Restoration or Disturbance:

Assessing the Impacts of a Salmon Habitat Restoration Project on Riparian Vegetation Composition

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Abstract

Invasive plant species can threaten the biodiversity and resilience of riparian ecosystems. A vegetation assessment of the riparian zone beside the Stoney Creek Off-Channel Habitat Project compared with a non-restored site and a previously replanted site showed that the sites were significantly different in their vegetation composition. All three sites had several invasive species of concern playing dominant roles in the ecosystem with the most common two species being English ivy *(Hedera helix)* and Himalayan blackberry (*Rubus discolor*). The previously restored site had significantly lower levels of invasive English ivy than the non-restored site. The non-restored site had greater total foliar cover than the other sites, but this was mostly covered by invasive species. The project site was only significantly different from the reference sites by having greater ivy levels on trees and a higher number of red alders *(Alnus rubra).* These results, along with the qualitative differences noted in the composition of the Off-Channel habitat from the previously restored stream area, suggests that further restoration and replanting needs to take place around the Off-Channel habitat area.

Introduction

In 2012, the Stoney Creek Environment Committee carried out a restoration project with the goal of improving salmon spawning habitat in Stoney Creek, Burnaby, British Columbia. Stoney Creek is located along the Burnaby Urban Trail, in close proximity to Lougheed Highway and Simon Fraser University. The restoration project involved the creation of three weirs along the stream and the formation of an Off-Channel pool to increase the availability of salmon spawning grounds along this urban salmon-bearing stream (Stoney Creek Environment Committee 2012). In this study, riparian vegetation composition at the stream adjacent to the Off-Channel pool was assessed to determine the levels of invasive and native plant species established at the site. The objectives were to compare the vegetation richness and abundance of the Off-Channel site with an upstream site with more restored vegetation and with a downstream site that had been relatively undisturbed and unrestored (see Figure 1 for a map of the 3 sample areas). The second objective of the Stoney Creek Environment Committee's restoration project was to establish native species and remove invasive plants (Stoney Creek Environment Committee 2012). The primary goal of our study was to determine the success of the native species establishment at the Off-Channel Project Site.

The Stoney Creek Environment Committee is concerned with six invasive species common in the Stoney Creek riparian zone: Himalayan blackberry (*Rubus discolor)*, English ivy (*Hedera helix)*, policeman's helmet (*Impatiens glandulifera*), English holly (*Ilex aquifolium)*, yellow lamium (*Lamium galeobdolon*), periwinkle (*Vinca minor)*, and Japanese knotweed (*Polygonum spp*. -*Fallopia japonica)* (Stoney Creek Environment Committee 2012). A bioengineering study from 2000 found that the risk of invasion was particularly high from Himalayan blackberry, English ivy, and policeman's helmet (Page, Murray, & Johnson 2000).

Riparian zones are particularly sensitive to anthropogenic disturbances such as the clearance of trees and changes in soil chemistry. These changes can cause an ecosystem to be particularly susceptible to invasive species that are able to exploit the light available due to open canopies and secrete allelopathic chemicals to prevent the re-establishment of native plants (Sala *et al.* 2000). In restoration projects where vegetation has been previously removed and not fully re-established, ecosystems may be susceptible to invasions by non-native plant species. Invasive plants can negatively affect biodiversity, ecosystem resilience, bank stability, and food web structure in riparian areas (Catling 2005; Easson & Yarbrough 2002; Ehrenfeld 2003; Holland-Clift *et al*. 2001; Scheiman *et al.* 2003). Vegetation composition and biodiversity changes have the potential to impact salmon abundance and productivity, which can be economically and biologically harmful (Mouton et al. 2012). The type of streamside vegetation determines the availability of macroinvertebrates, which are important food sources for juvenile salmon (Allan *et al.* 2003) Riparian habitats can be particularly susceptible to certain invasive species, such as policeman's helmet, which reduces pollinator visits, negatively impacting other plant species (Chittka and Schurkens 2001). Additionally, in riparian areas, removal of invasive species along a stream bank can introduce substantial amounts of sediment into the channel and widen banks (Pollen-Bankhead 2009). Riparian vegetation assessments, therefore, are an important way to determine the health of a stream ecosystem.

Assessing both the overall biodiversity of an area and the abundance of native and invasive plants can be useful for determining the quality of the restoration in terms of returning the ecosystem to its natural condition. Measuring the distribution of invasive plants and overall species diversity in riparian areas can be a way to measure the level of disturbance around a stream ecosystem, and in this case, how well it has been restored. By comparing data collected from each of the three reference sites in our Post Project Appraisal (PPA) we hope to either catalogue the improvement of the Off-Channel Restoration Project over conditions that likely previously existed, or demonstrate the potential of the Off-Channel Habitat Restoration Site following continued restoration efforts.

The research questions addressed in this PPA were:

1) How do riparian basal vegetation and tree diversity differ between a previously restored site, a non-restored site, and the Off-Channel habitat site?

2) Are there differences in the presence of invasive plant species between the three sample sites?

3) What recommendations can be made to reduce the amount of invasive plant species along Stoney Creek to better meet Objective 2 of the restoration project?

Methods

In order to draw conclusions about the success of vegetation restoration at the Off-Channel pool of Stoney Creek, reference sites were used to establish a baseline. Vegetation was assessed at three sites: a downstream "unrestored" site (Site 1-Figure 2), the Off-Channel project site (Site 2-Figure 3), and the upstream "restored" site (Site 3-Figure 4). Figure 1 shows the location of each of these sites. Site 1 was selected to act as a control, to demonstrate what the vegetation composition of the Off-Channel habitat would likely have been prior to the restoration project. Site 3, was upstream and had been previously fully restored through the removal of invasives, planting of natives, and the addition of large woody debris to the stream channel. This site gave an indication of the potential for restoration at the off-channel habitat site. The sites were selected not only for their history, but also for similarity in topography such as bank slope (measured with a clinometer) and bankfull width (measured using an eslon measuring tape) of the channel at each site.

Different methods exist for completing a vegetation assessment, each with its own limitations. Differences in the amount of time and resources required, precision, and measurement capacity are found between methods, with the best one to use depending on the type of results required (Korb, Covington, & Fulé 2003). In determining which method would be best to use for our vegetation assessment, some preliminary research was conducted examining the costs and benefits of point-intercept transects, Daubenmire transects (ocular method), belt transects, and Modified Whittaker plot methods of sampling. The ocular method of recording foliar cover was determined to be the most suited for this project. Our objective was to measure species richness and abundance and this method was described to be the best for determining total species richness, somewhat subjective for estimating foliar cover, and relatively quick to use (Godinez-Alvarez et al. 2009; Korb, Covington & Fulé 2003). Foliar cover was used as a way to measure plant abundance as it is least impacted by the size of a plant and rather measures the area that it covers (Korb et al. 2003).

Taking inspiration from the Daubenmire method (Korb et al. 2003) or ocular method (Godinez-Alvarez et al. 2009) for this study, two 1m x 1m plots (created by securing together 4 meter sticks into a square) were placed randomly along transects that cross Stoney Creek (one on each side of the creek). Five transects were placed 10m apart for a total length of 40m at each of our 3 sample sites (see Figure 5 for a diagram of sampling procedure at Site 2). Total sample site length (40m) was measured by walking upstream from a designated starting point with a hip chain measuring tape and marking the transects with flagging tape, while the transect length was measured with an eslon measuring tape. Transects reached 10 m from the bankfull width to represent a riparian zone of 10 metres in width based on previous studies of riparian zone impacts on streams (Ringold et al. 2008). This resulted in a total sample area of $800m^2$ at each site. Of this total area, $10m^2$ or 1.25% was sampled with the plots.

Species diversity, foliar cover of each species, and total foliar cover was assessed within each quadrat by visual estimation (Figure 6). Herbs, shrubs, and trees of less than 10 cm in diameter of both native and invasive origin were identified within each quadrat to the lowest taxa level possible. If plants were unable to be identified, they were given an arbitrary label (i.e. unknown herb 1). Assessing presence of individual species was useful to provide the most information possible, especially for noting the presence of invasive species. However, it was not absolutely necessary because only the total number of species, total foliar cover, and the foliar cover of invasive plants were required for this study.

As the area being sampled with the plots was quite small, trees were sampled in a different manner, using the point-centered quarter method (Watts 1996). With this method, the closest tree in each direction (ie. NW, NE, SW, SE quarters) from the center of each plot was sampled, and the distance to the tree was measured, thus giving an estimate of the density of trees around each sample plot (Figure 7). The definition of a tree was any woody plant greater than 3m in height and greater than 10 cm diameter at breast height (International Society of Arboriculture 2001). For the point-centered quarter tree survey, the distance, type of tree, diameter and ivy cover were recorded for four trees within 12 meters of each sample point. When a quarter had no trees closer than 12 meters, no trees were recorded for that quarter and a distance of 12 meters was assumed. This was to allow for a comparison of average density of trees between sites.

The method selected for data analysis was Analysis of Variance (ANOVA), which compares the average values between groups and can determine whether they are significantly different. This method was then used to compare the average quadrat and sample point values of the measured attributes at each site for differences. These analyses were done on JMP version 10.0 software. Within ANOVA, a Tukey-Kramer HSD test with a confidence level of 95% was used to determine which specific means were significantly different. This method assumes random sampling, equal variation between groups, and a normal distribution of values in each group (Kleinbaum, Kupper, Nizam & Muller 2008). ANOVA is robust, so it is still relevant even if these assumptions are not fully met. The assumptions of equal variances and normality were analyzed (Appendix 1) and random sampling was used to determine the placement of quadrats along the transects.

Results

Basal Vegetation Survey

The original data collected in quadrats is attached in Appendix 2. Between the three sites, there were significant differences in total foliar cover, English ivy foliar cover, and the ratio of blackberry and English ivy cover to total foliar cover (Table 1). Comparisons of species richness and blackberry foliar cover were not significantly different between sites. Other invasive plants of concern to the Stoney Creek Environment Committee were not captured within quadrats, but Japanese knotweed was observed in Sites 1 and 3 and English holly was observed in Sites 2 and 3.

It was found that for total foliar cover, the downstream site (Site 1) had a significantly higher foliar cover than the upstream (Site 3) reference site. The project site appears to have a level of foliar cover that is in between the two reference sites (Figure 8). However, when broken down into sides of the bank, foliar cover is the lowest between all three sites on the left side of the Off-Channel pool in site 2 (Figure 9). This low average foliar is not significantly different from the foliar cover of Site 3. An analysis of the bank side and site differences resulted in little significant difference, likely because the sample size of five quadrats was small and the variation quite large.

The analysis of total foliar cover demonstrates that there is greater foliar cover at the unrestored Site 1 than the other two sites. However, Site 1 also has significantly higher English ivy foliar cover and ratio of invasive foliar cover to total foliar cover than the other two sites (Table 1). This shows that Site 1 has greater number of invasive species than the other two sites. The Off-Channel site appears to be closer in composition to the previously restored site, although it still has slightly higher invasive foliar cover.

Tree Survey

Between the three sites, the frequency of alders and the frequency of English ivy on trees were significantly higher in the Off-Channel site when compared to the previously restored site. Table 2 shows the attributes that were compared and the letters indicating whether the means for each site were significantly different according to the Tukey-Kramer HSD. The differences between density, diameter, and overall richness did not appear to be significant.

Reference Site Assessment

The means of the site geography were also compared to see how similar the measured attributes actually were. Bank widths were significantly higher at Site 2 when compared to Site 1 (Table 3). It was also qualitatively observed that Site 1 had faster flow than the other upstream sites. Average bank slope measured by a clinometer was not significantly different between the three sites (Table 3). This suggests that the reference sites were comparable.

Discussion

Increased species diversity and reduced invasive species were expected at the restored site when compared to both the Off-Channel (Site 2) and the unrestored site (Site 1). The latter had many invasive species, and the Off-Channel site had invasive species as well as areas that were disturbed by machines during the restoration. We also expected a higher density of trees and greater total foliar cover at Site 1 and 3 than at the Off-Channel site due to the removal of trees during construction.

The results obtained were not consistent with our expected results for tree diversity and invasive species abundance between the project site and the reference sites. The lack of statistical significance for invasive species abundance may be due to our limited sample size. Sampling protocol recommends a 5% of the total sample area be measured, but due to time constraints, this requirement was not met; therefore the total area that was sampled was only 1.25% of total sample area (Watts 1996). This could also be a reason why other invasive plants of concern to the Stoney Creek Environment Committee were not captured within quadrats, although, Japanese knotweed was observed in Sites 1 and 3 and English holly was observed in Sites 2 and 3. This small sample size also influenced the accuracy of the ANOVA assumptions by limiting the variation of values that were captured (Appendix 1).

Another source of bias could have been introduced as a result of the data being collected on different days with different observers; however, an attempt to correct this bias was taken into account by meeting prior to data collection to review the foliar cover estimation procedure.

The results of tree diversity we obtained were not consistent with our expected tree diversity because we anticipated that the diversity of trees would be higher at Site 3 compared to Site 1 and Site 2. Nonetheless, Site 3 consisted of trees such as Sitka spruce *(Picea sitchensis)*, Indian plum *(Oemleria cerasiformis)*, black cottonwood *(Populus trichocarpa)*, western red cedar *(Thuja plicata)* and alder *(Alnus sp.)*, all of which provide shade for the undergrowth and prevent the spread of invasive species like blackberry, which require sufficient sunlight for growth (Caplan & Yeakley 2006). The lower total foliar cover on the left side of the stream bank in Site 2 may have been due to the development of the Off-Channel habitat. However, there is a possibility of our results being confounded by the fact that the assessment was performed at a time where foliar coverage was low, which was in early spring.

An important finding was that the number of trees that were covered in ivy and the proportion of alder trees were greater in the project site as compared to the restored site. This is consistent with our expectations as an extensive invasive removal was not conducted as a part of the Off-Channel project. The presence of ivy growing on trees can have a variety of negative effects on tree health. Ivy growing on trees often competes for nutrients and sunlight and could possibly make the tree susceptible to being blown down by strong winds. In addition, the high proportion of alders suggests a higher level of disturbance because of the early successional stage of the forest (Langley Environmental Partners Society n.d.).

Conclusion

The objective of the PPA was to monitor riparian area condition after a restoration project had taken place. The restoration portion itself was only half of the process of fully restoring an ecosystem. The purpose of the restoration project was to have a self-sustaining ecosystem without the aid of further human assistance. At the Stoney Creek site we assessed the impacts of a salmon habitat restoration project on the riparian vegetation composition. Through collection of data at the project site, and the two reference sites, comparisons between riparian vegetation were made to determine the success of the restoration project. To measure the success of the salmon habitat restoration project, riparian vegetation was assessed through components of plant species diversity, total foliar coverage, and tree abundance, which were then analyzed through multiple statistical procedures.

It is apparent that the restoration projects have altered the plant composition of each site. The greater abundance of invasive species at the un-restored site in comparison to the restored sites upstream show how effective the restoration projects upstream have been on the ecosystem. The large woody debris present in the restored site shows effort towards creating an optimal salmon-spawning habitat. Through data analysis we find that the restoration project can be deemed a success in terms of keeping invasive species at a lower abundance in the riparian vegetation of the salmon spawning site.

Due to time limitations and work load constraints it was difficult to capture the complete vegetation of all three sites and fully assess how successful the salmon habitat restoration project truly was. However, through selective methodology and statistical analysis our Post Project Appraisal goal to assess and analyze riparian vegetation was met.

Future Restoration Management

Restoration projects are extremely important in maintaining a healthy environment. After a restoration project takes place it is just as important for continual monitoring of the site to occur to fully determine the success of the project. At the Stoney Creek site in Burnaby, BC, efforts have been made to maintain healthy salmon spawning habitat. However, the establishment of invasive plant species at this site may cause problems for the riparian ecosystem. Invasive plant species are capable of major alteration to an environment, which ultimately affects the growth and development of native species. Removal of invasives will help preserve native plant taxa and the ecosystem as a whole.

In the future, current restoration management should continue, as it is notable that previous restoration projects have had a positive impact on the ecosystem by reducing invasive species, as concluded from the results of this PPA. Efforts to manage the site should include scheduled invasive plant removal, as well as replanting of native plant species on a regular basis. Also, bank stabilization and the maintenance of the streams hydrologic properties are important for the success of spawning salmon. Therefore careful placement of boulders and tree stumps along the streams channel boundary will aid in maintaining an idealized water flow and habitat for optimal salmon spawning. Efforts in restoration management projects would not be as successful if continuous monitoring of the site had not occurred. For that reason, regular observation and monitoring of the sites is crucial for a restoration project to reach its full potential.

References

Allan, J.D., Wipfli, M.S., Caouette, J.P., Prussian, A., and Rodgers, J. 2003. Influence of streamside vegetation on inputs of terrestrial invertebrates to salmonid food webs. *Canadian Journal of Fisheries and Aquatic Sciences* 60: 309-320.

Caplan, S.J., and Yeakley, J.A. 2006. Rubus Armeniacus (Himalayan Blackberry) Occurrence and growth in relation to soil and light conditions in Western Oregon. *Environmental Sciences & Resources Program, Portland State University* 1-9.

Catling, P. 2005. Effects of invasive alien plants on birds: some examples from North America. *Biodiversity* 6(3): 30-39.

Chittka, L., and Schurkens, S. 2001. Successful invasion of a floral market: an exotic Asian plant has moved in on Europe's river-banks by bribing pollinators. *Nature 411*(6838), 653.

Easson, G., and Yarbrough, L.D. 2002. The effects of riparian vegetation on bank stability. *Environmental & Engineering Geoscience 8*(4): 247–260.

Ehrenfeld, J.G. 2003. Effects of exotic plant invasions on soil nutrient cycling processes. *Ecosystems* 6:503-523.

Godínez-Alvarez, H., Herrick, J.E., Mattocks, M., Toledo, D., and Van Zee. J. 2009. Comparison of three vegetation monitoring methods: their relative utility for ecological assessment and monitoring. Ecological Indicators **9**: 1001–1008.

Holland-Clift, S., O'Dowd, D., and Macnally, R. 2011. Impacts of an invasive willow (Salix x rubens) on riparian bird assemblages in south-eastern Australia. *Austral Ecology* 36(5): 511-520.

International Society of Arboriculture. 2001. *Guidelines for Developing and Evaluating Tree Ordinances* Retrieved from http://www.isa-arbor.com/education/resources/educ_TreeOrdinanceGuidelines.pdf

Langley Environmental Partners Society. n.d. English Ivy. *Invasive Plants of Southwestern British Columbia* Retrieved April 15, 2013, from http://www.shim.bc.ca/invasivespecies/_private/englishivy.htm

Mouton, A.M., Buysse, M., Stevens, M., Van Den Neucker, T., and Coeck, J. 2012. Evaluation of riparian habitat restoration in a lowland river. *River Research and Applications* 28: 845–857.

Page, N., Murray, D., & Johnson, C. 2000. *Stoney Creek Bioengineering Assessment Study* Vancouver, BC.

Pollen-Bankhead, N., Simon, A., Jaeger, K., and Wohl, E. 2009. Destabilization of streambanks by removal of invasive species in Canyon de Chelly National Monument, Arizona. *Geomorphology* 103(3): 363–374.

Ringold, P.L., Magee, T.K., and Peck, D.V. 2008. Twelve invasive plant taxa in US western riparian ecosystems. *Journal of the North American Benthological Society 27*(4): 949–966. doi:10.1899/07-154.1

Sala, O.E., Chapin III, F.S., Armesto, J.J., Berlow, E., Bloomfield, J., Dirzo, R., Huber-Sanwald, E., Huenneke, L.F., Jackson, R.B., Kinzig, A., Leemans, R., Lodge, D.M., Mooney, H.A., Oesterheld, M., Poff, N.L., Sykes, M.T., Walker, B.H., Walker, M., and Wall D.H. 2000. Global biodiversity scenarios for the year 2100. Science 287, 1770 pp.1770-1774.

Scheiman, D., Bollinger, E., Johnson, D. 2003. Effects of leafy spurge infestation on grassland birds. *The Journal of Wildlife Management* 67(1): 115-121.

Schultz, R. and Dibble, E. 2012. Effects of invasive macrophytes on freshwater fish and macroinvertebrate communities: the role of invasive plant traits. *Hydrobiologia* 684:1-14.

Stoney Creek Environment Committee. 2012. George Hungerford Award Project Description.

Watts, Simon. 1996. *Essential Environmental Science: Methods & Techniques*. Taylor & Francis. Retrieved 18 April 2013, from <http://lib.myilibrary.com?ID=9894>

Figures

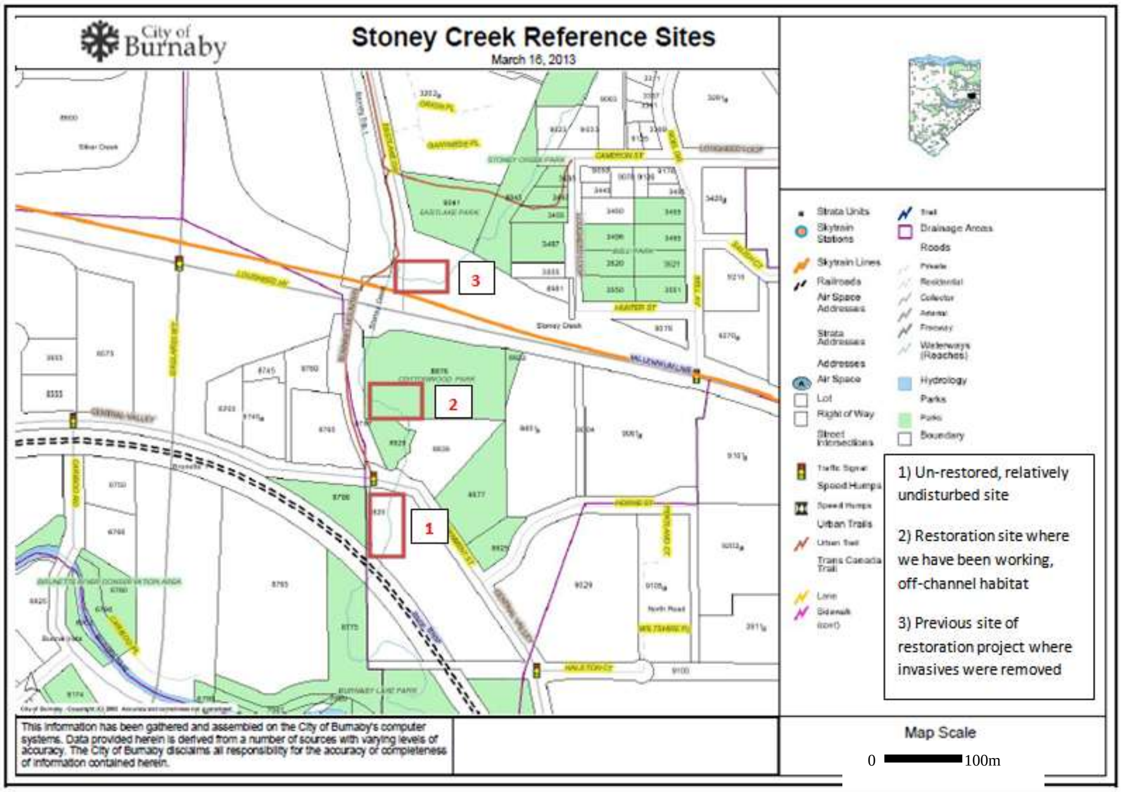


Figure 1. Map of vegetation assessment sites produced from City of Burnaby's GIS website: http://webmap.city.burnaby.bc.ca/publicmap/viewer.htm

Figure 2. Site 1: Unrestored downstream site

Figure 3. Site 2: Off-Channel restoration project site

Figure 4. Site 3: Upstream restored site

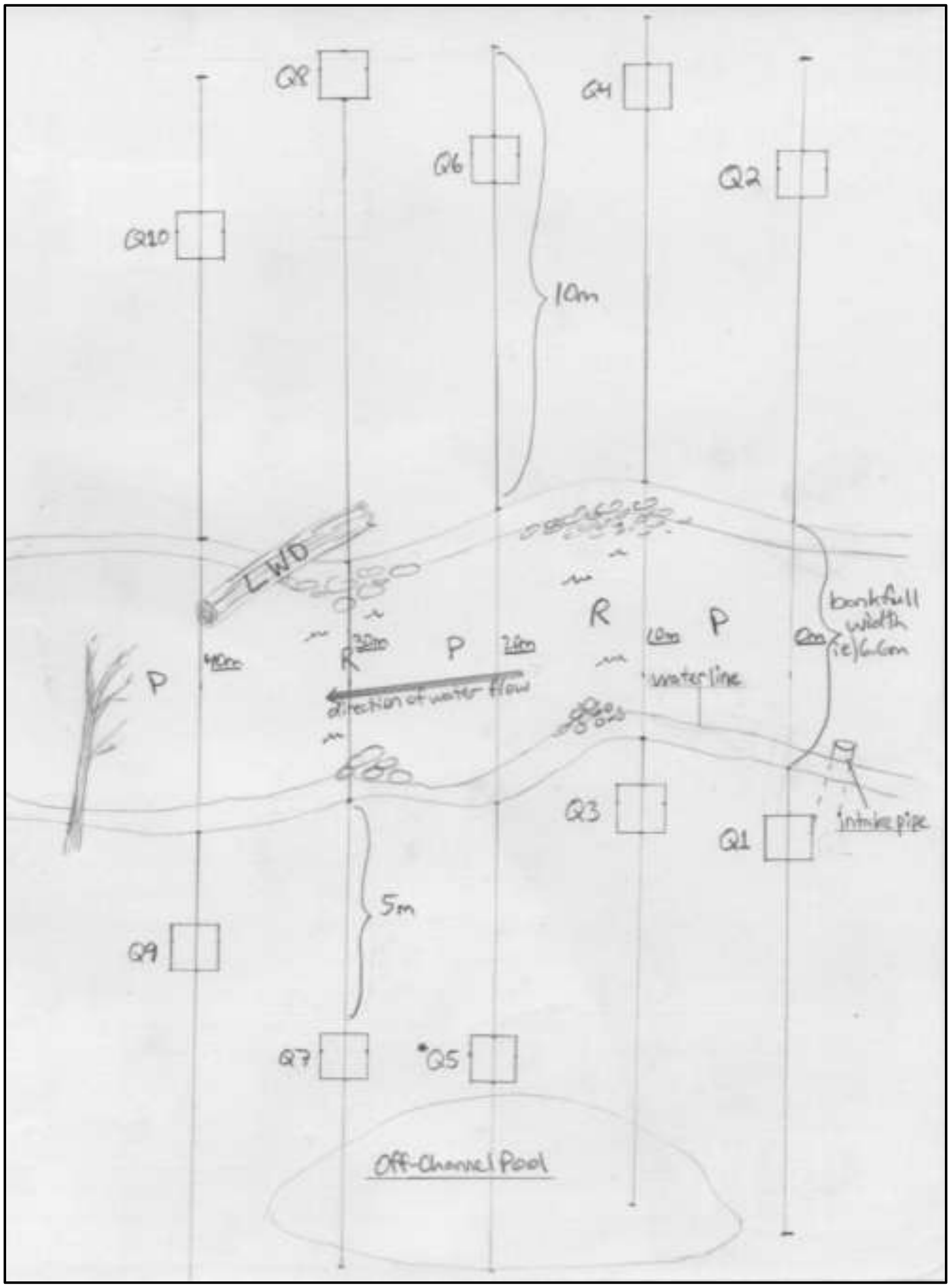


Figure 5. Diagram of sampling procedure and qualitative observations taken at Site 2: Off-Channel Habitat Restoration Site. Q1=quadrat 1, P=pool, R=riffle, LWD=large woody debris.

Figure 6. A typical quadrat or plot. Foliar cover was estimated visually for both total cover of the plot and for each species.

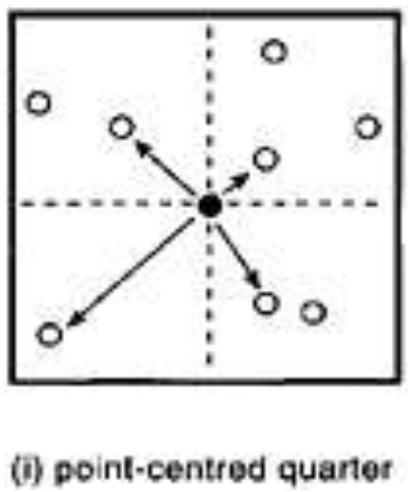


Figure 7. Sampling method used to survey tress. Center point represents center of quadrat, from that point the closest tree within 12m in each of the quadrants (NW, NE, SE, SW) were sampled.

Source: Watts, Simon. 1996. *Essential Environmental Science: Methods & Techniques*. Taylor & Francis. Retrieved 18 April 2013, from http://lib.myilibrary.com?ID=9894

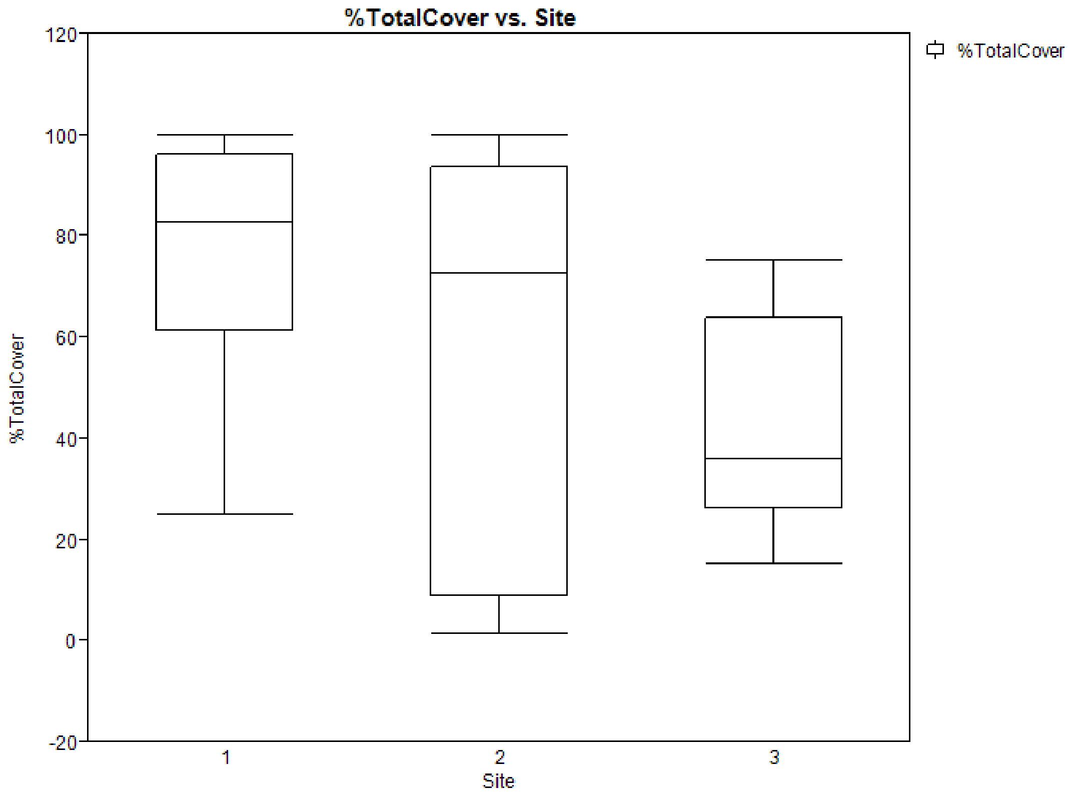


Figure 8. Comparison of mean total foliar cover between sites. The difference between Sites 1 and 3 is significant with a $p<0.05$.

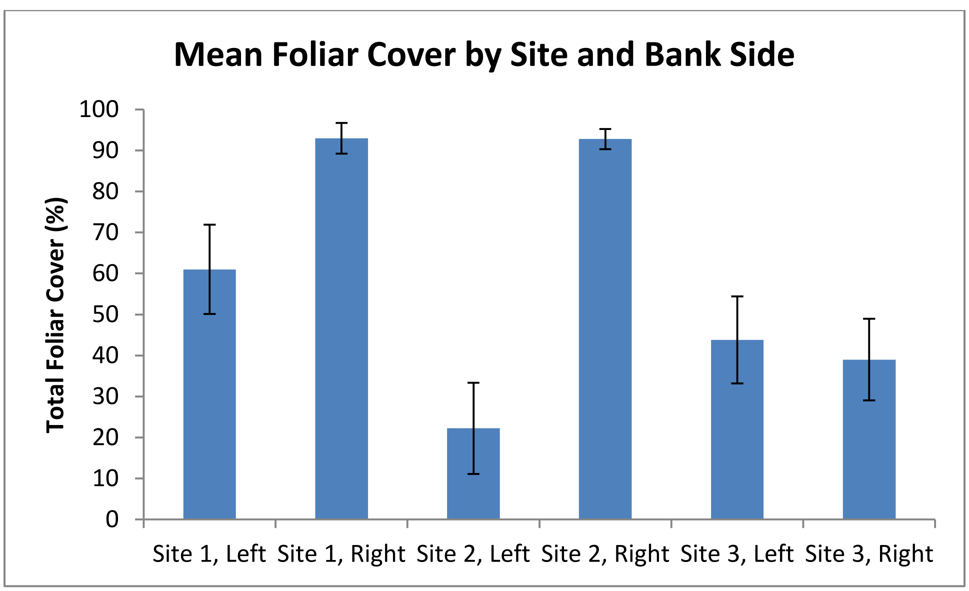


Figure 9. Comparison of mean foliar cover between sites and between banks for each site with standard error bars shown. One can see that the lowest foliar cover occurred at Site 2 on the left bank, where the off-channel pool was dug.

Tables

Attribute	Site 1 (No restoration)	Site 2 (Off-Channel Project)	Site 3 (Previously replanted)	p-value for ANOVA
Total Foliar Cover	A	A,B	B	
Species Richness	A	A	A	
% Blackberry	A	A	A	
% Ivy	A	B	B	
Ivy and Blackberry Cover: Total Foliar Cover	A	B	B	

Table 1. Summary of Tukey-Kramer HSD Letters Report showing significant differences between means of basal vegetation survey. Different letters across a row mean significant differences between sites (any site with only the letter A is significantly different from a site with the letter B).

Attribute	Site 1 (No restoration)	Site 2 (Off-Channel Project)	Site 3 (Previously replanted)	p-value for ANOVA
Tree Richness	A	A	A	0.9243
Number of alders	A,B	A	B	0.0219
Average Distance	A	A	A	0.4736
Average Diameter	A	A	A	0.3486
Number of trees with ivy	A,B	A	B	0.0133

Table 2. Summary of Tukey-Kramer HSD Letters Report showing significant differences between site means of tree survey. Different letters across a row mean significant differences between sites.

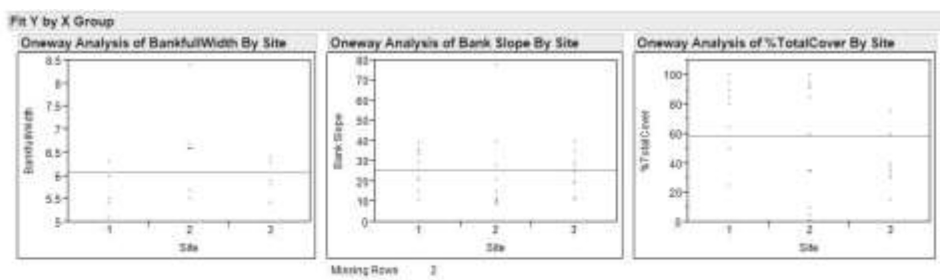
Attribute	Site 1 (No restoration)	Site 2 (Off-Channel Project)	Site 3 (Previously replanted)	p-value for ANOVA
Bank Width	B	A	A,B	0.0233
Bank Slope	A	A	A	0.8951

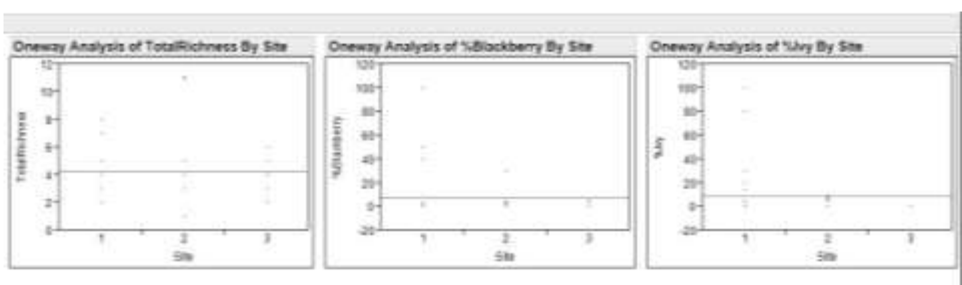
Table 3. Summary of Tukey-Kramer HSD Letters Report showing significant differences between site means of geography attributes. Different letters across a row mean significant differences between sites.

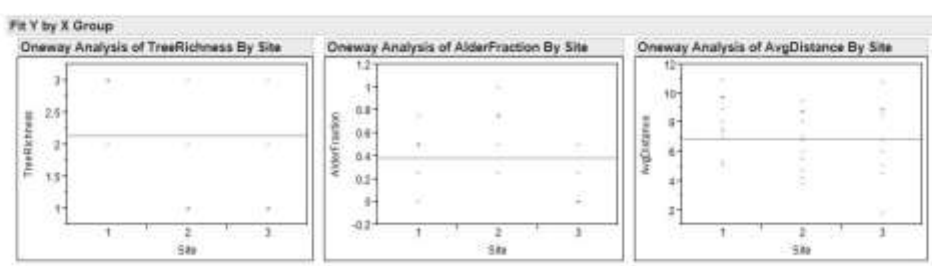
Appendices

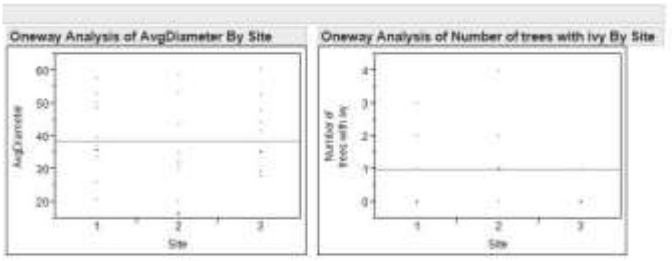
Appendix 1: Testing ANOVA Assumptions

Testing equal variance:
In the plots below, one can see that due to the small sample size the assumption of equal variation between sites is not consistently met, especially in the percent invasive attributes where there certain sites did not have any invasives, while others had a range of higher values.

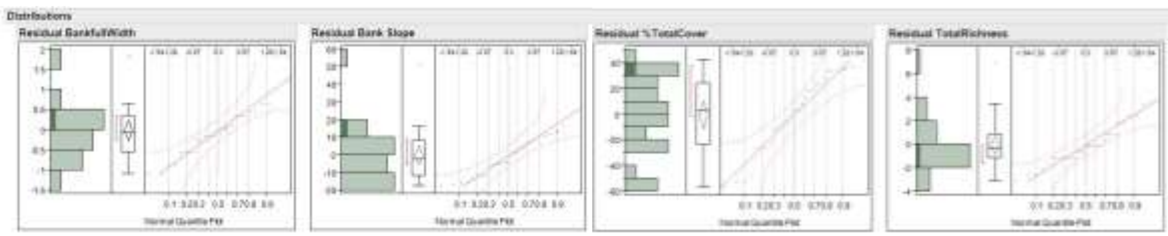


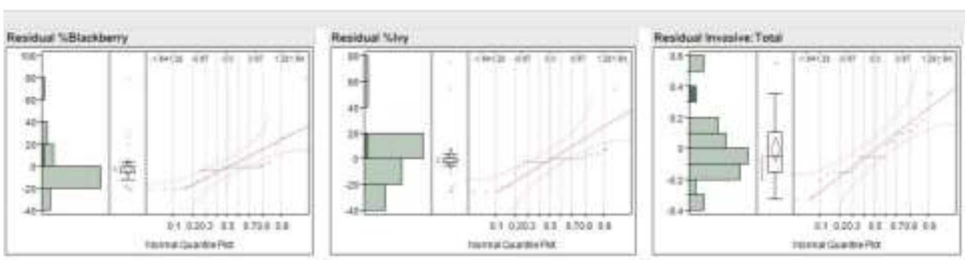


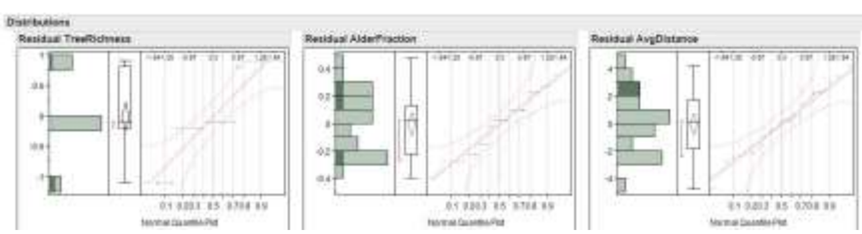


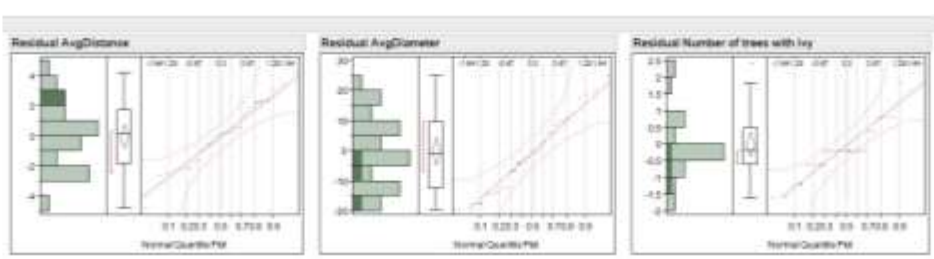


Testing normality of residuals:
As can be seen in the Normal Quantile plots of the response variable residuals below, which represent the variation of the values from the average values for each site, most variables measured follow a relatively normal distribution (by staying within the red dotted lines). However, the blackberry and ivy foliar cover data does not appear to be consistently normal, probably due to the many observations of zero foliar cover. In addition, the tree richness data does not appear normal because of the overall low tree richness at the sites.









Appendix 2: Original Data

SITE 1: Downstream Unrestored Reference Site

Quadrat Location	Species Name	Species Foliar Cover (%)	Total Cover (%) and Total Richness	Notes
8 m in on right bank	Stinging Nettle	18.0	80.0/3	
	Blackberry	40.0		
	Unknown herb	0.3		
4 m in on left bank	Indian Plum	20.0	25.0/4	There was knotweed
	Blackberry	2.0		beside the left bank.
	Salmonberry	2.0		
	Moss 1	5.0		
0 m right	English Ivy	14.0	90.0/7	
	Salmonberry	12.0		
	Moss 1 (dark moss)	60.0		
	Indian plum	10.0		
	Moss 2 (fern moss)	25.0		
	Bitter cress	0.5		
	Moss 3 (fern like)			
5 m left	False lily of valley	20.0	50.0/5	Knotweed along transect
	Salmonberry	5.0		
	English Ivy	20.0		
	Knotweed	0.1		
	Moss 1	0.3		
9 m right	English Ivy	100.0	100.0/2	
	Himalayan Blackberry			
0 m left	English Ivy	80.0	85.0/7	
	Salmonberry	13.0		
	Indian Plum	3.0		
	Blackberry	8.0		
	Fern moss	2.0		
	Spiky big moss	1.0		
	sprout-like herb	0.1		
2 m right	Salmonberry	12.0	95/7	
	English Ivy	4.0		
	Horsetail	0.3		
	fern moss	30.0		
	Spiky big moss	1.0		
	Indian plum	75.0		
	Unidentified herb	0.1		
1 m left	English Ivy	30.0	65.0/4	
	Salmonberry	30.0		
	Piggy Back Plant	20.0		
	Blackberry	3.0		
10 m right	Blackberry	100.0	100.0/2	English holly @ right bank
	English Ivy	5.0		
2 m left	Himalayan blackberry	50.0	80.0/5	
	Tolmeti menziesi	9.0		
	Salmonberry	2.0		
	English Ivy	1.0		
	small germinating herb	0.5		

Plot data for Site 1: Downstream Unrestored Reference Site

Quadrat Location	Point	Species	Distance from center of quadrat (m)	Diameter (cm)	Notes
8 m right	1NE	cottonwood	8.2	110.0	little bit of ivy
	1NW	alder	13.8	12.0	
	1SW	no trees	>12		
	1SE	alder	11.7	36.9	
4 m left	2NE	cotton wood	8.4	70.8	lots of ivy
	2NW	black cottonwood	3.3	56.5	
	2SW	black cottonwood	4.0	55.0	
	2SE	alder	4.8	17.5	
0 m right	3NE	cottonwood	13.1	26.0	
	3NW	alder	3.5	30.0	ivy
	3SW	alder	0.8	37.0	ivy
	3SE	cottonwod	12.4	70.8	a lot of ivy
5 m left	4NE	cottonwood	1.4	70.8	a lot of ivy
	4NW	n/a	>12		
	4SW	alder	7.3	28.5	
	4SE	cottonwood	9.7	74.0	ivy (a little)
9 m right	5NE	western hemlock	2.6	23.0	ivy
	5NW	alder	5.2	15.0	
	5SW	alder	6.9	13.0	
	5SE	alder	5.9	32.5	
0 m left	6NE	alder	5.4	21.0	lots of ivy
	6NW	alder	8.7	46.2	
	6SW		>12		
	6SE	cottonwood	6.4	78.8	lots of ivy
2 m right	7NE	alder	2.3	20.5	
	7NW	alder	2.2	37.5	
	7SW	cottonwood	5.0	61.5	
	7SE	n/a	>12		
1 m left	8NE	n/a	>12		cleared for trestle
	8NW	bigleaf maple	2.6	38.5	
	8SW	cottonwood	7.6	35.5	some ivy
	8SE	n/a	>12		
10 m right	9NE	black cottonwood	6.6	82.5	
	9NW	alder	9.1	9.0	
	9SW	spruce	11.9	35.0	
	9SE	alder	11.4	17.0	
2 m left	10NE	cottonwood	9.2	13.5	
	10NW	alder	8.2	27.0	ivy
	10SW		>12	n/a	tresle cherry
	10SE	big leaf maple	9.5	37.5	

Tree data for Site 1: Downstream Unrestored Reference Site

Transect	Bankfull Width (m)	Slope of Bank (from bankfull to 10 m) (%)	Slope of Bank (from bankfull to 10 m) (°)
1.0	5.1	21.0	12.0
2.0	5.1	11.0	5.0
3.0	6.0	39.0	21.5
4.0	6.0	15.0	8.5
5.0	5.5	35.0	19.0
6.0	5.5	22.0	12.5
7.0	6.3	34.0	19.0
8.0	6.3	26.0	14.5
9.0	5.4	36.0	20.0
10.0	5.4	30.0	26.5

Transect data for Site 1: Downstream Unrestored Reference Site

SITE 2: Off-Channel Project Site

Quadrat Location	Species Name	Foliar Cover (%)	Total Cover (%) and Total Richness	Notes
1 m from left bank	English Ivy	6.3	35/11	
	Common horsetail	0.3		
	Salmonberry	3.0		
	Goldenshort Capsuled Moss	19.0		assume all moss same in quadrat
	Himalayan Blackberry	3.0		
	Creeping Buttercup	1.5		between western + creeping (spots on leaves)
	Tall Grass	1.5		
	Short Grass	2.0		
	Bitter cress	1.5		few seeded or western
	Purplish stem herb	3.0		Negar has pics and ID
	Lobed, pinnately veined herb	3.0		Negar has pics and ID
7 m from right bankfull width	Moss 1	35.0	93/4	
	Indian Plum	29.0		
	English Ivy	9.5		
	Himalayan Blackberry	4.0		
1m left	English Ivy	5.0	10/4	
	Pacific bleeding heart	0.3		
	False lily of the valley	5.0		
	Salmonberry	0.5		
8 m right	Himalayan Blackberry	2.0	91/4	
	Moss 1	24.0		
	Salmon berry	31.0		
	Sword fern	10.0		
5 left bank	False lily of the valley	0.3	1.3/3	8m from bank was in pool, so we
	Few seeded bitter cress	0.3		shifted to closest bank of off
	Unknown herb 1	0.3		channel pool, which was 4.95 m
7 m right bank	Salmonberry	8.0	85/4	
	Himalayan Blackberry	30.0		
	Indian Plum	6.0		
	Moss 1	40.0		
5 m left	lily like plant	3.0	5/3	
	moss	4.0		
	herb plant	1.0		
10 m right	Sword Fern	90.0	95/5	
	Geranium Liver	2.0		
	2 leave sprout	3.0		
	Moss 1	10.0		
	Small herb	17.0		
2 m left	Lily like plant	40.0	60/3	
	moss	10.0		
	salmonberry	5.0		
6 m right	Sword fern	1.0	1/1	

Plot data for Site 2: Off-Channel Project Site

Quadrat Location	Point	Species	Distance from center of quadrat (m)	Diameter (cm)	Notes
1 m left	1NE	Red alder	5.2	12.5	
	1NW	Red alder	8.8	27.0	English ivy
	1SW	Vine Maple	7.3	13.0	
	1SE	Alder?	6.8	29.0	English ivy
7 m right	2NE	vine maple	7.0	12.0	
	2NW	bigleaf maple	1.5	62.0	English ivy
	2SW	bigleaf maple	3.9	29.0	
	2SE	Red alder	2.8	27.0	English ivy
1 m left	3NE	Alder	3.6	30.0	English ivy
	3NW	Alder	6.1	56.0	English ivy
	3SW	Alder	11.4	42.5	English ivy
	3SE	red alder	3.0	46.0	English ivy
8m right	4NE	alder	2.2	25.0	
	4NW	Vine Maple	2.2	20.0	
	4SW	Alder	5.5	10.0	
	4SE	Red alder	7.1	10.4	
5 m left	5NE	black cottonwood	7.8	113.2	English ivy
	5NW	Red alder	9.2	48.5	English ivy (a little)
	5SW	black cottonwood	4.9	60.0	English ivy (a little)
	5SE	Vine Maple	5.1	13.5	English ivy
7 m right	6NE		> 12 m		
	6NW	Red alder	10.0	25.0	
	6SW	bigleaf maple	11.0	40.1	English ivy
	6SE	Red alder	5.0	30.0	
5 m left	7NE	Cedar	3.2	14.5	
	7NW	Cottonwood	4.5	113.7	
	7SW	Cottonwood	6.7	36.0	
	7SE	Alder	4.4	49.0	
10 m right	8NE		> 12 m		
	8NW	red alder	5.8	30.0	
	8SW	big leaf maple	2.5	40.1	English ivy
	8SE		> 12 m		
2 m left	9NE	Alder	2.9	43.0	
	9NW	bigleaf maple	3.2	17.0	
	9SW	bigleaf maple	>12	11.0	
	9SE	Alder	4.0	49.0	English ivy
6 m right	10NE		> 12 m		
	10NW		> 12 m		
	10SW	Alder	9.6	23.0	English ivy (a little)
	10SE	Alder	1.5	10.0	

Tree data for Site 2: Off-Channel Project Site

Transect	Bankfull Width (m)	Slope of Bank (from bankfull to 10 m) (%)	Slope of Bank (from bankfull to 10 m) (°)
1.0	6.6	11.0	6.0
2.0	6.6	40.0	28.0
3.0	6.7	9.0	5.0
4.0	6.7	21.0	9.0
5.0	5.5	10.0	6.0
6.0	5.5	15.0	85.0
7.0	5.7		
8.0	5.7	28.0	15.5
9.0	8.4		
10.0	8.4	78.0	28.0

Transect data for Site 2: Off-Channel Project Site

SITE 3: Restored Site

	Species Name	Foliar Cover (%)	Total Cover (%) and Total Richness	Notes
8 m right	Salmonberry	15.0	15/2	
	Moss	1.0		
6 m left	Indian plum	15.0	15/4	
	Horsetail	0.5		
	Moss	2.0		
	Salmonberry	7.0		
4 m right	Salmonberry	30.0	35/3	
	Moss	10.0		
	Herb 1	5.0		
0 m left	Salmonberry	15.0	75/5	
	Moss	25.0		
	Indian plum	20.0		
	Herb 2	34.0		
	Herb 3	2.0		
9 m right	Indian plum	10.0	75/4	
	Moss	50.0		
	Strawberry	15.0		
	Grass	8.0		
1 m left	Horsetail	2.0	37/8	
	Tall grass	7.0		
	Short grass	9.0		
	Herb 1	3.0		
	Herb 2	4.0		
	Moss	9.0		
	Dandelion	2.0		
	Leaflets	1.0		
4 m right	Moss	15.0	30/3	
	Short grass	4.0		
	Horsetail	0.5		
3 m left	Indian plum	6.0	60/3	
	Moss	7.0		
	Tall grass	1.0		
6 m right	Himalayan blackberry	5.0	40/5	
	Sitka spruce	10.0		
	tall grass	4.0		
	salmonberry	7.0		
	moss	1.0		
9 m left	Sword fern	11.0	32/6	
	moss	7.0		
	leaflets	5.0		
	herb 3	3.0		
	shrub 1	3.0		
	himalayan blackberry	3.0		

Plot data for Site 3: Restored Site

Quadrat Location	Point	Species	Distance from center of quadrat (m)	Diameter (cm)	Notes
8 m right	1NE	alder	5.9	33.9	
	1NW	alder	7.5	31.0	
	1SW	cottonwood	4.2	57.3	English ivy
	1SE	cottonwood	6.5	69.1	moss at bottom
6 m left	2NE	sitka spruce	2.3	10.1	
	2NW	cottonwood	1.4	34.5	
	2SW	cottonwood	2.5	61.2	
	2SE	cedar	1.1	11.2	
4 m right	3NE	alder	7.1	29.4	
	3NW	n/a	>12	n/a	
	3SW	n/a	>12	n/a	
	3SE	n/a	>12	n/a	
0 m left	4NE	n/a	>12	n/a	
	4NW	n/a	>12	n/a	
	4SW	alder	2.1	16.9	
	4SE	cottonwood	8.0	72.1	English ivy
9 m right	5NE	alder	8.3	42.0	
	5NW	cottonwood	3.5	53.0	
	5SW	cottonwood	3.6	86.7	
	5SE	n/a	>12	n/a	
1 m left	6NE	alder	7.1	18.2	
	6NW	black cottonwood	10.5	68.0	
	6SW	black cottonwood	8.6	99.0	
	6SE	big leaf maple	1.2	25.0	
4 m right	7NE	cottonwood	3.5	59.0	
	7NW	alder	2.3	19.8	
	7SW	alder	>12	19.8	
	7SE	cottonwood	2.6	68.5	
3 m left	8NE	cottonwood	11.2	69.5	
	8NW	alder	11.9	19.3	
	8SW	western red cedar	2.4	11.0	
	8SE	western red cedar	1.7	10.8	
6 m right	9NE	cottonwood	1.0	57.0	
	9NW	cottonwood	3.5	57.5	
	9SW	big leaf maple	>12	25.5	
	9SE	cottonwood	1.5	51.0	
9 m left	10NE	big leaf maple	2.8	45.0	
	10NW	big leaf maple	8.7	25.5	
	10SW	n/a	>12	n/a	
	10SE	n/a	>12	n/a	

Tree data for Site 3: Restored Site

Transect	Bankfull Width (m)	Slope of Bank (from bankfull to 10 m) (%)	Slope of Bank (from bankfull to 10 m) (°)
1.0	6.3	19.0	11.0
2.0	6.3	12.0	7.0
3.0	5.8	20.0	11.5
4.0	5.8	11.0	6.0
5.0	6.4	30.0	20.0
6.0	6.4	35.0	19.0
7.0	5.9	28.0	16.0
8.0	5.9	40.0	22.0
9.0	5.4	25.0	12.0
10.0	5.4	20.0	35.0

Transect data for Site 3: Restored Site