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Restoration of Dune Habitat, Coburg Peninsula, Vancouver Island, British Columbia.

An Interim Report by

David Blundon, PhD
Environmental Technology Program
& Biology Department,
3100 Foul Bay Rd,
Camosun College,
Victoria, B.C.
V8P 5J2 Canada

Submitted to
Esquimalt Lagoon Stewardship Committee
July 9, 2013

Abstract

Coburg Peninsula, a barrier spit approximately 2 km by 100 m (20 ha), is within the Capital Regional District of Victoria the capital of British Columbia, Canada. The barrier spit has sustained major impacts from recreational activities, use as a transportation corridor and winter storms. Foredune habitat on the barrier spit; an important habitat for migratory birds, a valuable defence against storm surge and strong winds, has been severely degraded.

A multivariate experimental design was established in 2007 to evaluate the effect of planting native species on degraded foredune sites. Sites (n = 4) were selected across the barrier spit, based on their degree of impact (disturbance and Scotch broom infestation), and split into a control plot (least degraded, not planted) and treatment plot (more degraded, planted). The native species, dunegrass (*Leymus mollis* spp. *mollis*), silver burweed (*Ambrosia chamissonis*), American sea rocket (*Cakile edentula*), entire-leaved gumweed (*Grindelia integrifolia*), and beach pea (*Lathyrus japonicus* var. *maritimus*)] were planted. Percent cover was determined for each species with a line intercept method. Invasive Scotch broom (*Cytisus scoparius*) was removed from the entire barrier spit.

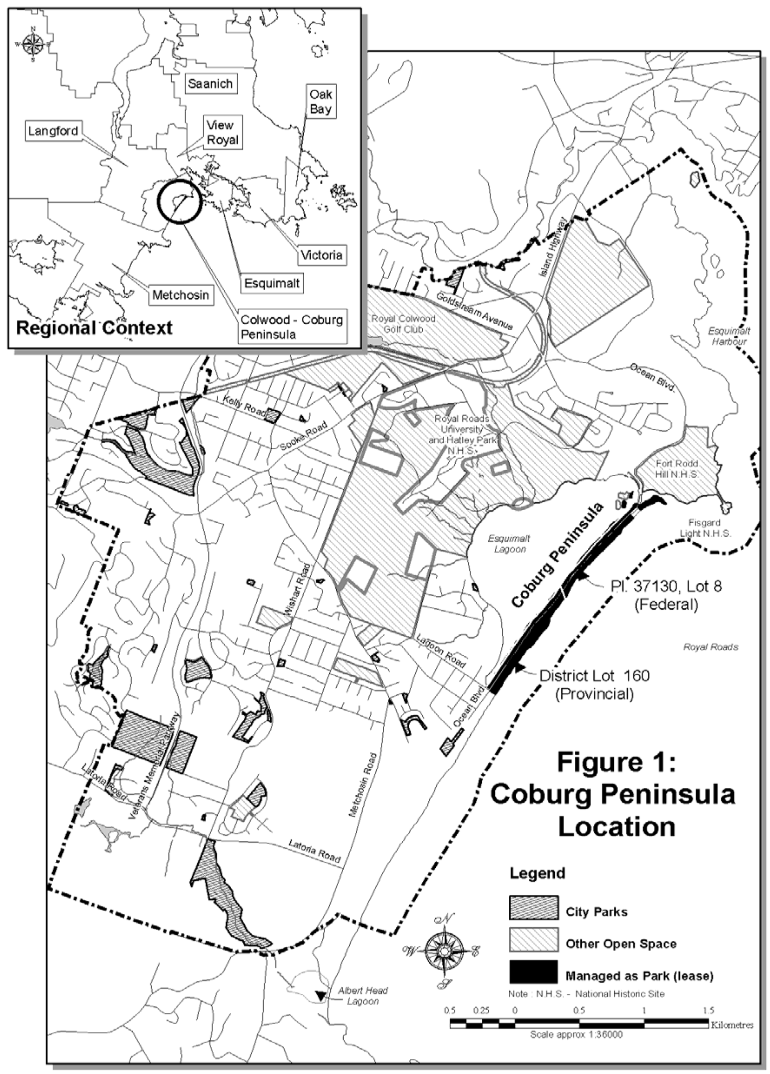
The null hypothesis, that there was no significant difference between plant cover composition for control and treatment plots over six years of monitoring (2007 to 2012), was statistically tested with Blocked Multi-response Permutation Procedures (MRBP). The null hypothesis was accepted (p = 0.608). Restoration plots that were degraded, planted with native species, may have revegetated comparable to undegraded control plots.

Total cover (%) of all plant species declined in both the control and treatment plots since planting in 2007. Over the same period, dunegrass and silver burweed increased on the treatment plots. Dunegrass declined on the control plots; however, silver burweed increased.

It is recommended that monitoring continue in order to assess long term recovery. It is also recommended that the current split-plot design (control – treatment) be expanded to include more sites on Coburg Peninsula.

INTRODUCTION

Coburg Peninsula is located within the Capital Regional District (CRD) of Victoria the capital of British Columbia, Canada. Coburg Peninsula is geologically classified as a barrier spit. It consists largely of sand and gravel that has developed from longshore transport of sediments by wave, tides and winds that has been historically supplied by backshore erosion (Seabulk System Inc. 2008; Nordstrom et al., 2007). Sediment supply to the beach at Coburg Peninsula may be diminished as a consequence of the recent closure of the Metchosin Gravel Pit. This pit south of the spit deposited sand into Royal Bay (Baxter, 2008). The diminution of sediment supply to beaches is a worldwide event resulting from natural and anthropogenic processes (Doody, 2013). The predominant landscapes on the barrier spit are beach and foredunes (first rise). There are no main dunes present. The barrier spit is approximately 2 km in length and 100 m across (20 ha). It forms the southern boundary of Esquimalt Lagoon which is approximately 100 ha. The lagoon receives fresh water from three creeks that drain the Esquimalt Lagoon watershed. Tidal sea water enters the lagoon under a bridge at the north end of the barrier spit. Coburg Peninsula comprises both Federal and Provincial land which are leased by the City of Colwood and managed as Park (Interim Management Guidelines for the Coburg Peninsula, 2006; see Figure 1).



Coburg Peninsula is a degraded ecosystem that has sustained major impacts from human activity and coastal erosion from winter storms. A paved road (Ocean Boulevard) used by approximately 3500 vehicles daily traverses the barrier spit. The road is 13 m wide and occupies approximately one quarter of the high water area. Adjacent to the road is a gravel parking area. The area has high visitor use (Wilson et al., 2002) because the road provides ready access to the ocean shore and lagoon. There is ample evidence of trampling of vegetation from foot traffic. Driftwood deposition and erosion of dunegrass habitat on the foredune is a constant reminder of the impact from winter storms.

Humans are converting shorelines all over the world to suit their needs (Nordstrom, 2008). Nordstrom et al., 2000 (as cited in Nordstrom & Jackson, 2013) point out "Once dunes are eliminated by human activities, they are lost from the consciousness of stakeholders, and attempts by managers to build new dunes are hampered by a lack of appreciation of their value."

Coburg Peninsula and Esquimalt Lagoon support a diversity of animal and plant communities and a federally designated Migratory Bird Sanctuary (Bein, 2005). An important plant species on the barrier spit is dunegrass (*Leymus mollis* spp. *mollis*) (ELSI, 2007). Dunegrass is a dominant species, on the upper strand (upper beach) and foredunes (first rise) of the Pacific Northwest coast, forming sparse grasslands with 10% to 50% total cover (Holland, 1986). These "foredune grasslands" are typically found in relatively high-energy sandy coastlines, where dunegrass foliage traps sand creating a gentle topography with open vegetation. Wind erosion is also reduced by the foliage of dunegrass. The horizontal rhizomatous growth-pattern of dunegrass ensures the sparse cover and partially stabilizes the foredune (Pickart, 2008). The open habitat of foredune grasslands leaves them susceptible to invasion by non-native species. Disturbed coastal sites are more prone to colonization by invasive non-native species than undisturbed sites (Greipsson, 2011).

Revegetation of foredunes with dunegrass, on coastlines of the Pacific Northwest, has a long history (Washington's Coast: Plants – Beachgrass). The planting of dunegrass is usually done to replace invasive European beachgrass (*Ammophila arenaria*) (Goodman, 2009;). European beachgrass has not colonized Coburg Peninsula. A long-term management problem, where dune grasses are used in restoration, is loss of dune grass vigour. According to Goodman (2009), within a few years it is common for transplanted dune grasses to experience a loss of vigor. This is manifest as a decrease in height and density of foliage, a reduced number of tillers and decreased seed yield. A number of factors have been implicated which include soil pH, soil aeration, soil microorganisms, plant age, reduced root growth and competition between plants for soil macronutrients - especially nitrogen (N) and phosphorous (P). To alleviate the latter problem Goodman (2011) recommends using local genotypes of native species (clonal offsets), and fertilizing the transplants to increase growth and tillering (cloning) rate.

Founded in 2001, the Esquimalt Lagoon Stewardship Initiative (ELSI) is a broad coalition of community and environmental groups, educational institutions, the business community, recreational user groups, First Nations and government. It is organized by a Harbours and Watersheds Coordinator employed by the CRD (Capital Regional District Board, 2013; ELSI Website).

The mandate of ELSI is to:

- restore 6.4 ha of degraded dune habitat;
- address human impacts on the estuary, which are avoidable, against a background of global climate change and sea level rise (Nadia et al., 2011); and
- evaluate whether the ecosystem can recover on its own or require some degree of intervention?

This restoration is driven by the need to overcome reductions in ecosystem habitat, biodiversity, habitat size and heterogeneity. All of these reductions result in the inability of naturally functioning ecosystem to provide erosion protection (Elliot et al., 2007).

Restoration was to be accomplished through:

I. realignment of beach access points and benches to reduce trampling across sensitive dune habitat;
II. raising public awareness of dune habitats and engage residents and visitors in stewardship of the dunes;
III. the establishment of experimental (demonstration) restoration plots; and
IV. monitoring the effectiveness of restoration.

The objective of the interim report is to present the results of six years of monitoring the revegetation in the experimental (demonstration plots) that were established in 2007. Recommendations are also included in the report.

METHODS

In the fall 2007 and 2008, 1628 and 843 native herbaceous species, silver burweed (*Ambrosia chamissonis*), American sea rocket (*Cakile edentula*), entire-leaved gumweed (*Grindelia integrifolia*), and beach pea (*Lathyrus japonicus* var. *maritimus*) were planted in restoration plots and decommissioned parking areas. In addition, 1900 plugs (3 cm wide) or containers (10 cm wide) of dunegrass (*Leymus mollis* ssp. *mollis*) were planted. This effort involved 160 volunteers who provided a total of 385 hours (Natalie Bandringa, personal communication, April 2010).

A multivariate experimental design with split plots was employed where four sites (n =4) were selected across the 2 km spit based on their degree of impact (trampling and Scotch broom infestation). Sites were split into plots with a control (least degraded, not planted) and treatment (more degraded, planted). Invasive Scotch broom was removed from each plot.

Each plot (control and treatment) was sampled using a line intercept method (Krebs, 1999). There were 4 transects sampled per subplot (= 8 subplots x 4 transects = 32 transects in total). A typical plot with four transects is illustrated in Figure 2. The baseline is a log anchored to the barrier spit substrate on the landward side,

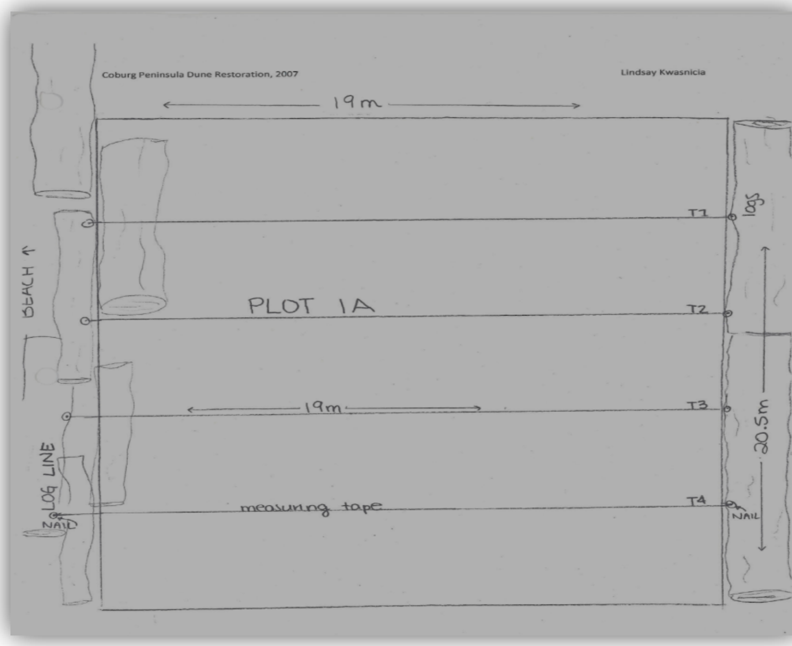


Figure 2. Drawing of a subplot with four transects from Kwasnicia (2008).

with permanent location pins, and is shown on the right side of the figure. Pseudoreplication was avoided by calculating the mean cover (%) for each species within a subplot. Cover of a plant species is the portion of the transect line that the plant came in contact with. Species estimates were based on canopy cover, gaps greater than 10 cm were not included. Sampling by Camosun College, Ecology students occurred in September of each year from 2007 to 2012.

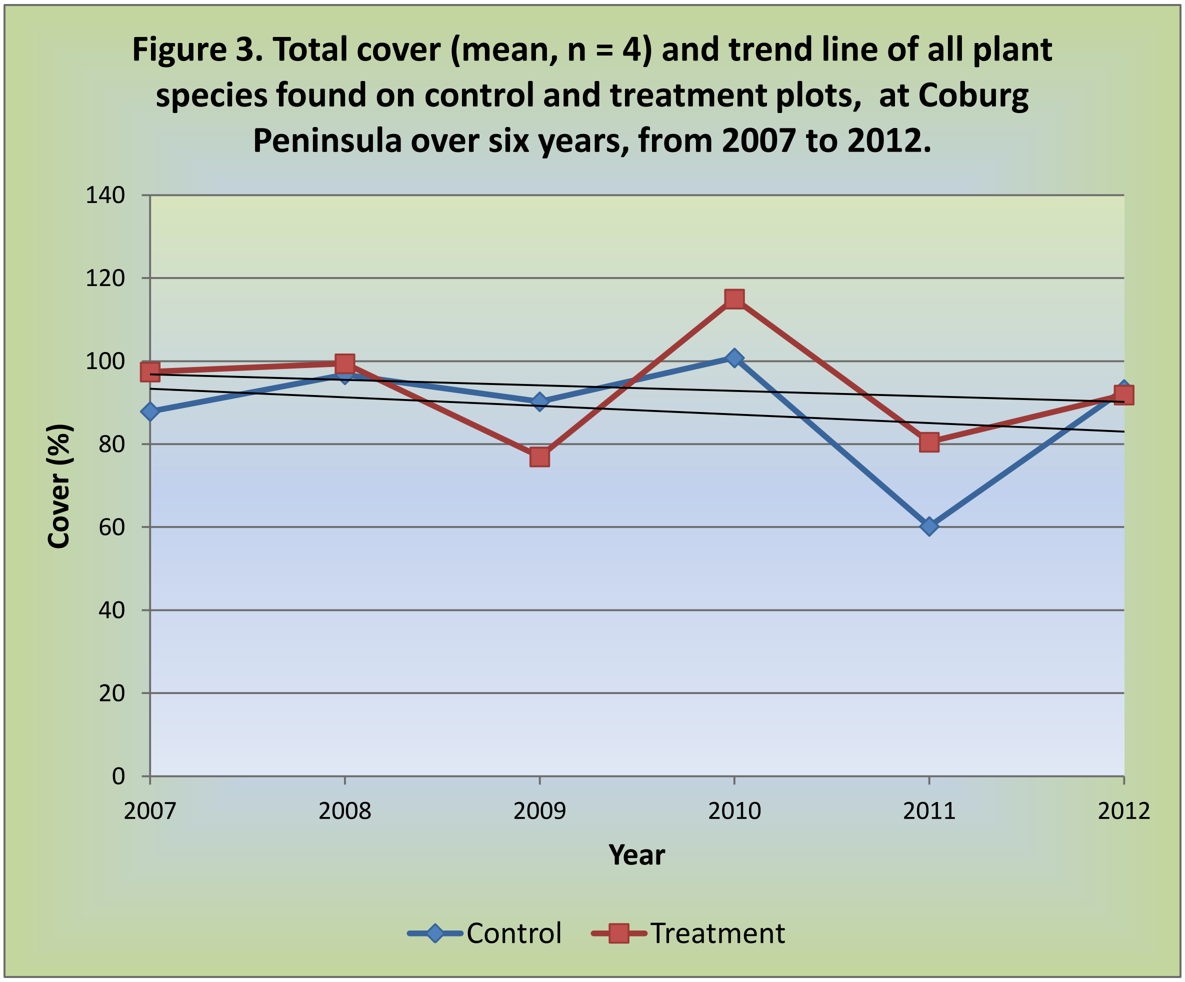
The null hypothesis that there is no difference between groups can be statistically tested with Blocked Multi-response Permutation Procedures (MRBP). The software PC-ORD was used to execute this test (McCune and Mefford, 1999). Blocked MRPP is a form of Multi-response Permutation Procedure (MRPP), limited to the use of Euclidean distance measure, and controls for the variation contributed by a blocking factor (Peck, 2010). This test is suitable for simple repeated-measures designs (McCune and Grace, 2002). For this multivariate experimental design, groups are the control and treatment plots and blocks are years. The split-plot layout and six years of sampling make this a simple repeated-measures design.

Blocked MRPP produces three test statistics. The *T*-statistic describes the separation between groups (control versus treatment plots). The more negative *T* is the stronger the separation. The within-group agreement value (*A*), is a measure of how similar sample units (transects) within a group (control and treatment plots) are to each other; where *A* varies from Amax = 1 (identical sample units), $A = 0$ (heterogeneity within groups equals that expected by chance alone) and $A < 0$ (more heterogeneity within groups than expected by chance). A small *p*-value from the permutation (randomization) test indicates that sample units (transects) from a group (control or treatment plot) are statistically more similar to one another than would be expected if they belonged to the other group.

RESULTS

After six years the total cover (%) of all plant species, on both the control and treatment plots, showed a parallel and declining trend line. Total cover on the control and treatment plots responded in a similar pattern each year (Figure 3). The total cover was very similar in the last year of sampling, 93.2% and 91.9% for the control and treatment, respectively.

Over the same period native species showed a small decline in percent cover on control plots (Figure 4). This trend was also exhibited by dunegrass (Figure 5, Table A1). Silver burweed showed a small increase (Figure 6, Table A1). The greatest decline in percent cover on control plots was by non-native forbs and the invasive shrub, Scotch broom (13.54% to 2.89%, see Table A3, Figure 4). Invasive grass cover on the control plots remained relatively unchanged (Figure 4, Table A2).



Over the six year sample period, native species showed an increase in percent cover on treatment plots (Figure 7). Dunegrass showed a general increase in percent cover (Figure 5, Table A1). The greatest decline in percent cover on treatment plots was by non-native forbs (17.02% to 2.24 %, see Table A3, Figure 7). Invasive grass cover on the control plots remained relatively unchanged (Figure 7, Table A2).

Figure 4. Mean cover and trend line of native plants, invasive grasses, and invasive forbs and shrubs on control plots (n = 4) at Coburg Peninsula from 2007 to 2012.

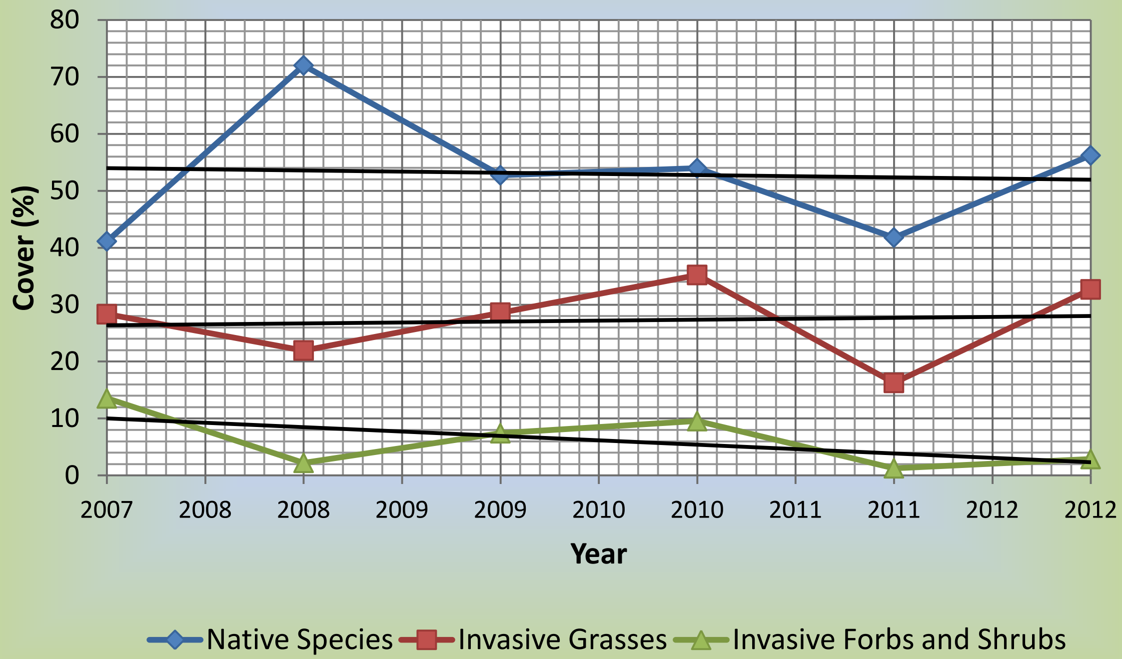


Figure 5. Mean cover and trend line of dunegrass on control and treatment plots (n = 4) at Coburg Peninsula from 2007 to 2012.

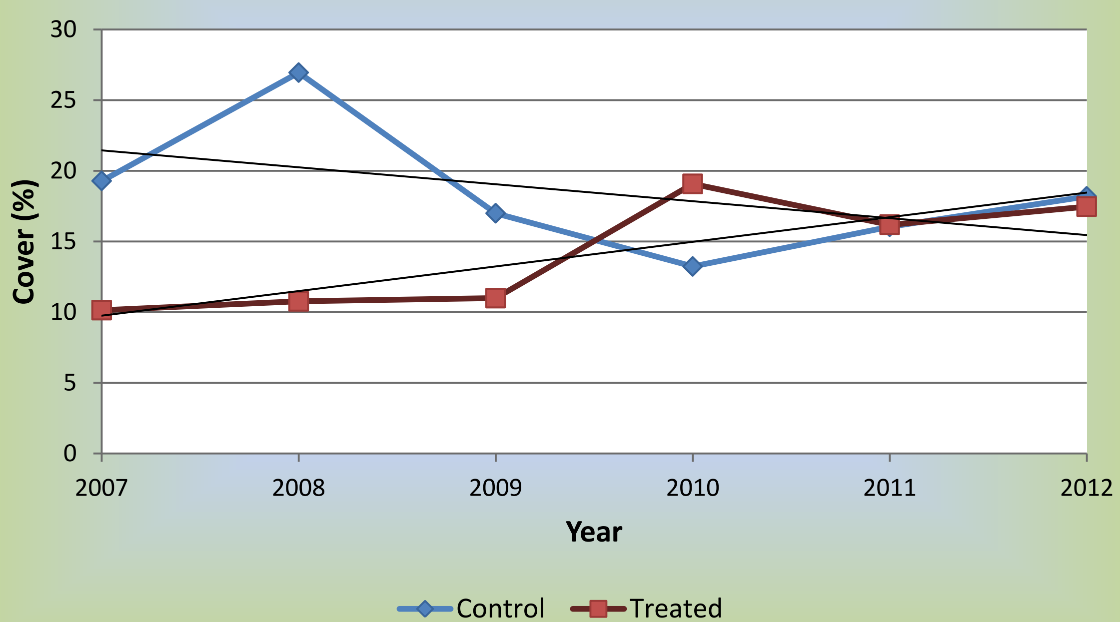


Figure 6. Mean cover and trend line of silver burweed on control and treatment plots (n = 4) at Coburg Peninsula from 2007 to 2012.

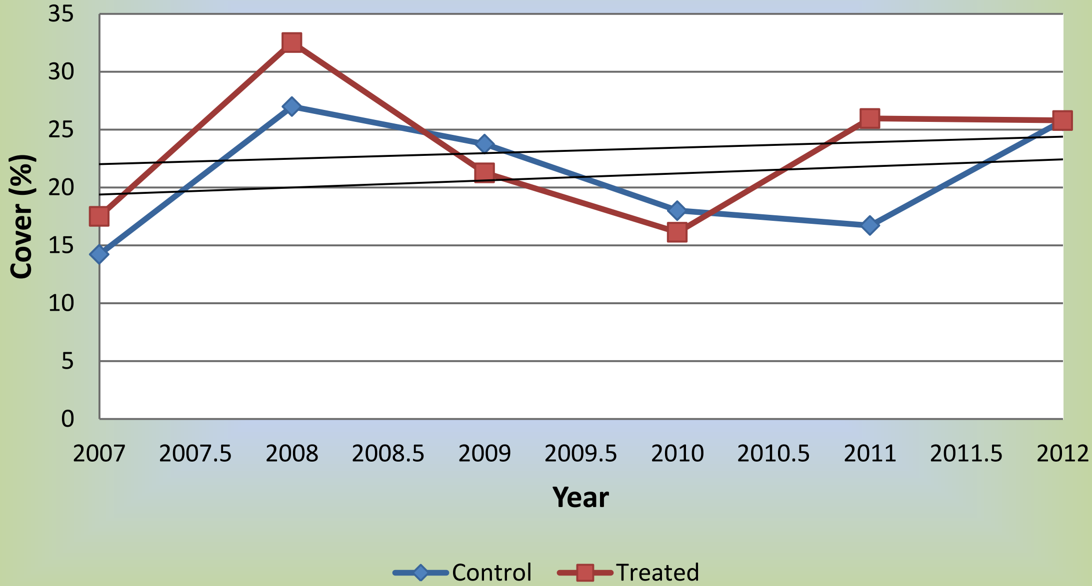
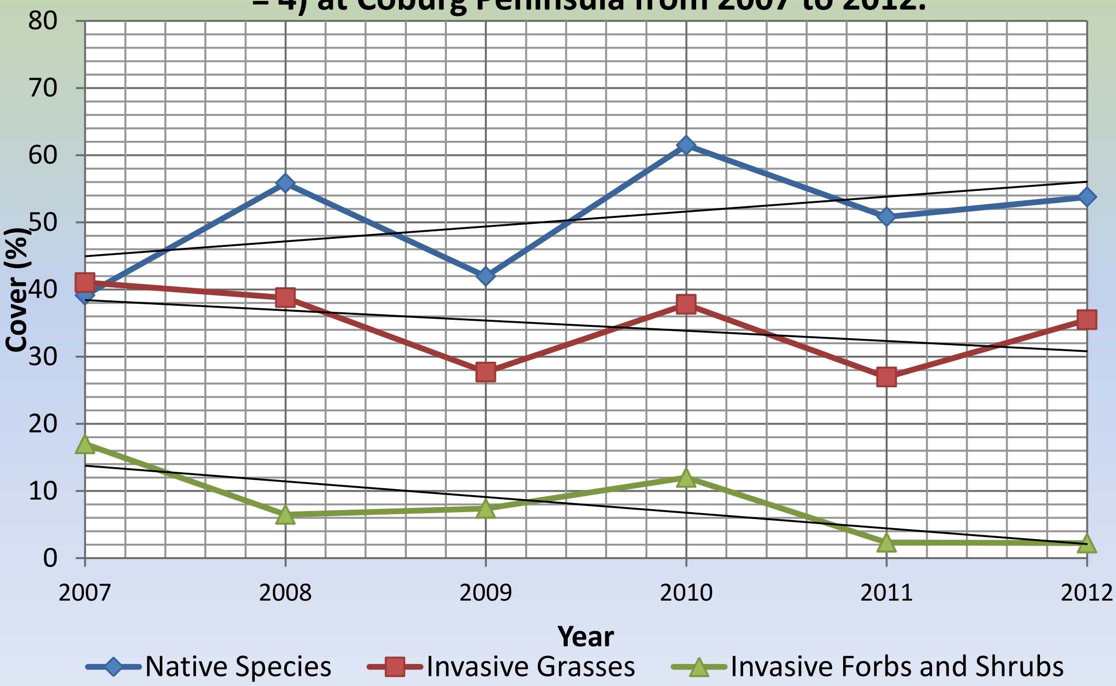


Figure 7. Mean cover and trend line of native plants, invasive grasses, and invasive forbs on treatment plots (n = 4) at Coburg Peninsula from 2007 to 2012.



The highest mean cover (%) of any species, for control and treatment plots over six years, was from silver burweed (*Ambrosia chamissonis*) and dunegrass (*Leymus mollis*) (Table A1). Red fescue (*Festuca rubra*) and early hair grass (*Aira praecox*) had the highest cover of non-native grasses (Table A2). Non-native forbs showed variable and generally low percent cover over the six years of sampling (Table A3).

American sea rocket (*Cakile edentula*), entire-leaved gumweed (*Grindelia integrifolia*) and beach pea (*Lathyrus japonicus* var. *maritimus*) did not contribute importantly to the revegetation of treatment plots (Table 1A). Entire-leaved gumweed (*Grindelia integrifolia*) did somewhat better on the control plots (Table 1A).

Results of the Blocked Multi-response Permutation Procedures (MRBP), which were grouped by treatment and control plots and blocked for years, produced a $T = 0.249$ (i.e., low separation between control and treatment plots) and an A = -0.0019 (i.e., more heterogeneity within control and treatment plots than expected). The null hypothesis, that there was no significant difference between plant cover composition for control and treatment plots over six years of monitoring (2007 - 2012), was accepted ($p = 0.608$).

DISCUSSION

After six years (2007 - 2012) the total cover (%) of all plant species, on both the control and treatment plots, responded in a similar fashion each year (Figure 3). Both control and treatment plots also showed parallel and slightly declining trend lines (Figure 3). Total cover was very similar in the last year of sampling, 93.22% and 91.878% for the control and treatment, respectively. This cover is much higher than the spare grasslands found on foredunes of the Pacific Northwest, which vary from 10% to 50% (Holland, 1986). Total plant cover on the control and treatment plots remain high, despite the continued disturbance from recreational activities and winter storm events. Both are evident from the high continued use by visitors, and movement and deposition of large driftwood from winter storms.

One promising trend was the decline in non-native forbs, on both control and treatment plots, over the six year sampling period. Non-native grasses did not increase over the six year period, remaining relatively constant on the control plots (Figure 4) and decreasing slightly on the treatments plots (Figure 7). This may be attributed to the increase in cover of dunegrass (*Leymus mollis* spp. *mollis*) and silver burweed (*Ambrosia chamissonis*) on the treatment plots and the increase of burweed on the control plots (Figures 5 and 6).

It is unclear why American sea rocket (*Cakile edentula*), entire-leaved gumweed (*Grindelia integrifolia*) and beach pea (*Lathyrus japonicus* var. *maritimus*) did relatively poorly on the treatment plots (Table 1A). This needs to be investigated further - It is important that foredune restoration not rely on single species management (Nordstrom & Jackson, 2013). Entire-leaved gumweed (*Grindelia integrifolia*) did somewhat better on the control plot. Presumable this is because it initially had higher cover on the control plots than the treatments plots (Table 1A).

The null hypothesis, that there was no significant difference between plant cover composition for control and treatment plots over six years of monitoring, was accepted ($p = 0.608$). Restoration plots that were degraded, infested with Scotch broom and planted with native species may have revegetated comparable to the less disturbed control plots. This conclusion can be reached if the treatment plots had lower plant cover than the control plots prior to planting and Scotch broom (*Cytisus scoparius*) removal. The native species, planted in the treatment plots, could then have contributed importantly to the revegetation of these plots. However, because the plots were not sampled prior to planting native species, this can't be assumed. If the plant cover (%) of control and treatment plots was similar at the start of the monitoring, and the planted native species increased in cover over the six years, it is hypothesized that the plant cover of treatment plots would be significantly greater than that of the control plots.

Sampling error could be a confounding factor that inflates cover estimates of some species. The cover estimates of small scattered plants with numerous small gaps (<10 cm) are easily inflated. Over the six years approximately 360 ecology students have been involved in transect sampling. Also, line transects are not placed exactly at the same locations each year. This is impossible to avoid, even though they are permanently marked at the landward side, because the ocean side of the plots are unstable and transects cannot be permanently marked (Figure 2).

CONCLUSION

Planting native species (dunegrass and silver burweed) and removing Scotch broom on degraded dune sites may lead to recovery (revegetation) comparable to adjacent less disturbed sites.

It is recommended that:

- monitoring be continue in order to assess long-term foredune recovery;
- the propagation of native species for revegetation (Camosun College and Coast Collective are presently growing dunegrass in containers;
- the current split-plot design (control – treatment) be expanded to include more disturbed sites on Coburg Peninsula;
- dunegrass be planted in the fall of 2013;
- pursue external funding for the propagation of a variety of native species;
- small-scale fertilizer trials be established to evaluate the responses of foredune plants to different combinations and rates of fertilizer;
- the nitrogen contribution of beach pea (*Lathyrus japonicus* var. *maritimus*) to foredune habitat be investigated.

ACKNOWLEDGEMENTS

I would like to acknowledge the support of the Esquimalt Lagoon Stewardship Initiative (ELSI), Evergreen Foundation (granting agency), Walmart (grant sponsor), Capital Regional District (CRD) and the City of Colwood. I would also like to thank Natalie Bandringa, Kitty Lloyd, Sue Askew, Coast Collective, Camosun College's Environmental Technology Program and Biology 228 (Ecology) students (2007-2012) for their effort in making this endeavor possible.

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APPENDIX

Table A1. Mean cover (%) of native species for control and treatment plots from 2007 to 2012.												
Species	**Control Plots (n = 4)**						**Treatment Plots (n = 4)**					
	Year						**Year**					
	2007	**2008**	**2009**	**2010**	**2011**	**2012**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**
American Sea Rocket (*Cakile edentula*)	0.00	0.23	1.17	0.60	0.87	2.99	1.32	2.65	1.78	1.35	0.79	4.02
Beach Pea (*Lathyrus japonicas*)	1.19	2.51	1.06	0.18	0.98	1.06	0.28	0.18	0.38	0.38	1.05	0.27
Dunegrass **(*Leymus mollis*)**	19.28	26.94	16.99	13.23	16.04	18.19	10.14	10.76	10.99	19.07	16.18	17.46
Entire-Leaved Gumweed (*Grindelia integrifolia*)	5.76	11.90	5.06	9.04	3.93	3.74	0.95	0.46	2.11	9.35	2.76	2.28
Large-Headed Sedge (*Carex macrocephala*)	0.00	0.00	0.03	4.76	0.07	0.49	0.00	0.13	0.00	2.46	0.00	0.00
Moss sp.	0.08	0.38	2.99	7.98	3.05	3.82	8.95	6.57	4.94	12.38	4.00	3.93
Nootka Rose (*Rosa nutkana*)	0.11	0.17	0.15	0.16	0.06	0.17	0.00	0.00	0.32	0.36	0.00	0.02
Silver Burweed (*Ambrosia chamissonis*)	14.23	26.99	23.75	18.00	16.72	25.76	17.51	32.52	21.27	16.13	25.96	25.79
Snowberry (*Symphoricarpos albus*)	0.47	0.00	0.21	0.00	0.09	0.00	0.00	0.28	0.08	0.00	0.09	0.01
Timber Oat-Grass (*Danthonia intermedia*)	0.00	2.90	1.32	0.00	0.00	0.00	0.00	2.29	0.10	0.00	0.00	0.00
Total	**41.12**	**72.02**	**52.73**	**53.96**	**41.79**	**56.21**	**39.14**	**55.83**	**41.96**	**61.47**	**50.83**	**53.78**

Table A2. Mean cover (%) of non-native grasses for control and treatment plots over six years from 2007 to 2012.

Species	Control Plots (n = 4)						Treated Plots (n = 4)					
	Year						Year					
	2007	2008	2009	2010	2011	2012	2007	2008	2009	2010	2011	2012
Barren Brome. (*Bromus sterilis*)	0.00	0.91	6.39	5.61	1.24	1.20	7.61	4.75	19.89	11.25	0.29	6.39
Early Hair Grass (*Aira praecox*)	4.17	6.72	6.76	3.84	9.20	19.04	6.71	13.99	2.17	6.55	11.21	9.39
English Ryegrass (*Lolium perenne*)	3.80	4.42	5.02	0.00	1.38	2.65	2.99	10.89	0.99	0.00	7.70	4.07
Hedgehog Dogtail (Cynosurus echinatus)	0.00	0.81	0.22	0.00	0.00	0.44	0.02	0.07	0.00	0.00	0.00	0.00
Kentucky Bluegrass (*Poa pratensis*)	0.00	0.14	0.08	0.00	0.34	0.00	0.00	0.04	0.14	0.00	0.07	0.62
Orchard Grass (*Dactylis glomerata*)	0.18	0.00	0.92	0.18	0.00	2.86	0.00	0.36	3.15	0.40	0.00	0.91
Quack Grass (*Elymus repens*)	6.14	2.93	3.47	0.00	1.22	1.09	6.61	4.79	0.00	0.00	0.01	0.67
Red Fescue (*Festuca rubra*)	14.03	6.02	5.73	25.58	2.89	5.40	17.09	1.61	1.26	19.58	7.70	13.46
Total	**28.32**	**24.84**	**29.91**	**35.21**	**16.27**	**32.68**	**41.03**	**36.50**	**27.60**	**37.79**	**26.97**	**35.49**

Table A3. Mean cover (%) of non-native forbs and the shrub, Scotch broom for control and treatment plots over six years from 2007 to 2012.

Species	Control Plots (n = 4)						Treated Plots (n = 4)					
	Year						Year					
	2007	2008	2009	2010	2011	2012	2007	2008	2009	2010	2011	2012
Chickweed (*Stellaria media*)	1.81	0.00	0.47	0.05	0.00	0.03	6.45	0.06	0.00	0.09	0.00	0.00
Common Dandelion (*Taraxacum officinale*)	0.00	0.30	0.19	0.09	0.17	0.00	0.24	0.27	0.20	0.19	0.02	0.00
English Plantain (*Plantago lanceolata*)	0.65	0.66	1.42	1.88	0.81	1.76	1.98	1.80	2.58	2.71	1.35	1.85
Hairy Cat's Ear (*Hypochaeris radicata*)	0.50	0.00	0.19	0.45	0.15	0.07	0.06	0.13	0.13	0.94	0.18	0.04
Robert Geranium (*Geranium robertianum*)	1.44	0.00	0.47	0.29	0.00	0.00	1.54	0.00	0.45	0.57	0.00	0.00
Small Hop Clover (*Trifolium dubium*)	2.63	0.00	0.89	3.15	0.00	0.00	0.50	0.37	0.57	0.01	0.00	0.00
Prairie Pepper-Grass (*Lepidium densiflorum*)	0.00	0.00	0.99	2.05	0.08	0.42	3.40	2.92	1.05	4.26	0.24	0.00
Scotch Broom (*Cytisus scoparius*)	3.45	0.64	1.19	0.86	0.00	0.02	0.31	0.50	0.19	1.67	0.21	0.09
Sheep Sorrel (*Rumex acetosella*)	3.06	0.63	1.60	0.72	0.06	0.60	2.55	0.46	2.23	1.58	0.37	0.26
Wild Carrot (*Daucus carota*)	4.92	0.54	1.50	2.09	0.89	1.45	0.22	0.56	0.00	3.71	0.35	0.36
Total	**13.54**	**2.23**	**7.42**	**9.55**	**1.27**	**2.89**	**17.02**	**6.51**	**7.41**	**12.02**	**2.36**	**2.24**