Restoration in the Rainshadow

Proceedings of the 2005 SER-BC Annual Conference, held Sept 30 to Oct 2 2005, Galiano Island, BC

Sponsored by The Society for Ecological Restoration – British Columbia And The Galiano Conservancy Association

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Program: SERBC 2005 – Restoration in the Rainshadow

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and The Galiano Conservancy Association

Friday Sept 30 2005

7 PM to 9 PM – Wine and Cheese reception, Galiano Hall

Saturday October 1 2005 – All events at the Galiano Hall

- 7:45 AM to 8:30 – Coffee and snacks
- 8:30 to 8:45 – Opening remarks – SER-BC and The Galiano Conservancy Association
- 8:45 to 9:30 – Opening Speaker - Florence James - Penelakut Tribe
- 9:30 to 10:30 – First Session – Restoration on Galiano
  - Galiano Island Restoration – Michael E. Keefer
  - A Monitoring Baseline for a Forest Restoration Project On Galiano Island – Odin Scholz, Nathan Gaylor, and Keith Erickson
- 10:30 to 11:00 – Coffee Break
- 11:00 to 12:30 – Second Session – Impacts
  - Herbivory and Non-native Grasses in Garry Oak Ecosystems – Emily Gonzales and Peter Arcese
  - The soil nutrient state of an ecological restoration area compared to natural regeneration on Galiano Island, BC, Canada – Nina Koele
  - Carbon, Climate Change and Restoration in the Rainshadow - Robert Seaton
- 12:30 to 1:30 – Lunch
- 1:30 to 2:30 – Third Session - Methods
  - Container Selection for Revegetation Success with Oak & Deep Rooted Chaparral Species - Brad Burkhart,
  - Some Aspects Of Vegetation Management: Bioherbicides And Other Methods For Control Of Four Exotic Plants On Federal Lands In British Columbia, Canada - R Prasad, J Benner and S. Bundel
- 2:30 to 3:00 – Coffee Break
- 3:00 to 4:00 – Fourth Session – Approaches
  - "Knowing Every Corner of the Land": The Ethnoecological Approach to Restoration - Brenda R. Beckwith
  - The Rockies Through the Lens of Time: Repeat Photography and the Challenge of Ecological Restoration – E. Higgs, L. Levesque, T. Smith, G. Watt-Gremm
- 4:15 to 5:45 – SER-BC Annual General Meeting
- 6:00 to 7:00 - Posters
- 7:00 to 9:30 – Banquet – Keynote Speaker – Richard Hebda

Sunday October 2 2005 – Field Trips – All field trips depart from the Galiano Hall

"Knowing Every Corner of the Land": The Ethnoecological Approach to Restoration

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Abstract
It has been written that George Rogers Sr., homesteader in the Christmas Hill area, Victoria, in the late 1800s knew every corner of his land. He managed this land as a working farm and as a wildflower preserve for white fawn lilies. Local knowledge, such as this reference, is a key component of ethnoecological research. This field of study combines archival, historical, and anecdotal information, the ecological knowledge of Indigenous peoples, and research in various academic disciplines to reconstruct the past cultural landscape. When integrated with contemporary ecological or horticultural studies, this multifaceted ethnoecological approach can provide valuable information for ecological restoration initiatives. This paper will outline the role of ethnoecology in the restoration of Garry oak and associated ecosystems in southwestern British Columbia. It is becoming more widely understood within the scientific community that the structure and function of these ecosystems were influenced by First Nations management practices, namely by landscape-scale burning. However, details regarding the extent, duration, timing, and specific ecological objectives of traditional resource management activities remain uncertain. Lessons for modern-day management programs will be described using information garnered from recent ethnoecological research on camas (*Camassia* spp.). Major themes that will be addressed include: the acknowledgement of the aesthetics of landscape; the challenges of restoring heterogeneous communities; the re-incorporation of Indigenous management practices in today's ecosystems; and, honouring the social role of restoration.

> [George Rogers Sr.] came to know every corner of the land, every tree in the woods. Because he loved the land and the woods he would not sell them and would not desolate them. In every field, though it increased the labor of harvest and reduced the yield, he left the best oak trees and sometimes he would stop his team to look at them. The white lilies [*Erythronium oregonum*] of the woods he left untouched so that they multiplied and the children played amongst them in the springtime…
>
> - Bruce Hutchinson quoted in an early article by Briony Penn (ca. 1976)

Introduction

George Rogers Sr. and his family homesteaded near Christmas Hill in the late 1800s. At this time the landscape, just north of Victoria on southern Vancouver Island, was likely a mosaic of mixed Douglas-fir (*Pseudotsuga menziesii*) and Garry oak (*Quercus garryana*) parkland. The Rogers family managed this land as a productive dairy farm for over five decades, although cattle continued to graze the area until 2000. They were farmers and conservationists with a comprehensive environmental understanding of the Christmas Hill region. This local knowledge was firmly rooted in place and maintained over generations, much like the traditional ecological knowledge of First Nations. Local knowledge, such as this account, is a key component of ethnoecology, a field of study that is gaining attention among restorationists of cultural landscapes.

This paper describes the role of local knowledge and ethnoecological methods in the restoration of Garry oak ecosystems in southwestern British Columbia. Information resulting from recent ethnoecological research on camas (*Camassia* spp.) on southern Vancouver Island provides the inspiration for a brief discussion regarding the need to recognize the role of people in these landscapes even though the challenges associated with the re-introduction of former people-environment interactions, such as camas harvesting and livestock grazing, are numerous.

Local Knowledge and Ethnoecology

Local knowledge, or knowledge that is local in geographical scale and solidly based in practice and observation, is commonly examined within the disciplines of cultural history, landscape ecology, ethnobotany, and ethnoecology. Ethnoecology, or the study of cultural landscapes and of the land-based economic systems which serve to maintain them, involves analyzing how Indigenous or local peoples affected the ecological structure and function of their resource communities (e.g., Crumley 1994; Berkes 1999; Nazarea 1999; Fowler 2000). This scientific field combines archival, historical, and anecdotal information, the environmental knowledge of Indigenous peoples, and research in various academic disciplines to reconstruct past people-environment relationships. Valuable information for ecological restoration initiatives can emerge when this multifaceted information is integrated with applied ecological or horticultural studies.

Local knowledge, however, is often difficult to assess because the historic contexts or the specific objectives or intent of the knowledge-holder were unknown. Furthermore, qualitative resources are inherently biased by the personal or professional objectives and moral values of the authors (Kennedy 1995). For instance, many early written accounts from the Fort Victoria period (1843 – 1860) describe the landscape at length but do not report clearly or considerately on the local Straits Salish peoples. Captain W. C. Grant, however, recorded some of the most thoughtful, albeit vague, observations regarding the Indigenous peoples found in the ethnohistoric literature. As an example, he wrote: "…[Indigenous peoples had] names for every fowl of the air, every fish of the sea & every herb & Tree of the ground which are to be found in their Country" (Grant 1849). Clearly, establishing a high level of continuity and corroboration among a variety of resources, providing both qualitative and quantitative information, will help to develop a more accurate representation of environmental and cultural history. In recognizing the current limitations of conservation policy, the best approach is to combine the talents of different knowledge-holders (see Soulé 1995). Though, concrete mechanisms for incorporating the environmental knowledge of Indigenous and long-standing residents into management or restoration planning still need to be explored (e.g., Garibaldi 2003; Higgs 2003).

The incorporation of culture into nature will require a re-evaluation and expansion of human ideologies and perceptions of what is natural. Some restoration writers have suggested that the eastern or Indigenous cultures should be consulted for clues as to how to model positive human relationships with the natural world (e.g., Janzen 1988; McMahan 1997; McGinnis 1999). Terms (e.g., ecocultural or focal restoration) to address the need of amalgamating both cultural practice and ecological process in restoration have been introduced (see Higgs 2003). Definitions of ecological restoration have become more generalized to reflect new models of the past landscape dynamics. For instance, Donald Gayton (2001) explains the complexities associated with the recognition and incorporation of Indigenous environmental knowledge into new ecological restoration theory:

> Life was much simpler when we assumed a clear separation between humans and ecosystems. Now, not only do we find that humans negatively impact ecosystems in new and unexpected ways, we are also discovering that certain ecosystems have evolved to rely on human disturbance.

The development of appropriate ecological restoration objectives can prove challenging when the "naturalness" of historical target ecosystems is obscured by the presence of former Indigenous landscape management, or when unmodified reference ecosystems are limited (MacDougall *et al*. 2004). Both of these conditions apply to the Garry oak ecosystems of southwestern British Columbia.

Ethnoecological Restoration of Garry Oak Ecosystems

Modern-day land management considerations for Garry oak ecosystems have focused conventionally on elements of the natural environment, including the presence and abundance of native and exotic species, connectivity and fragmentation of habitats, and ecosystem integrity (Povilitis 2002). For the most part, restoration activities have included volunteer-based exotic plant removal programs, specifically "broom bashes" and "ivy pulls." There have been noteworthy strides in native plant rescue, but nurseries specializing in native plants have remained unsuccessful in this region. More sophisticated restoration programs and science-based recovery organizations, such as the Garry Oak Ecosystems Recovery Team (GOERT), are gaining momentum in the region.

It is now becoming more widely understood within the scientific community that the structure and function of Garry oak and associated ecosystems were influenced by First Nations land stewardship. Despite the advances of GOERT and other conservation groups there is a limited understanding of the overall biological complexity of Indigenous resource management objectives and methodologies in pre-European contact times. For example, one of the more accepted forms of traditional management formerly employed by Straits Salish peoples in Garry oak ecosystems is burning. Specific information regarding the extent, duration, timing, and specific ecological goals of fire use, however, remains uncertain. Excerpts from the Fort Victoria Journal of the Hudson's Bay Company clearly state that extensive fires burned annually in the area, although the fires were not always directly attributed to First Nations. Additionally, select historic accounts (see Turner 1999; MacDougall *et al.* 2004) place Indigenous burning practices in the late summer and describe the extent as on a landscape scale, but do not necessarily explain the objectives for the burns. An account from Captain Grant (1849) once again provides an exception to the rule:

> …the frequency of the fires kindled promiscuously by the Natives both in wood & prairie between the months of August & October. Their object is to clear away the thick fern & underwood in order that the roots & fruits on which they in a [great] measure subsist may grow the more freely & be the more easily dug up.

Much less has been recorded in the ethnohistoric literature about the ecological objectives or effects of other Indigenous management activities, such as the harvesting practices associated with roots (e.g., camas bulbs, bracken rhizomes) and fruits (e.g., trailing wild blackberry, wild strawberry).

In general, the environmental knowledge held by contemporary First Peoples has been viewed by restoration ecologists as subjective or imprecise because of, in part, the presumed loss of traditional knowledge (Blackburn and Anderson 1993). The cessation of Indigenous resource use and land management was strongly affected by rapid social and environmental change, including the alienation of First Peoples from their traditional resource sites (Arnett 1999), the introduction of agricultural food alternatives (Suttles 1951, in press; Deur 1999; Beckwith 2004), and the decimation of large numbers of Indigenous practitioners and knowledge holders (Boyd 1990). It is important to remember that Garry oak ecosystems have intrinsic cultural value and have sustained human economies for thousands of years. Indigenous peoples' conceptual or symbolic relationships with this landscape have remained intact even though the vast majority of the human-resource interactions have been lost.

The ecological consequences of the cessation of long-term occupation and land stewardship activities practiced by First Nations have not been examined adequately for Garry oak ecosystems in this region, even though this issue is beginning to be addressed in the human ecology and restoration literature elsewhere (e.g., Anderson 1996; Gadgil and Berkes 1991; Deur 2000). A correlation between the loss of Indigenous culture and loss of biological diversity is a largely unexplored concept (but see Anderson 1993; Berkes 1999; Boyd 1999; Deur and Turner in press). The conservation of threatened species and ecological integrity are principal goals of restoration ecologists, yet often policymakers and practitioners do not give due attention to the anthropogenic components of the past and the continuity of cultural integrity and identity into the future. Indigenous peoples in this region (e.g., Songhees, Cowichan, Saanich nations), however, have begun growing and consuming traditional plant foods and managing resource communities on reserve lands (C. Bryce, pers. comm. 2005). This reclaimed expression of traditional cultural practice is an important component of community-driven restoration initiatives for Garry oak ecosystems.

Ethnoecological Insights for Restoration Practitioners

This final section will describe two main lessons for the ethnoecological restoration of Garry oak ecosystems: the challenges associated with re-introducing traditional or historic management practices in today's heterogeneous landscape and, the seemingly contradictory need to acknowledge and honour the role of people and their values in Garry oak ecosystems. These insights were inspired from recent applied ethnoecological research on camas (*Camassia* spp.) on southern Vancouver Island (Beckwith 2004). The edible bulbs of camas (*Camassia leichtlinii, C. quamash*), a prominent wildflower within Garry oak and associated ecosystems, were the principal root vegetable in the diet of Straits Salish peoples and other Coast Salish groups. These "roots" were prepared by prolonged pit-cooking, dried and stored for winter, used for traveling provisions and trade, and served as offerings at feasts and ceremonies. Camas resource sites were actively cultivated to maintain the availability and productivity of high quality bulbs for thousands of years (Beckwith 2004). Hence, camas has a long-standing ethnoecology; no other traditional food plant in the Garry oak ecosystems of British Columbia has such a complex and enduring history.

The Use of Traditional and Historic Management Practices Today

Ethnoecological restoration of Garry oak ecosystems should strive to meet with clear scientific objectives and methodologies, but also attempt to acknowledge and integrate cultural values and goals whenever it is possible and appropriate. However, the consumption of “wild” native foods and the simulation of Indigenous traditional management practices are not actions that are easily implemented or widely accepted. These activities could be perceived as another form of cultural appropriation, regardless of the good intentions of the restorationists. Consultation and collaboration with Indigenous peoples should be encouraged as much as possible in the restoration of Garry oak ecosystems with both ecological and cultural objectives given equal consideration (Beckwith 2002).

The restoration of former people-environment interactions, such as harvesting of camas bulbs by Indigenous peoples or livestock grazing by European settlers, can be controversial and challenging within the modern social and environmental landscape. The area of Garry oak ecosystems has been reduced significantly and fragmented into reserves of parks, municipal right-of-ways, gardens, and other types of small urban and suburban patches. The Garry oak ecosystems of today are generally characterized as fragile shallow soiled communities (e.g., rock outcrop and coastal bluff), that probably were not managed regularly or intensively by Indigenous peoples in the past. In addition, Garry oak ecosystems are part of the greater heterogeneous landscape of the coastal Douglas-fir zone. The degree to which these ecosystems remained biologically diverse and ecologically dynamic was a function of the intensity, frequency, and scale of past anthropogenic and natural disturbance regimes. The suppression and control of these disturbance patterns helped to shape the ecosystems of today.

Historic land management practices, such as digging and burning by Straits Salish peoples or livestock grazing by European settlers, could be highly controversial restoration strategies within the conservation community today. For instance, many restoration ecologists oppose soil disturbance because of the likelihood of enhancing the conditions for seed germination of weedy species (e.g., Polster 2002). The intensification of human activities in restoration will increase the probability of biological invasion (Luken 1994), just as the management activities by Indigenous peoples included the maintenance of native weedy species. The use of prescribed fire in urban or populated settings is contentious because of the potential risk of wildfire and its threat to property and life, and the effects of smoke emissions on public health. Lastly, the use of livestock as a disturbance agent in restoration is rarely considered, even though research on the role of native ungulates or domestic livestock in the maintenance of open Garry oak ecosystems could prove informative and represent a practical alternative to prescribed burning.

The restoration of disturbance patterns may not achieve the prescribed results in all cases because of inherent heterogeneity of these ecosystems. Burn treatments may be unsuccessful in ecosystems which have been long fire-suppressed (Huffman and Werner 2000), or in ecosystems where other disturbance regimes are suspected, such as former Indigenous root harvesting grounds. The reintroduction of fire use may need to be accompanied by supplemental management procedures, such as replanting with native species, in order to maintain native plant assemblages (MacDougall 2002; Polster 2002) and prevent increases in exotic plant populations. Repeated burns in Garry oak habitats with shallow soils, such as rock outcrop, could result in reduced cover of native herbaceous plants. Alternatively, the cumulative ecological effects of multiple treatments (i.e. digging and burning) may result in more favourable environmental conditions for the growth of native herbs (common camas [*Camassia quamash*]), than if one treatment was applied alone (Beckwith 2004).

Garry oak parklands are continuously threatened and are nationally recognized for their rarity, but, in some cases, ecosystem fragility should not be mistaken for species vulnerability. The growth and development of some native plants, namely camas, can be enhanced by periodic disturbance patterns. Despite habitat loss and introduced species, many native perennial species have persisted in degraded ecosystems because of their tenacious adaptations to disturbance. For example, the habitat of the yellow montane ('prairie') violet (*Viola praemorsa* ssp. *praemorsa*), a red-listed species, may have been maintained by periodic disturbance in the past. A large population of this violet species is found in the former Rogers Farm area of Christmas Hill that was seasonally grazed (i.e. summer time after wildflowers bloomed) by cattle for over one hundred years, and heavily grazed for the last 20 years, before the land became part of a protected nature sanctuary in 2000. It is uncertain whether the cattle themselves maintained the open habitat that the yellow montane violets require or if the cattle provided a disturbance agent for the violets directly. The stability of the violet population is now threatened by the encroachment of snowberry (*Symphoricarpos albus*) and likely other invasive plants in the area.

Finally, there are several reasons why the restoration of traditional plant foods, such as camas bulb processing and use, may prove to be problematic in a modern-day context. Indigenous practitioners with traditional harvesting knowledge are rare because the bulbs have not been regularly harvested in many decades. The deep-soil sites where Straits Salish peoples likely maintained extensive and productive camas grounds are either nonexistent or inaccessible. Ecologically productive camas populations are locally restricted and more judicious ethnoecological research needs to be accomplished before wild harvesting or cultivation could be considered in many areas. Finally, the possibility of harvesting the bulb from a poisonous plant, such as death camas (*Zygadenus venenosus*), by mistake is a very important issue when the harvesting of camas bulbs is undertaken by inexperienced people from unmanaged camas sites.

The Role of People and their Values

It is important to bear in mind that not all human activities have led to negative ecological consequences and, as a community, people need to sift through past and present landscape values and policies in an integrative approach to restoration (McCann 1999). The land management regimes of Straits Salish peoples were imbedded in long-standing economies that evolved over generations. The cultural landscapes first viewed by Europeans in the late eighteenth century were the product of both cultural practices and environmental processes. Many of the European homesteaders on southern Vancouver Island (e.g., George Rogers Sr.) were also highly dependent on the sustainability of their lands, an, subsequently, they managed their farms to meet with personal and economic, and often aesthetic, needs.

The restoration of degraded Garry oak ecosystems to productive and functional natural habitats will require a firm commitment to on-going stewardship and protection. The potential commitments of human involvement and investments of time associated with ethnoecological restoration challenges public inclinations. Although most people favour restoration in principle, some remain unsupportive of altering nature in an active and manipulative way. For people reconnecting to nature, for example, trees have strong symbolic value; restoration volunteers prefer to plant trees, not clear or cut them down (Barro and Bright 1998). These perceptions would appear to be contradictory to the objectives of meadow or savanna restoration initiatives commonly associated with the recovery of Garry oak ecosystems.

Ethnoecological restoration activities that are firmly situated and have longevity could aid in the restoration of community. Community-based restoration allows people to develop a *sense of place* within their local environments, a widely heralded objective of ecological restoration today. However, even though place implies a history, the sentiment generally does not delve into the intricacies of Indigenous people's interactions and relationships within their landscape. Hence, a *sense of origin* could also be considered as a necessary ingredient for ethnoecological restoration (c.f. McGinnis 1999). This concept supports the recognition of the past environmental and cultural elements that shaped the landscape of today.

Through ethnoecological restoration a landscape can resonate again through the human activities of mindful caring and skillful practice (c.f. Ingold 1993; Higgs 2003). In this context, information is gathered based on participation and observation, but also assessed by scientific procedures and theory and hands-on experience. The argument that participation is integral to restoration process runs deep in the restoration and landscape theory literature (e.g., McGinnis 1999). Through intimate experience, as well as imaginative and integrative education programs, community-based restoration can affect human behaviour and initiate the reconnection between people and landscape (c.f. Janzen 1988; Whittey 1997; Helford 1999). People who feel disengaged from nature could once again begin to develop positive human-environment relationships within their natural lands and a shared local knowledge.

Acknowledgements

Much of this essay came from my Ph.D. research on the ethnoecology of camas at the University of Victoria. Many people contributed to the development of the dissertation. Specifically, however, I thank Dr. Nancy Turner for the opportunity to study under her gracious mentorship and Cheryl Bryce for introducing me to the local Indigenous culture and the cultural aspects of ethnoecological research in a meaningful, applied way. This essay is dedicated to Willie MacGillivray and all others who have spent countless hours restoring Garry oak ecosystems long before the days of recovery strategies and management plans. Their local knowledge should not be underestimated nor overlooked.

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Container Selection for Revegetation Success with Oak & Deep Rooted Chaparral Species

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Abstract
A discussion of container size specification considerations for revegetation success with a particular focus on deep and taprooted species used in southern California habitat restoration projects. Research results will be presented for three typical deep rooted species: California live oak (*Quercus agrifolia*), lemonadeberry (*Rhus integrifolia*), and laurel sumac (*Malosma laurina*) used San Diego County California comparing revegetation success using different container types an irrigation regimes over a 4-5 year period. The presentation concludes with a discussion of the relevance of the southern California data to habitat restoration project design using similar species such as Garry Oak (*Quercus garryana*) in the western coastal regions of Canada and the U.S. Pacific Northwest.

Reframing our Picture of Non-native species

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Abstract

Conservation biology is described as a crisis discipline because its purpose is to solve urgent problems such as habitat destruction, non-native species, and overexploitation (Soulé 1985). The eradication of non-native species has been seen as the "nasty necessity" to protect native species diversity (Temple 1990). Unfortunately, the drive to preserve natural systems has often provoked *ad hoc* (Pressey 1994) and reactive responses to perceived threats to the integrity of species, communities, and ecosystems (Hager and McCoy 1998). In the face of a crisis, many in the conservation field feel that it is better to make a decision and 'save' the situation rather that wait for the results from scientific testing and potentially loose everything (Soulé 1985; Coblentz 1990; Ruesink et al. 1995). Coincident observations may be taken as causation and, in an effort to meet conservation goals; policy and management decisions may be made without the benefit of hypothesis testing. Given the high cost of controlling non-native species, however, strategic approaches to restoration are needed. This paper summarizes recent academic articles discussing the relative role of anthropogenic landscape change and the competitive impact of non-native species on native species. Using examples from my research, I will reframe the role of key factors that influence the composition of biological communities. Once the relative importance of abiotic factors, intertrophic interactions and intratrophic interactions on the composition of communities is understood, restoration ecologists can make strategic decisions for restoration actions.

Introduction

Invasive species have been widely considered the second greatest threat to biodiversity next to habitat loss (Wilcove et al. 1998). Recent papers, however, have questioned the relationship between invasive species and extinction (Sax et al. 2002, Davis 2003, Gurevitch and Padilla 2004). Although non-native predators, herbivores, and parasites have caused numerous extinctions, competition-driven (intratrophic) extinctions are absent from the literature (Davis 2003). In many cases of apparent competitive displacement, habitat loss and disturbance are confounding factors. Lodge and Shrader-Frechette (2003) argue that academic discussions about whether non-native species have depleted global diversity confuse the public and that the focus should be on reducing the economic and ecological impacts of non-native species. Accomplishing this in an efficient manner is challenging, however, given, that most non-native species are benign. The concept that 'non-native species are bad' has become reified (Slobodkin 2001) so that research on non-native species is rarely neutral or objective (Browne and Sax 2005). Even the language, "invasive", "introduced", "exotic", and "weedy", is ambiguous and lacks neutrality (Richardson et al. 2000, Davis and Thompson 2000, Colautti and MacIsaac 2004). The presumption that non-native species have negative effects on native species biases research and restoration. Increases in non-native species can be concurrent with declines in native species, but empirical data is needed to understand why the changes in abundances are occurring (Parker et al. 1999). The real culprit may be a confounding effect such as changes in landscape structure that favour the spread of non-native species and reduce habitat for native species.

Untested observations have been sufficient in the past to launch expensive control and eradication programs prior to understanding the mechanism of the observed displacement. This may be a contributing factor to why control of non-native species is often an on-going process and one of the reasons why eradications fail. To effectively reduce the negative impacts of non-native species, research must take one step back to examine the underlying factors that facilitate species invasions. Control and restoration efforts must then address that factor, which may not be the non-native species themselves. The purpose of this paper is to examine the importance of competitive interactions as a mechanism for ecosystem degradation relative to other factors, such as habitat loss and intertrophic interactions. I will summarise recent discussions on this topic in the academic literature and use some of the most well-known invasive species as illustrative examples. I will conclude with recommendations for the restoration biological communities that are based on ecological research.

For this discussion, it is important to define the types of interactions that can occur between non-native and native species. Species can interact across different trophic levels, intertrophic interactions; or within a single trophic level, intratrophic interactions. Intertrophic interactions include predator-prey, herbivore-plant, and pathogen-host relationships while intratrophic interactions include competition for resources. Non-native and native intertrophic interactions have been demonstrated to have profound effects on ecosystems. Notable examples include brown tree snakes (*Boiga irregularis*) causing the extinction of several endemic vertebrates on Guam (Rodda 1992), avian malaria causing the decline and extinction of honeycreepers in Hawaii (Atkinson et al. 2000), and domestic cats causing the extinction of endemic birds and mice (Nogales et al. 2004, Vazquez-Dominguez et al. 2004). Non-native and native competitive interactions, however, have not been found to cause extinctions (Sax et al. 2002, Davis 2003, Gurevitch and Padilla 2004). For example, 4000 plants have been introduced to North America. Approximately 400 of those have become naturalized. Although these non-native plants represent 20% of North America's vascular plant species, none of them has been attributed with the extinction of native plants (Davis 2003).

The 10% of introduced plants that have become naturalized to North America illustrates an often overlooked fact, that the vast majority of introduced species fail to establish (Williamson 1996). Novel environments, stochastic events, and small population (allee) effects present insurmountable challenges for the majority of introduced species. Roughly 10% of introduced species can persist in novel environments and will become naturalized and the majority of these naturalized species will not have negative effects on native species (Huston 1994, Williamson 1996, Davis 2003). The small percentage of introduced species that do become pests can have catastrophic effects, but what is not clear is whether there are other factors mediating these effects nor whether eradication of the introduced species will ameliorate the problem (Gurevitch and Padilla 2004). What follows are some well known examples of intratrophic native and non-native species interactions from diverse taxa to explore whether there are underlying factors that may be facilitating the decline of native species. I give a brief summary of zebra mussels (*Dreissena polymorpha*), purple loosestrife (*Lythrum salicaria*), and Brown-headed cowbirds (*Molothrus ater*) from other studies and discuss eastern grey squirrels (*Sciurus carolinensis*) and Garry oak ecosystems from my own research in more detail.

Examples from the Literature

Zebra mussels are considered to be the major threat to North American freshwater unionid bivalves. Forty of the 281 native unionids are known or thought to be extinct and the rest are threatened, endangered, or of concern. Zebra mussels require a hard substrate for attachment and the shells of native bivalves offer the most abundant substrates for zebra mussel settlement. Zebra mussels clearly have a negative effect on native unionids by making it difficult for them to burrow, occluding unionid openings making respiration, feeding, and reproduction difficult or impossible, and zebra mussels may compete with uniodids for food. Nevertheless, no unionid species have gone extinct since the introduction of zebra mussels in the late-1980's and the decline of unionids began long before their arrival. The extinction and decline of unionids was caused by habitat destruction and deterioration resulting from water diversion, erosion, an increase in eutrophication, pesticides, harvesting, etc. (Gurevitch and Padilla 2004).

Purple loosestrife is widely believed to fill in wetlands, create monotypic stands, and competitively displace native species (Thompson et al. 1987). Individuals, community groups, and government organizations have implemented expensive and labour-intensive control measures. Control efforts include the introduction of non-native insects for biological control even though native herbivores can reduce the growth and flower production of purple loosestrife (Rachich and Reader 1999). The hypothesis that purple loosestrife has detrimental effects on North American wetlands was based on observational studies (Hager and McCoy 1998). The quantitative studies that have followed have been equivocal. While purple loosestrife grows successfully and, in some cases, more quickly than native species in disturbed wetlands, purple loosestrife has not been found to form monotypic stands nor fill in wetlands (Hager and Vinebrooke 2004). In fact, purple loosestrife is positively related to plant diversity (Houlahan and Findlay 2004). The positive association between native and non-native species diversity is a common phenomenon (Sax and Browne 2000), suggesting that site or landscape factors have a greater influence on community diversity than non-native species.

Brown-headed cowbirds are native to North America but have been expanding their range with landscape conversion to agricultural lands (Peterjohn et al. 2000). Brown-headed cowbirds feed in agricultural fields and are strongly associated with domestic cattle. They are nest parasites and will travel to shrub and forest ecosystems to seek out songbird nests (Rothstein et al. 1984, Tewksbury et al. 1999). Cowbirds reduce the reproductive output of hosts by removing host eggs (Sealy 1992), inducing abandonment of parasitized nests (Ortega and Ortega 2001), out-competing host species nestlings for parental care (Hauber 2003), and depredating unparasitized nests (Arcese et al. 1996). The songbirds feed and care for their large, foreign chick, often at the expense of their own that may still be in the nest. For example, on Mandarte Island, song sparrows raise 38% fewer fledglings in parasitized nests than song sparrows with unparasitized nests (Smith et al. in press.). Brown-headed cowbirds arrived in the southern B.C. coast in the 1950s and may be having a negative effect on a number of native songbirds. Although removal of the cowbirds benefits songbirds (Smith et al. 2002), the effects are temporary as cowbirds will reinvade as long as agricultural lands are available. The solution to the "cowbird problem" resides in reversing the changes to landscape structure.

Eastern grey squirrels

Eastern grey squirrels have been introduced to Great Britain, Ireland, Italy, South Africa, Australia, and cities throughout western North America. The first introduction of eastern grey squirrels to British Columbia, in Stanley Park in Vancouver, occurred in 1909 (Steele 1985). There was a failed introduction in Beacon Hill Park in Victoria in 1945 (Ringuette 2004) and a successful one to Metchosin in 1967 (Guiguet 1975). Eastern grey squirrels have negative economic and ecological effects in Europe where they strip the bark from trees and displace native Eurasian red squirrels (Kenward and Parish 1986, Gurnell et al. 2004). There has been some speculation that eastern grey squirrels have negative effects on native species in British Columbia. Eastern grey squirrels may compete for resources with squirrels endemic to southwestern British Columbia [Garry Oak Ecosystem Recovery Team (GOERT) 2003], Dickson 2005) which include North American red squirrels (*Tamiasciurus hudsonicus*) on Vancouver Island and Douglas squirrels (*Tamiasciurus douglasii*) and Northern flying squirrels (*Glaucomys sabrinicus*) in Greater Vancouver. It has also been hypothesized that eastern grey squirrels eat and damage a sufficient number of Garry oak acorns as to impede their regeneration (Bruemmer et al. 2000).

We used wildlife shelter data that spanned 20 years, the same timeframe when eastern grey squirrels were most actively spreading throughout the region, as an estimate of the abundance of eastern grey and Douglas squirrels in Greater Vancouver (Gonzales et al. unpublished data). If eastern grey squirrels had negative effects on Douglas squirrels, we would expect a negative relationship between the abundance of eastern grey and Douglas squirrels. Eastern grey squirrels were positively correlated with Douglas squirrels, suggesting that environmental factors have a greater effect on the abundance of squirrels than intratrophic interactions between the two species. Further, eastern grey squirrels co-occur with North American red squirrels throughout much of their range where habitat specialization and not competition determines the differences in their distributions (Riege 1991). Given that eastern grey squirrels are predominantly found in residential habitats (Gonzales 2005) and native squirrels are generally found in forested areas (Gonzales 2000), competitive interactions would only be expected in localized areas where these two habitats overlap. It is unlikely; therefore, that eastern grey squirrels would displace Douglas squirrels at a regional scale as long as Douglas squirrels have suitable, contiguous habitat (Gonzales et al. unpublished data).

Native squirrels have declined in Greater Victoria and Greater Vancouver and it is probable that direct and indirect conflict with humans is the cause rather than competition with eastern grey squirrels. The decline of native squirrels began with the removal of forests in Greater Vancouver and Victoria in the 1800's. The replacement of conifer forest with development has significantly reduced the available habitat for native squirrels. A resident of Victoria remembered red squirrels disappearing from developing areas in the 1940's (Gonzales 2000). Results of a landscape analysis found that Douglas squirrels in Greater Vancouver were significantly correlated with undeveloped land types (Gonzales et al. unpublished data). As undeveloped areas become isolated by developed areas, native squirrels may, in time, decline due to dispersal barriers, inbreeding, and stochastic events (Gonzales et al. unpublished data). Pet attacks, vehicle impacts, and interference by humans have been directly responsible for a large number of submissions of squirrels to wildlife shelters (Gonzales et al. unpublished data).

The hypothesis that eastern grey squirrels reduce the regeneration of Garry oaks, while untested, is contradictory to the literature that supports a net benefit for tree regeneration from scatter hoarding squirrels (e.g., Vander Wall 2001, Goheen and Swihart 2003). For example, North American red squirrels have recently expanded their range in Indiana, areas previously dominated by eastern grey squirrels. Eastern grey squirrels are concurrently declining due to increasing agriculture. Goheen and Swihart (2003) developed a model that predicts the replacement of scatter hoarding eastern grey squirrels with larder hoarding red squirrels will result in the decline of Black Walnut (*Juglans nigra*), Red Oak (*Quercus rubra*), and Bur Oak (*Quercus macrocarpa*) regeneration.

Garry Oak Ecosystems

The mechanisms underlying the loss of native plants in Garry oak ecosystems, one of Canada's most endangered ecosystems, are poorly understood (MacDougall 2002). Understanding the mechanisms that are continuing to degrade Garry oak ecosystems is vital to its restoration success. For my Ph.D., I am exploring the role of ungulate herbivory, competition by non-native grasses, and drought on native plants and community composition in Garry oak ecosystems in the Gulf Islands. Non-native grasses dominate Garry oak ecosystems, even in many ecological reserves, parks, and other protected areas. It appears as if non-native grasses have competitively displaced native plants. Herbivory may also play a role in the decline of native plants and facilitate the invasion of non-native grasses. Here I describe the components of my research that quantifies the impact of herbivores and above ground competition by non-native grasses on the performance of native plants.

Competition is difficult to test in the field. I focused on above ground competition by non-native grasses because shading and litter accumulation can have significant and cascading effects on plant communities (Facelli and Pickett 1991). Shading and litter accumulation has also suppressed the germination and establishment of native plants in Garry oak ecosystems (MacDougall and Turkington 2005). Although not a complete removal of below ground competition, I also reduced the effects of root competition and alleleopathy by spading around the edges of the experimental plots. Experimental treatments involved fencing half the plots to exclude ungulate herbivores and clipping the above ground vegetation in half the plots to remove non-native grasses and litter in a two by two factorial design.

The treatments described above were used to test whether ungulate herbivory or competition by non-native grasses had a greater effect on native plants. A seed addition experiment and a plant addition experiment tested the effects of herbivory and competition on different plant life history stages. Shading and litter accumulation were predicted to reduce the germination and establishment of native seeds while herbivory was predicted to reduce the growth and leaf and flower production of established native plants. Experimental plants varied in their life history characteristics, were typical to Garry oak ecosystems, and had general habitat characteristics. The seed addition experiment took place on three different islands while the plant addition experiment occurred on one island. Native black-tailed deer (*Odocoileus hemionus*) are abundant on all three islands but Salt Spring also has about 12 sheep and Saturna has approximately 200 feral goats which allowed a test along a gradient of herbivory for the seed addition experiment.

A final field season remains, but preliminary results support some of the predictions. Shading and litter accumulation reduced the germination and establishment of four (out of eight) native plant species on Gabriola. There were no differences between treatments on Salt Spring and Saturna. The results can be explained by differences in productivity of the sites. Both Saturna and Salt Spring are shallow soil sites while Gabriola is a deep soil site. Non-native grasses are pervasive in the shallow soil sites, but do not shade or accumulate litter. The lack of litter accumulation may also be related to herbivory, as there are no feral livestock on the Gabriola site. Finally, the species of dominant non-native grass differs between deep and shallow soil sites. Orchard grass (*Dactylis glomerata*), a grass that forms thick clumps, produces much biomass, and creates a thick thatch that takes years to degrade, dominates on Gabriola but is rarely present on Salt Spring or Saturna.

Shading and litter accumulation had no effect on the growth or leaf or flower production in the plant addition experiment but herbivory significantly reduced the growth and leaf and flower production in the plant addition experiment. Sea blush (*Plectritis congesta*), an annual, responded to herbivory by becoming locally extinct in some plots that were exposed to herbivory and dominating in some of the plots that were protected from herbivory. Ungulate herbivory also reduced the growth of camas (*Camassia quamash*) in all years and arbutus (*Arbutus menzeisii*) in 2003. Arbutus did not survive the 2003 drought and new arbutus saplings were planted for 2004. These saplings showed no difference in performance between treatments and also succumbed to the 2004 drought. Garry oak (*Quercus garryana*) acorns and saplings showed no difference in performance between the treatments. Insect herbivory, drought, and the stress of transplantation, however, led to the death of over 300 Garry oak saplings over two years, nearly 80% of the experimental plants. To summarise, soil depth determined whether non-native grasses had competitive effects on the growth and establishment of half of the seeded native species. Deep soil sites favoured grasses that shaded and accumulated litter while shallow soil sites did not. Ungulate herbivory had no effect on the germination and establishment of native seeds but significantly reduced the performance of sea blush, camas, and the arbutus in 2003. Non-native grasses and herbivory did not reduce the performance of arbutus in 2004 or Garry oaks in any year, but insect herbivory and drought caused the mortality of the majority of these planted trees.

The native species used in the experiments were probably abundant historically; however, these species are not common on the sites now. The successful addition of seed in this experiment supports work found by others (Foster and Tilman 2003, Seabloom et al. 2003, MacDougall and Turkington 2005), that native species are limited by dispersal and not prevented from germinating and establishing in the presence of non-native species. This suggests that landscape change is a driver for the shift in vegetation from native to non-native species. That is, non-native grasses are not necessarily superior competitors but rather may dominate because of prior disturbance and the low dispersal abilities and current rarity of native plants. The loss of native plants in Garry oak ecosystems has likely been a negative feedback loop. I hypothesize that the loss of native plants in Garry oak ecosystems has been due to:

a) Landscape fragmentation which reduced the total area of habitat available and partitioned the landscape into isolated remnants.
b) Isolation which limited opportunities for the dispersal of native seeds. The remnants of Garry oak ecosystems are generally surrounded with land types that are abundant with seed from non-native species.
c) Herbivory that reduced the growth, production, and recruitment of native plants. As native plants became rare, they were increasingly selected over less palatable native grasses putting further pressure on the declining populations.

Therefore, the transition from native to non-native plants may appear to be the result of active competitive displacement when the underlying processes were facilitated by land conversion, fragmentation, herbivory, allee effects, and other associated factors. Once the abundance of native seeds declined and non-native grasses dominated the area, shading and litter accumulation by non-native grasses further reduced the establishment and recruitment of native seeds in deep soil sites. In shallow soil sites, below ground competition may have further reduced the establishment of native plants.

Discussion

The presence of non-native species is highly correlated with anthropogenic disturbance (Williamson 1996). In each of the examples above, changes in landscape structure caused the declines of native species and non-native species may simply have been correlated with the process. Preventing the disturbance and the subsequent invasion of non-native species would be the most efficient method to conserve native species. Disturbed areas, however, are the raison d'etre for restoration ecologists. Understanding the mechanisms that underlie the degradation of ecosystems has direct relevance to restoration ecology because the field needs strategic approaches for effective restoration. Reframing the role of non-native species in ecosystem degradation is critical because conservation and restoration funds are finite.

For example, millions have been spent trying to control eastern grey squirrels and purple loosestrife while a tiny fraction of that has been devoted to understanding how they actually affect native species. Over £100,000 was spent trying to eradicate eastern grey squirrels in Great Britain from 1953 to 1958 with no apparent impact (Sheail 1999). In 1973, Warfarin was used to manage eastern grey squirrels but there are no reports as to its effectiveness and non-target species were also killed (Wood and Phillipson 1977, Sheail 1999). There are over 200 academic publications about eastern grey squirrels in Great Britain, possibly one of the most studied organisms in the country. Yet no formal studies to study the impact of eastern grey squirrels in Eurasian red squirrels were conducted prior to either control attempt. Recently, the role of landscape structure is emerging as the primary cause of the replacement of Eurasian red squirrels. Eurasian red squirrels are more successful in conifer forests than eastern grey squirrels and the maintenance of these forests has been recommended for their conservation (Kenward and Hodder 1998, Bryce et al. 2002). Had this been tested and understood decades ago, eastern grey squirrels may have been managed more effectively or the funds dedicated towards failed control efforts could have been dedicated to Eurasian red squirrel conservation. Similarly, the belief that purple loosestrife had negative impacts on native species were based on observational studies (Hager and McCoy 1998). Experiments testing the negative impacts of purple loosestrife were initiated after millions of dollars had been spent on control, including biological control, which introduces its own host of risks (Hager and McCoy 1998). The hypotheses that purple loosestrife out competes native species or has negative effects on native diversity has yet to be supported (Rachich and Reader 1999, Hager 2004, Houlahan and Findlay 2004, Hager and Vinebrooke 2004).

The precautionary principle may imply that we should treat all non-native species as guilty of negatively impacting native species. Limited research funds, however, do not permit the luxury of treating the symptoms and not the solution. Control and eradication of non-native species is a frequent component of restoration and the decision to control non-native species should be weighted with other restoration techniques that may be more effective, such as the augmentation of native species. Non-native species have not, on the whole, actively displaced native species in unaltered landscapes (Houlahan and Findlay 2004, Gurevitch and Padilla 2004, MacDougall and Turkington 2005). The common threat to native ecosystems is changes in landscape structure. Obviously, development reduces habitat for native species but in each of the examples given, it is the fragmentation of the landscape and areas developed proximately to the habitat of native species that has led to the decline of these species and the subsequent invasion of non-native species. Given the role of dispersal limitation in the decline of native species, seed and plant addition is emerging as a critical component of restoration.

Conclusions

When assessing the impact of non-native species on native species, researchers and restoration ecologists should consider all possible mechanisms acting on native species to address potential confounding factors such as anthropogenic factors. The examples given above provide an illustration of how landscape level changes are responsible for declines in native species. Restoration ecologists act locally, but should think regionally with regards to invasion of non-native species and dispersal limitations on native species. Focusing solely on the control of non-native species may be inefficient and ineffective because the structure of the landscape favours reinvasion of non-native species and limits the recolonization of native species. Restoration efforts may be more successful by augmenting dispersal limited native populations and shifting from non-native to native species dominance.

Ecological research can provide heuristics for restoration ecologists. Communities are structured, in order of importance, by 1) abiotic factors such as microclimate and soil depth, 2) landscape structure, 3) intertrophic interactions such as predators and prey, herbivores and plants, and pathogens and hosts, and 4) intratrophic interactions, such as species that compete for the same resources. Application of these principles would involve:

1) Abiotic factors: while it may be challenging to alter abiotic factors, their importance in structuring plant communities can guide restoration ecologists in locating reference ecosystems. For example, Garry oak ecosystems can be highly heterogeneous between sites and a restoration site should use a reference site with the same soil structure.
2) Landscape structure: if the restoration site is dominated by non-native species and isolated from sources of native species, native species will need to be added to the site in addition to non-native species removal. Buffers and, ultimately, the formation of contiguous natural areas will increase the long-term viability of native species.
3) Intertrophic interactions: it may be necessary to manage predators, herbivores, or pathogens prior to native species augmentation. Landscape structure changes can concentrate predators, herbivores and pathogens into smaller areas effectively increasing their densities. This may increase the pressure on native species that are already compromised by their contracting habitat area. Non-native predators, herbivores, and pathogens may also reduce native species.
4) Intratrophic interactions: Control is most effective before introduced species establish but once they are established, eradication is expensive and prone to failure. Management of non-native species should be strategic and based on an understanding of why the species is successful in the ecosystem and how it affects native species. In some cases, conservation

and restoration funds may be better spent protecting undisturbed land, increasing the abundance of native species, and educating the public.

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The Rockies Through the Lens of Time: Repeat Photography and the Challenge of Ecological Restoration

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Abstract
Working with perhaps the largest systematic collection of historical mountain photographs--more than 70,000 survey images used to map the mountainous regions of western Canada in the late 19th and early 20th centuries—our team has undertaken repeat photography with a portion of the collection to interpret and analyze the qualities and extent of change in Waterton Lakes National Park. Waterton, one of Canada's most celebrated and vulnerable protected mountain areas, is part of the Waterton-Glacier International Peace Park and is a World Heritage Site. Our goal is providing finely resolved historical information for effective ecological restoration of vulnerable landscapes. This presentation provides an overview of the historical and repeat photographic surveys, the challenge presented to restoration planning by snapshots of historical information, and three specific research projects based in part on the photography: disturbance regimes in subalpine forest communities; the dynamics of aspen (*Populus tremuloides*)-grassland communities in areas of heavy human use; and, tracking the content and use of the imagery in the development of Canadian attitudes toward nature. Historical photographic surveys cover many regions of British Columbia, and future research is planned for areas such as the Flathead Valley, Kootenay-Yoho and Vancouver Island.

An Adventure in Restoring Private Forest Land on Galiano Island

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Abstract
The forests of Galiano Island have seen intensive logging since roughly 1900, with some sites now in their third rotation. In the early 1990's, a large industrial tree farm on more than half of the island was dispersed as quarter sections to a diversity of new land owners. Most of this area urgently needs tending for objectives of restored biodiversity, scenic and recreational values, enhanced timber quality, and the reduction of fuels. This paper describes forest restoration in progress on District Lot 79, which has four distinctive forest types: a shoreline of older Douglas fir and cedar, Douglas fir plantations from the mid 1960's, much younger Douglas fir plantations, and areas dominated by big leaf maple and alder. Treatments have included pruning and spacing conifers, thinning maple coppices, and removing noxious weeds. Unlike traditional forestry, the deciduous component and particularly arbutus have been encouraged to flourish. These sites have responded positively with formerly depauperate areas now being covered by swordfern, salal and other species. The vision of this ongoing forest restoration is to produce diverse stands of fewer, larger trees with improved carbon sequestering ability and reduced wildfire hazards. A key question arising from this work is how to create positive incentives for other landowners to practice enlightened forestry.

Introduction

Galiano Island is a spectacularly beautiful island of roughly 6000 ha. Close to 50% of its area has been clearcut logged within the last 50 years (Scholz et al 2004). Much of this land area was reforested in the form of Douglas fir (*Pseudotsuga menziesii*) plantations. With such a large percentage of its landmass in a homogenous plantation form, there are numerous concerns from the perspective of biodiversity. Until the early 1990s, this land was maintained under a management regime of high timber production that included planting, spacing and other silviculture activities by MacMillan Bloedel. Since the former owner sold the forest land, much of this forest land has seen little tending, with most of the area in a state of at best benign neglect. Extensive areas have been intensively logged with no associated silvicultural activities. This accumulated neglect has resulted in an increased fire hazard, a further reduction in understory species, a continued loss of tree diversity, and an increase in noxious weeds around the recently logged properties.

This paper is concerned with the initial restoration of a small piece of highly fragmented land by a couple of hardworking forest eccentrics. Roughly 95% of District Lot (DL) 79 has been logged since 1960, with a few strips of mature forest remaining along the seashore. Though the author is experienced and trained in ecological restoration, this work has taken place informally in the context of recreational restoration. As the owners gained experience, their initial experimental approach was refined with advice from myself, and much mutual assistance by members of the Galiano Island Forest Association. The subject property, DL 79 is a highly fragmented property of roughly 136 acres. The work that has taken place on this property has primarily occurred in two areas, the upper area of the property above the paved road, and the southern half of the area between the road and the waterfront. Treatments have included pruning, thinning of conifers (both non-commercial and small logs), the thinning of maple coppices and the removal of noxious weeds.

While the author's family have owned a one third interest in DL 79 since 1993, they subsequently also acquired DL 10 (also about 136 acres) on the flank of Mount Galiano in order to pursue their interests in forest land restoration and recreational trailbuilding on a larger canvas.

Methods

Unlike projects in the more formal style, this project began in an incremental way with Bowie Keefer (my father) becoming an obsessive pruner of the then 40 year old plantation Douglas fir. If we were practising conventional commercial forestry, pruning trees of that age would not be considered worthy, due to the limited return of only another 20-30 years of tree growth prior to the end of the rotation. From a broader perspective, however, such pruning is an excellent investment as this activity enhances the non-timber species and makes the forest a brighter and more visually attractive place for humans. The majority of Douglas fir trees of more than 15 years age have now been pruned up to the 5 metre level.

The second major phase of this project occurred in 1993 when we wrote an application to the now lapsed federal/provincial forestry program called FRDA. This proposal was backed by our own mapping of the forest inventory, including air photo analysis. In this program, we applied to conduct a 'conifer release' program and were funded to treat roughly 30 acres of 10 year old plantation. After discussion with the forester in control of the program, it was agreed that we didn't have to do a standard conifer release program and that managing for both arbutus (*Arbutus menziesii*) and red alder (*Alnus rubra*) as desired species was an acceptable option. I undertook this work with a group of friends who were also silvicultural workers at the time. At the time we were all University of Victoria Environmental Studies students and we felt that we were being severe on the land by killing so many trees. The effect of our work was a significantly lowered tree density with the canopies of the trees no longer connecting. With hindsight, the initial thinning could have been much more intensive; or better, followed by a second pass two or three years later.

The southeast corner of DL 79 is roughly 10 acres in area and was logged in 1985. The plantation in this area was largely unsuccessful, the result being a mixed stand of alder, bigleaf maple (*Acer macrophyllum*), bitter cherry (*Prunus emarginata*), grand fir (*Abies grandis*), a few arbutus (*Arbutus menziessii*) and minority Douglas fir in a varying composition. From the perspective of tree diversity, this area undoubtedly makes a clean break from plantation monoculture, yet it is lacking in structure. Typically bigleaf maple and alder are the lead species and are often of a high density that can be favourably reduced by treatment. In 1995 it was becoming apparent that the maples and alder were occupying a large amount of the canopy area, not growing appreciably in diameter, choking the understory and the competing conifers. In 1995 we began thinning the alders to roughly 3 m spacing. Starting in 2000, we began thinning the maple coppices down to two to four stems per stump. Thinning maples can be dangerous as maples have weak wood with a high percentage of tension wood and interlocking canopies, thus making it an unpredictable species to fall. As of 2005, most of this stand has now been treated so that each coppice only has 2-3 stems.

Initially the noxious weed of concern was Scotch broom (*Cytisus scoparium*), which was located along skid roads and throughout the more xeric sites on the plantations. Broom was generally removed with either chainsaw or loppers. Recently tansy ragwort (*Senecio jacobaea*) has greatly increased in prominence in openings dominated by grasses. The tansy ragwort is being removed by handpulling whenever the author is on the property

DL 10 was clearcut on about 40% of its area by the previous owner. Fortunately, the remaining area still has attractive groves of high quality second growth fir in the age group of 30 to 60 years, and a few veteren Douglas fir. Most of the recently logged areas were replanted quite successfully by the previous owner. Our initial work on DL 10 has been conducted informally, without detailed baseline inventory or the use of historical photography. This work has concentrated on logging debris cleanup, broom removal, and pruning of second growth forest for aesthetics and fire risk reduction.

Current work is now directed toward pruning and thinning the younger plantation areas on DL 79, primarily seeking to enhance tree and forest floor species diversity, and to reduce wildfire risk as an urgent priority. The even younger third growth replanted fir areas on DL 10 are now ready for initial pruning and some selective thinning. Subsequently, our next phase of work on both DL 79 and DL 10 will extend to thinning plantation trees in the age group of 25 to 50 years with the same main objectives of diversity enhancement and fuel load reduction. As this work progresses, the process of restoring the impoverished formerly industrial plantation into an almost natural forest is accelerated visibly.

Plantation grown logs that would be removed in thinning are often so inferior (open grain, large knots, excessive taper and crookedness) as to be commercially suitable only as pulp logs. We have experimented with using these logs for short-log construction, achieving very satisfactory results on three prototype buildings. This suggests an excellent opportunity to combine local job creation with a self-financing mechanism for private forest land restoration and management.

Results

Throughout the different treated stands, the results indicate that the thinning has enhanced the non-timber species and has resulted in the release of the trees. In the older pruned plantations, salal (*Gaultheria shallon*), swordfern (*Polystichum munitum*) as well as chanterelles have noticeably increased. The conifer release program, though it seemed harsh at the time for a team of young green idealists, was not intense enough and is ready for another treatment. Undoubtedly this program did slow the process of canopy closure, but a lesson was learned. The results of the work on the southeast corner of DL 79 have been the most dramatic. A number of the areas of alder were close to depauperate in the understory, following treatment and a decade of time; these areas have close to 100% cover in the understory with swordfern and salmonberry (*Rubus spectabilis*) and a component of other species.

The broom removal in the areas where we have worked has mostly been successful; however, it is likely better to attribute the success to forest succession than to our activities. In the northern portion of DL 79 whose owners have been latterly absent as the result of health problems, broom has achieved climax occupation of areas disrupted by roadbuilding 10 years ago. Despite the modest efforts of ourselves and others, broom and tansy ragwort have continually increased in prominence throughout much of Galiano and are likely affecting the quality of ungulate habitat.

Discussion

This type of project requires large amounts of energy, an understanding of forest ecology, chainsaw training and most importantly dedication. Having toured much of the Island on vehicle, foot and mountain bike it is apparent that the vast majority of forest stands on the Island are not receiving this type of stand tending and are in need. It may be debated whether one should simply let nature restore itself over time or whether people should actively be engaged in the healing of the land. My personal opinion is that we need a balance of benign neglect and active management depending on the location and the values of the property owners and community. In the case of Galiano Island, it is clear to me that there are many values which we must be managing the forest for, these include: ecological diversity, wood production (from a diverse range of species), wildlife habitat, recreational and scenic amenity, non-timber forest products (NTFPs) and increasingly fire prevention. In order to meet these values, it is apparent that we cannot depend on the personal labour of the largely recreational or retired property owners – neither can we depend on the generosity of granting agencies to cover the relatively vast area of lands in need of tending/restoration.
The remarkably low level of positive management in most of the privately owned Galiano forest lands might be attributed in part to the discouragement of many owners of the former MacMillan Bloedel lands, stuck in a position of limbo regarding residential zoning and proposed subdivisions since 1995. Conceivably, more active forest stewardship by the owners might contribute to the resolution of this peculiar local conumdrum. Meanwhile, much of the forest remains neglected and scruffy, aesthetically and biologically impoverished, and at increasing risk of wildfire.

It is most desirable for the fortunate owners of forest land to be motivated and to invest in the forest for their own objectives of fire protection, recreational aesthetics, conservation, value enhancement, etc. The successful motivational approach will be by helpful education, inspirational examples, and a positive community atmosphere celebrating all aspects of life within the forest. Whether positively committed owners work on their own lands or create jobs within the community by investing to hire contractors, the results will be in the direction of a healthy forest and a more happy community.

The scale of investment required from the owners can be greatly reduced, while the job creation benefits in the community can be greatly multiplied, by creative entrepreneurship to capture revenue streams from NTFP's and pre-commercial timber thinning.

In Oregon, plantations are being thinned in order to promote late successional stand attributes in younger stands and to encourage NTFPs (Kerns et. al 2004); such activities will undoubtedly promote growth of the understory species. Such thinning has also taken place on Galiano as described by Schulz et al (2004), though this thinning was for the former reason. I would suggest that a new approach be developed for the Island that integrates the harvest of NTFPs on its lands that will see a diversity of treatments of whose costs will largely be offset by the harvesting of non-timber forest products (NTFPs) and small diameter wood suitable for short log construction and other uses. Galiano Island is rich with NTFPs, many of which are already being harvested, albeit largely illegally. Perhaps most notable is the salal, whose harvest in coastal BC is likely to be currently worth over $60 million on an annual basis (Darcy Mitchell per. com. 2005).

By managing the plantations on Galiano for biodiversity, the continued production of salal and a host of other NTFPs will be ensured. Depending on the particular species, timing of harvest is limited by its season of availability or alternatively the market. In the autumn, there is the opportunity to prune the conifer species and sell the boughs to the Christmas floral greens market. To offset the costs for pruning in other seasons there are interesting possibilities to explore with the production of essential oils.

A key problem with NTFPs in BC has been property rights (Darcy Mitchell personal communication 2005), typically violated by the harvester. The fact that about 80% of Galiano Island is privately held offers a possible opportunity to manage the NTFPs on a sustainable basis by creating a form of tenure for harvesters on these private lands. In order to offer a tenure, the harvester(s) should either be experienced or trained and ideally both; in addition, the harvester(s) must have a plan that outlines their species of harvest as well as volumes. Depending on the richness of the NTFPs and the level of offsetting forest management labour contributions, this tenure could either be free or paid for by a modest fee. Such arrangements would need to be managed very carefully on behalf of the owners, perhaps by a cooperative that could be an offshoot of the Galiano Island Forest Association.

A further challenge with NTFP management is the general lack of inventory that is specific to these species (Ehlers et. al. 2004). In areas of northern Vancouver Island, the Slocan Valley and the Robson valley, there has been inventory work that used biogeoclimatic mapping, forest cover and ground-verification to develop a predictive algorithm. Extending from the mapping work of the Galiano Conservancy Association, such a predictive mapping system could readily be developed on Galiano that would predict rare plants, ecosystems and NTFPs. An important challenge is to engage the willing participation and active involvement of the private owners in exploring alternative approaches that they might find desirable for managing their own forest lots, and to encourage their enthusiastic commitment going forward with their own plans.

Conclusions

The opportunities for NTFP development in combination with ecosystem restoration are of high potential on Galiano Island. There is a need to develop such proposals in discussion with the various land owners, firstly to exchange ideas, and then to build understanding and possibly consensus. There is also a need to build on existing inventory work in order to be able to assess possible impacts of this industry.

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The soil nutrient state of an ecological restoration area compared to natural regeneration on Galiano Island, BC, Canada

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Abstract
In a restoration area on Galiano Island, BC, Canada, a 25 year old Douglas-fir plantation is being thinned. The effects of thinning on the soil nutrient status was investigated by determining the pH, exchangeable aluminum, organic matter content, the extractable ammonium and nitrate, the available phosphorus, CEC and exchangeable bases (Mg, Ca, Na and K) of both the restoration area, the original plantation a mature forest and a natural regenerated alder forest.
Most interesting results are a strong decrease in nitrate and available phosphorus in the restoration area compared to the plantation. Furthermore all sites are oversaturated with Al^{3+}, organic matter content is the same in all sites, the pH is lower in the alder forest, the CEC is higher in the plantation and the exchangeable bases are higher in the mature forest and the plantation.
The CN ratio of the mature forest shows that it is nitrogen limited, for all the other sites it shows a nitrogen excess.
The data indicate that the restoration area has experienced a loss of nutrient through the uptake by plants. Moreover the soil seems more active in mineralizing organic matter. The study thus reveals that the restoration work in the plantation leads to a more healthy soil system and a more rapid natural regeneration, as was already observed in the increased vegetation growth.

Key words: ecological restoration, Douglas-fir (*Pseudotsuga menziessi* ssp. *Menziessi*) plantation, red alder (*Alnus rubra),* soil nutrients, natural regeneration.

Introduction
The Galiano Conservancy Association on Galiano Island, B.C., Canada (48°56’N, 123°29’W), one of B.C.’s first land trusts, protects several environmentally sensitive properties on Galiano Island. One of their projects is an ecological restoration, which focuses on a 25 year old monoculture Douglas-fir (*Pseudotsuga menziessi* ssp. *Menziessi*) plantation.
The approximately 70 hectare site is located in the mid-island, in district lot 63. In the 1970’s this section of the island was logged. Before replanting the area in 1980, the site was windrowed (all coarse woody debris and the organic topsoil were scraped away and deposited in heaps) and the windrows partially burned. The Conservancy started a restoration project two years ago (2003) and developed methods to thin the forest and move coarse woody debris (CWD) without the use of heavy machinery. (For more on the methods see Scholz et al., 2004) Another unique feature of their approach is that all the woody material that is thinned is not removed from the forest. Thinning is done by pulling trees out, girdling and topping of trees. The pulled out trees remain in the stand and simulate the natural dynamics of trees blown over by wind; this results in a hummocky soil surface and the natural decay of the logs. Coarse woody debris is pulled from the windrows and distributed over the plot. Some of the larger logs from the windrows are erected to provide wildlife with snags. Woodpeckers have been observed to locate right after a snag was erected, and other wildlife has

been reported to become abundant (Scholz and Millard Galiano Conservancy, personal communication).

Over the two years wildlife has increased, and the vegetation cover has changed dramatically. Instead of the dark monoculture Douglas-fir plantation with almost no other species growing, *Gaultheria shallon* (salal), *Mahonia nervosa* (oregon grape), *Polystichum munitum* (swordfern), *Alnus rubra* (red alder), *Acer macrophyllum* (big leaf maple) and more are now invading the understory, or closing their canopy in the case of the trees. The Conservancy also plants native species, such as *Thuja plicata* (western red cedar), *Abies grandis* (grand fir), maple and different berry shrubs.

Since the vegetation cover in the restoration area has changed so dramatically, it was considered important to learn more about the soil properties and how these are affected by the restoration work. It is generally known that clearcutting has a negative effect on soil nutrient status through leaching, and that monoculture stands cannot mimic the soil dynamics of a mature forest stand (e.g. Antos et al. 2003). But little is known about the effects of a restoration project like this one on soil properties. Therefore this study was set up in order to compare soils from the area along a regeneration transect that included a mature forest, a natural regeneration of alder, both the 40 and the 25 year old plantations and the restoration area. In this article the focus will be on the restoration site compared to the 25 year old plantation, since the differences between those two will tell whether the restoration treatment is changing soil properties.

Study area

Located on Galiano Island, on the West coast of Canada, the study site belongs to the coastal Douglas-fir biogeoclimatic zone (Krajina, 1969). Although the Island belongs to the moist maritime climate, it lies in a rainshadow and has dry summers. Parent material is sandstone, sometimes overlaid by glacial deposits. General soil type is brunisol (Canadian soil classification) or arenosol (FAO classification). (Green et al. 1989)

Methods

From each forest site (mature, alder, plantation and the restoration area) 5 samples of the top mineral soil were taken (A horizon), and these were analyzed at the soil lab of the University of British Columbia. A horizons were chosen over LFH horizons, because nutrient state of the LFH is influenced by different litter types and by treatment (all four forests have different LFH properties). A horizons are more stable and thus better comparable.

Table 1: chemical properties per forest type, average and standard deviation of 5 samples.

	Mature		Alder		Plantation		Restoration	
	Average	Stdev	Average	Stdev	Average	Stdev	Average	Stdev
pH [H_2O]	6.29a	0.25	4.99b	0.16	5.90c	0.11	5.86c	0.07
pH [$CaCl_2$]	5.38a	0.45	3.94b	0.09	5.06c	0.24	4.83c	0.05
pH [KCl]	5.33a	0.49	3.95b	0.05	4.99c	0.33	4.72c	0.07
LOI [%]	14.61	6.88	21.63	3.52	20.29	6.55	17.89	4.22
bases [meq/100g]	6.58a	2.49	2.27b	0.42	4.81ac	1.76	3.27c	0.61
CEC [meq/100g]	24.47a	8.14	32.00ab	6.92	39.08b	6.36	33.82ab	4.10
NH_4 [ppm]	8.61	5.00	8.49	1.93	8.38	3.31	8.25	2.40
NO_3 [ppm]	0.40a	0.12	17.19b	4.36	12.97b	4.48	4.56c	1.44
P [ppm]	4.54a	0.88	7.78b	1.99	95.00c	31.64	17.87d	2.65

T test significant differences ($\alpha = 0.05$) indicated with letters; different letters = significant difference, same/no letter = no significant difference.

Analyses performed on air dry 2 mm sieved material are: pH (in H_2O, KCl and $CaCl_2$), exchangeable aluminum by titration, organic matter (loss on ignition), total carbon and nitrogen (Leco CN analyzer, with ground soil), available phosphorus (Bray method), extractable ammonium and nitrate (colorimetrically), cation exchange capacity (colorimetrically) and exchangeable bases (ICP). All analyses followed standard procedures as described in Page et al. (1982), as modified for the UBC Pedology Laboratory by Lavkulich (1978).

Results

In table 1 the chemical properties that are determined are summarized. Significant differences are indicated, if present, with different letters. Figure 1 shows the CN ratio and table 2 gives the median and range of exchangeable aluminum (median and range were used because of high variability between samples of the same site).

The pH (table 1) in water averages 6, and is significantly lower (about 1 pH unit) in the alder stand and in the plantation and restoration area (0.5 pH units) compared to the mature forest. pH in $CaCl_2$ and KCl are close to each other and are 0.5 to 1 pH unit lower than pH in water.

Table 2: exchangeable Aluminum median and range.

		Al [meq/100g]	pK
Mature forest	Median	2,4	-16,82
(N = 5)	Range	69	3,38
Alder forest	Median	102	-13,87
(N = 5)	Range	112,32	0,32
25 yr plantation	Median	85,92	-16,88
(N = 5)	Range	122,88	1,61
Restoration area	Median	92,28	-16,11
(N = 5)	Range	57,12	0,74

pK = pAl-3pH (Matzner et al., 1998)

Exchangeable aluminum (table 2) is significantly lower in the mature forest and very high in the other sites. The pK value (= pAl-3pH, indicator of Al^{3+} saturation of the soil, defined by Matzner et al. (1998)) is low for all sites. This will be explained in the discussion.

There are no differences in organic matter (LOI, average 18.61%) between the four forest sites observed (table 1).

Exchangeable bases (table 1) are significantly higher in the mature forest and the plantation, with lowest values in the alder site (average 2.27 meq/100g). No significant difference is observed between the plantation and the restoration area.

CEC (table 1) is significantly lower in the mature forest compared to the plantation.

Extractable ammonium is average 8.43 ppm and the same in all sites.

Extractable nitrate (table 1) is significantly different between the mature forest, the alder forest and the plantation, and the restoration area. It is highest in the alder forest and the plantation, around 15 ppm and lowest in the mature forest. The restoration has significant lower nitrate than the plantation and the alder sites, but higher than the mature forest.

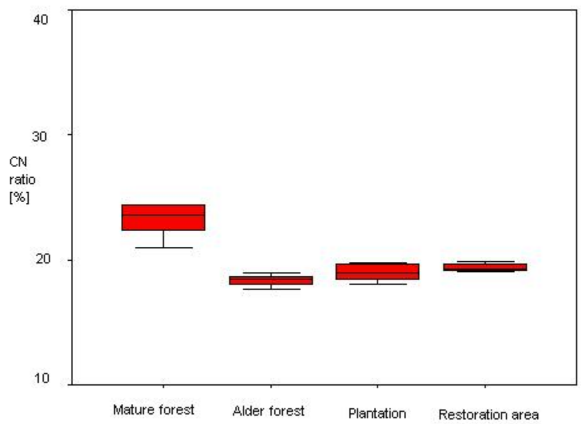

Figure 1: CN ratios of the four sample sites, averages with standard deviation.

The CN ratio (figure 1) is significantly highest in the mature forest (above 20). The other three sites are all the same; around 18.
Available phosphorus (table 1) is significantly different between all sites. It is highest in the plantation, followed by the restoration area, the alder forest and the mature forest has lowest available phosphorus.

Discussion
The pH of all the sites is rather low, which can have impact on the soil processes that take place (McBride, 1994). These will be discussed later. The reason for the low pH lies probably in the poor parent material. In the case of the alder forest the lowest pH is linked with the fixing of nitrogen by alder and the *Frankia* bacteria that are associated with alder (Hart et al., 1997, Rojas et al., 2001). With the nitrification of N tot nitrate the amount of H^+ ions increases.

The Al^{3+} saturation of the soil, defined by Matzner et al. (1998) as pAl^{3+} - 3 pH, is in all samples less than -8.99 which is considered to be over saturated with respect to synthetic gibbsite. This suggests that disturbance has disrupted not only the younger forest types, but also the natural equilibrium of the mature forest.

The organic matter content of all sites are similar since the mineral soil was sampled, and in the mineral soil the amount of organic matter is less variable than in the organic soil horizons. According to Lavkulich (UBC soils department, personal communication) less than 30% organic matter is standard for the A horizons of this soil type.

Exchangeable base quantities (the sum of exchangeable Ca, K, Mg and Na) are mainly controlled by exchangeable calcium that has the highest proportions of all exchangeable bases. Alder forests have generally lower exchangeable Ca due to more rapid absorption of Ca by alders or through leaching of Ca after its replacement of H^+ ions (from H^+ released after nitrification) (Bollen and Lu, 1967) This is why the pH of the alder stands is lower than the other stands.

The CEC is low for all sites because the parent material is mostly sand. Significant differences between the mature forest and the plantation may be due to slight differences in parent material; in some places more clayey glacial material is present. CEC is positive correlated to organic matter, which is found by most researchers (e.g. Heilman, 1981, Franklin et al., 1968)

Nitrogen in soil is controlled by organic matter microbial dynamics. At neutral conditions, bacteria are prevalent, and they favour nitrate for their energy. At lower pH values, fungi take over the decomposition of organic material because they can use ammonium (Killham, 1994). The fact that there are no significant differences between ammonium contents, indicates that in all sites bacteria are decomposing most.

Thomas and Prescott (2000) observed that a 25 year old Douglas-fir plantation mineralizes more N than other coniferous species and as a result has higher ammonium concentrations. Thomas and Prescott's results suggest that a component of Douglas-fir in a coniferous stand may improve N availability in coniferous forest soils. This might be one of the reasons why the plantation with monoculture Douglas-fir has such high nitrate availability, although the high available phosphorus concentration in the plantation may indicate fertilizing with N and P. This is strongly doubted by the Conservancy though, and it is known that for the last 15 years no fertilizers have been added.

A reason why the restoration site has less nitrate than the 25 year old plantation may be that the opening of the closed canopy enhances understory growth and the vegetation takes up more nitrate from the soil than the plantation. Antos et al. (2003) observed a negative correlation between extractable nitrogen and plant biomass, which indicates that N availability is reduced by plant growth. On the other hand canopy openings in a forest can contribute to N mineralization through increased soil temperature and higher soil moisture content that both favor microbial activity (Hope et al., 2003) This is not observed in the study area; the restoration has lower ammonium and nitrate available than the plantation itself.

Nitrate can also have leached from the soil as a result of thinning, when less trees are available to hold the nitrate on to the soil. Most likely the decrease in nitrate in the restoration area compared to the 25 year old plantation is a combination of increased uptake by plants and some leaching. Leaching is less likely because the organic matter content in the restoration area is not lower in the restoration than in the 25 year plantation. Nitrogen dynamics are closely related to organic matter (Heilman, 1981, Franklin et al., 1968), so it can be assumed that the nitrogen that was in the organic matter is now incorporated into the increased biomass and has not leached from the soil. In addition exchangeable base concentrations are not lower in the restoration plot, had leaching taken place this would have been the case.

It is generally assumed that a C/N ratio around 20 represents soil equilibrium; for mineralization of N this is the optimal ratio in a forest soil. If the ratio is above 20, nitrogen becomes limited, such as in the mature forest. For all the other sites the CN ratio is slightly under 20, which indicates an abundance of nitrogen over carbon so that the nitrogen can be used for plant growth. And although the alder forest, the plantation and the restoration area do not differ significantly it can be noted that the restoration area has the highest CN ratio and thus has used more nitrogen lately to increase the biomass of the stand.

Apart from the changed nitrate concentration in the restoration area, available phosphorus has also dramatically decreased compared to the plantation. For all samples the available phosphorus is higher than was expected on basis of the pH. At pH (KCl) values lower than 5 available phosphorus will be bonded to Al^{3+} $\{Al(PO_4)_3\}$ and thus become unavailable to plants . The pH in KCl is generally lower than or around 5, indicating that at least some of the P has become attached to aluminum. This indicates there should be correlation between P and pH and P and exchangeable Al, but this is not observed. The assumed fertilizing can not be the cause for this since even when those samples are left out there is no correlation. Perhaps the bindings to Al^{3+} are the reason.

Giardina et al. (1995) studied the P dynamics in a pure Douglas-fir stand and a mixed red alder/Douglas fir stand (comparable to the restoration area where red alder grows) and found that there is an increased P availability in stands with alder. In mixed alder stands there is an increased cycling of P, root turnover, increased microbial activity and more effective mycorrhizal associations. The high need for P from alder may still limit the P availability in soil though. However, if the alders eventually die and give way to other species, the P from alder litter and wood may be valuable.

Conclusions

The restoration work as performed by the Galiano Conservancy is not only enhancing vegetation regeneration and wildlife habitats; it is also supporting the natural soil system by means of an active nutrient cycling. The observed vegetation increase (both species diversity increase and canopy broadening by older trees) has indeed activated the soil: the uptake by plants of the available nutrients will enhance the soil microbes to recycle the nutrients that fall on the ground as litter. The data found in this study strongly suggest that restoration work done by the Conservancy increases microbial activity, creating a healthy soil system that will eventually turn into a natural mature forest system. The restoration area is different from the plantation in the most essential elements nitrogen and phosphorus. It is not yet the same as the mature forest, this will take decades as the forest matures and the nutrient balance settles in. It is hard to compare the natural regenerated alder forest and the restoration area, since the alder trees influence the soil largely by fixing nitrogen. It shows though that it is an advantage there is alder trees in the restoration area, where they can help other species with their supply of nitrogen.

Still it should be noted that this was a preliminary study and that repetitive sampling is needed to fully support the hypothesis that the restoration work helps the soil. More sampling at different sites of the restoration area and monitoring of easy to measure soil parameters should be continued in the future. The restoration work is still taking place and since it only started two years ago more soil research is definitely needed.

Implications for practice

- Soil research is necessary for restoration practices: a healthy soil is the basis for any successful restoration
- Soil health can be improved by thinning: more light increases plant growth, plant growth increases litter decomposition
- A more diverse forest creates a more dynamic soil: different litter types attract different soil animals
- A decrease in soil nutrients is not bad as long as there is an equilibrium between input of litter and uptake by plants
- Thinning by hand (without electrical machinery and heavy soil compacting trucks) gives the opportunity of observing wildlife during the work

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Some aspects of vegetation management: Bioherbicides and other methods for control of four exotic plants on federal lands in British Columbia, Canada

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Abstract
Scotch broom (*Cytisus scoparius),*Gorse *(Ulex europaeus)* Daphne *(Daphne laureola)* and English ivy *(Hedera helix)*, are four prominent, invasive plants that pose a serious threat to Garry oak and associated ecosystems on federal lands in Victoria, British Columbia. These plants colonize disturbed areas quickly, form dense monospecific stands, remain persistent for long time and defy any easy eradication program. They suppress and inhibit the growth of native plants, and ultimately arrest forest succession. Several federal departments including the Dept. of Environment, Dept. of National Defence, Dept. of Fisheries and Oceans, Dept. of Indian Affairs, and Parks Canada have expressed great concerns regarding their rapid incursion, adverse impacts and degradation of native habitats. With a grant from the Dept. of Environment and the Dept. of National Defence, we have, therefore, conducted research to examine the population dynamics, phenology and control methods of these invasive plants on federal lands near Victoria, BC. Of the several methods of control tested, including manual cutting, application of a registered herbicide (Release- triclopyr*)*, fungal bioherbicides (*Chondrostereum purpureum*, *Fusarium tumidum,*) and a commercial plastic mulch, it was found that some treatments (mulch and herbicide) provided 100% efficacy on resprouting behaviour of the all four invasive species. While one bioherbicide (*Fusarium tumidum*) was very effective on Scotch broom under the greenhouse conditions, the other one (*Chondrostereum purpureum*) produced a variable response under the field conditions. Manual cutting was found to be the least effective. Also a novel prospective bioagent was isolated from dying and dead samples of Daphne from the field and results suggest that it may hold great potential for control. Continued and additional research is necessary to determine the appropriate formulations of these bioagents as well as the effectiveness of the different and integrated control treatments over a period of years.

Carbon, Climate Change and Restoration in the Rainshadow

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Abstract
Global climate change and the response to it presents restoration projects with a number of inter-related issues. The obvious challenge lies in predicting what successional patterns and species complexes will be part of a specific ecosystem under conditions of global climate change. However, as we know, restorationists often undertake projects which include consideration not only of natural processes, but also of human goals. In this context, restorationists will also have to deal with a wide range of issues which will impact on goal setting for restoration projects, including:

- How is management of carbon pools integrated into the restoration.
- How does climate change impact on amenity migration and development patterns, and human risk mitigation,and therefore on issues such as interface fire management, which may be a key issue in restoration design

These issues are true in almost every ecosystem, but take on particular significance in the CDF zone, for two key reasons:

- The CDF zone is highly settled and highly impacted by settlement
- The differences in carbon pools and fire dynamics between the CDF ecosystem and the Garry Oak Savanah ecosystem are major.

This paper examines the interactions between these factors, in the context of CDF restoration.

Introduction
That we live in a carbon constrained world has recently become a common recognition. While the physical effects of that constraint are now well recognized, how we will respond to that constraint is not clear, as the success of the Kyoto accord remains in some doubt, and as it appears more possible that countries like Canada may not meet their Kyoto goals. However, there are several key similarities between all of the systems for reducing carbon emissions proposed to date:

- Assignment of carbon emission targets to major emitters, and use of penalties for emitters failing to meet those targets
- Substitution of government action for regulation of small emitters
- The use of market mechanisms to allow major emitters and governments to minimize the cost of meeting carbon emission targets
- A reluctance to use carbon taxes or other direct mechanisms which would impact all emitters.

The reasons for the similarity of approach in all of the major carbon regulation schemes lie in the complex intersection of economics and politics. However, the basic impacts of this approach, the creation of a market for one or more type of atmospheric CO2 "carbon credit", is clear.

Biological Carbon in a Carbon Constrained World
At this point the place in the market of carbon sequestered in the biosphere is less clear. There has been considerable early pressure to limit the use of carbon sequestration in the biosphere as a tool for managing anthropogenic carbon emissions. However, over the long term, given the enormous potential inputs and outputs of atmospheric carbon from the biosphere, we may expect that biologic al carbon will be a part of any regulation system. For this reason we may expect that

the carbon content of a biosphere will in the future become one of the “values” which we assign to an ecosystem, and will be a factor in all decision making regarding ecosystem management.

Typically, within a decision making process, our tendency is to attempt to maximize the quantity of things to which we assign positive value. This basic tendency lies at the heart of economic theory, and is of course subject to an arcane variety of mechanisms, exceptions, limitations, etc. Where biological carbon is concerned, however, one factor in particular concerns us: the link, in most ecosystems, and certainly in the CDF, between carbon content and ecosystem risk. For while it is not true that there is a simple linear relationship between ecosystem carbon content, fuel density, and fire risk, to name only one risk mechanism, there is a relationship between these variables.

Thus the role of ecosystem carbon content in ecosystem management decision making is not simple, for there is a trade-off between the amount of carbon stored and the risk of that carbon being lost in a fire, pest and disease attack or other disturbance event.

Carbon in Natural Systems

As restorationists, our decision making processes regarding our management of ecosystems are typically based on criteria defined in terms of the degree to which we can bring a restored ecosystem close in processes and dynamics to some “undisturbed” or preferred reference ecosystem.

Introducing a carbon value into our restoration decision making creates both interesting questions and problems.

A critical question which forms the background to carbon management in restoration is the question of how ecological systems without human management deal with the balance between carbon content and disturbance risk. It is tempting to think that over very long time horizons the natural balance between carbon content and carbon risk will lead to maximization of the carbon content of the ecosystem. Carbon content, after all, is critical to all ecosystems, as a building block of biological material when contained in living organisms, and serving a myriad of host and regulatory functions when contained in dead organic matter in an ecosystem.

However, it is clear that this theory is may be too simple. It may not properly acknowledge the role of disturbance adapted organisms. For instance, in a northern interior lodgepole pine stand, the fire adaptedness of pine tends to limit the success of spruces in establishing in the stand, although over the long term it seems likely that fire resistant, long lived spruce stands would have higher average carbon values.

Carbon Effects of Restoration

The theories discussed above may, however, at least point us toward some interesting thinking about carbon, ecosystems and restoration. As we have heard, a major element of restoration of disturbed Douglas Fir dominated ecosystems on Galiano has consisted of thinning of the young Douglas Fir, to increase the light available in the understory, as well as the rate at which the remaining trees grow. Both of these changes should over time move the ecosystem more rapidly toward what we now call “old growthedness” as well as increasing the biodiversity of the stands in the meantime.

Clearly the immediate result of this treatment is to reduce the carbon content of the ecosystem through the gradual rotting of the thinned trees. Over the longer term, it is assumed that the carbon content of the thinned and unthinned stands will approach equality, since natural thinning would presumably have had the same effect over time.

From the risk point of view, however, once the fine fuels resulting from the thinning have begun to degrade, it is assumed that in most cases the thinned stand will have a lower fire risk than the unthinned stand. Whether or not this is true will depend on the intensity of thinning and other variables, but certainly at higher thinning rates the reduction of crown density may reduce the likelihood of crown to crown fire transmission, and may result in healthier trees which are more resistant to pest and disease..

All of this appears fairly academic as long as the carbon content of the ecosystem is only of theoretical or scientific interest. However, if, as is expected, future agreements on global atmospheric carbon include biological carbon pools, the impacts of restoration on ecosystem carbon content will almost certainly have economic consequences. If biological carbon had a price today in Canada, for instance, restorations such as that undertaken on Galiano might carry an additional cost burden for the released carbon.

Carbon Content versus Carbon Risk

The assumed costs associated with reductions in carbon content in a given ecosystem are based on an assumption of a simple dollar figure per tonne of CO2 equivalent. Current trading systems under Kyoto have been designed to reinforce this simple pricing model, and to enhance the equality of a tonne of carbon, where-ever it may be. However, while this simple approach works well for industrial emissions and fossil fuel use, it tends to break down when dealing with carbon in the biosphere, since it ignores the risk factor. Thus, for instance, in the Galiano example, it might be true that there was less carbon in the ecosystem, but the remaining carbon was at less risk of catastrophic loss. No carbon trading or valuation system has yet systematically analyzed this issue. The mechanisms currently in use within the Kyoto Clean Development Mechanism acknowledge that forest carbon is likely to have a degree of impermanence, but do not actually quantify risk. Even the insurance industry has yet to come to terms with risks associated with forest biomass, although this kind of risk analysis is their core business. During recent discussions with major insurance and reinsurance companies regarding the issuance of insurance policies for biological carbon projects in developing countries, where such projects are permitted under Kyoto, the quoted premiums were so high as to essentially indicate that the insurers were unable to properly analyze the risk.

Impact of Global Warming

Without a proper assessment of risk, the value of carbon will tend to remain as a factor potentially distorting our management and/or restoration of ecosystems. The effects of this distortion will be increased by the feedback effects of global warming itself.

The actual effects of global warming on any particular ecosystem are difficult to predict. The global effects of a warmer climate will almost certainly include shifts in precipitation patterns, with some areas growing drier, and others wetter. They may also include more frequent climatic extremes, larger storm events, and so on. However, if recent years are any indication, there is a good chance that the effect of global warming on the CDF will be to increase the length of the summer moisture deficit period.

Currently, as a result of the extended moisture deficit of the last few years (although not this year), we are seeing extensive mortality in species such as western red cedar, for which the CDF climate has always been on the margin of their drought tolerance. Increased drought periods will increase the risk of catastrophic fire events, and may tend to drive the ecosystem toward a more fire dependent model, in which frequent fire maintains forests in a more savannah like condition, with little opportunity for crown fire spread between widely separated trees.

If this is indeed the likely direction in which the ecosystem is moving, we must then question what the correct reference ecosystem for our restoration efforts is. Should we consider restoring forests such as those on Galiano to a condition more nearly approximating a Garry Oak/Douglas Fir savannah? If this is the direction that the ecosystem will move in, the resulting ecosystem will have a much lower carbon content than the current closed Douglas Fir forests, closing the feedback loop.

Such adaptation will therefore carry a significant cost, in terms of ecosystem carbon balance. However, global warming and other environmental problems are also driving another change which may significantly impact our management of CDF ecosystems.

Amenity Migration

At a recent conference it was noted that: "An irony of increased environmental awareness in a free-market society is the commoditization of the environment, so that demand for a piece of the action is chopping it up into one to five-acre fenced lots."[1] This trend is often called amenity migration. Essentially, increased awareness of ecological problems like global warming increases the demand for environments which are seen as "natural". This process should be familiar to anyone living in the the CDF zone. Close to major centers and with a mild climate, the CDF zone has been subject to settlement pressures for at least a century. However, recent trends show rapidly increasing levels of forest "interface" housing on small acreages throughout the region. This results not only in increasing density of housing and other infrastructure within the ecosystem, but also in rapid increases in the value of that infrastructure as housing prices soar in the face of limited supply and increasing demand.

This increase in the density and value of forest interface homes and other infrastructure increases the pressure to reduce the risk of fire in the ecosystem. Reducing fire risk to interface infrastructure is the driving force behind large scale forest thinning efforts in the US and Canada. A single fire within the CDF zone could easily impact large numbers of homes, leading to similar forest thinning efforts here

Whence Restoration

Based on this discussion, the drivers which may need consideration in determining goals for future restoration projects are:

- Increased recognition of ecological costs, and imposition of associated financial costs, associated with release of biological carbon.
- Possible recognition of carbon release risk in accounting of biological carbon at some point in the future
- Increased fire risk to increasingly valuable homes and infrastructure
- Increased population pressure, and increased demand for "natural" landscapes
- Possible shift toward a fire maintained ecosystem in portions of the CDF

If these drivers all become significant in determining restoration goals, it appears likely that the risk drivers will substantially trump the demand for maintenance of biological carbon. In this case thinning and fuel reduction will be biased toward greater reductions in stand density and fuel removal. Higher light levels in the understory combined with dry conditions will favor the

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[1] Moss, Laurence A. G. 2003. Amenity Migration: Global Phenomenon and Strategic Paradigm For Sustaining Mountain Environmental Quality. Proceedings of the Conference: Sustainable Mountain Communities, Banff, June 14-18, 2003. Mountain Culture at The Banff Centre

increase in grasses and associated species as a component of the ecosystem. Species typically associated with Garry Oak savannahs may be suitable for a wider range of sites.

It is not clear at this point how or if market based systems will be used to manage both biological carbon pools and risks within those pools. Although there has been a distinct trend toward using market based mechanisms to drive management of ecological values, other mechanisms, such as regulatory mechanisms based on permitting or other approaches may be used.

Techniques and Mechanisms

What mechanisms do we have for taking into consideration these issues?

- Fire risk modeling.

  Fire risk assessments have been undertaken for portions of the CDF zone. However, no modeling or planning has addressed possible restoration efforts which might reduce this risk where overdense second growth stands are present. Since fire risk reduction is a potential major source of funding for restoration, and since fire dynamics should be a key element in planning restorations, development of models and plans should be a priority.
- Bioenergy utilization

  Throughout much of the CDF zone firewood is extensively used for heating. Typically the alternative to wood heating is electric heating, and given the very substantial contribution of hydroelectricity to our energy grid, the amount of reduction in fossil fuel use associated with wood heating is not as great in BC as in other jurisdictions. However, utilization of a portion of the trees felled during restoration thinnings for firewood or other bioenergy applications does currently have some offset value, in terms of reduction of fossil fuel use, and this offset value is likely to increase in the future. However, bioenergy utilization will have to balanced against maintaining enough dead wood in the ecosystem to meet the habitat and other requirements for this ecosystem component
- Carbon modeling

  As carbon value begins to be considered, modeling of stand development and carbon content will assist in determining the long term effects of restoration efforts on ecosystem carbon content. Since stand thinning will initially reduce the carbon in the ecosystem, it is important to understand whether these impacts continue over the long term, or are in fact only temporary.

Conclusion

Whatever the mechanisms used to account for and manage ecosystem carbon content, fire risk, and other issues, the key effect of the atmospheric carbon issue is to tie together every local action with a global consequence, and to cause that global consequence to be a key driver of every local action. Whether or not biological carbon pools at a local level are directly valued or regulated, it is no longer feasible to undertake ecosystem management and restoration without consideration of both the impact on the global atmospheric carbon balance, and the feedback from global atmospheric carbon content on the development of local ecosystems.