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Factors Influencing the Success of Riparian Planting Aspects of Fish Habitat Restoration Projects in the City of Surrey and Recommendations for Future Planting Plan Improvements.

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ABSTRACT Long-term monitoring of fish habitat restoration projects undertaken in conjunction with municipal capital works projects in fulfillment of Fisheries and Oceans Canada (DFO) Section 35(2) Authorizations have been conducted for a significant period of time within the City of Surrey. The accumulated data have provided an opportunity to assess the reasons for success or failure of riparian planting work conducted as a component of overall habitat restoration work. The author's of this study believe that relatively little science is available to environmental professionals creating riparian fish habitat restoration plans for the Lower Fraser area resulting in depressed survivorship and increased short and long term costs. To determine which biophysical characteristics influence the long-term viability of riparian restoration projects, the City undertook a quantitative assessment of the cumulative data for ten restoration projects. Through statistical analysis we were able to determine which biophysical parameters influenced plant survivorship, thus affecting the efficacy of the planting plan as a whole. The results can be used to develop strategies to improve plant survivorship and cost effective techniques for future riparian fish habitat restoration/ creation that meets the DFO "no net loss" guiding principle.

Keywords: Riparian, Fish, Habitat, Restoration, Functional, Plant

Introduction

As a result of capital works projects within or in close proximity to watercourses with fisheries values, the City of Surrey (the City) is often required to seek an Authorization from Fisheries and Oceans Canada (DFO) pursuant to Section 35(2) of the *Fisheries Act* for the harmful alteration, disruption or destruction (HADD) of fish habitat. A DFO Authorization typically requires a habitat compensation plan, which details the agreed to measures that will be undertaken to mitigate the HADD of fish habitat and ensure "no net loss" (NNL) as per DFO's guiding principle. One of the conditions contained in an Authorization to make certain, in an adaptive fashion, that NNL is achieved is the monitoring program. The multi-year post-construction monitoring program typically stipulates that in each given year tree survivorship will equal 100% and shrub survivorship will meet or exceed 80%. Due to the high costs associated with continually replanting to meet the survivorship criteria, it is imperative the trees/shrubs proposed in planting plans are properly selected and installed based on site specific characteristics and ecological requirements of the species chosen. The City is now exploring ways and means to reduce the cost and effort associated with the DFO monitoring requirement and in turn provide a healthy, functional riparian corridor.

Between 2000 and 2002, Jacques Whitford Limited (Jacques Whitford), on behalf of the City, undertook post-construction monitoring of the City's fish habitat compensation projects. The resultant accumulation of data has provided a unique opportunity to assess the reasons for success or failure of the riparian planting work conducted as a component of the overall habitat compensation projects. Success and/or failure of riparian planting work may be due to one or more factors, including aspect, slope, existing vegetation, upland drainage, soil moisture conditions, competing vegetation, use of imported topsoil, native soil conditions, and stock quality.

Jacques Whitford and the City joined collaboratively to analyze the long-term monitoring data and provide a quantitative assessment of compensation success or failure and the causes of the success or failure.

Methods

Phase I Site Selection

Long-term monitoring data was used in the first phase of the study to determine sites suitable for detailed analysis . Data from the 2002 long-term monitoring program were used, with the exception of the Pattullo Drainage Channel. The Authorization for this project required monitoring every second year; therefore, the most current data available for this project (2001) were used. Projects with extremely high survivorship (over 100%), indicating over planting, were removed from the project list.

Phase II Data Collection

In addition to the initial monitoring data, supportive data was collected on November 6 and 7, 2003. Data collected included:

- topsoil addition;
- topsoil depth;
- aspect of the site;
- slope of the site;
- native soil conditions; and
- presence of competing vegetation.

Phase III Data Analysis

The first step in analyzing the data was to determine survivorship of individual species. Total number of each species specified in the planting plans and total number observed during monitoring were used to determine total survivorship. Species that were used as substitutions, and were not specified in the planting plans were removed from totals, as numbers planted were unknown and including them would skew results. Species with greater than 100% survivorship were considered equal to 100%. In the absence of detailed "as built drawings", it was also assumed that species showing zero survivorship had been installed as planned and since perished.

The SAS Institute statistical analysis program JMP IN 4.0 was used to analyze the data. One-way analysis of variance (ANOVA) and t-tests were used to compare survivorship of each species against site variables. Analysis of variance was used for variables with more than two categories (*i.e.* aspect and native soil conditions). T-tests were used for variables with only two categories (*i.e.* topsoil and competing vegetation presence/absence). Results were considered significant when the probability of rejecting the null hypothesis was less than the 5.0% significance level ($P<0.05$). Regression analysis was used to determine if significant relationships between continuous variables existed (*i.e.* slope and topsoil depth).

After individual species were analyzed, species were then separated into three groups, riparian, upland forest and edge species, based on their respective ecology and autoecology. The groups were formed based on past personal observations and species specific notes contained in Pojar and MacKinnon 1994. Survivorship of the three groups was analyzed against each of the listed variables.

The whole data set was then grouped into two sub-sets consisting of tree and shrub species. Survivorship of both sub-sets was analyzed against each variable. Survivorship against species was also analyzed to determine if certain shrub or tree species showed greater than average survival in the compensation plantings compared with other species and were, therefore, more suitable for use in compensation planting plans.

Results

Phase I Site Selection

A total of 10 projects were analyzed and are provided in Table 1. Three of these projects had more than one compensation site associated with them. The sidewalk construction project on 144th Street had three sites, the storm flow diversion works on Dingwall and Southward creeks had two sites and the Pattullo Channel Drainage Improvements had two sites. These projects were broken down by site and each site was analyzed independently, resulting in a total number of 14 sites.

Table 1 - City of Surrey Long-Term Monitoring Projects Selected for Analysis

PROJECT NAME	SURREY PROJECT NO.	DFO AUTHORIZATION NO.	MWLAP FILE NO.
Bolivar Creek Culvert Installation at 115th Avenue	unknown	98-HPAC-PA2-000-000020	76910-60/98.1863C
Installation of High Flow Pipe on Knudson Creek between Marine Dr. and Semiahmoo Bay	D2/99 4899-002	99-HPAC-PA2-000-000107	A2004848
Slope Stabilization Works on Fergus Creek at 1250 King George Highway	4899-324	98-HPAC-PA2-000-000121	76910-60/99.2303H
Sidewalk Construction Along 144th Street: 64th Avenue to 67th Avenue	1701-007	-	76910/60-2897
Culvert Replacement on Delta Creek	4898-005	99-HPAC-PA2-000-000117	76910-60/2211
Bank Stabilization and Outlet Modifications on Peacock Brook	4800-055 (4800-703)	00-HPAC-PA2-000-000309	76910-60/2000.2621F
Pattullo Channel Drainage Improvements	4800-006 (4800-703)	00-HPAC-PA2-000-000147	76910-60/2000.2303B
Stormflow Diversion Works on Dingwall and Southward Creeks	4800-016 (4800-703)	00-HPAC-PA2-000-000418	76910-60/2000.2621C

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Extension of Culvert on Unnamed Tributary of Mahood Creek at 84th Avenue	1799-308	99-HPAC-PA2-000-000141	unknown
Bolivar Creek Diversion Sewer	4899-055	01-HPAC-PA2-000272	A2004980

Phase II Data Collection

Table 2 provides a summary of the results of the data collection.

Table 2 – Results of the Data Collection at Each of the Study Sites

SITE	SITE CONDITION					
	Topsoil (Y/N)	**Topsoil Depth (mm)**	**Aspect**	**Slope (°)**	**Native Soil Conditions**	**Competing Vegetation (Y/N)**
Extension of Culvert on Unnamed Tributary of Mahood Creek at 84th Avenue	Y	300	S	15	>300mm of topsoil	Y
Bolivar Creek Culvert Installation at 115th Avenue	Y	300	S	0	>300mm of topsoil	Y
Installation of High Flow Pipe on Knudson Creek between Marine Dr. and Semiahmoo Bay	Y	300	S	20	>300mm of topsoil	Y
Slope Stabilization Works on Fergus Creek at 1250 King George Highway	Y	200	N	35	200mm of topsoil over sand & gravel	Y
Sidewalk Construction on Archibald Creek at 144th Street	N	0	W	35	sand & gravel	Y
Sidewalk Construction on Hyland Creek at 144th Street	N	0	W	32	sand & gravel	Y
Hyland Creek at 64th Avenue	Y	450	S	0	>600mm of topsoil	Y
Culvert Replacement on Delta Creek	Y	75	W	20	150-250mm of topsoil	N
Bank Stabilization and Outlet Modifications on Peacock Brook	Y	150	S	23	thin layer of topsoil over gravel	Y
Patullo Drainage Channel North of 110th Avenue	Y	200	N	35	sand & gravel	N
Patullo Drainage Channel South of 110th Avenue	Y	200	N	35	sand & gravel	N
Southward Creek at 137A Street	Y	450	W	15	100-150mm of topsoil over gravel	Y
Dingwall Creek	N	0	N	45	sand & gravel	N
Bolivar Creek Diversion	Y	50	N	30	topsoil over riprap	Y

Phase III Data Analysis

Analysis of the data set and subsets produced some interesting and significant results in terms of relative plant species survivorship. The outcomes, which fell within our prescribed P-value ($P<0.05$), are described below.

Mean survivorship of all species in the data set showed significant results ($P=0.0052$) when tested using a one-way ANOVA, thus we proceeded to compare mean survivorship of each species against the grand mean (66.4%). Based on the grand mean, a list was generated of species expected to exhibit superior survivorship relative to those species with survivorships below the grand mean (Table 3). Species with exceptional persistence were western redcedar (*Thuja plicata*) (81.4%), Douglas-fir (*Pseudotsuga menziesii*) (89.7%) and red alder (*Alnus rubra*) (82.0%). Significant results were also discovered when matching survivorship of the whole data set against the list of variables.

Table 3 – Species with Survivorship Greater than Grand Mean (66.4%)

Species	Mean %	Std Error
Douglas-fir	89.7	11.2
Hooker's willow	86.0	22.4
Nootka rose	72.8	10
Pacific crab apple	75.0	22.4
Pacific ninebark	79.0	12.9
Pacific willow	67.0	22.4
Sitka spruce	78.2	22.4
bitter cherry	95.0	22.4
common snowberry	77.3	9.5
red alder	82.0	12.9
red-osier dogwood	73.0	11.2
salal	95.5	22.4
salmonberry	81.1	9.5
shore pine	100	31.6
sword fern	72.3	12.1
vine maple	67.6	12.0
western hemlock	74.0	18.2
western red cedar	81.4	11.2

The aspect comparison showed the northern perspective had significantly greater survivorship ($P= 0.007$, 82.4%) when compared to western and southern (61.0% and 67.9% respectively) facing slopes. Competing vegetation also demonstrably affected survivorship ($P=0.043$), indicating that plants had a higher survivorship in the absence of competing vegetation (74.3%) than when competing vegetation was present (62.1%).

Survivorship of all 39 species when compared against the listed variables only yielded significant results for red elderberry (*Sambucus racemosa*) and Douglas-fir.

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Red elderberry showed significant results when related to aspect (P=0.007). In this regard, red elderberry was shown to flourish when planted on north facing slopes (79.3%) relative to the west (1.3%) and south (12.0%) perspectives. No red elderberry were planted on east facing slopes in the data set. Red elderberry also showed significant results when compared against competing vegetation (P=0.0011) as evidenced by 79.3% survivorship at sites with no competing vegetation and a low 5.6% at sites with competing vegetation present. Furthermore, tests proved that Douglas-fir survivorship is appreciably influenced by slope (P=0.030). The mean slope Douglas-fir was planted on was 21.5 degrees and the mean slope of all six sites exhibiting 100% survivorship was 23.6 degrees. The other two sites, both with 15.0 degree slope, yielded a much lower average survivorship of 59.0%.

The riparian, upland and edge subsets also showed several noteworthy correlations. Imported topsoil depth was shown to significantly effect edge species survivorship (P=0.034). Topsoil depths of between 0-200 mm yielded higher plant survivorship (73.3%) than did the 201-900 mm category (49.8%). The mean topsoil depth added during planting of edge species was 228 mm. Slope was also found to significantly affect survivorship of edge species (P=0.0206). Slopes between 0-30 degrees had a much higher survivorship (76.0%) than did the 31-45 degree category, which demonstrated poor survivorship (41.0%).

Similar to edge species, upland forest species survivorship was also affected by imported topsoil depth (P=0.031) and slope (P=0.0014). Imported topsoil depths between 0-200 mm showed a dramatically positive influence on mean survivorship (82.7%) when contrasted with 201-900 mm, which had a poor outcome (40.8%). Within upland forest species, steeper slopes prevailed. The 16-45 degree slope category posted higher mean survivorship (81.3%) than did the lower gradient sites, 0-15 degree, which had a 38.8% mean survivorship. Upland forest species survivorship was also significantly influenced by native soil condition (P=0.0015) (Table 4).

Table 4- Mean Survivorship of Upland Forest Species in Different Native Soil Condition.

Native Soil Conditions	Mean Survivorship (%)	Comments
Sand and gravel	74.0	Mixed sites
Thin layer of topsoil over gravel	98.0	Peacock Brook
100-150mm topsoil over gravel	21.5	Southward Creek @137A
151-250mm topsoil over gravel	77.4	Delta Creek culvert repair
200mm topsoil over sand and gravel	95.8	Fergus Creek slope stabilization
300-599mm topsoil	59.8	Mixed sites

The final category, riparian species, generated no significant outcomes through the analysis of variance with the list of variables; however, riparian species analysed against survivorship showed a statistically relevant relationship (P=0.0440).

In addition, when the mean survivorship of all species in each ecosystem group was averaged, there was no significant difference between the three groups. All three means were very similar (riparian=68.0%, edge species=63.6%, upland species=68.8%).

Regression analysis did not yield any significant results. Similarly, no significant results were reached when trees and shrubs were grouped and compared against the list of variables. However, a significant relationship between shrub species and survivorship was produced (P=0.0044), but not for trees.

Discussion

Results from this study are useful in terms of developing and implementing cost effective riparian restoration planting. The incorporation of plants determined to have higher than average survivorship (Table 3) in planting plans will contribute to reduce maintenance/replacement costs for fish habitat compensation/restoration projects.

The data analysis showed that in some instances competing vegetation had a significant influence on survivorship. This suggests that maintenance of restoration sites to remove competing vegetation until plants have become established will increase survivorship. Both weed suppression and weed control have been recommended for riparian restoration sites by others (Sweeney *et. al.* 2002; Sweeney 1999; US Department of Agriculture 1999; Pannill *et. al.* 2001).

Typical invasive species found to be affecting riparian restoration sites in the City include Himalayan blackberry (*Rubus discolor*), reed canary grass (*Phalaris arundinacea*), and orchard morning glory (*Convolvulus arvensis*). Options for control of Himalayan blackberry include hand pulling, hand hoeing, digging/grubbing/cutting, herbicide use and prescribed burning (Hoshovsky 1989). Planting fast-growing or larger trees/shrubs, may increase survivorship as Himalayan blackberry, reed canary grass and morning glory are largely shade intolerant species.

Spreading mulch around planted material is a commonly used weed suppression technique. Mulch has been used to suppress invasive species with great success (Haywood 1999). Mulches and crop residues are widely used in agriculture, although to a lesser extent in forestry, throughout the world to suppress weed development, retain moisture, and reduce erosion and sedimentation (Haywood *et. .al.* 2003). Mulch is typically composed of either a mat of cotton, hemlock and polyester, pine straw, woven polypropylene, or perforated polyethylene and functions as a photo barrier. While mulch is effective at suppressing weed growth, it may also inhibit regeneration of desirable native species.

The significance of aspect, slope and native soil conditions on survivorship suggests that attention must be paid to individual habitat requirements when selecting species for restoration plans. Although the composition of vegetation and its spatial structure is influenced by many soil factors, when water is a limiting factor, the soil moisture balance is the most important variable controlling vegetation patterns (Tinley 1982). Aspect, slope and native soil conditions all play a role in the moisture regime of a site. Northern aspects tend to provide cooler, moister conditions than southern aspects, as they do not receive direct sunlight. For example, red elderberry survivorship was highest on slopes with northern aspects. Red elderberry is a shade tolerant species that prefers moist environments, typical of slopes with northern aspects.

Steeper slopes will tend to drain faster as a function of gradient, generally creating drier conditions at the upper slope with a continuum of progressively moister conditions down the slope. Additionally, soil conditions can affect soil moisture and drainage. Certain soil types absorb and hold water better than others. For example soils with higher sand and gravel content will drain better and hold less moisture than soils with high silt or organic content, therefore creating heterogenous moisture conditions on sites with varying soil types.

The addition of topsoil to a site significantly affected the survivorship of edge species in that the lower topsoil depths had higher survivorship than sites with higher topsoil depth. This suggests the addition of topsoil to restoration sites may be a needlessly incurred cost included in compensation plans. This is somewhat contrary to the results of a literature search on topsoil effects on plant growth, which showed that typically, the addition of topsoil resulted in high plant density richness and improved seeding (P.M. Holmes 2001 and B.A. Pinchak *et. al*. 1985).

It would also be interesting to compare, on the same site, plants that received supplemental watering against those with additional topsoil and determine which of the two conditions exhibited higher survivorship. Soil moisture is likely the premier limiting factor in survivorship of newly planted trees and shrubs. Water stress substantially alters plant metabolism, decreasing plant growth and photosynthesis and negatively affecting ecosystems (Tezara *et al.* 1999). Water limitation can cause restricted diffusion of CO_2 into leaf as a result of stomatal closure and inhibition of CO_2 metabolism (Teraza *et al.* 1999).

The results generated from this study broadly point to the importance of creating a detailed and specialized planting plan for each site. Tree, shrub and forb species should be selected with recognition of the spatial heterogeneity characterized by the site. In other words, to maximize survivorship, plants should be selected according to the soil, light and moisture conditions present on the site as a whole or exhibited by the varying regimes contained within. Similarly, it is important to prescribe plant species based on those already established in vegetated polygons identified in surrounding areas.

Planting Plan Options to Explore

As part of the compensation plan development, DFO typically requires all trees and shrubs be planted according to the DFO/MELP, “A Guide to Riparian Revegetation”. This guideline publication includes advice for maximizing survivorship and planting criteria and recommends tree stock be a minimum 1.2 m high and planted on 2 m centers with shrubs planted on 1 m centers. DFO habitat practitioners typically adhere to the tenets of this guideline document quite closely, thus limiting creative approaches and innovative planting plan concepts. The following are two planting strategies being considered, after contemplating the results of this study, to maximize plant survivorship and optimize functionality as fish habitat.

Firstly, the City is exploring a riparian restoration strategy, which will enhance survivorship as well as mimic the natural recolonization process typical of the Coastal Western Hemlock (CWH) biogeoclimatic zone. The staged or phased planting concept involves initially planting early seral stage pioneer species such as red alder, salmonberry (*Rubus spectabilis*) and cottonwood (*Populus balsamifera*), which naturally colonize disturbed areas. Red alder is an aggressive, fast growing species, which thrives on moist, disturbed sites and contributes up to 350 kg/ha of nitrogen to surrounding soil per year (Pojar and McKinnon 1994). Nitrogen is essential for the growth and functioning of all plants, and its availability in the soil is crucial in the growth of terrestrial ecosystems (Rodriguez-Iturbe et al 1999). Following the successful establishment of the pioneer species, selective thinning should be undertaken to provide space and light for introduction of mid to late climax species such as western hemlock (*Tsuga heterophylla*) and shade tolerant shrubs like Indian-plum (*Osmaronia cerasiformis*). The advantages of the red alder staged planting approach are several; 1) fast soil stabilization and ground cover, which will limit erosion; 2) nitrogen fixing capacity, which will enhance survivorship of subsequently planted later seral species; 3) red alder is relatively short lived and provides a "quick" source of woody debris for nearby watercourses and food and refugia for invertebrates and herpetifuana; and 4) out competes most shade tolerant invasive species like reed canary grass. On the down side, staged planting requires long-term coordination, which may be logistically problematic from a municipal and regulatory standpoint.

Secondly, the City is contemplating using larger, more mature stock (greater than 2 m in height), which will have an advantage over most competing vegetation, thus requiring less effort in weed control. This strategy would mainly apply to trees and larger, more robust shrubs. By planting larger trees on 2 m centres (or wider if deemed appropriate by the regulatory agencies), there may be opportunity to forgo the full complement of shrubs and spread an appropriate seed reclamation mix in their stead, hence offsetting the cost of the larger plants. The larger stock also provides an immediate benefit to fish and fish habitat in terms of shade and food and nutrients. It is recommended by the authors that the seed composition be closely inspected for weedy invasive grasses, such as reed canary grass. Use of an all-native, low growing seed mix is recommended. This strategy works well in areas which may be subject to mowing or high pedestrian traffic, as the large stock is much more visible, thus more likely to persist.

Conclusions

The strongest message presented through data analysis appeared to be related to site moisture conditions, light level and weed suppression techniques employed. Species survivorship was directly related to the local moisture regime (aspect, slope and topsoil depth), competing vegetation management and ambient light level. Again, specific species should be selected based on their respective affinity for water and ability to out-compete weeds and other prescribed tree or shrub species. As a result of this study, we recommend planting according to the spatial variation in habitat characteristics exhibited by the restoration site in question. Recognizing site spatial heterogeneity will allow for maximizing species richness through consideration of natural site bio-physical variations and allow for customizing planting plans based on polygons and niche type microenvironments defined by local fluctuations in light, moisture and soil type. There may be occasions where the typical planting plan style may not be appropriate and alternatives should be explored to provide functional riparian fish habitat in a timely fashion. As fish habitat practitioners are responsible for reviewing and accepting the final compensatory planting plan, practitioners should be open to considering new, innovative approaches to riparian fish habitat creation/restoration.

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