediment. Fencing was found at both control and impact reaches at the project sites. Exclusion fencing in the impact reach was intact throughout all years of monitoring; however, in Year 5 there was a gate open and signs of cattle within the exclosure. Year 3 also had signs of cattle within the exclosure and it was assessed that cattle were accessing the area from upstream. Though not typically assessed, since the control reach should not have had fencing, the control reach fence had an open gate in Year 1 and the fence had washed away in Year 3, though it was intact in all other years of sampling.

Table A-7. Summary statistics for pre- and post-implementation monitoring 206-283a Johnson Creek. Con = control reach; Imp = impact reach; PTF = pool tail fines.

	Year 0 6/7/06		Year 1 6/28/07		Year 3 6/16/09		Year 5 7/13/11		Year 10 6/3/17	
Variable	**Con**	**Imp**	**Con**	**Imp**	**Con**	**Imp**	**Con**	**Imp**	**Con**	**Imp**
Canopy Cover (1-17)	16.1	6.8	15.3	14.0	16.8	15.5	16.4	16.1	12.6	11.4
Riparian Structure (%)	0	0	5	5	14	5	5	5	0	9
Bank Erosion (%)	4	80	77	75	4	26	12	12	20	39
PTF <2 mm (%)	---	---	---	---	---	---	---	---	57	34
PTF <6 mm (%)	---	---	---	---	---	---	---	---	70	52
Fencing Intact	Yes	N/A	No	Yes	No	Yes	Yes	No	Yes	Yes

Exclusion fencing in the control reach during Year 10 of monitoring.

Impact reach during Year 10 of monitoring.

Discussion

The exclusion of cattle from the impact reach seemed to have a positive impact on the stream itself as all variables improved compared to pre-project monitoring. Because the control reach also had fencing, it was difficult to assess the true impact of the exclusion. Conditions within the control reach likely fluctuated over the years due to changes in cattle access to the reach when gates were open or the fence had washed away. Though no cattle were found in the impact reach, there were some signs of their presence over the years of sampling. Fencing needs to be checked to make sure all gates are closed so cattle continue to be excluded from the impact reach for recovery.

206-357 Middle Fork Malheur River Bank Stabilization Project – OWEB

Introduction

The Middle Fork Malheur River project area has been in agricultural production since the early 1900s. Downcutting and erosion along the river are partially the result of livestock in the area accessing the creek as a water source. As part of this project, Rosgen J-hook vane structures, bank sloping and re-vegetation, and buffer fencing were used to re-direct stream flows away from eroding banks to reduce excessive bank erosion, create pool habitat, and re-establish riparian vegetation. Approximately 100 head of cattle were excluded from over one mile of the Middle Fork Malheur River when the project was completed. This project was expected to benefit approximately 1,610 m of stream habitat and improve fish habitat, including habitat for Bull Trout *Salvelinus confluentus* listed on the Endangered Species List.

Methods

The project area is near the town of Burns, Oregon in Harney County within the Middle Fork Malheur River subbasin. The control and impact reach were both 375 m in length. The Middle Fork Malheur River Bank Stabilization Project was monitored according to the Washington Salmon Recovery Funding Board Protocol for Monitoring the Effectiveness of Livestock Exclusion Projects (Crawford 2011). Baseline monitoring of livestock exclusion projects was conducted in Year 0, prior to implementation of the project, to capture pre-existing conditions at both the control and impact reaches. Following implementation, the same sites were surveyed in Years 1, 3, 5, and 10 to assess changes that result from the project. Use of a control reach helps discern between changes resulting from project actions and changes due to natural causes. At the control and impact reaches, riparian conditions were assessed for vegetation structure, canopy cover density, and percent of actively eroding banks. During 2017 surveys, the relative quantity of fine sediments in pool tails were assessed for the first 10 plunge or scour pools encountered in the channel. The fencing in the impact reach was evaluated each year to determine if it was intact (not fallen over, no holes, etc.) and functioning (closed gates, etc.) to exclude livestock from the stream.

Results

Canopy cover density in both reaches fluctuated throughout the different years of monitoring, though it remained low throughout all the years of sampling. Most of the vegetation calculated in the canopy cover density was overhanging grasses on the banks and little to no cover mid-channel. Riparian structure levels in both reaches remained consistently low, except for a slight increase in Year 3. Bank erosion in the impact and control reaches had a downward trend across the years, with similar shifts seen in each reach during each year of monitoring. Overall, bank erosion decreased by 30% in Year 10 when compared to pre-project data. Pools in both reaches had low levels of fine sediments in Year 10. In Years 5 and 10, the exclusion fence in the impact reach had fallen into the river on the right bank due to streambank erosion and had been covered in debris and sediment on the upstream portion of the left bank. Signs of cattle were not found in Year 10 even with the fencing not functioning properly.

Table A-8. Summary statistics for pre- and post-implementation monitoring 206-357 MF Malheur. Con = control reach; Imp = impact reach; PTF = pool tail fines.

	Year 0 8/16/06		Year 1 8/21/08		Year 3 8/11/10		Year 5 9/11/12		Year 10 6/25/17	
Variable	**Con**	**Imp**	**Con**	**Imp**	**Con**	**Imp**	**Con**	**Imp**	**Con**	**Imp**
Canopy Cover (1-17)	1.6	3.7	7.1	3.1	6.1	5.3	6.5	5.2	6.0	3.6
Riparian Structure (%)	5	0	5	0	32	14	9	0	0	0
Bank Erosion (%)	59	71	34	42	45	37	12	7	26	29
PTF <2 mm (%)	---	---	---	---	---	---	---	---	9	3
PTF <6 mm (%)	---	---	---	---	---	---	---	---	15	5
Fencing Intact	N/A	N/A	N/A	Yes	N/A	Yes	N/A	No	N/A	No


Bank erosion on the left bank in the impact reach in Year 10 of monitoring.


Bank erosion on the left bank in the control reach in Year 10 of monitoring.

Discussion

The lack of change in canopy cover density and riparian structure over the monitoring period is likely due to the climate of the project area and the deeply incised channel. The project is in a semi-arid region (mean annual rainfall = 54 cm), with banks dominated by grasses and small shrubs and little to no upper canopy story (>5 m). Even with more years of monitoring, it is not likely that there will be much of an increase in these variables. The bump in riparian structure seen in Year 3 in both reaches is likely due to a small shift in the way transects were laid out along the reaches among years. Exclusion fencing in the impact reach was most effective at reducing bank erosion. Much of the bank erosion measured in Year 10 seemed to be from hydrologic conditions and channel incision within both reaches, not due to cattle. By Year 10 monitoring, the exclusion fence was still washed into the river on the right bank as it had been in Year 5. Portions of the fence on the left bank were easy to step over due to the amount of sediment that accumulated around the fence, likely attributed to extremely high flows in the previous winter. It will be important to fix the fence to continue to exclude cattle beyond Year 10 to allow stream and bank conditions to continue to improve, since there were not yet signs of cattle in the impact reach.

River right fencing in the impact reach that has fallen into the river seen in Year 10.

Left bank portion of fencing at the upper section of the impact reach covered by sediment seen in Year 10.