GIC FINAL REPORT 2013- GALIANO ISLAND, BC. DISTRICT LOT 57

Percent Abundance of Shrubs using the Line-point Intercept Method

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Dynamic Solutions for a Dynamic World

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ES 470

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ES 470 Final Report

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Abstract

We examined the percent cover of invasive and native shrubs on District Lot 57 (DL57), Galiano Island, British Columbia (BC). Our research was aimed at determining whether invasive species removal was needed at this site. We found no invasive species within the sample area, which indicated that restoration was not necessary. These results should not be considered conclusive for DL57 as a whole, because only a small area was sampled in our survey. However, our study uncovered potentially important mechanisms that may be influencing the shrub composition throughout DL57. Intense sheep and deer herbivory, as well as forest canopy shading, are likely suppressing the proliferation of invasive species. Utilizing an adaptive management framework, we propose research and restoration recommendations that can be implemented to mitigate the spread of introduced invasive species on DL57.

Introduction

By introducing invasive species to new habitats, humans can seriously impact native ecosystems and landscapes. Many alien species find a niche in disturbed sites that have been previously altered by human activity, for example, a logged stand. Not only can invasive species change the fundamental ecology of an area, leading to decreased native biodiversity, but they can materially damage economies, and the livelihoods of people who rely on the land to make their living (Van Der Wal et al. 2008). These losses motivate humans to remove non-native invasive species, often resulting in costly projects; It is estimated that invasive species cost the US economy approximately $120 billion per year (Yearwood-Lee, 2008). These actions are important, since unabated non-native invasive species are capable of creating monocultures across ecosystems, and reducing benefits from ecosystem services, and the overall resilience of ecosystems (OSU, 2008).

It is crucial to understand the interaction between invasive shrubs and herbivory for the implementation of restoration on District Lot 57 (DL 57). An introduced, invasive or 'alien' species is one that is not native to a region and significantly modifies or disrupts the new ecosystem it colonises

(Britannica, 2012). Many invasive shrubs were brought to North America by European settlers to be used for ornamental purposes (Niemiera and Von Holle, 2009). Species such as English holly (*Ilex aquifolium)* and scotch broom *(Cytisus scoparius)* are aesthetically pleasing but can be environmentally destructive (Prasad, 2005; Province of British Columbia, 1999; Rodriguez, Peco and Gurrera, 2011).

To curb future economic and environmental impacts stemming from the proliferation of non-native invasive species, it is prudent to understand the mechanisms behind exotic invasions (Keane and Crawley, 2002). Due to the lack of top predators and the legacy of commercial logging on DL 57, the site may be especially susceptible to exotic invasions. One prominent mechanism thought to facilitate the proliferation of invasive species is described by the Enemy Release Hypothesis (ERH). ERH is the process in which invasive species are able to infiltrate a new region based on a lack of natural predators (Keane and Crawley, 2002). Essentially, enemy release may allow invasive species to flourish as there are no other species in the new region which have co-evolved to prey on the introduced species (Keane and Crawley, 2002; Blair and Wolfe, 2004; Colautti et al, 2004). The successful implementation of classical biological control supports the ERH (Keane and Crawley 2002).

Herbivores generally prey on their favourite food species which are typically native (Hill and Kotanen, 2010). Overabundant herbivores can strip native biomass from the forest floor, and make forests more susceptible to invasion (Martin, Arcese and Scheerder, 2011; Beguin, Pothier and Cote, 2011). Allowing herbivores to control invasive shrubs is not always plausible, as it may not control specific species. However, the herbivores on DL 57 are generalist herbivores, meaning that they do not discriminate between native and non-native shrubs. Generalist herbivores will eat whichever plants are readily available, meaning native and invasive shrubs have the same likelihood of being browsed. The Columbian black-tailed deer (*Odocoileus hemionus columbianus)* and feral sheep present at DL57 are generalist herbivores, and can thus provide natural bio-control for introduced species (Schaffner et al., 2011).

If the predators (generalist herbivores) which are prevalent on DL 57 are not active in bio-control, we will see this through the data we collected. If the percent abundance of invasive shrubs is below the threshold of 10%, then herbivory is a positive form of bio-control. If percent abundance is above the threshold, then there may be a need to introduce new herbivores to DL 57 or choose a new plan of action. We will use 10% as the maximum limit for percent abundance of invasive shrub species as surveys have put the estimated biomass percentage of introduced vascular plant species in the Southern British Columbia (BC) region at around 29% (Rankin, 2004). If the level of invasive shrubs is below our threshold (10%), we know that there is substantially less invasive species on DL 57, when compared to the region. The research questions that directed the project are as follows: Is the percent cover of non-native invasive shrub species over 10% on DL 57? And if so, is invasive shrub control necessary on the site?

Methods

Data Collection

We measured invasive shrubs by using the line point intercept method. 16 transects were spaced 100 metres (m) apart, and 6 transects were chosen using a random number generator. The 6 transects ran North to South across DL 57. We measured from a 50m baseline using a compass with a declination of 17° N, recording the GPS startpoint (UTM). Each baseline had 5 randomly generated numbers and orientations along the baseline (i.e.: 5 m, west). We placed a 1 x 1 m quadrat at each point and documented the percent cover of shrub species within its parameters. For identification and quality assurance, photos were taken at each quadrat. The quadrat was then flipped, continuing on the same orientation until 5 quadrats were completed, giving us a 5 x 1 m plot. Once one baseline was completed we recorded the UTM of the baseline. We then walked 50 m and started a new baseline along the same transect in order to create independent data along the transects. At the start of the new baseline a GPS recording was taken and the process was repeated. Due to time constraints we were unable to sample the breadth of the property which we would have liked, thus the data only represents a small sample size of DL 57.

Results

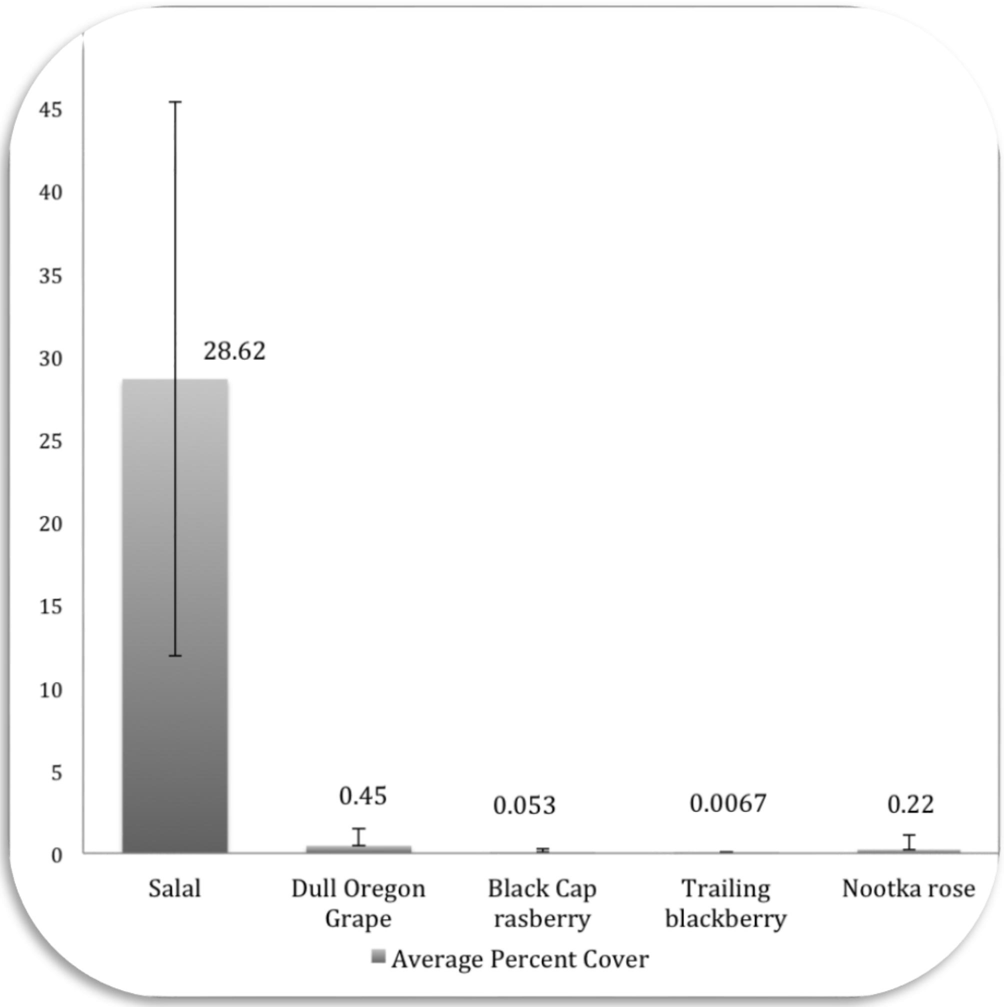

Figure 1. Average percent cover of native shrub for all areas sampled at DL57.

No introduced species were found within the sample area. Salal (*Gaultheria shallon*) was the most abundant, followed by dull oregon grape (*Mahonia nervosa*), cap black raspberry (*Rubus* *leucodermis*), trailing blackberry (*Rubus ursinus*), and nootka rose (*Rosa nutkana*). Approximately 69.6% of the area sampled was not covered by shrubs.

Discussion

Our results illustrate that the average percent cover of invasive shrubs within the sample area was 0 (Figure 1). We determined that the site was composed entirely of native species. These findings satisfy our management target and indicate that restoration is not necessary within the sample area. These findings are likely associated with natural processes that suppress the spread of invasive species. Forest cover can offer beneficial ecosystem services by suppressing the proliferation of invasive species. For example, shade intolerant species such as scotch broom are not able to colonize low-light understory areas (LeBlanc, 2001). Also, established forests generally have higher biodiversity and are considered to have greater resilience that allows them to withstand minor disturbance without losing ecological integrity (Elmqvist et al., 2003). The resilience of the forested area on DL57 may have helped resist the spread of invasive species. In the deforested or disturbed areas sampled, as well as in the edge habitats of forested areas, it is likely that high levels of herbivory effectively control the spread of invasive shrubs. The management of herbivory provided by sheep and deer, together with shaded forest understory, is crucial to controlling invasive species on DL57 (Funk et al., 2008)

Our findings are likely not representative of the entire site, as only a small portion of the land was sampled. This discrepancy could be due to the heterogeneity of the landscape and the inability of our sampling methods to capture the diversity of habitats. Our method did not allow us to gather data quickly over a large area of land. Specifically, the lack of multiple baselines across the full length of the transects resulted in data that does not accurately represent the percent cover of invasive shrubs at DL57. Also, the considerable effort put into percent cover estimates within each plot did not allow for fast data collection. Although time consuming, our methods did give good percent cover estimates for the sample area, but this was not substantial enough to draw any conclusions for DL57 as a whole.

Research Recommendations

Future studies of invasive shrubs at DL57 would benefit from using the line intercept method without embedded percent cover plots. This would allow for faster data collection over a larger area. Also, future researchers should be made aware of the intense herbivory by feral sheep and hyper-abundant deer. These ungulates are suppressing the proliferation of invasive shrubs such as scotch broom and English holly in the area, and should be considered when deciding on an ecological restoration monitoring plan for DL57 (da Silveira Pontes et al., 2012 ; Mitchell et al., 1996).

Generally, it is expected that introduced invasive species experience a decrease in natural enemies and consequently increase in abundance and distribution (Keane and Crawley, 2002). As this is not evident on DL57, it is possible that sheep and deer are acting as a bio-control. It is necessary to test this hypothesis through a research experiment. Within a simple adaptive management framework we suggest establishing an experimental trial in order to determine the effect of sheep/deer on native and non-native shrubs. To accomplish this, we suggest constructing paired plots, one that is exposed to herbivores and another that is fenced to exclude deer and sheep. Baseline species identification of all shrubs should be conducted within these plots to allow for later comparison with subsequent surveys. This plot design should be replicated throughout DL57 to account for variation in habitat conditions. Similar methods have been used to elucidate the impacts of herbivory on native and non-native plants (Gonzales and Clements, 2010). This study will not only show what effects sheep are having on invasive species, but also the likely effects of their removal. It will be necessary to allow the continued inhabitancy of the feral sheep until the results of this proposed study are available to restoration decision makers. If the sheep are removed without proper consideration and preparation, an increase in the proliferation of invasive shrubs is a likely consequence. Within the adaptive management framework it will be necessary to change the research question and restoration methods if the results of this study do not support our hypothesis.

Other important inquiries into invasive shrub percent cover on DL57 should focus on targeted surveys. A few areas of investigation include: broom proliferation along the southern shoreline, and English holly abundance and maturity through the site. Also, if larger scale property-wide plant surveys are to be conducted at DL57, they should not be limited to shrubs but instead should sample the total plant biodiversity. This method would provide a better understanding of the percent cover of invasive species at DL57. As approximately 69.6 % of the area within our sample site was devoid of shrubs, it is possible that many non-shrub invasive species were present but not identified.

Management Recommendations

We suggest the priority species for management are English holly and Scotch broom, with a focus on their removal from disturbed sites, namely the open agricultural areas. These species are listed by the Coastal Invasive Plant Committee as 2 of 19 priority invasive alien plant species in the CIPC's area of operation (Noel, 2010). In conjunction with the removal of these species, we recommend benefiting from the herbivory of the small herd of feral sheep and hyper abundant deer. These ungulates provide a natural bio-control by suppressing both Scotch broom and English holly. On sites that are inaccessible to ungulates (i.e.: cliffs on the southern shoreline of the property), manual and mechanical removal of invasive shrub species, specifically Scotch broom and English holly, is needed. The removal of these alien species, especially in the grassy lowland sites of the property, will enable native species, such as the Farewell-to-Spring (*Clarkia amoena var. caurina*), a summer-blooming plant, to recolonize their range. The conservation of this and other native flower, shrub and tree species hinges on the diligent removal of non-native invasive species, especially shrubs, such as Scotch broom (Galiano Conservancy Association, 2013b). Exploiting the herbivory of sheep and deer can facilitate this effort.

In order to utilize the intense herbivory provided by feral sheep and wild deer, we strongly recommend allowing the sheep to continue to graze on DL57 until the end of their natural lives. These ungulates are currently providing a great service by suppressing the spread of Scotch broom and English holly. Removing this disturbance may have adverse effects on the success of native grasses, forbs, and shrubs. For example, on Santa Cruz Island, California, removing sheep and cattle led to an explosive expansion of several invasive species such as the exotic fennel (*Foeniculum vulgare)*, starthistle (*Centaurea solstitialis*), and other introduced herbs, and a general increase in the relative cover of exotics (Klinger et al, 1994; Wehtje, 1994; Zavaleta et al, 2001). This had resounding implications in the ecosystem as the expansion of exotic forbs provided abundant food for feral European bee *(Apis mellifera),* colonies, and complicated eventual bee eradication from the island (Wenner et al. 2000; Zavaleta et al 2001). At DL57 similar implications may flow from the eradication of herbivory on site.

By taking advantage of the natural bio-control provided by the feral sheep, the process of invasive species removal and planting of native species can be facilitated. As the ungulates continue to browse the invasivescotch broom, we recommend planting native saplings in the disturbed area in order to create forest canopy cover. In addition to enhancing structural diversity and encouraging native growth, this will provide a long-term solution to suppressing the growth of shade intolerant invasive species such as scotch broom. We recommend planting native trees from the following species, preferably from Galiano Island genetic stock: Arbutus (*Arbutus menziesii*), Bigleaf maple (*Acer macrophyllum*), Black cottonwood (*Populus balsalmifera*), Douglas-fir (*Pseudotsuga menziesii*), Grand fir (*Abies grandis*), Red alder (*Alnus rubra*), Redcedar (*Thuja plicata*), Western hemlock (*Tsuga heterophylla*), Western yew (*Taxus brevifolia*). Saplings of this variety are available through the Galiano Native Plant Nursery (Galiano Conservancy Association 2013a).

Although there are a variety of options available for controlling competing shrubs, biological methods provide a good management tool that can be applied in this situation (Ministry of Forests, 2012). In BC, 5000-6000 ha of forest land are grazed by sheep each year (Silviculture Note 26, 2000). Sheep and goats have been known to effectively graze both Scotch broom and English holly. One example is the utilization of Lamancha goats on southern Vancouver Island, who effectively grazed Scotch broom (Zielke et al, 1992). If the herd of sheep is removed from the site, this efficient control will be lost, and other energy intensive methods would have to be employed to control the shrubbery. This would include hand pulling and cutting, the use of machinery (ie backhoes to uproot plants, or bulldozers, power tools; dependent on budget) and would incur time and cost. Once an area is sufficiently cleared, it is recommended that native shrubs and saplings are planted, and canvas moss/landscape fabric is spread about them to prevent the Scotch broom from out-competing the newly planted shrubs/trees. Although the sheep are providing this service, once saplings are planted, they must be protected from herbivory. We recommend using tree shelters/tree guards. This will accelerate growth in the early stages as well as protect the saplings from herbivory. We feel this strategy will assist with the reinstatement of traditional ecosystems in previously disturbed sites.

English holly is another introduced plant present on DL57. It has naturalized in BC (USDA, 2010). Unlike Scotch broom, English holly is a shade-tolerant species, giving saplings an added advantage. It is considered a significant urban pest, and is readily dispersed by birds into forested areas. Much like Scotch broom, English holly can become abundant and a significant part of the understorey/tall shrub layer, in this way shading out native species. However, this plant colonizes more slowly, and could therefore be overlooked as a restoration priority. The management of English holly is dependent on the maturity of the plant. Small seedlings of holly (which resemble Oregon grape (*Mahonia aquifolium*)) can be pulled out of the soil relatively easily, while the larger trees should be felled (City of Nanaimo, 2013). Their stumps should be damaged with an axe or similar tool in order to reduce re-sprouting. It is best to remove large trees before berries emerge to avoid dispersing them in the surrounding area. If felled it is important to remove debris using a tarp or garbage bag, taking care not to disperse seeds along the removal route. Alternately, mature trees may be girdled in order to reduce disturbance and provide habitat and soil conditions for the growth of mycorrhizal fungi (Erickson et al, 2002) . Despite its spinescence, especially on lower lying leaves, one experiment shows that deer and rabbits enthusiastically browse the foliage and bark of holly plants (Potter and Kimmerer, 1998). Sheep, too, have been known to browse on holly—another study shows that sheep are likely to browse on current year's sapling shoots significantly in the summer, while browsing of shoots planted the previous year in the winter (Mitchell et al. 1996). The feral sheep on site are therefore a great asset to the management of holly as well as scotch broom, and should be considered in their ongoing management.

Conclusion

Ecosystems are dynamic. Therefore the management plans used to restore them must be adaptable to change. We have outlined both research and restoration recommendations in an effort to design a site-specific adaptive management plan for DL57. We focused on the presence of invasive species as an indicator for restoration and also examined the mechanisms driving species composition. We propose that the intense sheep and deer herbivory, as well as forest canopy shading, are likely suppressing the proliferation of invasive species. This hypothesis should be scientifically tested but it is likely that these natural processes could be utilized for controlling the spread of invasive species at DL57.

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References

Beguin, J., D. Pothier and S.D. Cote. 2011. Deer browsing and soil disturbance induce cascading effects on plant communities: a multilevel path analysis. *Ecological Applications* **21**: 439-451. [online] URL. http://www.esajournals.org.ezproxy.library.uvic.ca/doi/abs/10.1890/09-2100.1

Blair, A. and L. Wolfe. 2004. The Evolution of an Invasive Plant: An Experimental study with Silene Latifola. *Ecology* **85**: 3035-3042. [online] URL: http://www.wou.edu/~tvannice05/Thomas_ref_titles/evolution%20of%20invasive%20plants.pdf

Bongers F, L. Poorter, H. Hawthorne and D. Sheil. 2009. The intermediate disturbance hypothesis applies to tropical forests, but disturbance contributes little to tree diversity. *Ecology Letters*. **12(8**): 798-805. [online] URL. http://www.ncbi.nlm.nih.gov/pubmed/19473218

Colautti, R., A. Ricciardi, I.A. Grigorovich, and H.J. MacIsaac. 2004. Is invasion success explained by the enemy release hypothesis?. *Ecology Letters* **7**: 721-733. [online] URL. http://web.ebscohost.com.ezproxy.library.uvic.ca/ehost/pdfviewer/pdfviewer?sid=e002ccac-a5dc-4db4-8ab4-fd90ffecd817%40sessionmgr11&vid=2&hid=10

da Silveira Pontes, L., D. Magda, M. Jarry, B. Gleizes, and C. Agreil. 2012. Shrub encroachment control by browsing: Targeting the right demographic process. *Acta Oecologica*, **45**: 25-30. [online] URL. http://www.sciencedirect.com/science/article/pii/S1146609X12001087

Elmqvist, T., C. Folke, M. Nystrom, G. Peterson, J. Bengtsson, J. Walker and J. Norberg. 2003. Response diversity, ecosystem change, and resilience. *Frontiers in Ecology and the Environment*, ***1*****(9):** 488-494. [online] URL. http://www.esajournals.org/doi/abs/10.1890/1540-9295%282003%29001%5B0488%3ARDECAR%5D2.0.CO%3B2

Encyclopædia Britannica. 2013. "invasive species." *Encyclopædia Britannica Online Academic Edition*. Encyclopædia Britannica Inc., 2013. [online] URL. http://www.britannica.com/EBchecked/topic/1238522/invasive-species.

Erickson K., N. Gaylor, and O. Scholz. 2002. Restoration plan for District Lot 63 of the Pebble Beach Nature Reserve, Galiano Island. Galiano Conservancy Association, Galiano Island, BC.

Funk, J. L., E.E. Cleland, K.N. Suding and E.S. Zavaleta. 2008. Restoration through reassembly: plant traits and invasion resistance. *Trends in Ecology & Evolution*, ***23*****(12):** 695-703. [online] URL. http://people.ucsc.edu/~zavaleta/pubs/Funk%20et%20al.%202008_TRENDS_EcoEvo.pdf

Galiano Conservancy Association. 2013a. Galiano Native Plant Nursery Retail Inventory List February 2012. [online] URL. http://galianoconservancy.ca/downloads/plant-inventory-retail-list-by-common-name.pdf

Galiano Conservancy Association. 2013b. Species at risk. [online] URL http://www.galianoconservancy.ca/sar.php

Gonzales, E. K., and D.R. Clements. 2010. Plant Community Biomass Shifts in Response to Mowing and Fencing in Invaded Oak Meadows with Non-Native Grasses and Abundant Ungulates. *Restoration Ecology*, ***18*****(5):** 753-761. [online] URL. http://onlinelibrary.wiley.com/doi/10.1111/j.1526-100X.2009.00535.x/abstract

Hill, S.B., and P.M. Kotanen. 2010. Phylogenetically structure damage to Asteracease: susceptibility of native and exotic species to foliar herbivores. *Biological Invasions* **12(9):** 3333-3342. [online] URL. http://link.springer.com.ezproxy.library.uvic.ca/article/10.1007%2Fs10530-010-9726-7

Keane, R. M., and M.J. Crawley. 2002. Exotic plant invasions and the enemy release hypothesis. *Trends in Ecology & Evolution*, ***17*(4):** 164-170. [online] URL. http://www.sciencedirect.com/science/article/pii/S0169534702024990

Klinger, R.C., P. Schuyler and J.D Sterner. 1994. Vegetation response to the removal of feral sheep from Santa Cruz Island. In The Fourth California Islands Symposium: Update on the Status of Resources(Halvorson, W.L. and Maender, G.J., eds), pp. 341–350, *Santa Barbara Museum of Natural History*

LeBlanc, J. W. (2001). Getting a handle on broom. *University of California Agriculture and Natural Resources, Oakland, USA*. 1-9 [online] URL. http://californiarangeland.ucdavis.edu/Publications%20pdf/8049%20Brooms%20in%20Calif.pdf

Martin. G., P. Arcese, and N. Scheerder. 2011. Browsing down our natural heritage: Deer impacts on vegetation structure and songbird populations across an island archipelago. *Biological Conservation* **144(1)** 459-469. [online] URL. http://www.sciencedirect.com.ezproxy.library.uvic.ca/science/article/pii/S0006320710004325

Mitchell, F. J., A.J. Hester, and K.J. Kirby. 1996. Effects of season and intensity of sheep grazing on a British upland woodland: browsing damage to planted saplings. *Transactions and Proceedings of the Botanical Society of Edinburgh and Botanical Society of Edinburgh Transactions*, ***48*(2):** 199-207. [online] URL. http://www.tandfonline.com/doi/abs/10.1080/03746609608684841

Niemiera, A.X., and B. Von Holle. 2009. Invasive Plant Species and the Ornamental Horticulture Industry. *Management of Invasive Weeds* **5:**167-187. [online] URL. http://link.springer.com.ezproxy.library.uvic.ca/chapter/10.1007%2F978-1-4020-9202-2_9

Noel, M. 2010. Coastal Invasive Plant Committee:Annual Report 2009. [online] URL.

http://bcinvasiveplants.com/iscbc/images/stories/documents/Committees/Committee_Handbook/doc122_Example_MALAnnualReport_CIPC.pdf

Oregon State University (OSU). 2008. English Ivy (*Hedera Helix)*. Invasive Weeds in Forest land. [online] URL. http://extension.oregonstate.edu/catalog/pdf/ec/ec1595-e.pdf

Potter, D.A., and T. W. Kimmerer. 1998. Do holly leaf spines really deter herbivory? *Oecologia.* **75(2**): 216-221. [online] URL. http://www.jstor.org/discover/10.2307/4218559?uid=3739400&uid=2129&uid=2&uid=70&uid=3737720&uid=4&sid=21102129360887

Prasad, R. 2005. Current Status and Management options of Exotic and Invasive Weeds of Forestry in Coastal British Columbia, Canada. *Outlooks on Pest Management* **16(5)**: 225-229. [online] URL. http://www.swetswise.com.ezproxy.library.uvic.ca/FullTextProxy/swproxy?url=http%3A%2F%2Fopenurl.ingenta.com%2Fcontent%2Fswetsnet-4.1.cd36224e173da000c3a47cf9ef7c0b47%3Fgenre%3Darticle%26issn%3D1743-1026%26volume%3D16%26issue%3D5%26spage%3D225%26epage%3D229%26aulast%3DPrasad&ts=1365370118442&cs=1405641723&userName=8900116.ipdirect&emCondId=8900116&articleID=154027902&yevoID=2586999&titleID=262202&referer=1&remoteAddr=142.104.240.194&hostType=PRO&swsSessionId=V1TmwCWY87-yUTPhHC12LQ__.pasc1

Province of British Columbia, Ministry of Environment, Lands and Parks. 1999. Coastal Douglas-fir Ecosystems. [online] URL. http://www.env.gov.bc.ca/wld/documents/douglasfir.pdf

Province of British Columbia: Ministry of Forests. 2012. Managing Vegetation with Sheep. Ministry of Forests and Range. Publications repository. [online] URL. http://www.for.gov.bc.ca/hfp/publications/00182/

Rankin. C & The Nature Conservancy of Canada. 2004. Invasive Alien Species, Framework for BC:

Identifying and Addressing Threats to Biodiversity. [online] URL

http://www.env.gov.bc.ca/wld/documents/alien_species_framework_BC_0205.pdf

Rodriguez, E., B. Peco and M.P. Gurrea. 2011. Effect of Scotch broom, *Cytisus scoparius*, pod size and patch density on *Exapion fuscirostre* (Coleoptera, Apionidae) seed weevil oviposition. *Australian Journal of Entomology.* **51(2):**127-132. [online] URL. http://onlinelibrary.wiley.com.ezproxy.library.uvic.ca/doi/10.1111/j.1440-6055.2011.00848.x/abstract

Schaffner, U., W.M. Ridenour, V.C. Wolf, T. Bassett, C. Muller, H. Scharer-Mueller, S. Sutherland, C.J. Lortie and R.M. Callaway.2011. Plant invasions, generalist herbivores, and novel defense weapons. *Ecology* **92(4):**829-835. [online] URL. http://dx.doi.org.ezproxy.library.uvic.ca/10.1890/10-1230.1

Silviculture Practices Section. 2000. Silviculture Note 26: Sheep Grazing in Forestry. Forest Service British Columbia: Forest Practices Branch. [online] URL http://www.for.gov.bc.ca/hfp/publications/00127/SN26.pdf

The City of Nanaimo. 2013. Invasive Plants: Characteristics and Removal Techniques: English holly. Controlling Invasive Plants: Information and Process Package. [online] URL http://www.nanaimo.ca/assets/Departments/Parks~Rec~Culture/Publications~and~Forms/invasive_plants.pdf

Van Der Wal, R., Truscott, A.M., Pearce, I.S.K., Cole, L., Harris, M.P., & Wanless, S. 2008. Multiple anthropogenic changes cause biodiversity loss through plant invasion. *Global Change Biology*, **14:6**, 1428-1436. [online] URL. http://onlinelibrary.wiley.com.ezproxy.library.uvic.ca/doi/10.1111/j.1365-2486.2008.01576.x/abstract

Wehtje, W. 1994. Response of a Bishop pine (Pinus muricata) population to removal of feral sheep on

Santa Cruz Island, California. In The Fourth California Islands Symposium: Update on the Status of Resources (Halvorson, W.L. and Maender, G.J., eds), pp. 331–340, *Santa Barbara Museum of Natural History.*

Wenner, A.M. et al..2000. Removal of European honeybees from the Santa Cruz Island ecosystem. In Proceedings of the Fifth California Island Symposium (Browne, D.H. et al., eds), *Santa Barbara Museum of Natural History*

Yearwood-Lee, E. 2008. Economic Impact of Invasive Species. *Legislative Library of British Columbia*. **3:** [online] URL: http://www.llbc.leg.bc.ca/public/pubdocs/bcdocs/439433/200803ci_invasive.pdf

Zavaleta, E.S., R.J. Hobbs, and H. A. Mooney. 2001. Viewing invasive species removal in a whole-ecosystem context. *Trends in Ecology & Evolution* **16(8):** 454-459. [online] URL http://www.ege.fcen.uba.ar/materias/general/Seminario%20Invasiones%202.pdf

Zielke, K., J.O. Boateng, N. Caldicott, and H. Williams. 1992. Broom and gorse in British Columbia: a forestry perspective problem analysis. *Queen’s Printer for British Columbia*. Victoria, BC. [online] URL. http://www.for.gov.bc.ca/hfp/publications/00042/broom-gorse.pdf

Appendix A

Standard Operating Procedure

Field Methods: Line Point Intercept

Objective

To examine the percent cover of native and non-native shrub species at District Lot 57 on Galiano island.

Materials needed, per group of two:

Reference materials:

Field guide, field notebook, pen, field methods sheet, data collection sheet, native/non-native plant reference sheet, plastic bag for plant samples, camera.

Equipment:

GIC will give you

1 measuring tape, 1 1mx1m PVC Pipe Quadrat, 1 compass, 1 GPS,

Data collection package including: Map, Field Methods sheets, Datasheets, shrub species list (with species codes).

You are responsible for

1 Clipboard, 1 Camera (can be cellphone camera), 1 Field Guide, Pencil, Pens, and any other equipment you find useful in the field.

General Procedures:

Each pair will be assigned a random starting point, which will correspond with one of the transect lines on the map (ie. T1-T16). These locations will be flagged and label by the group leaders before data collection. From this location the group will determine the bearing that the transect falls on and proceed 20m off the road before establishing the baseline (to avoid edge effect). If the start of the transect lines is not on the edge of a road begin the baseline at this location.

Once the baseline is in place the employees will begin with plot one at the specified distance along the baseline as indicated on the Plot Card. The quadrat will be placed on either side of the baseline as per the specified orientation (ie. West or East) indicated on the plot card. Within each of the five consecutive quadrats in the plot the percent cover of shrub species will be estimated and recorded on the data sheet. This will be repeated for a total of five plots per baseline.

Step by step Procedures:

1) Collect equipment and reference materials from GIC reps.

2) Walk to given GPS starting point (transect starting point on map).

3) Determine transect bearing

4) One person holds tape, other member walks 20 meters along bearing **(only if the transect starting is on a road side.)**

5) Record the baseline start point (GPS coordinates) at this location.

6) One person holds tape, other member walks 50 meters. Employee on the baseline checks to make sure line is straight by using compass.

7) If your baseline is runs into a large (greater then 10m) shrub-less area (Ex: pond, grassland) make sure you record the GPS point where you stopped, and continued your baseline. Ex: If you do 50m baseline and intersect a pond at 30m, record where you stopped and then record where you start on the other side of the pond and finish the last 20m.

8) Record baseline end point. (GPS coordinates) at this location.

9) Walk to first randomized plot location (Plot 1) from baseline start point

10) Lay PVC quadrat directly beside the baseline in the specified orientation (west or east)

11) One person records plant species and the corresponding percent cover within the quadrat on the data sheet, using species list and field guide for reference.

12) We are only interested in shrubs, so do not record grasses or trees on data sheets.

13) Photograph the quadrat and Label Picture Number on Data Sheet.

14) Flip the quadrat and repeat this process 5 times along the 5 metre plot.

15) Note any peculiarities at your transect. For example anything obscuring the transect such as fallen logs, or discarded materials. Weather, drainage, wildlife sightings, human disturbance, etc.

16) repeat steps 8 through 14 until all 5 plots have been completed the baseline.

17) When finished one baseline, start the process again 50m along the transect from the end of the first baseline. Make sure to record a new GPS starting point for your next baseline.

Appendix B

Transect Map