How have First Nations' past sites of habitation influenced present-day ecology on the Central Coast of British Columbia?

by

Julia Fisher
B.Sc. (Biology, Environmental Studies), University Of Victoria, 2012

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Supervisory Committee

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Humans have transformed much of the earth's surface through a wide range of activities of varying intensities and scales, shaping the landscape we see today. The combination of time and complex human-environment interactions within the Hakai Lúxvbálís Conservancy on the Central Coast of British Columbia has resulted in a landscape with many anthropogenically-generated modifications, such as shell middens which can be found at sites with histories of long-term habitation. Globally, shell middens (and in general, habitation sites) have been found to be factors in shaping site ecology. This thesis seeks to investigate this relationship between human activity and occupation and the landscape.

The goal of this project is to examine the legacies from past land use, and subsidies from shell middens, within the present-day plant communities. I conducted an observational study to determine if species richness and overall plant communities on these habitation sites differed from sites without a history of intense occupation. To do this I selected ten habitation sites with known extensive shell middens and paired them with ten control sites with similar site conditions (but without the same site history or shell middens). I measured species abundances within 540 1 m x 1 m quadrats. I also surveyed a select group of culturally significant plant species and culturally modified trees within belt transects at each site. Data regarding the water table level and soil and foliar samples were also collected. A variety of environmental factors, along with the site history were evaluated as explanatory variables. Principal component analyses were used to describe how the gradients within the vegetation communities at three vegetation layers (ground, herb, shrub) to see if they respond differently to long-term site use. The habitation sites were found to be characterized by N-rich plant communities, which were significantly different from the plant communities on the control sites at the ground layer, herb layer, and with all layers combined, at both transect distances analysed, but the shrub layer was only significantly different when the entire transect was considered. The results show plant community composition is most strongly influenced by a combination of factors including site type, canopy cover, slope, topography, and distance from shore, with the weight of their importance depending on what vegetation layer is considered. The habitation sites had a lower average species richness at all layers, compared to the control sites, and their plant communities were shown to change differently with distance from the marine shoreline. Habitation sites also differed by having higher soil nutrient content, lower water table levels, and contained culturally important plant species that were absent on the control sites.

This research highlights the influence that humans have had on landscapes in this region. This study shows how the patterns within the plant communities at the habitation sites differ from what is expected within the Coastal Western Hemlock zone. The research improves our understanding of the factors influencing vegetation patterns on the Central Coast of British Columbia with this examination of the complex intersection of historical practices and environmental changes.

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Acknowledgments

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Dedication

To all the beings, past and present, who call the Central Coast their home. I'm inspired and humbled by my experience and I warmly bask in the memories of my time in this region.

Chapter 1: Introduction and Thesis Goals

"…in nature nothing exists alone."
-Rachel Carson, *Silent Spring*

1.1 Humans and Land Use

It is widely recognized that humans have played a large role in transforming the earth's surface and that few, if any, ecosystems are free from human influence. Ellis & Ramenkutty (2008) estimate that up to three-quarters of land surfaces that are not covered in ice have been influenced by humans, whether through intentional or unintentional disturbances. Current landscapes not only reflect contemporary influences, but also embody, to different degrees, the effects of past human activities. The result is a landscape with characteristics determined by long and complex interactions of human activities and the natural environment. The damaging effects of activities such as habitat destruction, fragmentation, and over-harvesting are recognizable and widespread, and human-dominated landscapes prevail globally (Ellis & Ramenkutty, 2008). Fortunately, this is not the only way that humans interact with their landscapes, and many cultures in the past and present have lived in their homelands for long periods in sustainable ways. In this thesis, living in a sustainable manner can be defined as meeting "the needs of current generations without compromising the ability of future generations to meet their own needs" as described in the Brundtland Report (United Nations, 1987). For an example of such a culture, we need not look further than the Central Coast of British Columbia (BC), where evidence of sustained long-term occupancy can be found (Deur & Turner, 2005; Groesbeck, Rowell, Lepofsky, & Salomon, 2014; Turner, Ignace, & Ignace, 2000).

1.2 Long-Term Occupation on the Central Coast of British Columbia

The Central Coast of British Columbia is located on the west coast of Canada, bordered by the Pacific Ocean. This regional district has a land area of approximately 24,600 km^2 with its coastal range spanning between Pine and McInnes islands. This region falls within the Coastal Western

Hemlock (CWH) zone as described by the Biogeoclimatic Ecosystem Classification (BEC) system. This zone which is known for high levels of precipitation, a mild maritime climate and, as the name suggests, western hemlock (*Tsuga heterophylla* (Raf.) Sarg) as one of the most commonly occurring tree species (Pojar, Klinka, & Demarchi, 1991). It is also part of the planet's largest coastal temperate rainforest (DellaSala et al., 2011). This region is characterized by a rich diversity of species and a complex landscape with many intact valleys, inlets, and islands.

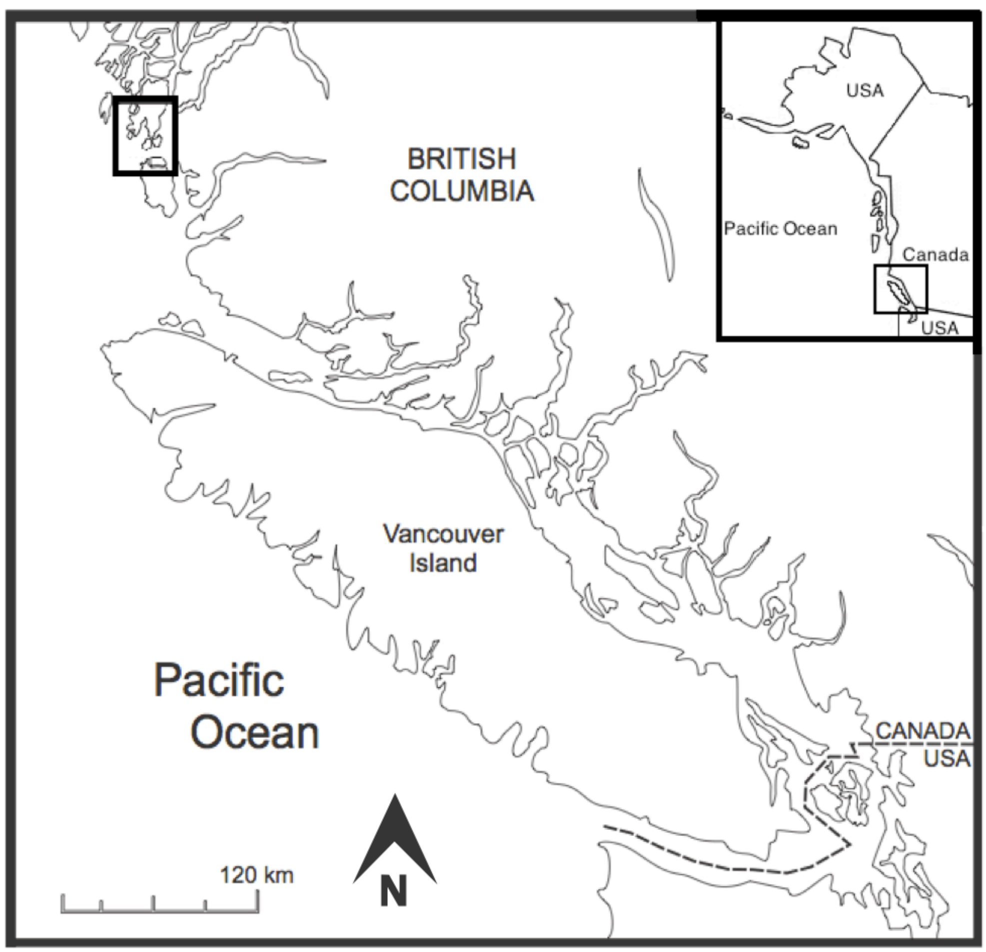

Figure 1. The area of study located on the Central Coast of British Columbia, Canada, north of Vancouver Island.

The Central Coast of BC is comprised of the traditional territories of four First Nations groups: the Kitasoo/Xai'Xais, Heiltsuk, Nuxalk, and Wuikinuxv. As evidenced by archaeological excavations, human presence has been repeated in this region for at least the past 10,000 years (see Cannon, 2000; Carlson, 1979). This timespan of occupation, using a conservative estimate, translates into approximately 400 human generations. Recently, ancient footprints have been discovered that have been carbon dated to 13,200 years ago, adding to the evidence of long-term occupation; these are the oldest known footprints on the continent of North America (Pringle, 2015).

Over this time, this landscape has been affected by a large diversity of technologies and cultural modifications, which can be observed along the coast at ancient habitation sites (areas where there is evidence of long-term site use and occupation – hereafter referred to simply as habitation sites), and in the form of lasting archaeological features such as stone fish traps, rock art, grave sites, culturally modified trees, intertidal lithics and other historical structures and artefacts (McLaren & Christensen, 2013; Pomeroy, 1980). Other evidence of occupation is present, such as persisting berry patches, root gardens, and orchards, as well as extensive shell middens found on habitation sites (Deur & Turner, 2005; Hobler, 1982 – as described in Cannon, 2000; Pomeroy, 1980). This depth and breadth of human and landscape interactions has drawn a long line of ethnographers and, more recently, archaeologists to study this region. Despite this research, the Central Coast is commonly perceived as a region that is "untouched" and "pristine" (see Deneven, 1992); however, it is in fact a modified landscape, shaped through generations of human use and occupation.

These sites are referred to here in an archaeological context, as many are no longer occupied or used in the way they were historically. Contact with European explorers in the 1700s and the ensuing colonization brought change to population numbers, activities and overall distribution for these First Nations groups (e.g. Duff, 1997; Harkin 1997). Estimates can only be made of what First Nations' population sizes were pre-contact throughout BC, but would have been likely much higher than 70,000 (Duff, 1997). The decimation of populations throughout BC can be attributed to epidemics (e.g. smallpox, tuberculosis, measles), and to the introduction of alcohol, and warfare, among other factors. This brought BC to reach a censused low of 22,605 First Nation individuals by 1929 (Duff, 1997). Currently, the Nations of the Central Coast have permanent communities where the majority of the populations live: the Heiltsuk in Bella Bella, Wuikinuxv in Wuikinuxv village, Nuxalk in Bella Coola and Kitasoo/Xai'Xais in Klemtu. The habitation sites have different timelines, with some used up until the late pre-contact (late 1700s), and others used into the early contact periods (1800s) (Cannon, 2003; Duff, 1997).

1.3 Habitation Sites

The timespan of human occupation on the Central Coast brings up many questions about past human-landscape interactions, while also raising questions about the current landscape. How have humans interacted with the landscape over time? What are these habitation sites like today, years after the shifts created by colonization? How different are these sites from areas without this history of human habitation? Within the context of the growing global desire to understand how humans affect long-term ecological change, these sites provide an opportunity for a glimpse into a particular way of interacting with a landscape and a chance to observe the ensuing legacy.

In this thesis, the focus of these questions will be directed towards the habitation sites, in particular those endowed with extensive shell middens. These sites may have been used year round, as temporary camps for resource gathering, or perhaps used differently over time depending on environmental conditions (Cannon, 2003). The shell middens present are landforms with cultural origins and are not only found on the Central Coast of British Columbia, but also associated with many coastal cultures globally, in places such as Scandinavia, the United Kingdom, South America, and other parts of the west coast of North America (e.g. California and Alaska) (Ceci, 1984). They are often described as accumulations of cultural refuse that have built up over time and generations of use (e.g. Cook-Patton, Weller, Rick, & Parker, 2014); however, it is also acknowledged that shell midden material could also have been placed intentionally (Blukas-Onat, 1985; Ceci, 1984). The composition of these accumulations can be seen as a reflection of activities at these sites. They may take the form of stratified berms and they contain materials such as clam and mixed shells, bones of land and sea mammals, fire-cracked rocks, and fish bones, stone tools, human remains and other organic artefacts (Pomeroy, 1980; F. Rahemtulla, personal communication, April 2014; Sawbridge & Bell, 1972).

The characteristics of shell middens have made them the focus of many studies, after they were first recognized in Denmark as human-made structures in 1849 (Bibby, 1956). Due to the components of shell middens, preservation of other deposits besides shell material is favourable; this can be attributed to the alkalinity of the shell deposits, which can protect artefacts from being destroyed by the acids in soils. In addition, the makeup of the shell middens can physically shield artefacts from being crushed and provide surface protection by deterring erosion (Andrus, 2011). Research on shell middens has added depth to our understanding of past activities and ecosystems, providing insights into human dietary choice and technology, species distributions and presence, and has also opened up new doorways to future research—such as the reconstruction of past food webs and advances in the field of sclerochronology (the study of accretionary tissue growth and its temporal context, Andrus, 2011; Burchell, Hallmann, Martindale, Cannon, & Schöne, 2013; Misarti, Finney, Maschner, & Wooller, 2009).

Even relatively short-term land use has the ability to transform ecological systems (Briggs, 2009), making these habitation sites with histories of long-term occupation likely candidates for ecological change. Globally, studies have found that shell middens have the potential to alter their local environment in terms of soil qualities and vegetation communities (e.g. Cook-Patton et al., 2014; Sawbridge & Bell, 1972; Vanderplank, Mata, & Ezcurra, 2014). This knowledge is the foundation for the hypothesis that these habitation sites will in fact be different in from other sites without histories of past habitation in terms of plant community composition.

1.4 Thesis Objectives

The objective of this thesis is to examine if the legacy of ancient land use and habitation by Coastal First Nations can be observed in the present day record of biodiversity on the Central Coast of BC. This will be accomplished by first examining the over-arching factors that contribute to the formation of these habitation sites in a cumulative fashion. The local environmental effects, general successional trends, and clearing, burning, and other manual changes will be considered in regards to their effect on the structure, function, and composition of these sites. Secondly, this thesis will share the findings from an observational study of the vegetation on 10 First Nations' archaeological sites (habitation sites) with known, extensive shell middens and on 10 control sites that do not have shell midden materials but are otherwise similar. This research was performed during the spring and summer (May-August) of 2014. The aim of this section is to examine if human occupation and land use (and marine-derived subsidies from shell middens) influence plant community composition by comparing the two site types.

This inquiry complements the surge of research that is emerging from the Central Coast and is a logical outgrowth of some of the other projects underway (e.g. research by A. Trant, F. Rahemtulla, and D. McLaren). Although vegetation surveys on habitation sites have occurred globally, this type of investigation, as noted by Sawbridge and Bell (1972), has occurred in a limited way on shell midden sites of the Pacific Coast. Indeed, the selected sites have not undergone intensive scrutiny of the vegetation beyond basic preliminary surveys. For this reason this project has been encouraged by the archaeological community working in this region. As archaeologists shift toward a focus on the regional context of sites (Cannon, 2000), the information generated from the large number of sites researched in this thesis should help to form broad understandings of the type of vegetation that can be expected (for example, see the vegetation guide for archaeologists in Appendix C). Overall, this research will serve as a bridge between the overlapping realms of ecology and archaeology, which as Briggs et al. (2006) assert, is “essential for understanding human-ecosystem interactions.”

This thesis will explore the following questions:

1) Are there differences between the vegetation on First Nations’ habitation sites with known extensive shell middens and the vegetation on areas without the presence of shell middens and occupation?

2) How does vegetation change with increasing distance from marine shoreline at both site types?

3) Which plants are uniquely associated with habitation sites? Why are species found at these sites?

4) What site-level processes shape the overall vegetation ecology of these sites?

The habitation sites were evaluated within, and beyond the expected shell midden boundaries to gain insights into the overall site use legacies, as well as those that can be specifically associated with shell midden subsidies. The results generated by these questions from surveying the 20 sites in this study will provide a broader understanding of the overall ecology on habitation sites found throughout this region.

Chapter 2: Making Habitat: Landscape Changes on the Central Coast of British Columbia

2.1 Introduction

The landscapes we see today are a complex combination of climate, geomorphological processes, ecological dynamics, and, as increasingly recognized, short- and long-term human activities. Humans have been successful in finding ways of making suitable places to live in almost every environment around the globe. The approximately seven billion people that currently inhabit this planet are responsible for being primary modifiers, altering approximately three-quarters of non ice-covered land (Ellis & Ramenkutty, 2008) to meet human needs or as a by-product of this effort. As humans radiated across the continents beginning around 70,000 years ago, they began to alter landscapes. In the past century, technological advancements and population increases have intensified the spread of human activities, leaving a mosaic of landscapes with different imprints based on the extent and type of human influence. The pervasiveness of human-induced change on landscapes from past and present activities can bring one to ask not whether the land has been modified, but, as reframed by Denevan (1992), how and to what extent.

This chapter will focus on the landscape influences of the First Nations of the Pacific Northwest of North America, specifically those on the Central Coast of British Columbia. In this region, evidence for continuous human occupation for over 10,000 years can be found at habitation sites (Cannon, 2000). This long-term presence at these sites has been enabled by a relatively stable sea level throughout the Holocene (McLaren et al., 2014). An understanding of past human activities has developed through archaeological investigations that have intensified since the 1980s (e.g. with the work of Pomeroy, 1980) and is complemented by ethnographic documentation (e.g. Boas, 2003) and shared knowledge from the members of the First Nations communities within this region.

The habitation sites that are discussed in this thesis are within the Coastal Western Hemlock (CWH) zone in the very wet hypermaritime subzone. This region is known for its acidic, nutrient-poor soils, and high annual precipitation. It is located in part of one of the largest tracts of intact temperate rainforests in the world (DellaSala et al., 2011). These habitation sites are characterized by extensive shell middens which are the result of past human occupancy and resource use (McLaren & Christensen, 2013), a higher count of culturally modified trees (CMTs), and unique plant communities and soil attributes (see Chapter 3). The landscape legacy measured through this research suggests that these sites are influenced by their historical interactions with humans, which have set them apart from the surrounding, broader landscape. The long-term land-use that researchers have identified suggests that sustainability was inherent in the activities that occurred on these sites, implying an understanding of ecological systems. As described in Mellin and Truitt (2013), cultures and landscapes are often reflections of each other.

Given the complex history and ecological uniqueness of these sites, one might ask how they have developed. The purpose of this chapter is to examine the intersection of cultural practices and environmental processes that contribute to the formation and maintenance of these persistent habitation sites on the Central Coast of BC. In doing so, I will discuss how the site structure (what the sites look like), site function (the processes on the sites), and site composition (what the sites are made up of) are influenced. The three primary factors I will investigate are: 1) ecological succession; 2) burning, clearing, and other manual changes; and 3) local environmental effects. I assert that the contributing factors shaping these sites work in a cumulative fashion and have led to the domestication of these sites.

2.2 Succession

Successional patterns and trajectories can be important factors in shaping the ecology of past habitation sites. As defined by Banner, LePage, Moran, and de Groot (2005), succession is the “change in species composition and cover of plant communities over time, ultimately leading to a climax or relatively stable type.” These changes can unfold over a wide range of scales, occurring over several years (several generations of a plant species), or over thousands of years. By examining tree rings (dendrochronology) and pollen and charcoal deposits, it is possible to learn about the timelines of the patterns of succession and develop hypotheses about successional trajectories (Banner et al., 2005). This, however, is a challenging endeavour because of the complexity of the interactions that occur during succession on broad temporal and spatial scales

(He & Mladenoff, 1999). For example the interactions with other large-scale variables, such as changing weather patterns due to climate change, or the introduction of a new species to the system. Stability may occur with the establishment of longer-living species that are characteristic of later successional stages, and a community remaining without change for generations (Connell & Slatyer, 1977). It is difficult to determine the presence of a stable or climax community, as this evaluation is dependent on time and space criteria for the landscape in question. In the CWH zone, the hypothesis for succession is that the system will generally progress from a pioneer forest, to a productive forest type, then to one that is lower in productivity and finally to a bog woodland (and in some cases, to an open bog stage, or back to a forest again) (Banner et al., 2005).

Succession can be restarted by disturbances, which is “any temporally discrete event that alters ecosystem, community, or population structure and changes resource or substrate availability or the physical environment” (White & Pickett, 1985). Connell and Slatyer (1977) argue that it may always be cut short, with succession never reaching a completely stable end point. Disturbances can alter environments so as to become more conducive to the growth of some species that may not have been able to succeed otherwise. The extent of the changes that a disturbance can make depends on where it occurs (geographically), the extent, the cause, magnitude, timing, and shape (Daniels & Gray, 2006). Some examples of disturbance are fires, storms, landslides, pathogens, insects, floods, avalanches, individual windthrow, and stand-level blowdown (Dorner & Wong, 2003; Banner et al., 2005).

For the CWH zone, Daniels and Gray (2006) assert that the main disturbance regime is a result of the region’s fine-scale gap dynamics. This is characterized by changes in the upper canopy species that free up limiting resources for understory species; this in turn allows the growth of species that were previously restricted, and provides an example of a mechanism of succession. Disturbances can be seen as part of the process, rather than disrupting it, and enabling the long-term patterns within vegetation communities (Heinselman & Wright, 1973).

Disturbances can also originate from human intervention or human mediated-activities, the extent of which can be impressive due to the number of people on Earth, and the range of environments that are inhabited. Examples of human-associated disturbances are innumerable, and contemporary examples of larger scale disturbance are often linked to practices of agriculture and deforestation, which has in turn led to widespread erosion (Proffitt & Kaiser, 2004). Globally, humans have had a dominant role in shaping their surroundings with disturbances that can meet or exceed those that are natural in origin in terms of impacting site ecology and influencing the successional trajectory of a landscape.

On the Central Coast of BC, it is also easy to find examples of human-caused disturbances (many of which are detailed in the following section). One of the primary examples that will be explored in detail is burning as part of a management strategy, which has the potential to influence site ecology and successional trajectory (Turner & Peacock, 2005). These anthropogenic disturbances could be classified as being lower-intensity and occurring at a large scale (this landscape level is distinguished from the restricted fires that are used for food preparation, warmth, etc. (Turner, 1999)). The result would be recovery recruitment based on the species that survived within the soils and surviving adult plants (Slatyer & Connell, 1977; Turner & Peacock, 2005). This differs from what could occur following a burn that was not managed (due to being a different intensity and perhaps at a different season), which could potentially destroy the plant remnants within the soils, changing the patterns of regrowth. Like the non human-mediated disturbances, it could also be argued that human disturbances have become part of the successional characteristics within this region.

This influence can be seen in my study of habitation sites (in Chapter 3), where it was determined that these sites are different from the control sites in plant species composition and abundances, among other qualities. Species assemblages on the habitation sites are characterized by species that, in general, prefer nutrient-rich environments. With increasing distance from the marine shoreline, it was found that the characteristic species assemblages generally stay the same on these sites. This differs significantly from the control sites, where, with increasing distance from shore, the plant communities were found to shift towards a plant community that was composed of characteristic bog-type species, such as *Sphagnum* spp. and Labrador tea. These different changes with distance from shore suggest that these sites may be responding to successional pressures differently. The cultural disturbances that are part of the site histories may be enabling the site species assemblages to resist the normal successional trajectories.

This idea of enabling a certain vegetative stage and soil condition, or "arrest[ing] succession", would have been done to maintain desired qualities such as productivity. As described by Banner et al. (2005), maximum productivity for the CWH zone is found with a medium disturbance level (not too rare or frequent) (following the intermediate disturbance hypothesis – see Connell, 1978), and with rapid drainage and metamorphic bedrock. Cultural disturbances are able to provide this level of disturbance, and can lead, for example, to enhanced growth of desirable plant species for the First Nations of this region, such as berry plants and early successional species (e.g. bracken fern– *Pteridium aquilinum* (L.) Kuhn), as in the case of prescribed burning (see next section). Such activities can be considered part of a sustainable strategy that enabled long-term site use by the First Nations who employed such methods (Gottesfeld, 1994; Turner & Peacock, 2005). Moreover, as Colding, Elmquist, and Olsson (2003, p.164) explain, without such understanding (of the role of disturbance), the systems in place will be ecologically "brittle." Although changes of the expected successional stages may have occurred unwittingly, it is likely that these ecological processes were understood, and that the knowledge of which serves as an example of traditional ecological knowledge and wisdom (TEKW) (Turner et al., 2000).

Research on post-anthropogenic landscapes (areas that once were in use by humans, but are no longer) shows that some landscapes quickly recover once human pressures are lifted (e.g. Aravena, Perez, & Armesto, 2002), while others, regardless of the intensity of the cultural footprint on the landscape, may continue to be affected by persistent arrested succession (e.g. Bardgett, 2005; Freschet, Östlund, Kichenin, & Wardle, 2014). The habitation sites discussed in this thesis are no longer influenced in the same way as they were historically by the disturbances associated with human presence and practices (e.g. with fire management). The end of habitation on these cultural sites on the Central Coast of BC may allow them to recover to their original successional trajectory; however, despite the "light footprints" of past management practices (Lepofsky & Lertzman, 2008), the sites may resist further changes in successional trajectories.

2.3 Clearing, Burning, and Other Manual Changes

2.3.1. Plant Management - Evolution of Thought

The study of human-plant relationships over time has led to various hypotheses regarding what these interactions looked like initially and how to characterize the different levels of interactions. Through the generation of hypotheses in academia, cultures were divided into two groups: those that obtain food as hunter-gatherers and those that are agrarian, producing and using domesticated plants and animals. This dichotomy is questionable, however, as defining these groups requires making distinctions that exclude some cultures. Cultures that have characteristics from each category are often termed as falling into the "middle ground" (Smith, 2005) This categorization raises other questions, such as how are the species that are "gathered" determined to be wild, as opposed to domesticated? When does a society become agrarian? And how do management practices for native species and habitats *in situ* fit into this classification system? Such theorizing has also been challenged by academics due to the lack of universal agreement on definitions put forth for agriculture, domestication, and cultivation.

An understanding of how these classifications emerged can be gained by examining the evolution of thought regarding human-plant interactions. This relationship has undergone much scrutiny, leading to the development of ideas such as the dump-heap theory, presented by Anderson (1952), the origin theory (Sauer, 1936), and evolutionary theory (Rindos, 1984). The dump-heap theory is built around the idea that the most common results of human occupation are cleared land and dump heaps (Anderson, 1952). Plant species connected to human consumption activities may also have an increased chance to germinate with the introduction of seeds and pits in kitchen mounds/dump heaps (Anderson, 1952). This postulated cause for the origin of plant-human interactions leading to agriculture suggests the following sequence: humans gathering plant species followed by unintentional domestication, leading to humans growing plants (Anderson, 1952).

The origin theory maintains that agriculture (along with technology and domesticates) arose from places of origin and radiated to other cultures. This idea for an "agricultural hearth" implies the invention of agriculture (Rindos, 1984). Sauer (1936) suggests this idea to have roots in Southeast Asia, emerging from fishing cultures. Rindos argues against this notion and instead advocates for evolutionary forces working on interactions between humans and plants, pointing out that his idea aligns with the dump-heap theory. Vavilov (1926, as cited in Rindos, 1984) states that human-plant interaction would have been subject to "successive environmental and cultural filters." Although the origin theory is now largely refuted, a byproduct was the rise of the perspective that agriculture is a step in the development or evolution of a culture (Rindos, 1984). This view implies that the middle ground, sometimes referred to as incipient agriculture, is moving towards an agrarian end point (Rindos, 1984; Smith, 2005), which is not necessarily the case (Deur & Turner, 2005; Smith, 2005). Such frameworks could have contributed to the development of the categories of “hunter-gatherer” and “agrarian”. In the case of the Northwest Coast Peoples, a different system of food production developed, in which perennial plant species provided food, materials and medicines for people (Turner & Peacock, 2005), and species and habitats were manipulated at a range of scales and through both social and ecological means (Turner, Deur, & Lepofsky, 2013).

This middle ground is in fact the category in which it is asserted that the cultures of the Pacific Northwest belong (Smith, 2005). For a long period of academic study time, mainstream society’s ideas bound these cultures by their designation as hunter-gatherers, stuck within the restrictive binary terms explained above. This pigeonholing was partially due to the early descriptions of the cultures of this region, which did not recognize the intentional strategies being employed for food production; First Nations food production areas perhaps appeared plan-less in contrast to European norms (Cronon, 1983). Bias in ethnographic recordings, such as skewed documentation toward activities other than gathering food plants, may have also precluded further recognition (Norton, 1985). This misunderstanding of a culture’s subsistence habits may be the most extreme example in the literature, but it is not alone. Many cultural practices have been classified inappropriately and as Anderson (1952) exclaims, the “average scientific agriculturist … has so much more to unlearn than to teach, but he seems frequently unaware of that fact.”

Despite the wide dissemination and longevity of such viewpoints, the middle ground, with its “active managers,” has gained recognition within recent literature (e.g. Deur & Turner, 2005; Turner, 2014; Turner, et al., 2013). Challenges remain in understanding this middle ground classification, such as how to distinguish among the cultures within this continuum (e.g. what percentage of the diet was in fact from domesticated species, even among agrarian societies (Smith, 2005)). Also, as posited by Smith, without intervention by outside cultures, would there be further shifts in the type of food production among the food producers of the middle ground?

2.3.2. Manual Changes

As we have introduced this “middle ground” occupied by the First Nations of the Pacific Northwest, it is important to explore the management practices covered by the concept that were and still are used to modify the landscape. It also becomes important to define domestication, which as mentioned is a term that has been fraught with inconsistent definitions. Following the lead of Smith (2005), we can distil the common elements from the definitions given, finding an area of agreement between the differing views of Ford (1985), Harris (1968), and Rindos (1984). They agree that domestication occurs when the species in question is changed (visibly or not) and relies on humans for survival. Rindos argues that intentionality cannot be part of this definition and that humans, the initiators, could favour a species, but could not knowingly domesticate it (i.e. predict the outcome of such selection overtime). The steps leading to domestication begin with intervention and support of a species, followed by changes in genetics, which can lead to observable behavioural or physical differences (Smith, 2005).

Using this definition, challenges remain in determining what is domesticated. Genetic research and archaeological evidence (such as technology used with domesticated species) can aid in this effort. Mellin and Truitt (2013) also bring attention to Living Artefacts which "owe their position, or characteristics in time and space to human involvement" as evidence for domestication. Differentiating these species from their wild counterparts is possible with an understanding of cultural associations of species for food, medicine, construction, or other uses. Clustering of such species (abnormally concentrated, different form, size and location, e.g. close to a village site) and in combination with other culturally significant plant species can also be indicative of domesticated species (and habitats or landscapes), or Living Artefacts (Mellin & Truitt, 2013; Turner et al., 2013). Visible enhancements, such as the pruning of crab apple trees can also be evidence for domestication (Turner & Peacock, 2005). The deliberate actions of management that led to these artefacts are part of systems that are built up over time (Berkes & Turner, 2006).

Management can take many forms, including the cultivation practices of domesticates, which, like domestication, have been defined in various ways. Deur and Turner (2005) provide the following definition: "peoples' repeated or intentional manipulation of both plants *and* their environments as a means toward plant resource enhancement." This definition encompasses a wide range of activities including, but not limited to, prescribed burning, transplanting, weeding, selective harvesting, tilling, mulching, the alteration of soil drainage, and the creation of plot boundaries (Deur & Turner, 2005). Examples of cultivation have been documented throughout the Pacific Northwest, and despite often being presented in relation to a certain region, cultivation can be assumed to have been practised more widely (Anderson, 2009; Turner et al., 2013; Turner & Peacock, 2005). Some specific examples of the Heiltsuk community's practices with domesticated species are the maintenance of berry patches, whose productivity is enhanced by thoughtful site selection, and the use of fertilizers (fish blood, guts, and bones, clam shells, ash) (Turner & Peacock, 2005). Ownership of berry harvesting areas (and other areas: root gardens, crab apple trees, and seaweed harvesting areas (Turner & Peacock, 2005; Turner, Smith, & Jones, 2005)) was found in many cultures of the Pacific Northwest. Being a designated owner imbued responsibility to maintain the productivity of the sites and to meet community needs when appropriate (Turner, 2014; Turner & Peacock, 2005).

2.3.3. Burning and Clearing

Prescribed burning is a practice that is important to recognize as another kind of human-orchestrated change. As asserted by Boyd (1999, p. 292), prescribed burning was the primary tool Indigenous people used to manage the environment in the Pacific Northwest. Oral and written records of this intentional and systematic practice are extensive throughout this region. Recognizing such fire disturbances as being cultural in origin is not without its challenges owing to similar physical results from naturally caused burns (e.g. those resulting from lightning strikes). As such burns were controlled, they may also be harder to record, as their range may be restricted, making them more difficult to locate (Lepofsky et al., 2005). However, lacking any oral history or historical records, abnormality in the frequency of cultural burns (shorter intervals or different season than expected for a natural burn) and intensity of burns (less intense than a natural burn because fire loads would be smaller) can allow researchers to determine whether fires are likely to have been human-caused (Lepofsky & Lertzman, 2008). Evidence supporting the prevalence of culturally prescribed burning can be found in the soil column (as charcoal deposits), using dendrochronological studies (bark scarring from burns), and also as ash layers found in peat bog cores or lake bottoms.

The subtleties of this landscape management practice may have escaped early settlers, as can be seen in journal entries that do not credit the indigenous people for open-spaced ecosystems (e.g. Captain George Vancouver when visiting the managed Garry Oak Ecosystems on Vancouver Island (Vancouver, 1798, as cited in Deur & Turner, 2005)). Some other records written by settlers in British Columbia, however, noted that fires were being "kindled promiscuously by the natives" (Grant, 1848, as cited in Turner & Peacock, 2005, p. 127); some took issue with these fires, while others recognized their purposefulness (Turner, 1999). Boyd

(1999) and Deur and Turner (2005) provide many case studies and evidence for prescribed burning activities throughout the Pacific Northwest, principally in the interior of BC, but also in the Coastal Rainforest. Current research (e.g. by K. Hoffman) along the coastal region of BC continues to find new evidence for this practice and offers deepening interpretations of locality, timelines, and cultural vs. natural designations of the burns. At all the habitation sites surveyed (see Chapter 3) that underwent soil profile testing and tree coring (by K. Hoffman, University of Victoria), evidence of burning was found; no evidence for burning was found at the control sites (personal observation, July 2014).

The importance of fire as a tool can be understood by recognition of the pervasiveness of prescribed burning within a diverse number of cultures and biogeoclimatic zones. Some place names even reflect this activity (e.g. the territory *Milgeelde,* or burnt shrubs in the Kitsumkalum Valley - McDonald, 2005, pp. 246). Landscape burns, using the definition from Turner (1999, p. 186), refer to intentional burning of larger tracts of vegetation and not to smaller fires, including those used for sustenance activities such as food and medicine preparation, or working with wood or hides. One of the main purposes of these controlled fires was to enhance resources so that harvests would be more predictable and consistent (Ames, 2005; Lepofsky et al. 2005). Controlled fires improve harvests because of fire's ability to alter the ecology of a site by reducing competition, opening space, adding nutrients to the soils, and restarting and generally promoting growth (Turner & Peacock, 2005). These fires, when applied to berry patches, would restrict woody growth on plants (essentially pruning them) allowing for energy to be saved for berry production (Lepofsky et al. 2005; Turner & Peacock, 2005). The time between burns would have varied, and fires are found to have occurred after crop production diminished. Peak production would then resume after about four years (McDonald, 2005; Turner, 1999). The low-intensity nature of the burns allowed for the survival of rhizomes and other underground parts within the soils, providing for regeneration (Turner, 1999). Examples of species that have been documented as being managed in this way on the coastal region are salal (*Gaultheria shallon* Pursh), gooseberry (*Ribes* spp.), and red huckleberry (*Vaccinium parvifolium* Sm.) (Turner, 1999). Anthropogenic burns at this scale were also used during hunting to clear brush for general ease of movement (trail creation/visibility improvement) (Turner, 1999, p. 187; Deur & Turner, 2005, p. 19).

Specific changes to the environment from low-intensity fires include nutrient pulses that are released from woody plant material, enhancing upper surface layers of the soil (Turner, 1999). These pulses release alkaline ions and can change the pH as a result. They can also affect the micro and macro fauna and immediate soil moisture availability, as well as the organic matter (González-Pérez, González-Villa, Almendros, & Knicker, 2004; Neary, Klopatek, DeBano, & Folliott, 1999). The extent of these effects depends on fire intensity, with a high-intensity fire negating potential increases in productivity and nutrient content. But lower-intensity burns would not generally kill the larger, thick-barked trees and would encourage growth and production of some species (e.g. berry producing species) (Lepofsky et al., 2005; Turner & Peacock, 2005).

Knowledge of this complexity surrounding fire as a management tool would have been built up over time through generations of use and experimentation (Turner, 1999). Overall, the prominence of this management strategy, its effectiveness, and its sustainability should lead one to expect evidence of this practice where indigenous people managed plants within this region (Lepofsky & Lertzman, 2008). Current burning bans restrict this type of management, maintaining the general view of the importance of fire suppression which began in the 1930s and 40s; this has allowed succession to proceed where it would have been arrested historically (Gottesfeld, 1994). Berry harvesting sites have become more difficult to locate and to harvest from in some regions without this management regime (McDonald, 2005; Turner, 1999).

The modifications and management strategies described above influenced these habitation sites at three levels: the individual plant species level, the plant communities level, and the landscape level (see Peacock, 1998). The changes that resulted from these strategies altered the productivity and overall form of the sites, supporting the idea of a "domesticated landscape" (Anderson, 2005; Peacock, 1998; Turner et al., 2013). Much like the definition of domestication given in the previous subsection, these landscapes are altered from their original successional trajectory and would not be the same without human intervention.

The purpose of this section was to emphasize the myriad of potential modifications that could have occurred in this region and on the habitation sites researched in this thesis. The large time scales involved in the human-landscape relationship led it to be substantially modified by complex management strategies involving domesticated species. This finding is important because First Nations in the Northwest Coast have been traditionally framed as "hunter-gatherers," ignoring many facets of the human-landscape relationships and the practices and principles they employed to sustain and enhance their plant and animal resources. The cultural influences from these activities combine with the natural processes of these sites, creating the environments we see today (Robbins, 1999).

2.4 Local Environmental Effects

This third section discusses the primary local environmental factors that further contribute to the structure, function, and composition of these habitation sites. The focus will be the general influence of shell middens (which are characteristic of these habitation sites) and their effect on the normal soil regime, and the way in which the understory is influenced by canopy cover and site topography. In a sense, these factors themselves are a result of the combination of natural environmental processes and the influence of humans as described in the preceding sections. The resulting combinations, however, exert their own unique influences at the landscape level, shaping the ecology of these sites.

Before describing the effects of these environmental factors, it is important to identify the characteristics that are generally associated with the study region, to understand how these characteristics change. As mentioned in the first section, all of these sites are located within the CWH zone in the very wet hyper maritime subzone, of the central variant (CWHvh2). This is an area characterized by a high level of rainfall which can lead to leaching of nutrients from the soils, and saturation. This produces soils that are under anaerobic conditions, which can hinder decomposition and allow for the accumulation of organic matter (Banner et al., 2005). This process is halted or diverted with the mixing or destruction of the soils by disturbances, such as windthrows.

The CWHvh2 zone is generally characterized by these qualities throughout the forested areas of this region; however, it is also known to deviate from these patterns and processes where shell middens have been formed. Shell middens are anthropogenically generated land forms found on coastal regions and are associated with most coastal cultures globally. Physically, they can be described as berms built up over time with deposits resulting from human activities. According to the law of superposition, these layers of deposits can sometimes be interpreted chronologically, with individual dumping events defining the strata (this could be from a period of hours or centuries). More specifically, the layers can be divided into ethnostratigraphic, lithostratigraphic, geochronometric, or chronostratigraphic units (Stein, Kornbacher, & Tyler, 1992). Shell middens are composed of a variety of objects and artefacts ranging from kitchen debris (e.g. bones and other animal remains), stone implements, plant material, human remains, and, characteristically, shells, which were used as tools and construction material and were also byproducts of consumption (Stein, 1992a). The human remains that have been found within many shell middens indicate that they were not simply refuse heaps, but had deeper, purposeful meanings behind them (personal communication, F. Rahemtulla, June 2014). The general pattern of the complex stratigraphy is for the bottom layers to be darker in colour and contain fewer full shells and for the upper layers to have a higher density of obvious shells and a lighter colour which has been hypothesized to be the result of weathering effects affecting the lower layers more significantly (thereby increasing the rate of the breakdown of shell material) (Stein, 1992b).

After the deposits that make up the shell middens have been made, the contents do not necessarily remain undisturbed and can undergo changes over time. Such disturbances can be due to flooding, compaction, movement (e.g. argilliturbation – a process where a flux in conditions, such as wet to dry, can lead to the movement of sediments within the deposit), and bioturbation (Stein, 1992b). This weathering and disruption can alter the state of the shell midden contents and is one of the reasons postulated for different layer colourings (Stein, 1992b). These disturbances can affect the pH, temperature, and moisture content, which, as noted by Whitmer et al. (1989), can in turn influence the breakdown of bone, among other materials, in this environment. In a general sense, the characteristics of shell middens allow for a high level of preservation of materials; however, this depends largely on the pH values associated with the soils, with breakdown accelerating within acidic *and* highly alkaline soils (Linse, 1992). The breakdown of shell midden materials can release components such as calcium phosphates and carbonate which can influence cycling within the soils and make previously limiting nutrients available for plant uptake. In this research, I found significant differences between the nutrients found in shell midden soils and those in soils of the control sites, with higher average values of boron (B), calcium (Ca), manganese (Mn), sodium (Na), phosphorus (P), zinc (Zn), exchangeable Ca, the effective cation exchange capacity (CEC), inorganic carbon (C), and pH. These are important to consider as they may influence plant growth as the limitations restricting plant growth imposed by the nutrient-poor soils in the CWHvh2 may be lifted (see Chapter 3, Discussion). Along with these nutrient changes, the shell midden materials cause structural changes. Because of the physical qualities of shells and other deposits, the shell midden zone is both porous and permeable (Ceci, 1984; Sanger 1981). This was demonstrated with my steel rod experiment (Chapter 3), where aerobic activity was shown to be deeper within the shell midden zones. Shell middens are an anthropogenic land form that continue to change over time. Consequently, so do their potential impacts on the natural environment.

The soil nutrient changes that are associated with shell middens have been documented throughout North America (e.g. Chapter 3; Cook-Patton et al., 2014; Sawbridge & Bell, 1975). Changes in plant communities are often attributed to the shell midden-altered soil structure and composition. The nutrients that may have been limited without the shell middens (e.g. Mn, P, Ca) and the different drainage qualities they create can shift the generally prevalent soil regimes. An example of this would be the normally limited P, which, when this limitation is lifted, allows for changes to nutrient cycling and microbial activity (see Kranabetter & Banner, 2000). Shell middens can also change the environment to be more appropriate for some detrivores that could not survive in acidic soils and that can be influential in catalyzing nutrient cycling (although there may be restrictions from Na that may be due to proximity to the marine shoreline) (Stein, 1983). As is well known, the parent material of the soils is significant in determining the soil qualities. However, according to Buol, Hole, and McCracken (1973), parent material is less important as other soil forming processes (e.g. weathering) proceed.

The potential of these limitations to be released has been acknowledged in recent research, which suggests that shell middens influence tree growth. As documented by A. Trant (unpublished data), western redcedar trees have been found to grow taller at these habitation sites. The proposed explanation is that Ca restrictions that are normally present in this environment are removed because Ca is made available by the shell midden. This provision of Ca, in turn, would affect the entire canopy structure and could alter the amount and quality of light that reaches the understory species. Furthermore, canopy cover has also been connected with changes in soil moisture availability. Habitation sites have not (at this point) been included in reports such as *The HYP3 project: Pattern, process and productivity in hypermaritime forests of coastal British Columbia: A synthesis of 7-year results* (Banner et al., 2005), which consider how to improve productivity in this region and how to compensate for nutrient limitations in soils. Accordingly, further research on these qualities could be useful for management practices and approaches.

Finally, shell middens (and habitation sites in general) can also affect the topography of a site. Stein (1992b) refers to such sites as being relatively level, and differences were also noted by Whittaker and Stein (1992), who make reference to the “new topography” at shell midden sites. In the study described in Chapter 3, the habitation sites, compared with the control sites, had over ten percent more quadrats that were located on what was designated as relatively flat terrain. This factor is influenced by the site history and can contribute to the shaping of plant communities. This was shown in Chapter 3 where topographical scores were shown to be a top factor in four of the top models presented to explain the plant community assemblages at different vegetation layers. Shell midden deposits, which are generally near shore, are also known to “drastically alter” (straighten) what would potentially be a non-uniform coast (Whittaker & Stein, 1992).

2.5 Conclusion

Landscape legacies from human occupation and land use can be found throughout the world. Such legacies vary with the intensity of human interactions, which can be difficult to perceive depending on the practices, technologies, and philosophies of the cultures that occupied the land. This occupation can result in sites that, still today, are affected by past activities. Along with potential human influences, landscapes are subject to a range of biotic and abiotic processes stemming from other sources. The resulting landscapes are a reflection of the intersection of cultural and natural pressures. In this section, I explored three different components that contribute to landscapes – one of human agency, one of natural agency, and one that encompasses the effects from a combination of both of these. Acknowledgement of these natural and human forces brings us to look at these sites with a more holistic understanding and serves as a reminder to those in other fields of research to consider both natural and human influences when examining landscape qualities.

Chapter 3: How have First Nations' past sites of habitation influenced present-day ecology on the Central Coast of British Columbia?

3.1 Abstract

Globally, humans have transformed much of the earth's surface through a wide range of activities of varying intensities and scales, shaping the landscape we see today. The combination of time and complex human-environment interactions within the Hakai Lúxvbálís Conservancy (on the Central Coast of British Columbia, Canada) has resulted in a modified landscape. To gain an understanding of the long-term impacts of human land-use, I conducted an observational study on habitation sites with extensive shell middens. Ten habitation sites with known extensive shell middens and ten control sites, in similar locales but without shell middens were selected for floristic surveys to gain insight into the expected differences in overall plant diversity and abundance, and how the vegetation of these sites changes with distance from the marine shoreline. The survey also included documentation of culturally modified trees (CMTs), edible berry plants, and other culturally important species. Soil and foliar samples from four plant species were collected at sites with and without shell middens to compare the fate of shell midden-derived nutrients. Water-table measures were also made. Overall, I documented 104 bark scars on 90 CMTs, with 55 located on the habitation sites and 35 on the control sites. Stem counts of berry plants and other culturally significant species varied between the sites, with seven of the species involved in the survey occurring exclusively on the habitation sites. Foliar sample analysis showed no significant trends, though soil samples from the shell midden sites were significantly higher in some micro and macronutrients (B, Ca, Mn, Na, P, Zn, exchangeable Ca, inorganic C), effective cation exchange capacity (CEC), and pH. Investigation of the water-table levels revealed significantly lower levels within the shell midden zones compared to the

control sites ($p=0.017$). Principal component analyses (PCA) were also used to describe the gradients within the vegetation community on these sites. The results indicate that vegetation layers respond differently to long-term site use. The extent of these differences depends on which area of the site is included in the analysis. Plant community composition is most strongly influenced by a combination of factors including: whether or not it was on a habitation site, canopy cover, slope, topography, ground covering, and distance from shore. Overall, the data collected from this study improves our understanding of the factors shaping the biodiversity on the Central Coast and provides a detailed inventory of these habitation sites.

3.2 Introduction

It is widely recognized that humans have played a large role in transforming the earth's surface and that few, if any, ecosystems are free from human influence. Ellis & Ramenkutty (2008) estimate that up to three-quarters of land surfaces that are not covered in ice have been influenced by humans, whether through intentional or unintentional disturbances. Current landscapes not only reflect contemporary influences, but also embody the effects of past human activities: the result is a landscape with characteristics determined by long and complex interactions of human activities and the natural environment. The damaging effects of activities such as habitat destruction, fragmentation, and over-harvesting are recognizable and widespread, and human-dominated landscapes prevail globally (Ellis & Ramankutty, 2008). Fortunately, this form of interaction is not the only way that humans interact with their landscapes, and many cultures in the past and present have lived in their homelands for long periods in sustainable ways. For an example of such a culture, we need not look further than the Central Coast of British Columbia (BC) in Canada, where evidence of sustained long-term occupancy can be found (Deur & Turner, 2005; Groesbeck et al., 2014; Turner, Deur, & Lepofsky, 2013; Turner et al., 2000).

The Central Coast of BC, Canada is an area known for its remoteness, large tracts of protected land, unique landforms, and wildlife. Somewhat lesser known is the fact that it is a region humans have occupied for many thousands of years. As evidenced by archaeological excavations and coring, human presence at some past sites of habitation (sites with evidence of long-term occupation and land use – hereafter referred to simply as habitation sites) has been continuous at the regional scale for the past 10,000 years or more (although locally, site use and occupation can be thought of as repeated, varying through time and with seasons) (see Cannon, 2000; Carlson, 1979). This timespan, using a conservative estimate, is equivalent to approximately 400 human generations. Recently, ancient footprints were discovered that have been dated to as long as 13,200 years ago, adding to the evidence of long-term occupation; these are the oldest known footprints in North America (Pringle, 2015).

Shell middens are a defining characteristic of these habitation sites, having accumulated throughout the long period of human occupation. Shell middens are anthropogenically generated land forms that are not only found on the Central Coast of British Columbia, but also associated with many coastal cultures globally, in places such as Scandinavia, South America, the United Kingdom, and other parts of the west coast of North America (e.g. California and Alaska) (Ceci, 1984). They are often described as accumulations of cultural refuse, or kitchen mounds, that have built up over time and over generations of use (e.g. Cook-Patton et al., 2014). However, it is also acknowledged that shell midden materials could have been moved around after their original deposition and placed more intentionally as foundational structures for houses or for other purposes (Blukas-Onat, 1985; Ceci, 1984). The composition of these shell middens can be seen as a reflection of the activities at these sites and may include materials such as clam and mixed shells, bones of land and sea mammals, fire-cracked rocks, fish bones, stone tools, human remains and other organic artefacts, forming stratified berms (Blukas-Onat, 1985; Pomeroy, 1980; F. Rahemtulla, personal communication, April 2014; Sawbridge & Bell, 1972).

The characteristics of shell middens have made them the focus of many studies, following their first recognition in Scandinavia as human-made structures in 1849 (Bibby, 1956). Shell middens provide a unique record of the past with the often exceptional preservation of deposits within. This can be attributed to the alkalinity of the shell material, which can protect artefacts from the acids in soils. The shell can also physically shield artefacts from being crushed and provide surface protection by deterring erosion (Andrus, 2011). These features have allowed shell middens to become repositories of knowledge, increasing our understanding of past activities and ecosystems and providing insights into human dietary choice and technology, and reflected species distributions. Furthermore, shell middens have opened up new doorways to future research—such as the reconstruction of past food webs through the analysis of C and N in animal bone collagen that has been preserved in the shell middens, and advances in the field of sclerochronology, which uses incremental growth records (e.g. of shellfish or otoliths) to interpret environmental changes through time (Andrus, 2011; Burchell et al., 2013; Misarti et al., 2009).

Even relatively short-term land use has the ability to transform ecological systems (Briggs, 2009), making these habitation sites with their long history of occupation and use likely candidates for change. Studies have found that shell middens have the potential to alter their local environment in terms of soil qualities and vegetation communities. Examples of such changes within plant communities include increased introduced species, increased species richness, and unique species assemblages found on sites with shell middens (Cook-Patton et al. 2014; Sawbridge & Bell, 1972; Smith & McGrath, 2011). Soils associated with shell middens have undergone scrutiny, and differences between samples from them and sites without shell middens have been observed. Trends include increases in pH, cation exchange capacity, and an overall enrichment of nutrients. Moreover, soils' compositional qualities have been noted in other studies conducted on North American shell midden sites to be different (Cook-Patton et al. 2014; Sawbridge & Bell, 1972; Smith & McGrath, 2011) potentially allowing for differing drainage qualities.

An inquiry into the land-use legacies of these ancient sites complements the surge of research that is emerging from the Central Coast and is a logical outgrowth of archaeological and ethnoecological projects underway. Although vegetation surveys on past sites of habitation have occurred globally, this type of investigation, as noted by Sawbridge and Bell (1972), has occurred only in a limited way on the shell midden sites of the Pacific Coast; indeed, the selected sites in this study have not undergone intensive scrutiny beyond basic preliminary surveys. Overall, this research serves as a bridge between the overlapping realms of ecology and archaeology, which as Briggs et al. (2006) assert, is "essential for understanding human-ecosystem interactions."

The goal of this observational study was to explore the idea of long-term land use and how such use has influenced the landscapes within this region. For this survey I selected habitation sites with histories of long-term use and known extensive shell middens. To elucidate potential trends within the plant communities of these sites, I used a paired-site study design, making a comparison with control sites that did not have shell middens or a known history of intensive occupation. As noted by Cook-Patton et al. (2014), beyond their own research few studies have attempted to survey middens in this way besides Vanderplank et al. (2014), and Karalius and Alpert (2010). I also investigated soil characteristics within the suspected shell midden areas and control sites and documented the unique floristic qualities of each site. The questions that I considered in this study include: 1) Are there differences between vegetation on habitation sites with shell midden and the vegetation on areas without evidence of past occupation? 2) How does the vegetation change with increasing distance from shoreline at both site types? 3) Which plants are uniquely associated with the habitation sites with shell middens? 4) What are the primary processes that shape the overall ecology of these sites? The habitation sites were evaluated within, and beyond the expected shell midden boundaries to gain insight into the overall site use legacies, as well as those that can be specifically associated with shell midden subsidies. Within the context of the growing global desire to understand how humans affect long-term ecological change, these sites provide an opportunity for a glimpse into a particular way of interacting with a landscape and a chance to observe the ensuing legacy.

3.3 Methods

3.3.1 Site Descriptions

The region of study is located on the Central Coast of British Columbia, Canada, within the Hakai Lúxvbálís Conservancy. All sites are within the biogeoclimatic zone CWHvh2—the Coastal Western Hemlock zone in the very wet hyper maritime subzone, of the central variant (Klinka, Pojar, & Meidinger, 1991). In general, the CWH occurs along the entire BC coast at low to mid elevations (sea level to 900 m) (Pojar et al., 1991). The hypermaritime subzone is characterized by cool summers and mild winters with a mean annual precipitation of about 2230 mm (standard deviation: 713) and mean annual temperature of 8.2°C (standard deviation: 0.9) (Klinka et al., 1991). Soil formation in these wetter zones occurs primarily by means of organic matter accumulation. These soils are generally nutrient-poor, as the high precipitation allows for nutrients to be easily leached; the mor humus form is dominant. Characteristic species of this zone include western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), western red cedar (*Thuja plicata* Donn ex D. Don in Lamb), Sitka spruce (*Picea sitchensis* Bong.), salal (*Gaultheria shallon* Pursh), deer fern (*Blechnum spicant* (Linnaeus) Smith), false azalea (*Menziesia ferruginea* Hook.), lanky moss (*Rhytidiadelphus loreus* Hedw.), and step moss (*Hylocomium splendens* Hedw.) (Green & Klinka, 1994). I conducted research from May to August 2014 on eight islands on the Central Coast: Calvert, Hecate, Starfish, Triquet, Edna, Hurricane, Hunter, and Stirling islands.

3.3.2 Experimental Design

A paired comparison study was used to gain an understanding of the relation between habitation sites (with shell middens) and control sites - those without a history of intensive human occupation (without shell middens). The control sites were selected based on proximity to the habitation sites, similarity of site slope, and suspected parent material, but testing negative for shell-midden material (determined by visual inspection, auger testing, and archaeological records), suggesting that they had not been occupied in an intensive manner. Three 72-m transects were placed parallel to one another at each site, starting from the forest-intertidal ecotone. Transects were placed perpendicular to the shoreline and centrally on the habitation sites; this made for varied spacing between transects with a range of 10 m to 25 m depending on the site configuration. The spacing on the respective control sites was arranged in the same configuration (see Appendix A for details of each study site). Along each transect a 1 m x 1 m quadrat was placed every 9 m, totalling 9 plots per transect and 27 plots per site. Data collected from each plot included: distance from shore, Universal Transverse Mercator (UTM) co-ordinates, slope, topography (hummocky, depression, relatively flat, or mixed), canopy cover percentage estimate (done visually, placed in bins of 0-25%, 25-50%, 50-75%, 75-100%), and percentage of cover for the shrub, herb, and ground layers of each species in each plot.

3.3.3 Soil Characteristics

Under an archaeological permit (2011-171, authorized by Dr. Duncan McLaren), I collected soil samples from both the control and habitation sites, within the confirmed shell midden zone. Using an auger, I obtained 60 samples (30 samples from each site type) of approximately 250 g of soil, which were taken from within the active rooting zone to a maximum depth of 30 cm. These samples were obtained at approximately 10 m from the forest-intertidal ecotone, where it would be likely within the shell midden zone (based on the supposition that, over time, shell middens accumulate toward the shoreline (Whittaker & Stein, 1992)). The samples were double-bagged and stored at approximately 2°C until they could be transported to the British Columbia Provincial Government Analytical Laboratory at 4300 North Road in Victoria. Each sample was analyzed by microwave digestion/ICP Spectrometer and by the combustion elemental analyzer for measurements of aluminum (Al), boron (B), total carbon (C), inorganic C, calcium (Ca), copper (Cu), iron (Fe), potassium (K), magnesium (Mg), manganese (Mn), sodium (Na), nitrogen (N), phosphorus (P), sulphur (S), and zinc (Zn). The samples were also tested for soil organic matter content, effective cation exchange capacity (CEC), exchangeable Al, Ca, Fe, K, Mg, Mn, and Na, and pH. I evaluated the soil samples from the two site types for each of these measures using a nested anova using RStudio version 0.98.493 (2013).

To gain insights into the site hydrology over the growing season I employed a simple and inexpensive technique used by Bridgham, Faulkner, and Richardson (1991) in which steel rod oxidation is used to infer water table levels. I inserted 144 rods (1/4 inch in diameter, 1 m in length) into the soils as deep as possible with reasonable force at four site pairs. These were selected for their proximity and accessibility (EjTa-13, EjTa-14, EjTa-15, EjTa-4, and their paired control sites). At each site, I placed three rods into the ground radiating out 4 m around a central point at both the 9 m and 18 m distances from shore along each of the three transects. After either 48 or 53 days, I retrieved the rods and immediately recorded the extent of the fully rusted area and the mottled area, and the level where the rust was not present.

To understand the soil-plant relationships at these sites and the fate of shell midden-derived nutrients, I collected samples of older salal leaves, deer fern fronds, bunchberry leaves (*Cornus* spp. Ledeb,, L.), and new growth of western hemlock needles. These were collected at both 9 m and 18 m from the forest-intertidal ecotone, along the transects at both site types. These species were selected for sampling because of their ubiquity in this region and because they differ in the way that they take up nutrients: salal has ericoid mycorrhizae, deer fern has arbuscular mycorrhizae, and western hemlock has ectomycorrhizae. Bunchberry also has arbuscular mycorrhizae; however, like other *Cornus* species it is known to accumulate Ca in their leaves (e.g. Thomas, 1969), which could allow this species to provide a unique reflection of the element's availability. The types of mycorrhiza are important to recognize as each strategy could differ in its ability to deliver nutrients, depending on the environment it is in.

After collection, I stored these plant samples in paper bags with desiccant satchets in warm, dry environments until they could be delivered to the same analytical laboratory mentioned earlier for drying and analysis of Al, B, C, Ca, Cu, Fe, K, Mg, Mn, N, Na, P, S, and Zn.

3.3.4 Indicator Species, Food Plants and Culturally Significant Species

Along the transect I established 10 m belt transects to survey the sites for culturally significant species and culturally modified trees. A culturally modified tree (CMT) as defined by Arcas Associates (1984, as cited in Mobley & Eldridge, 1992), is "a tree that has been intentionally altered by Native people participating in the traditional utilization of the forest." These trees (especially western redcedar and yellow-cedar) can be found throughout the Pacific Northwest—from the Oregon Cascades to the Kodiak Archipelago in Alaska—and have been recorded eastward in Idaho and Montana. I used the guidance provided in *Culturally Modified Trees of British Columbia - A Handbook for the Identification and Recording of Culturally Modified Trees* (Lawrie, 2001) to describe and differentiate the modifications that are cultural in nature from those caused by other things (e.g. fire, lightning, falling trees, broken branches, animals, fungi, sun-scalding, standing water, falling or sliding rocks, and/or nutrient deficiencies (Mobley & Eldridge, 1992, pp. 97, based on Arcas Associates', 1984)). For each CMT on the transect, I took a photograph and recorded the UTM co-ordinates, distance from intertidal zone, diameter at breast height, a total height estimate, and type of cultural modification.

Within this belt transect I also recorded further information for 14 plant species, which included berry producing and other culturally significant species (i.e. skunk cabbage (*Lysichiton americanus* Hult. & St. John), Pacific yew (*Taxus brevifolia* Nutt.), Cascara (*Rhamnus purshiana* DC), Pacific crab apple (*Malus fusca* (Raf.) Schneider), and Labrador tea (*Rhododendron groenlandicum* (Oeder) K.A. Kron & W.S. Judd)) in hopes of creating a more complete inventory of species at each site. The culturally significant species were selected based on *Food Plants of Coastal First Peoples* (Turner, 1995) and *Plants of Coastal British Columbia* (Pojar & MacKinnon, 2004). These species may also signal site qualities that may not have been obvious by simply using data obtained from within the 1 m x 1 m quadrats (e.g. salmonberry (*Rubus spectabilis* Pursh) which can indicate N-rich sites (Klinka, Krajina, Ceska, & Scagel, 1989)). These are also species that are easily seen, which would add to the consistency in data collection. The number of stems and distance along the transects (from the forest-intertidal zone interface) for these species were recorded; this was done at both site types along the entire length of the belt transects.

Table 1. Species included in stem count conducted on the three 10 m x 72 m belt transects at all sites.

Code	Common Name	Scientific Name
AMAL	Saskatoon berry	*Amelanchier alnifolia*
MAFU	Pacific crab apple	*Malus fusca*
RUSP	salmonberry	*Rubus spectabilis*
TABR	Pacific yew	*Taxus brevifolia*
VAOVAL	oval-leaved blueberry	*Vaccinium ovalifolium*
VAPA	red huckleberry	*Vaccinium parvifolium*
RIBR	stink currant	*Ribes bracteosum*
RUPA	thimbleberry	*Rubus parviflorus*
RILA	black gooseberry	*Ribes lacustre*
RHPU	cascara	*Rhamnus purshiana*
RHGR	Labrador tea	*Rhododendron groenlandicum*
RUPE	five-leaved bramble	*Rubus pedatus*
LYAM	skunk cabbage	*Lysichiton americanus*
LOIN	black twinberry	*Lonicera involucrata*

3.3.5 Statistical Analysis

From the 20 sites surveyed, I evaluated the data with eight principal component analyses (PCA). This consisted of four analyses using the data from the entire length of the transects, and four using the data exclusively from the front 36 m. This was done to isolate the effects of the shell midden zone which, as noted, has a tendency to form near the shoreline. With the latter I included the PC1 scores from the soil nutrient data as an explanatory variable. With both of these distances I performed the analyses separately on the ground, herb, and shrub vegetation layers, as well as these layers in combination. The species included in the analysis were those that occurred in over 10% of all quadrats. Although not present in this threshold value, skunk cabbage, Labrador tea, black gooseberry (*Ribes lacustre* (Pers.) Poir), thimbleberry (*Rubus parviflorus* Nutt.), and salmonberry were also included in the analyses. This was done because they may be reflective of site qualities that are not easily apparent (e.g. water table levels), and may reflect historical site activities (e.g. berry gardens), making them potentially key species that differentiate these site types. All species abundances were log transformed prior to analysis to make distributions more normal, in order to meet the assumptions of statistical methods used.

Subsequently I created a linear model of the PC1 and the habitation site "treatment" to determine the significance of the relationship at each layer combination. Next, I used a linear mixed effects model fit by maximum likelihood (Pinheiro, Bates, DebRoy, Sarkar, & R Development Core Team, 2013) to predict the variation across sites based on the correlation of the fixed effects; this informed and was part of the criteria to determine the top combination of variables that contribute to the vegetation communities described. The random effect was set as the site pairs (10) nested within the sites surveyed (20). The fixed effects that I included are treatment type (habitation or control site), distance from shore, canopy cover, slope, topography measures, site, transect, site pair (treatment and respective control), leaf litter, coarse woody debris, and soil nutrient data (PC1 scores). Candidate models (Table 2) were generated for a general purpose (not specifically for a vegetation layer or distance from shore). I used the multi model inference (MuMIn) package (Bartoń, 2013) for model selection and I determined the ranking of the models for all model combinations in terms of relative importance by using the Akaike Information Criteria (AICc - corrected for sample size) which was generated from linear mixed effects modelling. A p-value of <0.05 set as the statistically significant level, with <0.01 considered to be highly significant. I used RStudio version 0.98.493 (2013) for these analyses.

Table 2. Candidate models to explain potential vegetation differences on habitation and control sites. (Canopy cover = Can; Dis = Distance from shore; Slp = slope; Trt = Site type - habitation or control; Dis:Trt = Distance by site type; Top = topography; CWD = Coarse woody debris; LL = leaf litter; Soil = Soil nutrient analyses PC1).

Model	**Explanation for differences in vegetation between site types**
Trt/Dis:Trt /Soil	Nutrients from shell midden material are most influential
Trt/Dis:Trt/Soil/CWD/ LL/Dis	Nutrients from shell midden material and other sources; ground conditions as most influential
Trt/Dis/Soil/Can/Trt:Dis	Legacies from human activities most influential
Top/Slp/Can/Dis	Environmental variables most influential, not necessarily human-influenced

I also compared the stem count data of culturally significant plant species from the two site types (habitation and control sites) using nonmetric multidimensional scaling (nMDS), and the analysis of similarity (ANOSIM). These counts were transformed by using the square-root function (so that the results would be both reflective of species with lower stem counts, as well as those with high counts) and then the sample similarity was prepared with the Bray-Curtis similarity measure. Based on the similarities, the sites were ordinated in a two-dimensional space. The ANOSIM was performed to calculate the significance of the sample statistic, and the R value. Finally the data was evaluated with a similarity of percentage (SIMPER) approach to rank the species involved in the analysis according to their weight in contributing to the dissimilarity of the sites. I analyzed this data set using PRIMER-E V6 (Clarke, 1993).

3.4 Results

3.4.1 Plant Biodiversity

The results from the floristic survey show that the past sites of habitation and the control sites are different. In the 540 plots that were surveyed on the 20 sites, I identified 90 species. Seventy species were found on the control sites and 75 on the habitation sites. These were differentiated into three layers of vegetation, and were found to have higher species richness (number of species) averages per plot on the control sites (Table 3). The species richness per plot ranged from 1-19 at the habitation sites and 4-21 at the controls. The species on the control sites that were encountered the most frequently were salal (on 266 plots), false lily-of-the-valley (*Maianthemum dilatatum* (Wood) Nelson & MacBride; 206 plots), lanky moss (230 plots), and step moss (227 plots). The most frequent on the habitation sites were also salal (257 plots) and false lily-of-the-valley (168 plots), with *Kindbergia* spp. (*K. oregana* Sull., *K. praelonga* Hedw.) occurring more often than other ground layer species (238 plots). Controls had 12 species (17.1%) occurring only once within a plot across all sites surveyed, whereas on the habitation sites, 18 species (23.4%) were found only once. Overall, the plots on the habitation sites contained 22 species that were not found on the control sites (12 herb, 3 ground, and 7 shrub species). All species recorded along the transects were within their expected geographical range.

Table 3. The average species richness within the plots sampled with standard error (SE) and overall species count at both habitation and control sites at each layer of vegetation and with all layers in combination and the significance (p-value) of the differences between the species richness at the two site types for each vegetation layer.

Vegetation	**Habitation Site**		**Control Site**		**All sites**	**p-value**
Layer described	**Av. species richness (SE)**	**Total species**	**Av. species richness (SE)**	**Total species**	**Total species**	
All layers	9.23 ± 0.198	75	10.9 ± 0.199	70	90	< 0.001
Ground layer	4.40 ± 0.116	22	5.03 ± 0.107	24	27	< 0.001
Herb layer	2.61 ± 0.102	36	3.38 ± 0.108	35	45	< 0.001
Shrub layer	2.21 ± 0.068	17	2.47 ± 0.072	11	18	0.006

The eight principal component analyses were performed to generate eigenvalues for the two transect distances (plots surveyed up to 36 m and plots from the entire transect) and the three vegetation layers - both apart and in combination. The values of the first axes of the PCAs ranged from as low as 10.62% (all vegetation layers using only plots from the front 36 m of the transects) to 22.09% (all distances with ground cover), and cumulatively the first four axes combined to explain a maximum of 61.58% of the variation (Table 4). These analyses were used to make an independent variable (PC1) with which relationships with other variables could be tested to explain the variation between the site types. Species loadings from each analysis can be seen in Appendix E.

Table 5 shows the top models for each analysis, and also distinguishes the variables that were of the greatest importance. Overall, treatment type (habitation or control site) was indicated as part of the top models for five of the eight analyses run, excluding the shrub layer at both transect distances and the herb layer for the analysis of the front 36 m. Each top model contained at least four explanatory variables.

Table 4. Principal component analysis results from the three vegetation layers separately and combined, at both the partial transect distance (front 36 m) and the full transect distance (72 m). The p-values are shown for the relationship between the treatment "habitation site" and the first principal component.

Distance	**Vegetation**	**PC1**	**PC2**	**PC3**	**PC4**	**Cumulative**	**p-value (PC1~trt)**	**r²**
Front 36 m	Ground	20.2	14.6	11.1	10.1	56.0	< 0.001	< 0.001
Front 36 m	Herb	20.3	14.6	12.9	11.2	58.9	< 0.001	< 0.001
Front 36 m	Shrub	17.7	16.8	14.6	12.6	61.6	0.933	< 0.001
Front 36 m	All Layers	10.6	7.33	6.53	5.70	30.2	< 0.001	< 0.001
Full Distance	Ground	22.1	14.4	10.8	10.4	57.7	< 0.001	< 0.001
Full Distance	Herb	21.2	14.7	12.0	10.9	58.7	< 0.001	< 0.001
Full Distance	Shrub	18.0	15.9	13.8	11.4	59.0	0.0294	< 0.001
Full Distance	All Layers	11.8	7.75	6.13	5.60	31.3	< 0.001	< 0.001

Table 5. The top models of the predictor variables for the three vegetation layers separately and combined, at both the partial transect distance (front 36 m) and the full transect distance (72 m) determined using AIC scores. (Canopy cover = Can; Dis = Distance from shore; Slp = Slope; Trt = Site type - habitation or control; Dis:Trt = Distance by site type; Top = Topography; CWD = Coarse woody debris; LL = Leaf litter; Soil = Soil nutrient analyses PC1).

Distance	**Vegetation**	**Top Model**	**Top Variables**
Front 36 m	Ground	Can/Dis/Slp/Trt/Dis:Trt/Top	Can
Front 36 m	Herb	Can/CWD/Dis/LL/Soil/Top	Can/Dis/LL/Soil
Front 36 m	Shrub	CWD/Dis/LL/Slp	CWD
Front 36 m	All Layers	Can/ CWD/Dis/ LL/Top/Trt/ Dis:Trt	Can/Dis/LL/CWD
Full Distance	Ground	Can/CWD/Dis/Slp/Top/Trt/Dis:Trt	Can/CWD
Full Distance	Herb	Can/CWD/ Dis/LL/Trt/Dis:Trt	Can/CWD/Dis/LL/Trt/Dis:Trt
Full Distance	Shrub	CWD/Dis/LL/Slp	Dis/LL
Full Distance	All Layers	Can/ CWD/Dis/ LL/Trt/Dis:Trt	Can/CWD/Dis/ LL/ Trt/Dis:Trt

Ground Layer

The first principal component for the ground layer species within the first 36 m of the transect and the entire transect have the species loadings arranged in the same order with similar values.

The species with the most positive loadings (in order from highest to lowest) are step moss, lanky moss, *Sphagnum* spp*., and Dicranum* spp. - all of which are characteristic of N-poor, acidic sites, and the first two are noted as being typical ground layer species in this region (Klinka et al., 1989). *Sphagnum* spp. are high water table species and are characteristic of nutrient poor, organic soils; *Dicranum* spp. are similar, however they are prone to be on drier sites (Klinka et al., 1989). These species are more closely associated with the control sites (Figure 2 and 3).

The other species included in this analysis were found to have negative loadings and can be seen as characterizations of the plant community for the habitation sites. These include (in descending order): *Scapania bolanderi* (Aust.)*, Plagiothecium undulatum* (Hedw.) B.S.G.*, Hookeria lucens* (Hedw.) Sm.*, Peltigera* spp.*, Rhizomnium glabrescens* (Kindb.) T. Kop., and *Kindbergia* spp. The first four are known to be found in N-poor soils as well, and are noted to be oxylophytic (tolerant to, or thriving in acidic soils); all are shade tolerant species (Klinka et al., 1989). *Kindbergia* spp. and *Peltigera* spp. tend to be on to water shedding sites with dry to moderately dry soils (Klinka et al., 1989). Both the analyses of the plots within the front 36 m of the transects, and those of the entire transect length on the habitation sites were found to be significantly different from the control sites ($p<0.001$).

Herb Layer

For the herb layer, the PC1 loadings for the species included were similar for both the analysis of the plots up to 36 m along the transects and the analysis involving all plots. In both analyses the treatment (site type) was found to be highly significant ($p<0.05$). Overall, the species with higher positive loadings (corresponding more so with the controls) included *Cornus* spp*.,* twinflower (*Linnaea borealis* L.), sedge and grass species, and deer fern*.* These species are characterized by their tendency to be in nitrogen poor soils (Klinka et al., 1989). Skunk cabbage falls somewhere near the middle in terms of species loadings in the analysis of plots from all distances, and is a little more prominent as a control species when considered in the analysis of plots up to 36 m. This species is an indicator of nutrient rich wetlands (Klinka et al., 1989). Species with lower loadings that characterize the habitation sites include heart-leaved twayblade (*Listera cordata* (L.) R.Br. in Ait), which can be found on moderately dry or fresh soils on either water shedding or receiving site, although often on N-poor soils (Klinka et al., 1989). False lily-of-the-valley and three-leaved foamflower (*Tiarella trifoliata* L.) are also species with lower loadings and are indicators of fresh-moist soils that are nitrogen rich (Klinka et al., 1989). Labrador tea is a shade intolerant species, and is found in wet to very wet nitrogen poor, and acidic soils that collect water; this species is characteristic of nutrient poor wetlands (Klinka et al., 1989). Overall, this species' loading corresponds to the plant assemblage characteristic of the control sites.

Shrub Layer

The loadings for the shrub layer were similarly grouped in the analyses at the two different distances with western hemlock, red huckleberry (*Vaccinium parvifolium* Sm.), false azalea (*Menziesia ferruginea* Sm.), and western redcedar having similar loadings, while thimbleberry, gooseberry, salal and salmonberry are similarly grouped together. The shrubs in the first grouping are characteristic of N-poor soils, while the second group contains species that are designated nitrophiles. Salal is also noted to be a dominant shrub covering at water-shedding sites, which aligns with the observed water-table differences at these two site types. Despite these groupings, the treatment types are not determined to be significantly different within the analyses of the front 36 m ($p=0.93$), however it is shown to be significant in the analysis that incorporates all transect distances ($p=0.03$).

Overall, when all species are considered together it has been shown that it is highly likely that a relationship exists between the treatment and PC1 scores at both distances analyzed (up to 36 m: p-value < 0.001, and for the full transect p-value < 0.001).

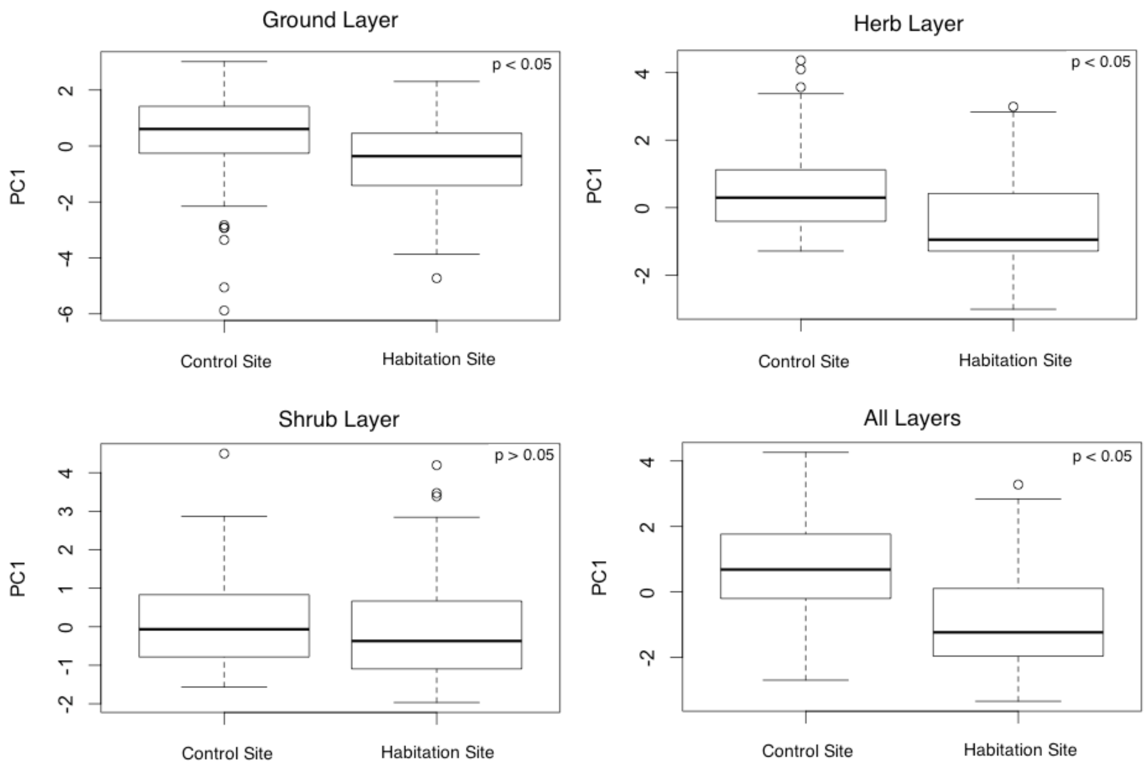

Figure 2. PC1 by habitation site or control site for front 36 m of all transects. From right to left, at the top is the plot for the ground layer and the herb layer, and at the bottom, the shrub layer and all layers together.

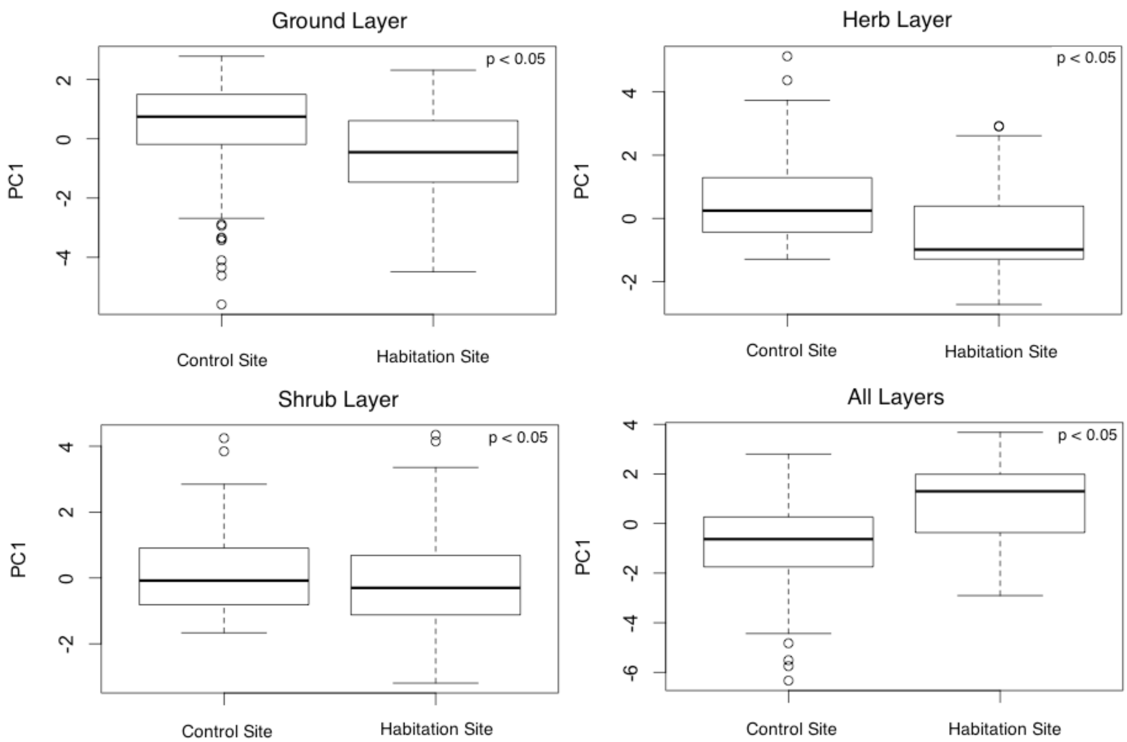

Figure 3. PC1 by habitation site or control site for all distances of transects. From right to left, at the top is the plot for the ground layer and the herb layer, and at the bottom, the shrub layer and all layers together.

Changes in vegetation with distance from shore across both site types

Analyses of the interaction between the PC1 score, the distance of the plot along the transect, and the treatment type (habitation and control sites) provide a visual representation of how the sites change with distance from the shore (Figure 4-7). Through linear modelling we are able to understand the relationship of the vegetation communities and the changes with distance at the two site types. The ground, herb, and all layer plots have slopes that are significantly different between the two site types ($p<0.05$). In these three plots the plant community assemblages on the habitation sites have similar PC1 scores throughout the entire distance of the transect. This contrasts with the control sites on the same plots, which have different PC1 scores at the end of the transects. This indicates that plant communities at habitation sites stay dominated by nutrient rich indicator species across the entire distance into the forest from the beach edge. In contrast, control site plant communities exhibited a strong shift towards nutrient poor species. This trend is observed beyond the shell midden zone.

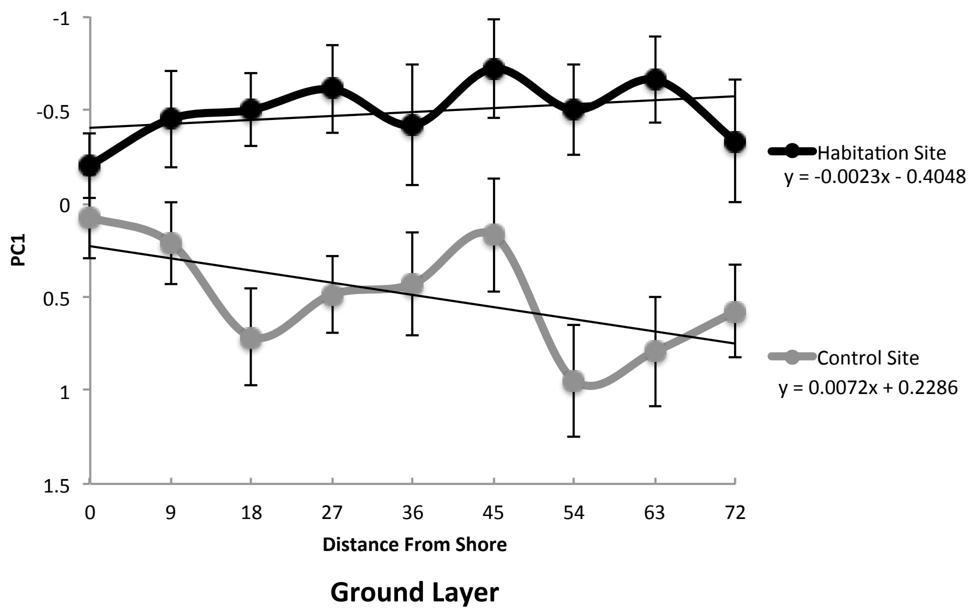

Figure 4. PC1 plotted against distance from shore for the ground layer vegetation with standard error bars of the PC1 scores. Habitation sites are shown in black and control sites are shown in grey.

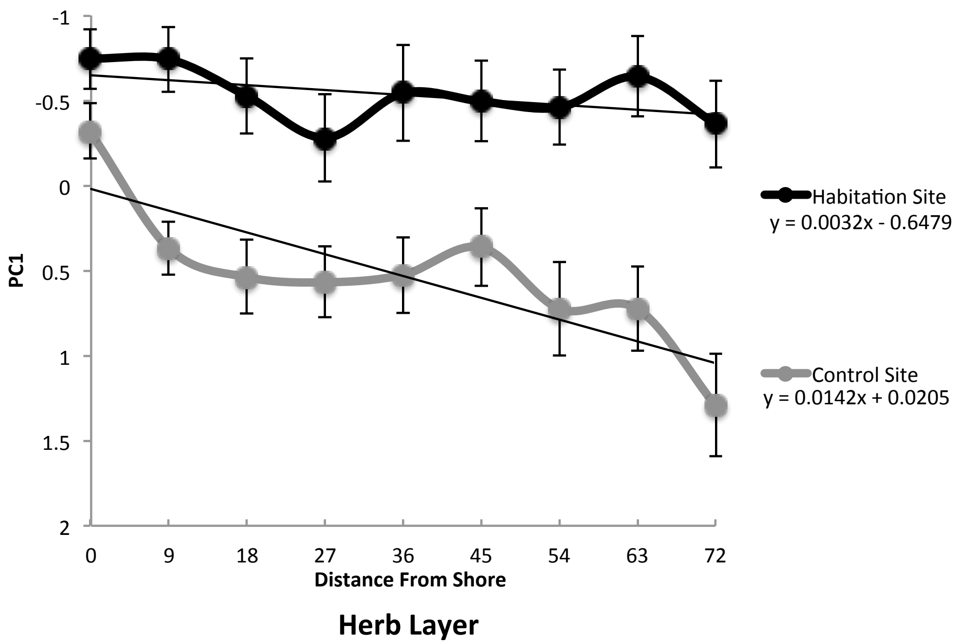

Figure 5. PC1 plotted against distance from shore for the herb layer vegetation with standard error bars of the PC1 scores. Habitation sites are shown in black and the control sites are shown in grey.

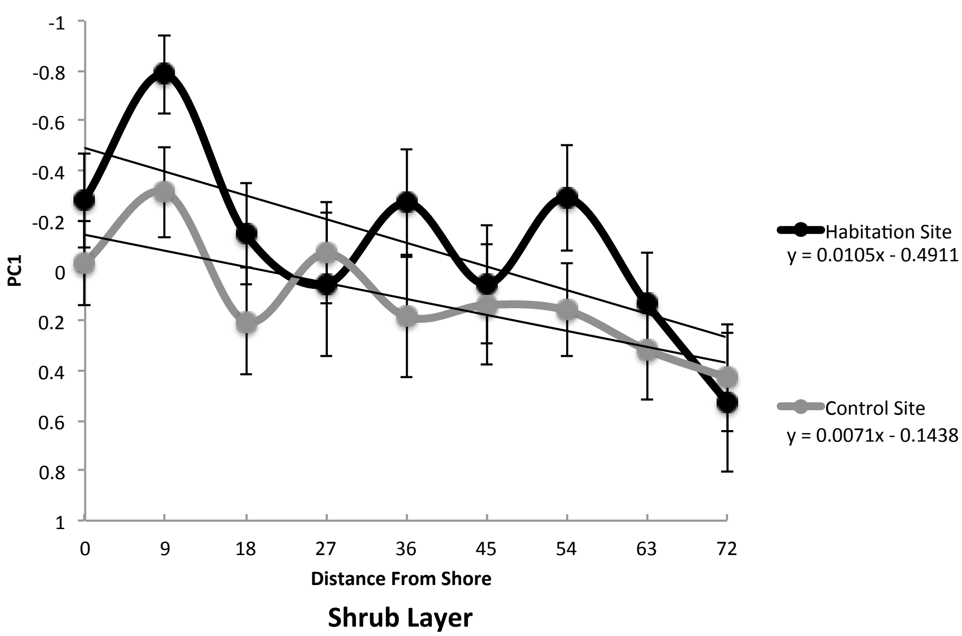

Figure 6. PC1 plotted against distance from shore for the shrub layer vegetation with standard error bars of the PC1 scores. Habitation sites are shown in black and the control sites are shown in grey.

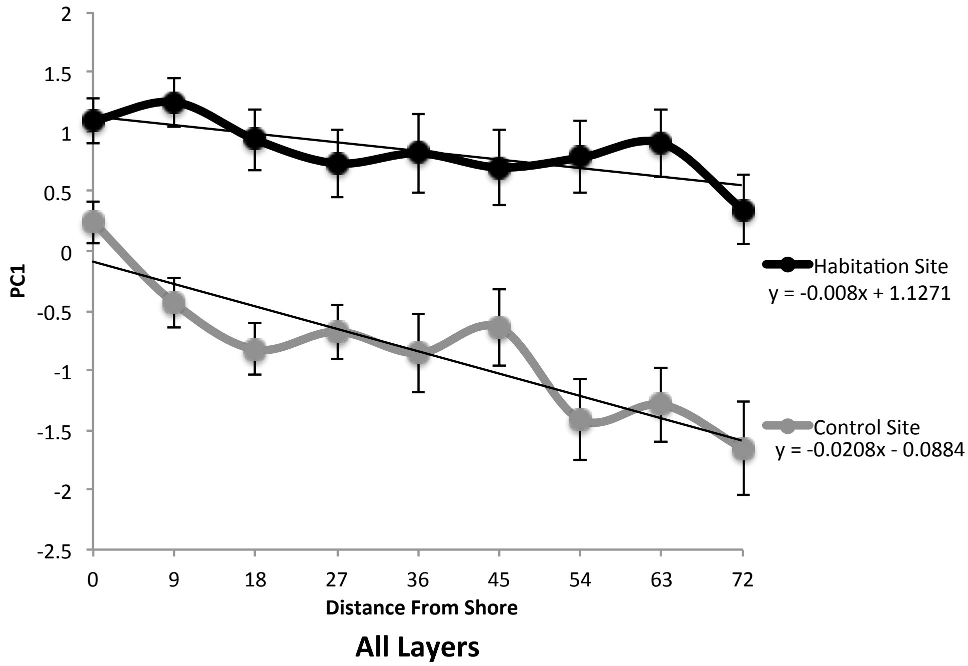

Figure 7. PC1 plotted against distance from shore for all vegetation layers with standard error bars of the PC1 scores. Habitation sites are shown in black and the control sites are shown in grey.

3.4.2 Soil Characteristics

Results from the soil samples obtained show significant differences in soil qualities between the habitation sites (within the shell midden zone), and the control sites (Figure 8-11). The average values from the shell midden sites are higher with regards to the B, Ca, Mn, Na, P, Zn, exchangeable Ca, effective cation exchange capacity (CEC), inorganic C, and pH. On average the control sites are higher in exchangeable Al, and exchangeable Fe. These sites were not significantly different with regard to the organic matter content, the content of C, N (although different in regards to C:N ratio), Cu, Fe, Na, S, and exchangeable values for K, Mn, Mg, and Na. All results were corrected to oven-dry (105 °C) basis. The results from the soil samples can be seen in full in Table 7 in Appendix E.

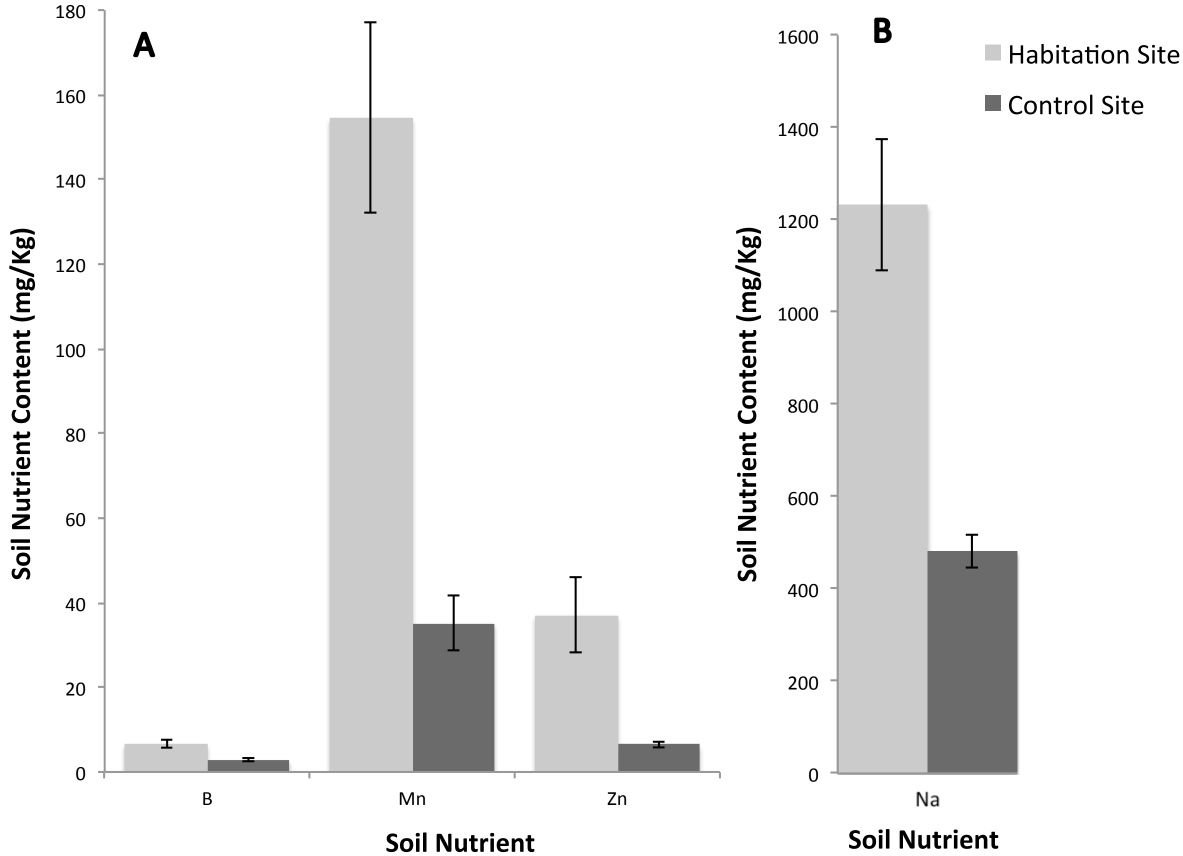

Figure 8. Soil sample average values for nutrients B, Mn, Zn, (A) and Na (B) with standard error bars from the means from all samples from both the habitation sites (light grey) and control sites (dark grey). B, Mn, Zn, and Na are significantly higher on the habitation sites.

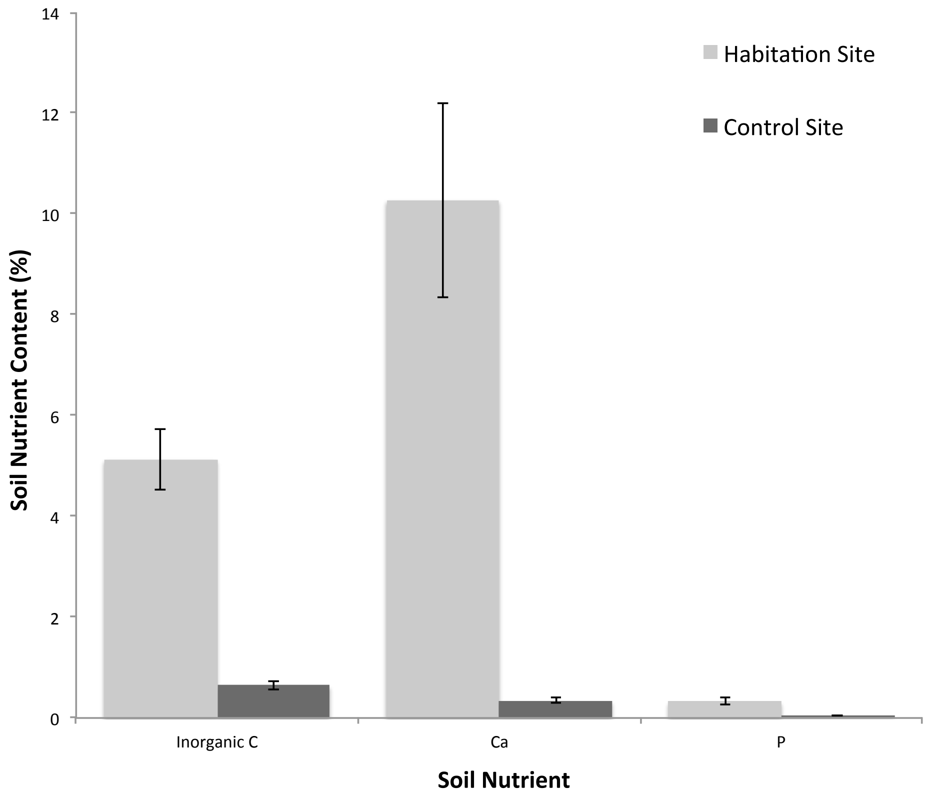

Figure 9. Soil sample average values for nutrients inorganic C, Ca, and P with standard error bars from the means from all samples from both the habitation sites (light grey) and control sites (dark grey). Inorganic C, Ca, and P are all significantly higher on the habitation sites.

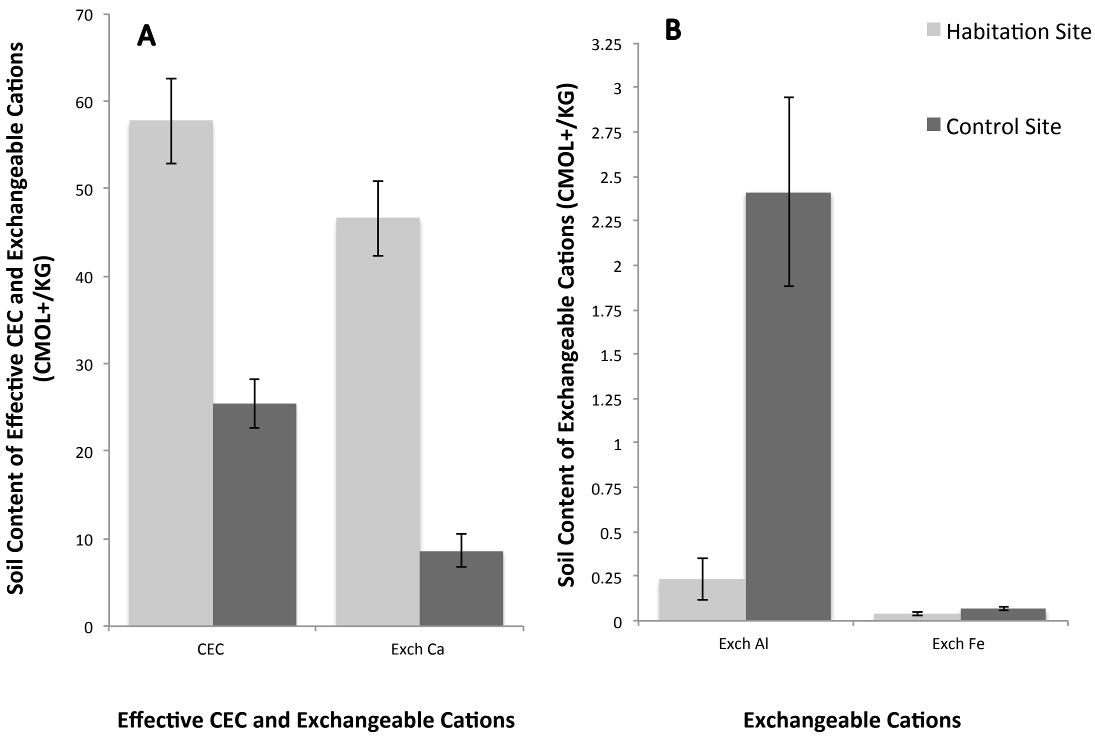

Figure 10. Soil sample average values for effective cation exchange capacity (CEC) and exchangeable cations with standard error bars from the means from all samples from both the habitation sites (light grey) and control sites (dark grey). CEC and exchangeable calcium (Exch Ca) (A) are significantly higher on the habitation sites, and exchangeable aluminum (Exch Al) and exchangeable iron (Exch Fe) (B) are significantly higher on the control sites.

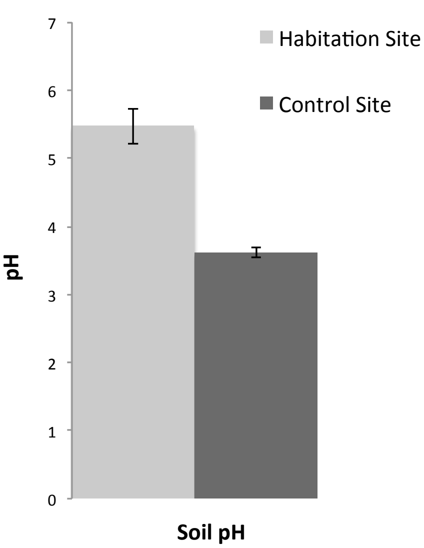

Figure 11. Soil sample average value for soil pH with standard error bars from the means from all samples from both the habitation sites (light grey) and control sites (dark grey). The pH is significantly higher on the habitation sites.

Leaf nutrient analysis results from the four selected species collected on the sites EjTa-13 and EkTa-19 and their respective controls were not significantly different in nutrient values between the site types. Because of this and the high cost of analysis, it was decided that the remainder of the collected samples should not be tested. The results could be due to the heterogeneity of the sites where the samples were taken; the inability of some elements of interest to enter the leaves when I would expect differences (e.g. aluminum); or perhaps more simply, the differences in plant community composition cannot be attributed to the differing available nutrients alone.

I compared the steel rod oxidation levels to infer the soil aerobic depths between the site pairs and across all sites (Figure 12). I removed them after allowing the rods either 48 or 53 days in the ground during the late spring and summer. The timing of this measurement reflects the water table when it would be most influential to plant growth. The top of the graph (Figure 12) represents the top of the ground, and each bar represents the steel rods inserted at each site or site type. The mean rusting extent on the shell midden sites (habitation sites) was significantly different from the control sites overall ($p=0.017$), with the average depth of full rusting on the rods on the shell midden sites measuring 82.1 cm SE ± 1.85, and the controls at 52.6 cm SE ± 2.30. The difference in rusting levels at the site level was also significant between all pairs ($p<0.05$).

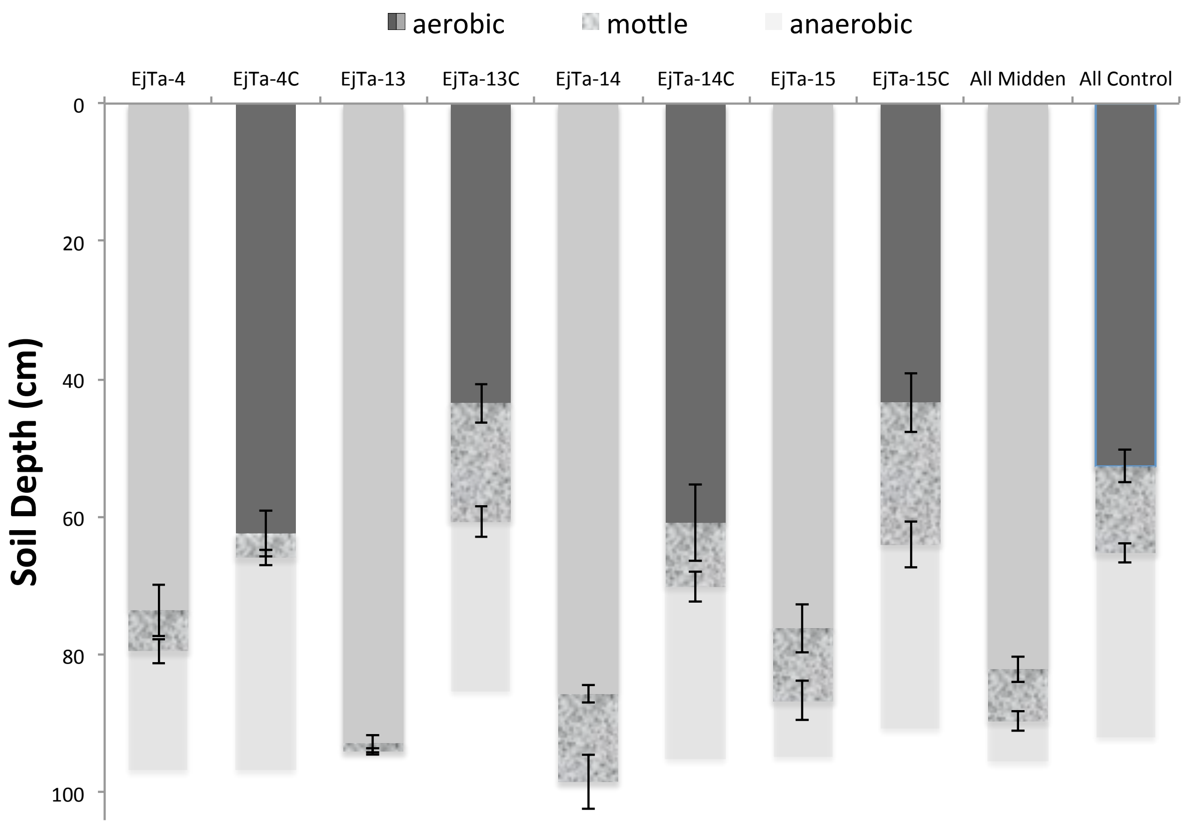

Figure 12. The average depths of oxidation on 1 m long steel rods that were inserted within the shell midden zone at habitation sites and respective control sites at four site pairs (18 at each site). This figure represents the average full rust level, the average mottled level, and the average non-rusting zones, shown with standard error bars for both the mottled and full rust means. A ‘C’ following the site designation indicates the control site.

3.4.3 Indicator Species, Food Plants and Culturally Significant Species

In total across all sites I observed 90 culturally modified trees. Thirteen of the 90 trees had more than one modification, and as many as three, allowing for a total of 104 observations. Of these 90 trees, 35 were found on the control sites and 55 were on the habitation sites, with site maximums of 15 and 11 respectively; this difference was not found to be significant ($p>0.05$). However, if the site pair for EkTa-38 is excluded from the survey, the total number of modified trees changes to 20 at the control sites and 49 on the habitation sites which is found to be significantly different ($p=0.005$). Figure 13 shows the distribution of the 90 CMTs that were documented. Out of the ten site pairs, only two pairs have controls with a higher number of CMTs recorded (ElTb-1 and

EkTa-38). In total, four species were found with modifications: 85 western redcedar trees, 3 western hemlocks, 1 Sitka spruce, and 1 Pacific yew. The distribution for modification type (Figure 14) is as follows: 41 healed (39.4%); 36 triangular (34.6%); 13 rectangular (12.5%), 13 lenticular (12.5%); and 1 columnar (>1%) (See Appendix D for representative photos of each type of modification). On average, the 90 trees had a diameter at breast height of 2.32 m SE ±0.132, and an average height of 14.5 m SE ±0.132, and were on average 37.8 m SE ± 2.07 from shoreline. I also recorded two trees with burn marks, both at habitation sites.

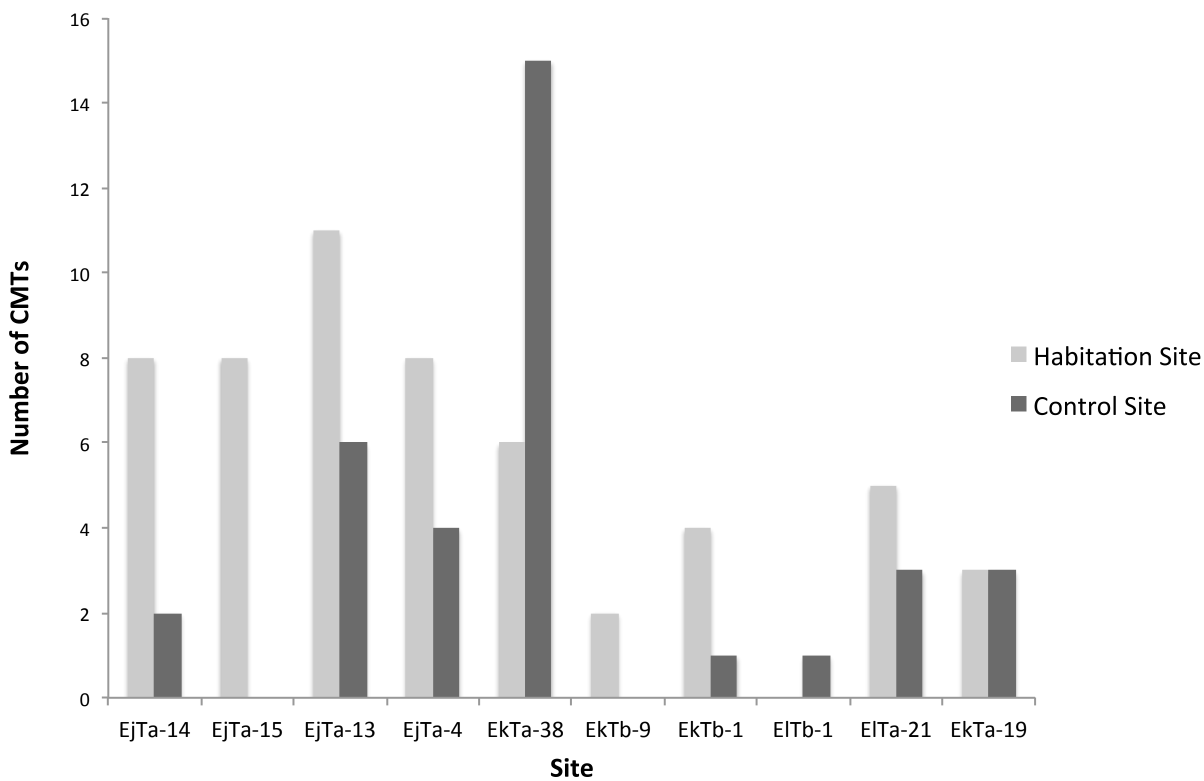

Figure 13. The distribution of the 90 culturally modified trees observed across the ten site-pairs.

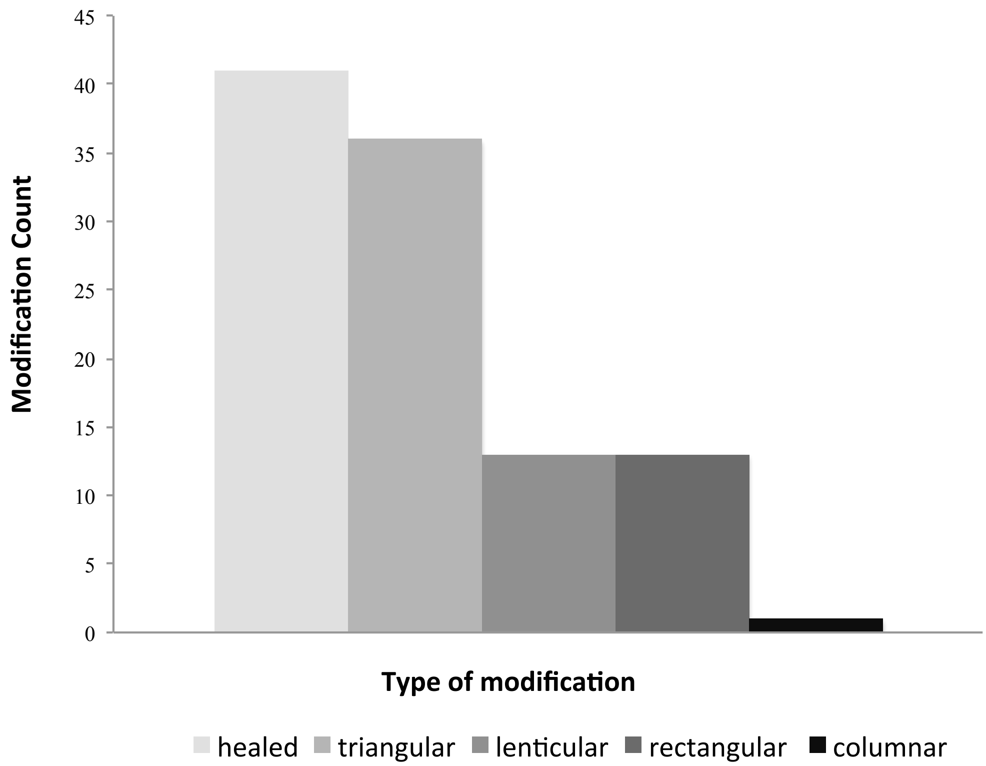

Figure 14. The distribution of the 104 observed modifications separated by type of bark-scar (healed, triangular, lenticular, rectangular, or columnar). This figure represents modifications on all culturally modified trees encountered on the belt transects at both the control and habitation sites.

The average stem counts of the 14 selected species conducted along the belt transect are shown in Figure 15 and 16. These figures indicate high variability between sites with large variability for most species. In this survey seven species were found uniquely on the habitation sites as shown in Figure 17. They include **Saskatoon berry**, **black gooseberry**, **cascara**, **black twinberry (*Lonicera involucrata* (Richards.) Banks ex Spreng)**, five-leaved bramble (*Rubus pedatus* Sm.), **stink currant (*Ribes bracteosum* Dougl. Ex Hook)**, and thimbleberry. The species indicated in bold are regionally rare. Species that were present more often on the control sites include: Labrador tea (on 7 control sites, 1 habitation site), skunk cabbage (on 4 control sites, 3 habitation sites), and oval-leaved blueberry (*Vaccinium ovalifolium* Sm.) (9 control sites and 6 habitation sites). A paired t-test was performed on the overall stem counts from each site for each species. The stem counts were not found to be significantly different between the controls and habitation sites ($p>0.05$) for the species surveyed except for Labrador tea ($p=0.043$) and black gooseberry ($p=0.044$). However, when all of the plant species surveyed in the stem count were considered together, they were found to be significantly different on the habitation sites compared to the control sites. The nMDS has a stress level of 0.17 and shows two clusters of sites with the habitation sites separated from the control sites (Figure 18). The differences are significant (ANOSIM R = 0.3, p = 0.002). The species that were most responsible for this difference were determined by the SIMPER analyses to be red huckleberry, Labrador tea, and thimbleberry. In combination, these three species contribute to approximately 50% of this dissimilarity (Table 8 – see Appendix E).

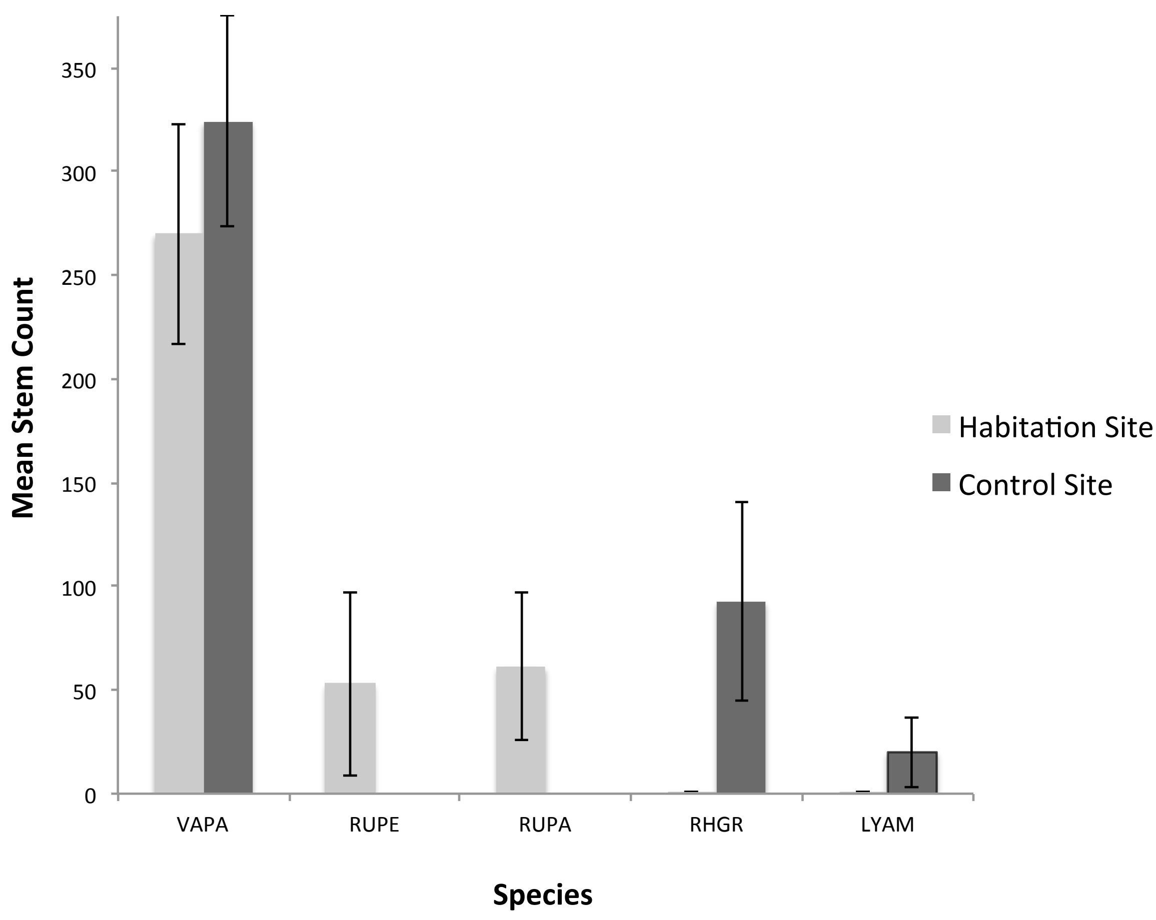

Figure 15. Average number of stems counted along the belt transects with standard error bars for red huckleberry (VAPA), five-leaved bramble (RUPE), thimbleberry (RUPA), Labrador tea (RHGR) and skunk cabbage (LYAM) separated by habitation and control site. The stem count for Labrador tea is significantly different between site types ($p<0.05$), and all other species are not significantly different between site types ($p>0.05$).

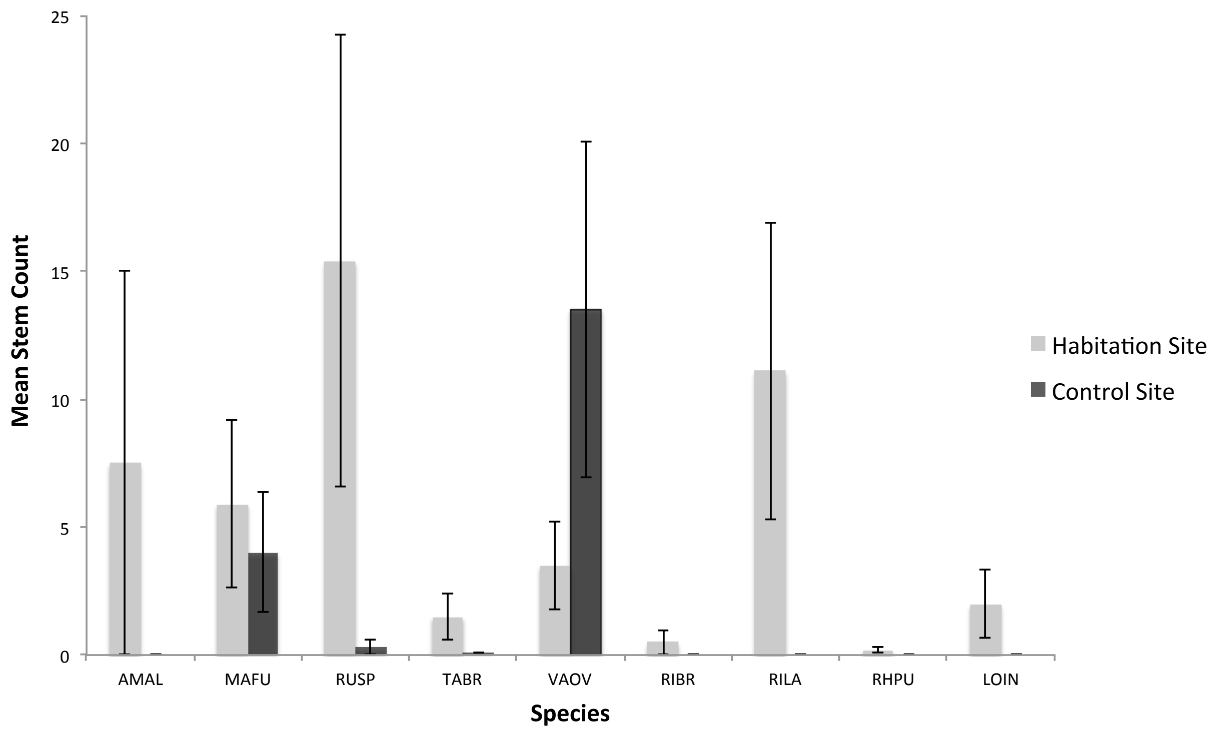

Figure 16. Average number of stems counted along the belt transects with standard error bar for Saskatoon berry (AMAL), Pacific crab apple (MAFU), salmonberry (RUSP), Pacific yew (TABR), oval-leaved blueberry (VAOV), stink currant (RIBR), black gooseberry (RILA), cascara (RHPU), and black twinberry (LOIN) separated by habitation and control site. The stem count for black gooseberry is significantly different between site types ($p<0.05$), and all other species are not significantly different between site types ($p>0.05$).

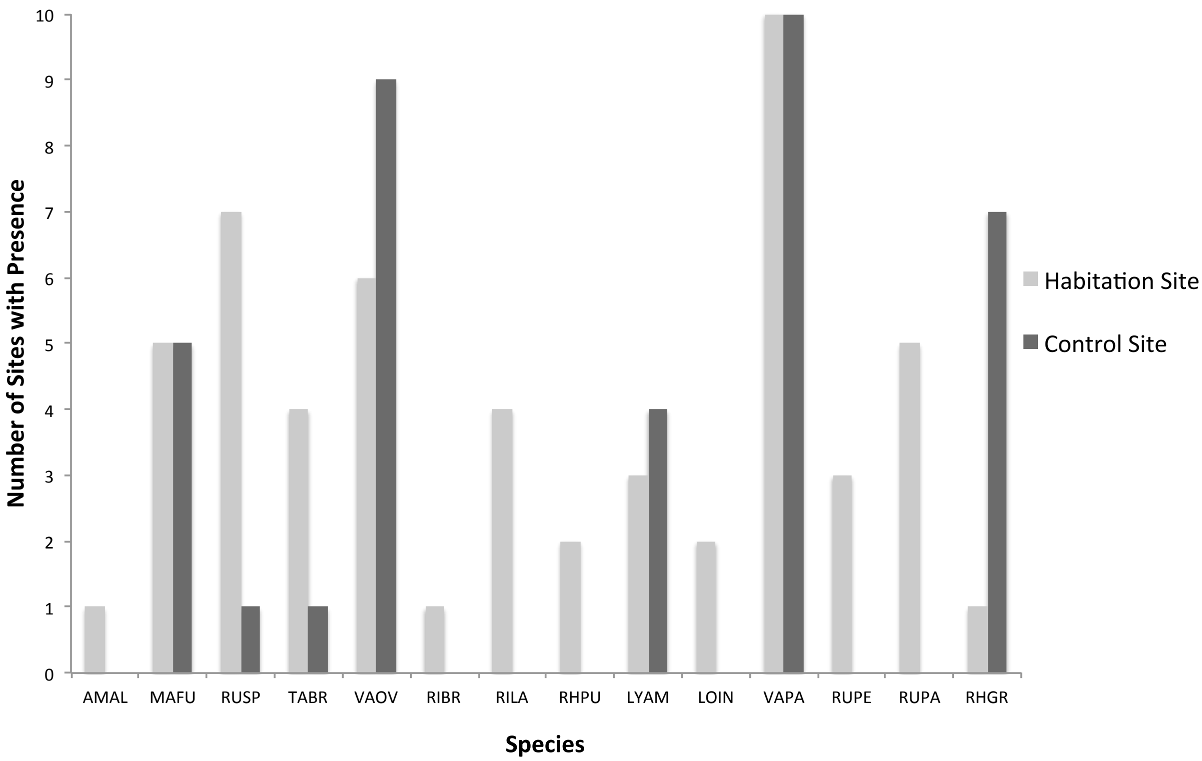

Figure 17. Number of sites with presence of the selected species within the belt transects on habitation and control sites. Species include: Saskatoon berry (AMAL), Pacific crab apple (MAFU), salmonberry (RUSP), Pacific yew (TABR), oval-leaved blueberry (VAOV), stink currant (RIBR), black gooseberry (RILA), cascara (RHPU), skunk cabbage (LYAM), black twinberry (LOIN), red huckleberry (VAPA), five-leaved bramble (RUPE), thimbleberry (RUPA), and Labrador tea (RHGR).

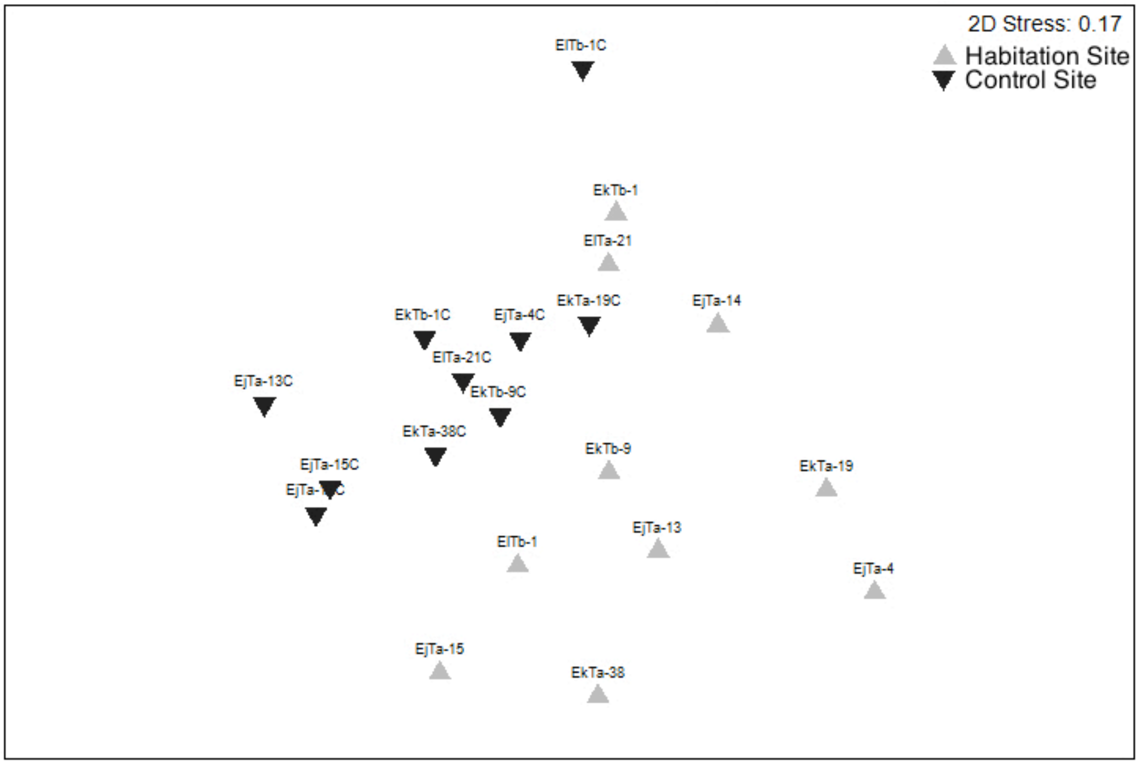

Figure 18. Nonmetric multidimensional scaling (nMDS) results based on the counts for the plant stem survey involving 14 species. The dark triangles represent the control sites, and the light triangles represent the habitation sites.

3.5 Discussion and Conclusion

3.5.1 Overview of Findings

I examined the impacts of long-term habitation and resource use on plant communities on the Central Coast of BC. Overall, I found that the components surveyed in this study suggest that these habitation sites are different from the control sites (those without evidence of long-term habitation) in terms of species composition and abundances, as well as in soil nutrient and structural qualities. This result shows that past human activity has affected the present-day ecology and is similar to the research findings of Hocking and Reynolds (2011) on the Central Coast, which also showed that nutrient enrichment (in their case, through salmon movement of marine-derived nutrients to land) has the ability to alter plant community composition. In this research, differences include average species richness per plot, which was found to be higher on the control sites (however, overall species richness is higher on the habitation sites). The results indicate that the habitation sites and control sites differ in terms of plant community composition at all vegetation layers surveyed, except for the shrub layer when considered for just the first 36 m. This analysis also reveals that the sites change differently with distance from shoreline in terms of the characteristic species composition. The community composition is most strongly influenced by a combination of factors, including site type (habitation or control site), canopy cover, slope, topography, ground covering, and distance from shore. Soil nutrient levels from within the shell midden zone (habitation sites) and on the control sites support the findings from the PCA analysis, with nutrient levels appropriate for the requirements of many species within the plant community characterizing each site type. Shell midden soils were elevated in micro and macronutrients B, Ca, Mn, Na, P, Zn, exchangeable Ca, inorganic C, effective cation exchange capacity (CEC), and pH. Results for the water table levels inferred from the oxidation levels of steel rods inserted into the soil at both site types support the findings of the given plant community of each site type. A higher number of culturally modified trees were found on the habitation sites than control sites within the surveyed belt transect (however this was not a significant difference), and seven culturally significant species included in the stem count were documented to occur uniquely at the habitation sites.

3.5.2 Plant Biodiversity

The floristic survey of the vegetation within the 540 quadrats at these 20 sites provide data to support the hypothesis that the control sites and the habitation sites have different species richness and abundances. The plant communities found on the control sites and habitation sites were significantly different at all layers analyzed and at all distances, except for the shrub layer, which was not significantly different when analyzed in the front 36 m of the transect (Figure 2 and Figure 3). Patterns within the shrub layer may be more difficult to detect due the sampling technique employed, which could potentially skip over shrub clusters; the larger spacing on quadrats was selected to get great site coverage though it could have resulted in smaller scale patterns being overlooked. Overall, the plant communities of the habitation sites are characterized by some species that, in general, have higher soil nutrient requirements and generally tend to be on well-drained sites. This corresponds with the soil nutrient data and water table measures that were collected at these sites.

Although data were collected from these sites in an intensive manner, this is an incomplete inventory of the species present. More species of mosses, liverworts, and perhaps herbs and shrubs are located at these sites that were not sampled within the quadrats. A larger number of species was detected on the belt transect (e.g. berry-producing species as noted in the results for the stem count). Other species that were not recorded in either of these survey methods were a black hawthorn (*Crataegus douglasii* Lindl.) – another fruit producing species that was noted at EkTa-38 (Starfish Island), fairyslipper (*Calypso bulboso* (L.) Oakes) at several of the sites, and sea-watch (*Angelica lucida* L.), among others. Also, contrary to some other shell midden vegetation surveys where the sites are found to be prone to exotic species (Karalius & Alpert, 2010), none were found on these sites. Although there are such species found on the Central Coast today (e.g. English Ivy, *Hedera helix* Rutherf.), perhaps the relative isolation of the study sites protects them from being colonized by introduced species, despite soil and site conditions that could meet the requirements of these plants.

The explanatory variables considered in this analysis, and the results of their relative importance in influencing the plant community composition confirms the initial hypothesis that site history is important to consider. The treatment type of the site, whether it was on a control or habitation site, was a variable that was in five of the eight top models generated from these analyses. As well as highlighting site history, the results also emphasize the importance of considering environmental variables at the same time. For example, canopy cover was found to be a top variable for six of the eight PCAs (only the shrub layers did not include this variable in the models). Canopy cover has the capacity to determine what amount of light (and heat) gets through to the understory and influences other variables in this way. An example of this is its potential to modify soil moisture (e.g. Joffre & Rambal, 1993). This variable plays a key role in the canopy gap dynamics which is the dominant disturbance regime in the CWHvh2 zone (Daniels & Gray, 2006).

Vegetation changes with distance from shore determined by site type

The pattern that emerges from plotting the average PC1 scores at each distance from shore surveyed is different between the two site types. When considering the ground and herb layers and all layers together, the slopes of the average values at the control and the habitation sites are significantly different. The habitation sites, in general, have slopes that are relatively unchanging in comparison to the control sites, staying within a smaller PC1 loading range throughout the full distance of the transect surveyed (Figure 4-7). This can be interpreted as an indication of a more similar species assemblage throughout, which in turn can be viewed as a reflection of the site qualities that enable the presence of such species, such as higher nutrient levels and improved drainage. Essentially, the habitation sites stay dominated by nutrient rich indicator species for the full transect distance. These results, along with the species richness results (where habitation sites were found to have significantly lower average species richness at all plant layers considered) suggest that these sites with shell middens may have a homogenizing effect, creating simpler, more even sites. In contrast to the habitation sites, the PC1 loadings of control sites change with distance from shoreline towards species assemblages that are characterized in general by lower nutrient requirements and more poorly drained soils. These species are known to be characteristic of the Coastal Western Hemlock zone. The shrub layer, although significantly differing across the two site types (i.e. control or habitation site) when considering the entire transect, does not display the same strong difference in slope.

These differences in the way the site types change with distance from shore may be indications of the capacity of habitation sites to resist successional shifts. Succession, as explained by Banner et al. (2005: p.47), is the "change in species composition and cover of plant communities over time, ultimately leading to a climax community or relatively stable vegetation type." Through the analysis of pollen records, researchers have been able to quantify successional shifts occurring over long time periods. In this region, the dominant successional trend is a shift from a pioneer forest to a productive forest type, then to one that is lower in productivity, and finally to a bog woodland (or open bog and sometimes back to a forest) (Banner et al., 2005). These changes are facilitated by the dynamics and build-up of organic matter, which accumulates when decomposition is hindered. This can occur with higher levels of pH and water saturation. The invasion of *Sphagnum* spp. is noted to be characteristic of these further successional stages and was characteristic of the control sites in this study.

Although the directionality of succession from productive forest type to a bog type environment is facilitated by the environmental conditions present, there are also natural inhibitors to these processes. Some examples are the processes associated with rivers and streams, the uprooting or breaking of trees, and landslides – all of which can expose soil horizons and disrupt the accumulation of organic matter at small or large scales, slowing paludification and the general shift of productivity (Banner et al., 2005). Along with the natural causes, human-induced disturbances are a retarding factor in these processes, which may be incorporated into the understanding of why these sites maintain similar species assemblages with distance from shore. Earlier land management practices, such as cultivation in its many forms (Deur & Turner, 2005), were an integral part of First Nations' activities as they domesticated their landscapes. Cultural practices such as prescribed burning, digging, and tilling, and the shells of the middens, and fish remains, and charcoal (among other things that might be placed around berry bushes) would have influenced the soil and hydrological regimes within the sites. These would have paralleled natural disturbance impacts, but with greater repetition at these sites. With these surveyed sites used as early as 13,200 years ago, human activity could be a contributing factor to their perceived resistance to this successional trajectory.

3.5.3 Soil Characteristics

The results from the steel-rod oxidation measures show a significant difference between the water table levels at the habitation sites (within the shell midden zone) and the control sites ($p=0.017$). Rusting levels were deeper on the steel rods within the shell middens zones, indicating a deeper level of aerobic activity and a lower water table level, on average, at these sites. The hydrology of a site is often a defining feature, and site water qualities vary in terms of movement, or lack thereof, and also in the overall table depth within the soil column. Water table levels can affect plant community structure and function in myriad ways. For example, a well-drained site would allow for a better oxygen supply, enhancing growth to most species and deterring potential toxicity within acidic soils (Brady & Weil, 2002). Water table levels can influence nutrient cycling, microbial activity, fungal disease infestations, and overall breakdown of organic residues, which is inhibited by anaerobic conditions (Brady & Weil, 2002). The conditions created by either extreme can favour some species while hindering the growth of others.

These findings raise questions concerning site selection by the people who first inhabited the area. Did they select the sites because they had a tendency to drain well, or are the drainage qualities that I observed a result of human occupation alone? Perhaps other qualities led to their selection, and over time, the desirable qualities emerged, making the sites more and more appealing for the following generations (Cannon, 2003). This idea of site development can favour incidental accumulation as well as Blukas-Onat's (1985) Community Engineering Model, which posits that people moved shell middens purposely, acknowledging the qualities of this material, and using it for everything from house flooring material, to agricultural purposes (in the post-European period).

The soil nutrient analyses indicate several differences in the collected samples between the two site types, which can be understood given the pH which can be a determining factor for most elements and the cation exchange capacity. This, in turn can influence which species are able to grow or which ones are not. In this case, there is a significant difference in the pH levels between the habitation and control sites ($p<0.05$) with the habitation sites having a value closer to neutral on average.

The micronutrients B, Mn, and Zn examined in this analysis were found to be higher within the shell midden zone within the habitation sites. This difference is expected because the acidic soils of the control sites can be prone to leaching nutrients (Brady & Weil, 2002). The level of the exchangeable Fe cations – the actual available levels of these nutrients – was also analyzed and was found to be higher on the control sites. This is expected as soils that are imperfectly drained often have more availability of Fe, and overall, the solubility of iron at a more basic state is lower; iron toxicity can occur below a pH of 4 in these anaerobic conditions (Brady & Weil, 2002). Sodium has also been shown to be important for certain plant species and was elevated in the shell midden soils, but was found in similar quantities at both site types in its exchangeable form. In an environment with less leaching, Na is also retained and can help to deter acidic cations from becoming more prevalent (Brady & Weil, 2002). Overall, the narrow range in which these nutrients are optimal may make these differences between the site types the determining factors for which plants will flourish. Overall, the marginally acidic soils of the shell midden on the habitation sites allow for more solubility of these nutrients than the soils of the control sites.

Macronutrients were also affected by the different soil histories presented. These effects can be seen in the results for Al, Ca, and P. Of significance, the exchangeable (available) Al was significantly higher on the control sites. Despite the variability inherent in plant species to avoid the detrimental effects of aluminum toxicity, this higher level may exceed the threshold for harmful effects on some species. This nutrient plays a strong negative role within acidic soils by binding with P, blocking Ca sites, and interfering with N cycling within the soil solution (Brady

& Weil, 2002). This is part of what curtails P in acidic soils, along with the other elements that bind with Ca as well, which is reflected in the results. Phosphorus is an element that is sometimes linked with human habitation sites, as horizons are often enriched with it (its source can be remains of shell and bone). The effect of pH depends on the type of P present, but soils that are more neutral will have this element maximally available (Brady & Weil, 2002), which is reflected in the results.

Ca (in both its exchangeable form and overall) is found at greater levels at the sites with shell middens owing to the release of elements as the shellfish remains (among other materials) dissolve. Overall, when soils have high cation exchange capacities, the cations are less likely to be leached (Brady & Weil, 2002). The higher levels of inorganic C ($p<0.05$) on the habitation sites within the shell midden soil samples can further be attributed to the breakdown of the shell deposits.

The results from this study are in agreement with other shell midden soil analyses, generally finding an increased level of many nutrients, pH, and exchangeable cation capacity – all of which can influence plant growth (Cook-Patton et al., 2014; Smith & McGrath 2011; Sawbridge & Bell, 1972). The complexity of the habitation sites due to variable site histories makes it difficult to generalize and qualify all of the findings. As each site is restricted to three samples, I am limited in my understanding of the sites. By chance I may have landed on some areas where deposits were accumulated continually, while others had irregular use, and still others may have deposits solely near the surface. Despite these challenges, the results provide a general understanding of the trends within these soils at these two site types.

3.5.4 Indicator Species, Food Plants and Culturally Significant Species

My census of CMTs was limited in scope because it was concentrated within the three 10 x 72 m areas that the belt transects covered at each study site. Consequently it can be expected that there could be other CMTs at each site that were not recorded. Modifications could also be missed if scars were to be overgrown or disguised beyond recognition (e.g. if the primary part of the tree rotted away, leaving just the healing lobes); this could lead to an under-representation of the intensity of harvest of materials from trees. Despite these challenges, I was able to document a large number of CMTs, all of which appeared to be bark-stripped trees (I did not observe any aboriginally logged trees, or tree ownership marks within these areas). I surveyed a total of 90

CMTs, with just under 95% of these being western redcedars and the other 5% represented by three other species. This disparity can perhaps be attributed to differing abilities of tree species to preserve their modification based on differing life histories. Alternatively this could be due to recording bias: as an observer I may be more expectant of western redcedar trees to be modified, resulting in an unbalanced intensity of scrutinizing this species. Another more likely option is that these numbers are appropriate and the dominance of this species can be attributed to it being central to technological and cultural requirements for many First Nation groups on coastal British Columbia (Stewart, 1984). Also known as the "tree of life," this revered species has been called a cultural keystone species (Turner & Garibaldi, 2004), noted for its geographical expansion being closely linked to population growth and cultural tool advances (Hebda & Mathewes, 1984). Other species were (and are) harvested from to meet diverse needs beyond bark collection. Some examples include harvesting and modifying trees for medicines, food, pitch, tool making, fuel, spiritual purposes, ownership, and trail marking (Lawrie, 2001, p. 59).

The data collected also reveal the spatial distribution of the CMTs, which can significantly inform cultural understanding at regional scales or larger, such as within the Pacific North West (Mobley & Eldridge, 1992; Turner et al., 2013). Sites with high numbers of CMTs can be referred to as tree resource area sites, or forest utilization sites (Haggarty & Inglis, 1985). This could have legal implications regarding site preservation (see Guujaaw, 1990, as cited in Stryd & Eldridge, 1993). The CMTs in this study were recorded at all distances from shoreline along the belt transects (72 m) and did not show an overall trend in location on the site. This corresponds with a Meares Island (BC) study that found CMT density to vary along the coast (Stryd & Eldridge, 1993). In the Meares Island study it is also noted that the bark-strip trees are not found with the trees that were aboriginally logged, or had planks removed; this is attributed to the different tree types (e.g. size, age) that these resource gathering practices would have been associated with, which would maybe be in stands together (Stryd & Eldridge, 1993), and may be an explanation for why we did not encounter these other modifications. The modifications that I observed were principally healed lines, or creases (39.4%), which can occur when the lobes grow to cover the scars, hiding the stripping scar (Stryd & Eldridge, 1993). The most common non-healed modification was the triangular strip (34.6%), which is the most common bark scar on the coastal region of BC (Stryd & Eldridge, 1993) (as opposed to other modifications, such as boxstrips, which have been suggested to occur primarily inland (Eldridge, 1988, as described in Mobley & Eldridge, 1992)).

Although the overall count of modifications and number of CMTs was greater on the habitation sites, some of these sites (and control sites) had unique qualities and countered the overall trend. For example, on EkTa-38C I recorded 15 CMTs – the greatest number found on a site, control or otherwise. On ElTb-1, an intensely used site dominated by Sitka spruce trees, I did not document any CMTs within the belt transects, however immediately adjacent to the area that was surveyed, I came across a large stand of CMTs with bark-strip modifications. This demonstrates that the configuration and surveys of the belt transects were not able to sample all trees present. Despite my best effort to find areas that were not occupied or used historically, I encountered CMTs on almost all control sites; this highlights the highly modified nature of this landscape. Further research and documentation of these CMTs will be limited as these living examples will persist for a finite amount of time.

Along these same belt transects, we gained insight into other culturally important species. Based on archaeological reports and informal observations I expected unusual densities of fruit-producing plant species (e.g. Cockett, Cook, & Madsen, 2013; McLaren & Christensen, 2013; Pomeroy, 1980). Such species have led to the discovery of habitation sites due to their conspicuous colouration, for example, with the light green, clustered leaves of thimbleberries (McDonald, 1969, as cited in Pomeroy, 1980), a known cultivated plant species of the Coastal First Nations' (Deur & Turner, 2005). All fourteen species surveyed are recognized by the First Nations of the Central Coast for various uses; nine of these were found to be present more often on the habitation sites than the controls (Figure 17).

Differences in stem counts between the control and habitation sites are not significant for any species surveyed, except for black gooseberry, which has significantly more stems recorded on habitation sites, and Labrador tea, which has significantly more stems recorded on control sites. Despite some of these species occurring uniquely on the habitation sites (Saskatoon berry, black gooseberry, cascara, black twinberry, five-leaved bramble, stink currant, and thimbleberry), their presence is not consistently found on this site type. Only salmonberry, oval-leaved blueberry and red huckleberry were found on over 50% of the habitation sites surveyed. This can perhaps be attributed to certain sites differing in site use: some may have been primarily resource gathering sites, used only during the spring and summer months, cultivated using fruit producing species. For example, EjTa-38 has ten of the species surveyed present, and a smaller shell midden zone (relatively), suggesting that it could have been occupied seasonally when the fruit producing species could be harvested from. All species recorded are within their normal geographic ranges; however it is possible that some species ended up in these locations due to transplanting efforts – a noted cultivation practice in the Pacific Northwest (Deur & Turner, 2005; Turner et al., 2013). The variety of these species occurring within these compact areas surveyed at the habitation sites suggest that they could be landscape legacies, remnants from one-time managed berry gardens. Overall, the multivariate analysis of the stem count data shows that, when considering all of these culturally significant species together, the habitation sites are more similar to each other than to the control sites

Berries were and still are an important food source for the First Nations of the Pacific Northwest, where they are harvested and preserved for the winter months. New spring shoots from some berry plants (e.g. salmonberry and thimbleberry) were also an important part of the diet, particularly after winter (Turner et al., 2013). Ownership and boundaries of harvesting areas would have been known and understood to belong to certain people, which in some cases, if contravened could be punished with death (N. Turner, personal communication, May 2015). Knowledge of the uses of plants and culture surrounding plant use has helped to shift the current literature from the long-standing idea of the hunter-gatherer society defining the people of the Pacific Northwest towards one that recognizes the important role of plants. Cultivation is part of this relationship, and can be described by Deur and Turner (2005) to be a "peoples' repeated or intentional manipulation of both plants *and* their environments as a means toward plant resource enhancement." This encompasses a wide range of activities which include, but are not limited to, prescribed burning, transplanting, weeding, selective harvesting, tilling, mulching, altering the drainage, and creating plot boundaries (see Lepofsky & Lertzman, 2008). These activities could contribute to the mosaic type environment on these sites. Support for cultivation on these sites can be found as evidence by archaeobotanists, with fire scars, pollen samples, nutrient elevations, and plot markings, among others (Lepofsky & Lertzman, 2008). The extensive shell middens on the habitation sites could also have been part of the cultivation, by providing a beneficial soil structure with greater drainage for berry production, or growth of edible shoots; this could have been incidental or placed intentionally, enabling these persisting microcosms (Blukas-Onat, 1985).

These species surveyed are also plants that can provide indications of site characteristics, such as soil nutrient content. The three species that were present on more control sites than habitation sites were oval-leaved blueberry, skunk cabbage, and Labrador tea. The latter two species are indicators of wet, water collecting sites (Klinka et al., 1989), which aligns with our results that indicate higher water table levels at control sites. Labrador tea, as well as oval-leaved blueberry, is an indicator of nitrogen poor soils, which is often a characteristic of these acidic, mor soils of the CWH zone. Overall, the stem counts and CMTs recorded along these belt transects provide further support for the recognition that these habitation sites are in fact different from the surrounding landscape.

3.5.5 Overview of Results and Conclusion

This study highlights the importance of considering land-use history when observing the ecology of a site. Globally, long-term pre-historic site use legacies can be detected from a variety of activities and on different temporal and spatial scales. This study suggests that human activities over millennia have left a legacy on the landscape. The habitation sites surveyed in this study differed from the control sites in terms of species richness and abundances. The soils were overall more nutrient rich and less acidic, and the water table levels were found to be lower within the shell midden zone at the habitation sites. The habitation sites also have a greater number of CMTs, and have culturally significant species that were found uniquely on these sites (including five fruit-producing species).

The anthropogenically determined qualities of these sites do not act alone in shaping the sites, as can be seen in this study. Along with the impact of human occupation, it is important to consider the modern environment – the impacts of climate, new disturbances, successional pressures, the cumulative effects of the breakdown of the shell midden material, the location of the site, and the hypermaritime conditions. This intersection of place, history and environmental factors all weigh in to determine the site ecology.

The fate of these habitation sites cannot be predicted with certainty. In a general sense, they will continue to be protected as they lie within the Hakai Lúxvbálís Conservancy, and they are also protected by law under the Heritage Conservation Act. This discounts, to some degree, further human influence; however natural shifts prompted by various disturbance agencies could further alter the sites over time. Ecological research on these sites can continue to incorporate archaeological knowledge as a tool for interpretation of these sites. The more detailed our knowledge is about these sites, the more one can add to the statistical models to understand the complex contributions towards the overall site ecology. Overall, the investigation of habitation sites can provide insight into past cultural practices, and a greater understanding of why the present-day ecology is the way it is.

Chapter 4: General Discussion

4.1 Overview of Results

Humans have been present on the Central Coast of BC for over 13,000 years, with records of continuous occupation dating over 10,000 years (see Cannon, 2000; Carlson, 1979). New studies are extending these dates even further into the past (e.g. the research of D. Fedje, R. Mathewes, and D. McLaren). This long-term occupation has created a landscape with lasting legacies which can be seen throughout the region. With this research I add further understanding of these legacies by acknowledging the effect that human activity has had on present day ecology, specifically the plant communities on recognized habitation sites. These habitation sites with their known extensive shell middens are different from the control sites that do not have shell middens or a history of occupation, in terms of species presence, richness, and overall composition. Water table levels, soil nutrient levels and physical qualities differ within the shell midden zones of these habitation sites when compared to the control sites. This research also shows that the plant community assemblages that characterize the habitation sites change differently with increasing distance from the shore, compared to the changes of the species assemblages of the control sites. Culturally modified trees (CMTs) were more common (though not significantly different) on the habitation sites surveyed, and also contained fruit producing species that are not present on the control sites, potentially indicating legacies from past resource gathering areas. Overall the processes that shape these community assemblages characterizing these sites are combinations of the site history (the intensive long-term human activity) and the present day environmental factors.

4.2 Methodological Strengths and Weaknesses

With this project I have been able to provide a unique contribution in this field of research. As mentioned earlier, this is one of only a few research projects to attempt to use control sites to evaluate shell midden and habitation site qualities, and the first to do so in this region. This study design posed the largest challenge during the fieldwork as the control sites were evaluated while on-site; this was done by locating sites with similarity in slope, aspect, cover, and elevation. The control sites also needed to be without shell midden material and to be unlikely candidates for human occupation. It is acknowledged that this area in general is in fact a highly modified landscape, which made it impossible to ensure that a given appropriately selected control site had no history of use. Therefore I cannot claim the control sites to be "untouched," but only that evidence of habitation, most notably in the form of shell middens, was not present. The CMTs identified even in the control sites are themselves evidence of human presence.

Another challenge that I faced was obtaining height estimates of the CMTs that were located on the belt transects. Although I had a hypsometer to work with, I generally estimated the heights because the dense nature of the forest canopy often would not allow the tool to find the top of the tree, its target. I also did not add an item to provide scale to each photo.

This research would have also been strengthened with the inclusion of interviews with community members from the Coastal First Nations in this region. Although the major human influences on the sites and site use and occupation may have occurred before living memory, the significance of these sites may still be well known to many.

Strengths from my field season include the inclusion of ten site pairs, which helped to paint a general picture of habitation sites on the Central Coast; repetition of the quadrats at the same distances from shore allowed for simplicity in the field and advantages when evaluating the effects of distance from shore on vegetation communities; and the ability to collect both soil and leaf samples and obtain water-table data, which enabled a greater understanding of the fate of the shell midden-derived nutrients and the overall influence of site characteristics.

4.2.1 Other Limitations and Challenges

A primary limitation in my research was that I could not be certain of the shell midden boundaries due to their inherent complexities. Not only do shell middens tend to be patchy at the surface layer, but also the depth of the shell middens vary. For example, a survey by Cannon (2000) revealed a habitation site's cores to have shell midden deposits with depths ranging from 1 m to 4.5 m. Within a single habitation site, one area may have been used in a certain manner for many generations, but perhaps at some point had a different purpose; this would create the possibility of a break in deposits at that location, while other locations could be continuing to accumulate shell midden-forming material. The reasons for these changes would be difficult to interpret and could have either cultural or environmental motivations (Cannon, 2003). Other activities on the site could act in conjunction with the shell midden material (e.g. cultivation sites using fertilizer), adding to the complexity of understanding the ecological implications, with variation linked to the site size (Whittaker & Stein, 1992).

As well as understanding the activities on these habitation sites, interpretation of the overall timeline relative to ecological succession is a challenge because of this patchiness. Despite the technology to obtain cores to learn about the layering of the shell middens being available and effective (e.g. the Environmentalist's Sub-soil Probe used in Cannon, 2000), the heterogeneity of the sites could still allow for cores that do not give a definitive picture of site use. Moreover, it is not an option to infer site occupation and use based on neighbouring sites, as it has been found that there is a great range of initial human site use in this region (Cannon, 2000). Without this knowledge, it is difficult to lump the habitation sites together within a study like this one without raising questions about whether one is comparing "apples to oranges." This problem was minimized by using habitation sites that were recommended by Dr. Duncan McLaren, an archaeologist, who has worked extensively within this region, where both intensive and non-intensive site use occur.

Adding to this dilemma is the general disinclination of archaeologists to radiocarbon date the upper layers of shell middens (Cannon, 2003; D. McLaren, personal communication, April 2014); generally the focus is on dating the earliest dates of occupation (the lowest layers). I suspect this may be due to the cost of the service and perhaps because there are other proxies or sources of this knowledge available, such as oral histories, or tree-ring data. Regardless, even if this were a priority, the radiocarbon dates that would be obtained may not be indicative of the true age of the sites. Using the Community Engineering Model (CEM) to interpret habitation sites (Blukas-Onat, 1985), one can expect that shell midden materials would have been moved and used where needed (e.g. around berry gardens, houses) and understood to have certain qualities (e.g. drainage). These adjustments would create layers that would not necessarily be in chronological order. For this reason, depth of deposit is not necessarily recommended as a proxy for the duration or time of site occupation.

Despite these challenges, I am fortunate that the habitation sites included in this study have all undergone some degree of archaeological scrutiny (with useful dating from either the original surveys in the 1970s or from the recent archaeological field season in 2013 and 2014), allowing for many insights necessary for this research.

A final challenge worth mentioning is the time constraints that I faced during my fieldwork. Due to the remoteness of the study area, a considerable amount of time was needed to arrive at the field station on Calvert Island (at the Hakai Institute), and because the dates of fieldwork were parcelled into one- or two-week periods, I needed to complete my goals or risk adding additional work to future visits to the Central Coast, or losing data from time-sensitive tasks (e.g. steel rod removal). I worked within the work-day schedule of the Hakai Institute when working on Calvert, Hecate, and Starfish islands, which unfortunately did not often match well with the rhythms of my vegetation surveys. I also made the choice to survey many sites in this project, which increased the overall travel time needed to conduct fieldwork; this could be up to two hours (return) for certain sites. Navigating the challenging terrain and ocean conditions resulted in schedule changes several times and led us to work under greater time pressure.

4.3 Overall Conclusions

With surveys of ten habitation sites and ten control sites on the Central Coast of British Columbia, I have examined the complex relationship between historical land use and the ecosystems that exist today. Increases in the occurrence of most berry producing plants and of culturally modified trees were observed on the habitation sites. Decreased numbers of some plant species with high nutrient requirements were found on control sites. Trends from the analysis of soil samples taken from these sites, as well as the inferred water-table measures, were in line with the findings from other similar studies of shell middens. The associated vegetation communities differed significantly between these two site types and changed with distance from marine shoreline in different ways. The site ecology was found to be driven by a variety of influences, including the canopy, site type, topography, slope and distance from shore, with the strength of each to influence the plant community depending on which vegetation layer was in question. Through this research, the evidence suggests that the habitation sites differ overall from natural variation present off-site.

Not only do these habitation sites reveal evidence of long-term human presence and activities, but they also serve as embodiments of the sustainable philosophies that allowed for such interactions to occur over so long a time period. A great contrast between the land-use legacies of these ancient habitation sites and of contemporary habitation sites in general can be observed. Although this form of subtle land-use has created a light footprint on the landscape, it is apart from nature and ubiquitous on the landscape. It requires us to redefine what is often termed a natural, pristine landscape, to be acknowledged for what it really is: a significantly modified environment with a history of long-term, sustainable and continuous occupation and resource use.

4.4 Future Directions

This research has helped to set the stage for future investigations of the structure of vegetation communities on the Central Coast of British Columbia. The information in this thesis has the potential to—and hopefully will—affect and inform the fields of ecology, archaeology and ethnobotany, all of which overlap in this environment. A natural progression of this research would be to conduct further similar floristic studies on these same sites, but with an increased number of quadrats and transects placed at each site for greater depth of understanding at a local scale. Such studies could also be achieved using biogeoclimatic ecosystem classification (BEC) plots. In addition, further soil sampling would help understand how soil qualities change with distance from shore. Overall, more samples would increase the confidence in obtaining representative samples from this mosaic-type environment (see 4.2.1). That said, the samples that I was able to collect under Dr. Duncan McLaren's archaeological permit were very helpful in this project, and for that I am grateful.

Future archaeological research would be able to complement this study as well. Details regarding the shell midden dimensions (and irregularities) and other site qualities (such as dwelling locations, hearth sites, kitchen areas, and fertilized berry gardens) will add to the interpretation of the data from each site. Collecting radiocarbon dates from the uppermost shell midden layers, as mentioned in section 4.2.1, has been less of a priority when compared with dating the layers associated with initial settlement; this is unfortunate, as such dating would help with interpreting the ecological legacies of these sites. Despite the findings of Sawbridge and Bell (1972), who did not find a correlation of vegetation and site age in their study plots, this dating is potentially an avenue that could still be explored and would allow for greater confidence in the appropriateness of habitation sites lumped together for the purpose of comparison.

Furthermore, more habitation sites may remain to be discovered and surveyed within this region. In the early 1980s over 300 shell middens were located in this region (Hobler, 1982; Pomeroy, 1980 – as described in Cannon, 2000); this abundance demonstrates the incredible level of historical activity and occupancy within this region. Habitation sites that have not yet been documented may be located in less obvious locations. Cannon (2000) found a correlation between older shell midden sites and higher elevations and discusses the potential for shell middens to be found "stranded" at terraces that are some distance from the current shoreline where shell middens tend to accumulate. This, however, may not be the case in this study area as the sea level is believed to have remained relatively stable over the past 15,000 calendar years (McLaren et al., 2014).

Overall, this research represents just one piece of the puzzle in understanding the ecological and cultural mechanisms at work on the Central Coast of British Columbia. By combining the data with that from other fields, intensifying the study designs and investigating the above-noted avenues, we can build on this work and learn more about the ecological structure and functions in this diverse, culturally modified landscape.

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Appendix A – Study Sites

*Data regarding age of earliest deposits is from testing done in January 2015 by Dr. Duncan McLaren and Dr. Darcy Matthews, except for sites ElTa-21, ElTb-1, which come from Cannon (2000), and EjTa-4 from Pringle (2015).

<u>**Site Pair 1: EjTa-13 & EjTa-13C**</u>

EjTa-13
Date surveyed: May 14, 15, 16 and August 18, 2014
Orientation of transects: 78°
Distance between transects: 25 m
Age of earliest deposits: ^{14}C age BP 2070 ± 25 (15 cm)
Other notes: N/A

EjTa-13C
Date surveyed: May 25, 26 and August 16, 2014
Orientation of transects: 40°
Distance between transects: 15 m
Other notes: Garbage (tubing) found in forest near shore.

<u>**Site Pair 2: EjTa-14 & EjTa-14C**</u>

EjTa-14
Date surveyed: July 9, 2014
Orientation of transects: 260°
Distance between transects: 15 m
Age of earliest deposits: ^{14}C age BP 560 ± 25 (15 cm)
Other notes: N/A

EjTa-14C
Date surveyed: May 19, 20, and August 13, 2014
Orientation of transects: 260°
Distance between transects: 15 m
Other notes: N/A

<u>**Site Pair 3: EjTa-15 & EjTa-15C**</u>

EjTa-15
Date surveyed: May 21, 22 and August 14, 2014
Orientation of transects: 288°
Distance between transects: 15 m
Age of earliest deposits: N/A
Other notes: N/A

EjTa-15C
Date surveyed: May 23, 24 and August 14, 2014
Orientation of transects: 218°
Distance between transects: 15 m
Other notes: N/A

<u>Site Pair 4: EkTa-38 & EkTa-38C</u>

EkTa-38
Date surveyed: June 4 and August 17, 2014
Orientation of transects: 268°
Distance between transects: 10 m
Age of earliest deposits: ^{14}C age BP 3605 ± 25 (35 cm)
Other notes: High abundance of fruit producing species on this site.

EkTa-38C
Date surveyed: June 5 and August 17, 2014
Orientation of transects: 268°
Distance between transects: 10 m
Other notes: N/A

<u>Site Pair 5: EjTa-4 & EjTa-4C</u>

EjTa-4
Date surveyed: June 6, 7 and August 15, 2014
Orientation of transects: 318°
Distance between transects: 15 m
Age of earliest deposits: 13,200 BP
Other notes: Known as the House of Clams.

EjTa-4C
Date surveyed: June 7, 8, 9 and August 15, 2014
Orientation of transects: 228°
Distance between transects: 15 m
Other notes: N/A

<u>**Site Pair 6: EkTb-9 & EkTb-9C**</u>

EkTb-9
Date surveyed: July 9, 2014
Orientation of transects: 218°
Distance between transects: 15 m
Age of earliest deposits: ^{14}C age BP 2460 ± 25 (32 cm)
Other notes: N/A

EkTb-9C
Date surveyed: July 12, 2014
Orientation of transects: 218°
Distance between transects: 15 m
Other notes: N/A

<u>Site Pair 7: EkTb-1 & EkTb-1C</u>

EkTb-1
Date surveyed: July 10, 2014
Orientation of transects: 238°
Distance between transects: 15 m
Age of earliest deposits: N/A
Other notes: Signs of fire on landscape with burn scars and charcoal found in soil test pit (dug by Kira Hoffman, University of Victoria).

EkTb-1C
Date surveyed: July 11, 2014
Orientation of transects: 238°
Distance between transects: 15 m
Other notes: Difficult to find suitable control. Similar bays close by show signs of human occupation with shell middens and high densities of culturally modified trees.

<u>Site Pair 8: ElTb-1 & ElTb-1C</u>

ElTb-1
Date surveyed: July 13, 2014
Orientation of transects: 338°
Distance between transects: 20 m
Age of earliest deposits: 805-410 B.C.
Other notes: Cedar plank structure remains on site and china debris on beach. Evidence of recent camping activity on site (burn marks) - likely used by recreational kayakers.

ElTb-1C
Date surveyed: July 14, 2014
Orientation of transects: 318°
Distance between transects: 20 m
Other notes: N/A

Site Pair 9: ElTa-21 & ElTa-21C

ElTa-21
Date surveyed: July 16, 2014
Orientation of transects: 108°
Distance between transects: 15 m
Age of earliest deposits: A.D. 140-425
Other notes: Unsure if this is the same site that is documented under this borden code; potentially new site without site form.

ElTa-21C
Date surveyed: July 17, 2014
Orientation of transects: 158°
Distance between transects: 15 m
Other notes: N/A

<u>**Site Pair 10: EkTa-19 & EkTa-19C**</u>

EkTa-19
Date surveyed: July 19, 2014
Orientation of transects: 199°
Distance between transects: 15 m
Age of earliest deposits: ^{14}C age BP 2025 ± 25 (19 cm)
Other notes: Litter on site; likely stop for recreational kayakers.

EkTa-19C
Date surveyed: July 20, 2014
Orientation of transects: 223°
Distance between transects: 15 m
Other notes: High density of crab apple trees in ravine adjacent to the site.

Appendix B – Species List

Table 6. List of species found on the transects on both habitation and control sites with designations of cultural importance for First Nations groups of the Pacific Northwest of North America. Further information on most of these species can be found on the website http://www.centralcoastbiodiversity.org/.

Cultural Importance
** some groups recognize with a name and possible minor use; ** named in some language(s) and with some documented cultural use or association; *** named and moderately important culturally in one or more ways; **** named in at least several languages and very important as food/medicine/material; widely recognized*
(Designations by Dr. Nancy J. Turner, University of Victoria)

Common Name	**Scientific Name and Authority**	**Cultural Importance**	**Code**
Ground Layer			
Step moss	*Hylocomium splendens* (Hedw.) B.S.G.	*	HYSP
Kindbergia spp.	*Kindbergia* spp. (various)	*	KIND
Clear moss	*Hookeria lucens* (Hedw.) Sm.		HOLU
Lanky moss	*Rhytidiadelphus loreus* (Hedw.) Warnst.	*	RHLO
Yellow moss	*Homalothecium fulgescens* (Mitt. Ex C. Muell.) Lawt.		HOFU
Coastal leafy moss	*Plagiomnium insigne* (Mitt.) Kop.	**	PLIN
Flat-moss	*Plagiothecium undulatum* (Hedw.) B.S.G.	*	PLUN
Common fold-leaf liverwort	*Diplophyllum albicans* (L.) Dum.		DIAL
Golden short-capsuled moss	*Brachythecium frigidum* (C. M│ll.) Besch.		BRFR
Yellow-ladle liverwort	*Scapania bolanderi* Aust.		SCBO
Sphagnum spp.	*Sphagnum* spp. (various)	**	SPHAG
Large leafy moss	*Rhizomnium glabrescens* (Kindb.) Kop.	**	RHGL
Comb liverwort	*Riccardia multifida* (L.) S. Gray		RIMU
Three-toothed whip liverwort	*Bazzania tricrenata* (Wahlenb.) Lindb.		BATRIC
Cedar-shake liverwort	*Plagiochila porelloides* (Torr. Ex Nees) Lindenb.		PLPO
Palm tree moss	*Leucolepis acanthoneuron* (Schwaegr.) Lindb.		LEAC
Bazzania trilobata	*Bazzania trilobata* (L.) S. Gray		BATRIL

Common scissor-leaf liverwort	*Herbertus aduncus* (Dicks.) S. Gray		HEAD
Shiny liverwort	*Pellia neesiana* (Gott.) Limpr.	**	PENE
Bottle-brush moss	*Amphidium lapponicum* (Hedw.) Schimp.		AMLA
Peltigera spp.	*Peltigera* spp. (various)	**	PELTI
Maritime reindeer	*Cladina portentosa* (Dufour) Follmann		CLPO
Dicranum spp.	*Dicranum* spp. (various)		DICRA
Blunt-leaved moss	*Scleropodium obtusifolium* (Jaeg. & Sauerb.) Kindb. ex Mac. & Kindb.		SCOB
Ulota sp.	*Ulota* sp.		ULOTA
Neckera sp.	*Neckera* sp.		NECK
Orthotrichum sp.	*Orthotrichum* sp.		ORTH
Herb Layer			
Labrador tea	*Rhododendron groenlandicum* (Oeder) K.A. Kron & W.S. Judd	***	RHGR
Deer fern	*Blechnum spicant* (L.) Sm.	**	BLSP
Spiny wood fern	*Dryopteris expansa* (C. Presl) Fraser-Jenkins & Jermy	***	DREX
Northern maiden-hair	*Adiantum aleuticum* (Rupr.) Paris	**	ADPE
Licorice fern	*Polypodium glycyrrhiza* D.C. Eaton	***	POGL
Sword fern	*Polystichum munitum* (Kaulf.) C. Presl	***	POMU
Bracken fern	*Pteridium aquilinum* (L.) Kuhn	***	PTAQ
Parsley fern	*Cryptogramma acrostichoides* R. Br.		CRAC
Lady fern	*Athyrium filix-femina* (L.) Roth	**	ATFI
Heart-leaved twayblade	*Listera cordata* (L.) R. Br.	*	LICO
Northwestern twayblade	*Listera caurina* Piper	*	LICA
Bunchberry	*Cornus* spp. Ledeb./L.	***	COAL
Beach pea	*Lathyrus japonicus* Willd.	***	LAJA
Alaska rein-orchid	*Piperia unalascensis* (Spreng.) Rydb.	*	PLUNAL
Skunk cabbage	*Lysichiton americanus* Hulten & H. St. John	****	LYAM
Three-leaved foamflower	*Tiarella trifoliata* L.	*	TITR
False lily-of-the-valley	*Maianthemum dilatatum* (Alph. Wood) A. Nelson & J.F. Macbr.	***	MADI
Fringecup	*Tellima grandiflora* (Pursh) Douglas ex Lindl.	*	TEGR
Spleenwort-leaved goldthread	*Coptis aspleniifolia* Salisb.	*	COAS
Western rattlesnake-root	*Prenanthes alata* (Hook.) D. Dietr.		PRAL
Indian hellebore	*Veratrum viride* Aiton	****	VEVI

Orchid species	*Platanthera* sp.		PLAT
Pacific water-parsley	*Oenanthe sarmentosa* C. Presl ex DC.	**	OESA
Northern rice-root	*Fritillaria camschatcensis* (L.) Ker Gawl.	****	FRCA
Rattlesnake-plantain	*Goodyera oblongifolia* Raf.	***	GOOB
Running club-moss	*Lycopodium clavatum* L.	*	LYAL
Red columbine	*Aquilegia formosa* Fisch. ex DC.	**	AQFO
Crowberry	*Empetrum nigrum* L.	**	EMNI
Clasping twistedstalk	*Streptopus amplexifolius* (L.) DC.	**	STAM
Cleavers	*Galium aparine* L.	**	GAAP
Sea milkwort	*Glaux maritima* L.	**	GLMA
Round-leaved sundew	*Drosera rotundifolia* L.	***	DRRO
Deer-cabbage	*Fauria crista-galli* (Menzies ex Hook.) Makino	*	FACR
Twinflower	*Linnaea borealis* L.	*	LIBO
Swamp gentian	*Gentiana douglasiana* Bong.		GEDO
Pacific hemlock-parsley	*Conioselinum gmelinii* (Cham. & Schltdl.) Steud.	**(***)	COPA
Western meadowrue	*Thalictrum occidentale* A. Gray	**	THOC
Five-leaved bramble	*Rubus pedatus* Sm.	**	RUPE
Pacific reedgrass	*Calamagrostis nutkaensis* (J. Presl) J. Presl ex Steud.	**	CANU
Dewey's sedge	*Carex deweyana* Schwein.	**	CADE
Bluejoint reedgrass	*Calamagrostis canadensis* (Michx.) P. Beauv.	**	CACA
Sitka sedge	*Carex sitchensis* Prescott ex Bong.	**	CASI
Carex sp.	*Carex* sp.	**	CASP
Shrub Layer			
Western hemlock	*Tsuga heterophylla* (Raf.) Sarg.	****	TSHE
Yellow-cedar	*Xanthocyparis nootkatensis* (D. Don) D.P. Little	****	CHNO
Mountain hemlock	*Tsuga mertensiana* (Bong.) Carr.	**	TSME
Red alder	*Alnus rubra* Bong.	****	ALRU
Pacific crab apple	*Malus fusca* (Raf.) C.K. Schneid.	****	MAFU
Sitka spruce	*Picea sitchensis* (Bong.) Carr.	****	PISI
Shore pine	*Pinus contorta* Douglas ex Louden	***	PICO
Pacific yew	*Taxus brevifolia* Nutt.	****	TABR
Western redcedar	*Thuja plicata* Donn ex D. Don	*****	THPL
Salal	*Gaultheria shallon* Pursh	****	GASH
False azalea	*Menziesia ferruginea* Sm.	**	MEFE
Red huckleberry	*Vaccinium parvifolium* Sm.	****	VAPA
Oval-leaved blueberry	*Vaccinium ovalifolium* Sm.	****	VAOVAL

Black twinberry	*Lonicera involucrata* (Richardson) Banks ex Spreng.	***	LOIN
Stink currant	*Ribes bracteosum* Douglas ex Hook.	***	RIBR
Thimble berry	*Rubus parviflorus* Nutt.	****	RUPA
Black gooseberry	*Ribes lacustre* (Pers.) Poir.	**	RILA
Salmonberry	*Rubus spectabilis* Pursh	****	RUSP
Saskatoon berry	*Amelanchier alnifolia* (Nutt.) Nutt. ex M. Roem.	****	AMAL

Appendix C - Plant Guide for Archaeologists

Here are the species that were found on the habitation sites during the observational study conducted as part of this thesis. Please note: this is not an exhaustive list of species present on these sites – these are just the ones that were located within the plots surveyed. The total number of quadrats surveyed on the ten habitation sites is 270, and the column "Number of quadrats occupied" is presented as a rough measure of how common the species is. Please see the Central Coast Biodiversity website (http://www.centralcoastbiodiversity.org/) to learn more about the species of this region, and follow the links provided below for further information about the listed species. Photos for the ground level species are not provided, but the voucher specimens can be viewed upon request.

Ground Layer

Common Name	Scientific Name	Code	Location	Number of quadrats occupied	Ratio of quadrats occupied – Habitation sites: Control sites (approximate)
step moss http://www.centralcoastbiodiversity.org/step-moss-bull-hylocomium-splendens.html	*Hylocomium splendens*	HYSP	EjTa-13, EjTa-4, EjTa-14, EjTa-15, EkTb-9, EkTb-1, ElTb-1, ElTa-21, EkTa-19	126	5:9
Kindbergia spp. *http://www.centralcoastbiodiversity.org/oregon-beaked-moss-bull-kindbergia-oregana.html*	*Kindbergia* spp.	KIND	EjTa-13, EjTa-4, EjTa-14, EjTa-15, EkTa-38, EkTb-9, EkTb-1, ElTb-1, ElTa-21, EkTa-19	238	8:7
clear moss http://www.centralcoastbiodiversity.org/clear-moss-bull-hookeria-lucens.html	*Hookeria lucens*	HOLU	EjTa-13, EjTa-4, EjTa-14, EjTa-15, EkTa-38, EkTb-9, EkTb-1, ElTb-1, ElTa-21, EkTa-19	83	2:1

lanky moss http://www.centralcoastbiodiversity.org/lanky-moss-bull-rhytidiadelphus-loreus.html	*Rhytidiadelphus loreus*	RHLO	EjTa-13, EjTa-4, EjTa-14, EjTa-15, EkTa-38, EkTb-9, EkTb-1, ElTb-1, ElTa-21, EkTa-19	170	3:4
yellow moss	*Homalothecium fulgescens*	HOFU	EjTa-14, EkTb-9	3	3:2
coastal leafy moss http://www.centralcoastbiodiversity.org/badge-moss-bull-plagiomnium-insigne.html	*Plagiomnium insigne*	PLIN	EjTa-13, EjTa-4, EjTa-14, EjTa-15, EkTb-1, ElTb-1, EkTa-19	24	12:1
flat-moss http://www.centralcoastbiodiversity.org/wavy-leaved-cotton-moss-bull-buckiella-undulata.html	*Plagiothecium undulatum*	PLUN	EjTa-13, EjTa-4, EjTa-14, EjTa-15, EkTa-38, EkTb-9, EkTb-1, ElTb-1, ElTa-21, EkTa-19	109	4:5
common fold-leaf liverwort	*Diplophyllum albicans*	DIAL	EjTa-15	3	3:0
golden short-capsuled moss	*Brachythecium frigidum*	BRFR	EjTa-14, EjTa-15, EjTa-4, EkTa-38, ElTb-1, EkTa-19, EkTb-1	24	2:1
yellow-ladle liverwort http://www.centralcoastbiodiversity.org/yellow-ladle-liverwort-bull-scapania-bolanderi.html	*Scapania bolanderi*	SCBO	EjTa-13, EjTa-4, EjTa-14, EjTa-15, EkTa-38, EkTb-9, EkTb-1, ElTb-1, ElTa-21, EkTa-19	103	4:5
Sphagnum spp. *http://www.centralcoastbiodiversity.org/fat-bog-moss-bull-sphagnum-papillosum.html*	*Sphagnum* spp.	SPHAG	EjTa-13, EjTa-15, EjTa-4, ElTa-21, ElTb-1	19	4:11
large leafy moss	*Rhizomnium*	RHGL	EjTa-13, EjTa-4, EjTa-14, EjTa-	138	9:8

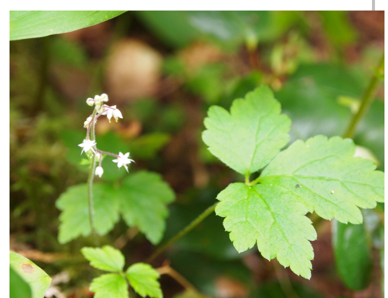
http://www.centralcoastbiodiversity.org/fan-moss-bull-rhizomnium-glabrescens.html	*glabrescens*		15, EkTa-38, EkTb-9, EkTb-1, ElTb-1, ElTa-21, EkTa-19		
comb liverwort	*Riccardia multifida*	RIMU	EjTa-4, EjTa-15, EkTa-38, ElTa-21	9	3:5
cedar-shake liverwort	*Plagiochila porelloides*	PLPO	EjTa-4, EkTa-38, ElTa-21, ElTb-1, EkTa-19	12	6:7
palm tree moss http://www.centralcoastbiodiversity.org/menzies-tree-moss-bull-leucolepis-acanthoneuron.html	*Leucolepis acanthoneuron*	LEAC	EjTa-4, EjTa-14, EkTa-38, EkTa-19	19	5:1
Bazzania trilobata	*Bazzania trilobata*	BATRIL	ElTa-21, ElTb-1, EkTa-19	13	13:5
common scissor-leaf liverwort http://www.centralcoastbiodiversity.org/common-scissor-leaf-liverwort-bull-herbertus-aduncus.html	*Herbertus aduncus*	HEAD	ElTa-21	2	2:5
Peltigera spp. *http://www.centralcoastbiodiversity.org/frog-pelt-bull-peltigera-neopolydactyla.html*	*Peltigera* spp.	PELTI	EjTa-13, EjTa-4, EjTa-14, EjTa-15, EkTa-38, EkTb-9, EkTb-1, ElTb-1, EkTa-19	58	2:1
Dicranum spp.	*Dicranum* spp.	DICRANUM	EjTa-13, EjTa-4, EjTa-14, EjTa-15, EkTa-38, EkTb-9, EkTb-1, ElTb-1, ElTa-21, EkTa-19	29	3:10
blunt-leaved moss	*Scleropodium obtusifolium*	SCOB	EkTb-9	1	1:1
Ulota sp.	*Ulota* sp.	ULOTA	ElTb-1, EkTa-19	6	2:3
Orthotrichum sp.	*Orthotrichum* sp	ORTH	EkTa-38	1	1:0

Herb Layer

Common Name	Scientific Name	Code	Location	Number of quadrats occupied	Ratio – Habitation sites: Control sites (approximate)	Photo
five-leaved bramble http://www.centralcoastbiodiversity.org/five-leaved-bramble-bull-rubus-pedatus.html	*Rubus pedatus*	RUPE	EjTa-13, EjTa-15, ElTa-21	7	7:3	
deer fern http://www.centralcoastbiodiversity.org/deer-fern-bull-blechnum-spicant.html	*Blechnum spicant*	BLSP	EjTa-13, EjTa-4, EjTa-14, EjTa-15, EkTa-38, EkTb-1, ElTb-1, ElTa-21, EkTa-19	96	3:5	
spiny wood fern http://www.centralcoastbiodiversity.org/spiny-wood-fern-bull-dryopteris-expansa.html	*Dryopteris expansa*	DREX	EkTb-9, ElTb-1, EkTa-19, EkTb-1	22	22:0	

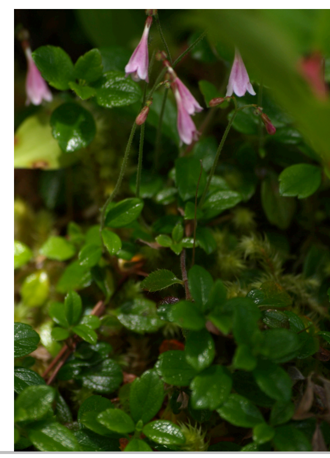
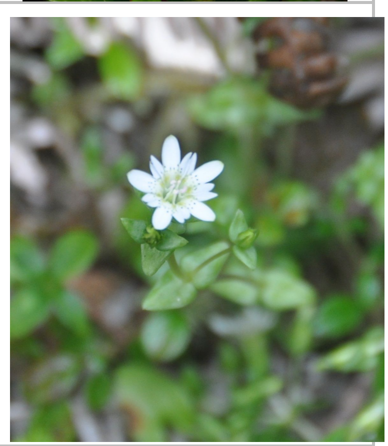
northern maiden-hair http://www.centralcoastbiodiversity.org/maidenhair-fern-bull-adiantum-pedatum.html	*Adiantum aleuticum*	ADPE	EjTa-4, EkTa-19	9	9:0	
licorice fern http://www.centralcoastbiodiversity.org/licorice-fern-bullnbsppolypodium-glycyrrhiza.html	*Polypodium glycyrrhiza*	POGL	Ekta-38, EkTa-19	2	2:1	
sword fern http://www.centralcoastbiodiversity.org/sword-fern-bull-polystichum-munitum.html	*Polystichum munitum*	POMU	EjTa-13, EjTa-4, ElTb-1, EkTa-19	10	10:1	
bracken fern http://www.centralcoastbiodiversity.org/bracken-fern-bull-pteridium-aquilinum.html	*Pteridium aquilinum*	PTAQ	EkTb-1	3	3:7	
parsley fern	*Cryptogramma acrostichoides*	CRAC	EkTa-19	1	1:0	

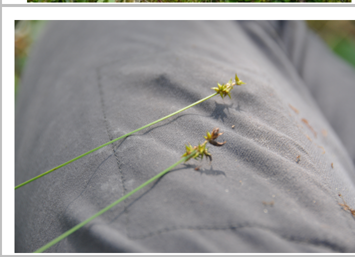
lady fern http://www.centralcoastbiodiversity.org/lady-fern-bull-athyrium-filix-femina-ssp-cyclosorum.html	*Athyrium filix-femina*	ATFI	EjTa-4, ElTb-1	2	2:0	
heart-leaved twayblade http://www.centralcoastbiodiversity.org/heart-leaved-twayblade-bull-listera-cordata.html	*Listera cordata*	LICO	EjTa-13, EjTa-14, EjTa-15, EkTa-38, EkTb-1, ElTa-21	51	5:7	
northwestern twayblade http://www.centralcoastbiodiversity.org/northwestern-twayblade-bull-listera-caurina.html	*Listera caurina*	LICA	EjTa-14, EkTa-38, EkTb-9, ElTb-1	8	1:1	
bunchberry http://www.centralcoastbiodiversity.org/bunchberry-bull-cornus-spp.html	*Cornus* spp.	COAL	EjTa-13, EjTa-4, EjTa-14, EjTa-15, EkTa-38, EkTb-1, ElTb-1, ElTa-21, EkTa-19	105	7:12	

alaska rein-orchid	*Piperia unalascensis*	PLUNAL	EkTa-38, ElTa-21, ElTb-1, EkTb-1	13	4:10	
skunk cabbage http://www.centralcoastbiodiversity.org/skunk-cabbage-bull-lysichiton-americanus.html	*Lysichiton americanus*	LYAM	EjTa-15, ElTa-21, ElTb-1	3	1:7	
three-leaved foamflower http://www.centralcoastbiodiversity.org/foamflower-bull-tiarella-trifoliata.html	*Tiarella trifoliata*	TITR	EjTa-13, EjTa-4, EjTa-14, EkTa-38, EkTb-9, EkTb-1, ElTb-1, EkTa-19	78	26:1	
false lily-of-the-valley http://www.centralcoastbiodiversity.org/false-lily-of-the-valley-bull-maianthemum-dilatatum.html	*Maianthemum dilatatum*	MADI	EjTa-13, EjTa-4, EjTa-14, EjTa-15, EkTa-38, EkTb-9, EkTb-1, ElTb-1, ElTa-21, EkTa-19	168	14:17	
fringecup http://www.centralcoastbiodiversity.org/fringecup-bull-tellima-grandiflora.html	*Tellima grandiflora*	TEGR	EkTa-19	1	1:0	

western meadowrue	*Thalictrum occidentale*	THOC	EjTa-13	1	1:0	
western rattlesnake-root	*Prenanthes alata*	PRAL	EjTa-15, EkTb-1	6	3:1	
Indian hellebore http://www.centralcoastbiodiversity.org/green-false-hellebore-bull-veratrum-viride.html	*Veratrum viride*	VEVI	ElTa-21	5	5:3	
orchid species	*Platanthera* sp.	PLAT	EjTa-15	2	2:1	
pacific water-parsley	*Oenanthe sarmentosa*	OESA	EjTa-15	1	1:0	

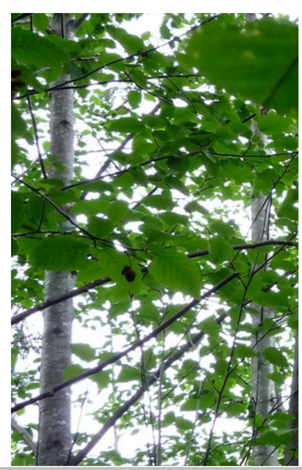
Northern rice-root http://www.centralcoastbiodiversity.org/northern-rice-root-bull-fritillaria-camschatcensis.html	*Fritillaria camschatcensis*	FRCA	EjTa-15, EkTa-38	5	5:2	
rattlesnake-plantain http://www.centralcoastbiodiversity.org/rattlesnake-plantain-bull-goodyera-oblongifolia.html	*Goodyera oblongifolia*	GOOB	EkTa-19, EkTb-1	3	3:1	
red columbine http://www.centralcoastbiodiversity.org/red-columbine-bull-aquilegia-formosa.html	*Aquilegia formosa*	AQFO	EkTa-19	1	1:0	
crowberry http://www.centralcoastbiodiversity.org/crowberry-bullnbspempetrum-nigrum.html	*Empetrum nigrum*	EMNI	EjTa-13	1	1:4	

clasping twistedstalk http://www.centralcoastbiodiversity.org/clasping-twistedstalk-bull-streptopus-amplexifolius.html	*Streptopus amplexifolius*	STAM	EjTa-4, EkTb-9, EkTb-1, ElTb-1, ElTa-21, EkTa-19	12	4:1	
cleavers http://www.centralcoastbiodiversity.org/cleavers-bull-galium-aparine.html	*Galium aparine*	GAAP	EjTa-15, EjTa 4, ElTb-1	3	3:0	
twinflower http://www.centralcoastbiodiversity.org/twinflower-bull-linnaea-borealis.html	*Linnaea borealis*	LIBO	EjTa-4, EjTa-13, EjTa-14, EjTa-15, ElTa-21, EkTb-1	59	5:8	
swamp gentian http://www.centralcoastbiodiversity.org/swamp-gentian-bull-gentiana-douglasiana.html	*Gentiana douglasiana*	GEDO	ElTa-21	1	1:5	

spleenwort-leaved goldthread http://www.centralcoastbiodiversity.org/fern-leaved-goldthread-bull-coptis-asplenifolia.html	*Coptis asplenifolia*	COAS	ElTa-21	1	1:0	
slough sedge http://www.centralcoastbiodiversity.org/slough-sedge-bull-carex-obnupta.html	*Carex obnupta*	CAOB	EjTa-15	12	1:5	
bluejoint reedgrass	*Calamagrostis canadensis*	CACA	ElTa-21	1	1:0	
Pacific reedgrass http://www.centralcoastbiodiversity.org/nootka-reedgrass-bull-calamagrostis-nutkaensis.html	Calamagrostis nutkaensis	CANU	ElTa-21	9	2:1	
Dewey's sedge	Carex deweyana	CADE	ElTa-21	3	1:1	

*All photos for the herb layer were taken by the author except for: clasping twistedstalk (Kelly Fretwell), crowberry (Chanda Brietze), western meadowrue (Heinz Baum), northern maiden-hair (Ian Cruickshank), Pacific reedgrass (Ian Cruickshank), and heart-leaved twayblade (Ian Cruickshank).

Shrub Layer

Common Name	Scientific Name	Code	Location	Number of quadrats occupied	Ratio – Habitation sites: Control sites (approximate)	Photo
western hemlock http://www.centralcoastbiodiversity.org/western-hemlock-bull-tsuga-heterophylla.html	*Tsuga heterophylla*	TSHE	EjTa-13, EjTa-4, EjTa-14, EjTa-15, EkTa-38, EkTb-1, ElTb-1, ElTa-21, EkTa-19	60	3:5	
Yellow-cedar http://www.centralcoastbiodiversity.org/yellow-cedar-bull-xanthocyparis-nootkatensis.html	*Xanthocyparis nootkatensis*	CHNO	EkTa-38	1	1:4	
red alder www.centralcoastbiodiversity.org/red-alder-bull-alnus-rubra.html	*Alnus rubra*	ALRU	EjTa-15	1	1:0	

Pacific crab apple http://www.centralcoastbiodiversity.org/pacific-crab-apple-bull-malus-fusca.html	*Malus fusca*	MAFU	EkTa-38, EkTa-19	2	2:1	
Sitka spruce http://www.centralcoastbiodiversity.org/sitka-spruce-bull-picea-sitchensis.html	*Picea sitchensis*	PISI	EjTa-13, ElTb-1, EkTa-19, EkTb-1	5	5:2	
shore pine http://www.centralcoastbiodiversity.org/shore-pine-bull-pinus-contorta-var-contorta.html	*Pinus contorta*	PICO	ElTa-21	1	1:0	
Pacific yew http://www.centralcoastbiodiversity.org/western-yew-bull-taxus-brevifolia.html	*Taxus brevifolia*	TABR	EkTa-38, ElTa-21	2	2:1	

western redcedar http://www.centralcoastbiodiversity.org/western-redcedar-bull-thuja-plicata.html	*Thuja plicata*	THPL	EjTa-13, EjTa-4, EjTa-14, EjTa-15, EkTa-38, EkTb-1, ElTb-1, ElTa-21, EkTa-19	34	1:2	
salal http://www.centralcoastbiodiversity.org/salal-bullnbspgaultheria-shallon.html	*Gaultheria shallon*	GASH	EjTa-13, EjTa-4, EjTa-14, EjTa-15, EkTa-38, EkTb-9, EkTb-1, ElTb-1, ElTa-21, EkTa-19	257	1:1	
false azalea http://www.centralcoastbiodiversity.org/false-azalea-bull-menziesia-ferruginea.html	*Menziesia ferruginea*	MEFE	EjTa-13, EjTa-4, EjTa-14, EjTa-15, EkTa-38, EkTb-9, EkTb-1, ElTb-1, ElTa-21, EkTa-19	95	19:23	
red huckleberry http://www.centralcoastbiodiversity.org/red-huckleberry-bull-vaccinium-parvifolium.html	*Vaccinium parvifolium*	VAPA	EjTa-13, EjTa-4, EjTa-14, EjTa-15, EkTa-38, EkTb-9, EkTb-1, ElTb-1, ElTa-21, EkTa-19	115	23:20	
oval-leaved blueberry http://www.centralcoastbiodiversity.org/oval-leaved-blueberry-bull-vaccinium-ovalifolium.html	*Vaccinium ovalifolium*	VAOVAL	EjTa-13, EkTa-38	3	1:2	

black twinberry http://www.centralcoastbiodiversity.org/black-twinberry-bullnbsplonicera-involucrata.html	*Lonicera involucrata*	LOIN	ElTb-1	1	1:0	
stink currant http://www.centralcoastbiodiversity.org/stink-currant-bull-ribes-bracteosum.html	*Ribes bracteosum*	RIBR	EjTa-13	1	1:0	
thimbleberry http://www.centralcoastbiodiversity.org/thimbleberry-bullnbsprubus-parviflorus.html	*Rubus parviflorus*	RUPA	EjTa-4, EkTa-38, EkTa-19	7	7:0	
black gooseberry http://www.centralcoastbiodiversity.org/black-gooseberry-bull-ribes-lacustre.html	*Ribes lacustre*	RILA	EjTa-4, EkTa-38	3	3:0	
salmonberry http://www.centralcoastbiodiversity.org/salmonberry-bull-rubus-spectabilis.html	*Rubus spectabilis*	RUSP	EjTa-15, EkTa-38, EkTb-9, ElTb-1, EkTa-19	8	8:0	

*All photos for shrub layer taken by the author except for: black twinberry (Kelly Fretwell), shore pine (Nancy Shackelford), Pacific yew (Ian Cruickshank), red alder (Chanda Brietzke), and yellow-cedar (Andrew Trant).

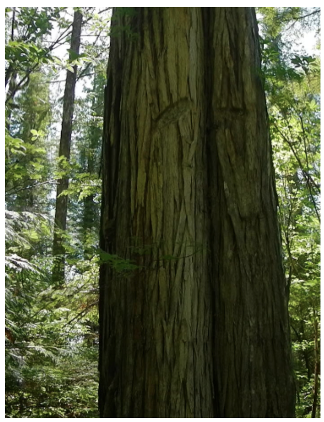
Appendix D – Culturally Modified Tree Scar Shapes


A) Columnar


B) Triangular (burned)


C) Lenticular


D) Rectangular


E) Healed

Appendix E – Statistical Analysis - Supporting Material

	PC1	PC2	PC3	PC4
HYSP	0.4511589	-0.14664883	0.06615855	-0.072762026
KIND	-0.4132476	0.20510072	0.23137852	-0.100971645
RHLO	0.2830892	0.02526287	0.61935533	-0.270951412
SCBO	-0.1777739	-0.55382539	0.16492712	-0.195301613
SPHAG	0.1861648	-0.21575766	-0.08211577	0.771084871
RHGL	-0.4037171	-0.32088697	-0.07061962	0.084172601
DICRAN	0.1143423	-0.41211108	0.52588782	0.166600431
PLUN	-0.2127518	-0.51442192	-0.25624469	-0.236785365
HOLU	-0.3409258	0.11491661	0.34703766	0.432958143
PELTI	-0.3764656	0.17853834	0.23853813	-0.004511705

Figure 19. Species loadings from PCA of the ground layer species within the first 36 m of the transect. Species included in analysis are: step moss (HYSP), *Kindbergia* spp. (KIND), lanky moss (RHLO), yellow-ladle liverwort (SCBO), *Sphagnum* spp. (SPHAG), large leafy moss (RHGL), *Dicranum* spp. (DICRA), flat-moss (PLUN), clear moss (HOLU), and *Peltigera* spp. (PELTI).

	PC1	PC2	PC3	PC4
RHGR	0.007935736	-0.19556701	0.08928548	-0.9473451421
ALL.BLSP	0.257306594	0.49992300	-0.21698893	-0.0782971949
LICO	0.111283527	0.35314618	0.47051520	-0.0061747862
COAL	0.517510420	-0.08871053	0.28694724	-0.0273743843
LYAM	0.261399402	0.12820905	-0.57183609	-0.1167365635
TITR	-0.352646190	-0.23973395	-0.33535152	0.1215584741
MADI	0.201439558	-0.59449324	-0.15594568	0.0077960279
LIBO	0.439980129	-0.37700130	0.20769319	0.2591411764
Sedge.and.Grass	0.476109117	0.09892745	-0.36648050	0.0006564672

Figure 20. Species loadings from PCA of the herb layer species within the first 36 m of the transect. Species included in analysis are: Labrador tea (RHGR), deer fern (BLSP), heart-leaved twayblade (LICO), bunchberry (COAL), skunk cabbage (LYAM), three-leaved foamflower (TITR), false lily-of-the-valley (MADI), twinflower (LIBO), and sedge and grass spp. (sedge.and.grass).

	PC1	PC2	PC3	PC4
ALL.TSHE	0.51536957	-0.11915002	0.07807487	-0.1776166
ALL.THPL	0.25787958	0.21119123	0.60349268	-0.2512662
GASH	-0.39828879	-0.13373480	0.19819880	-0.6617897
ALL.MEFE	0.49379666	0.07779811	0.05288638	-0.3787596
ALL.VAPA	0.50653911	-0.24809427	-0.34912411	0.1034165
RUPA	0.04171394	0.57269438	0.27677361	0.4018280
RILA	0.05964052	0.63606727	-0.21229871	-0.1710296
RUSP	-0.05953417	0.35093135	-0.58656556	-0.3499734

Figure 21. Species loadings from PCA of the shrub layer species within the first 36 m of the transect. Species included in analysis are: western hemlock (TSHE), western redcedar (THPL), salal (GASH), false azalea (MEFE), red huckleberry (VAPA), thimbleberry (RUPA), black gooseberry (RILA), and salmonberry (RUSP).

	PC1	PC2	PC3	PC4
ALL.TSHE	0.264063263	-0.002353402	0.128937285	-0.18680142
ALL.THPL	0.110758602	-0.113649223	-0.049027156	0.01858405
GASH	-0.075630764	0.059480215	-0.348697539	-0.15040484
ALL.MEFE	0.140208184	-0.016815986	0.093132044	-0.29626358
ALL.VAPA	0.069229321	0.011870856	0.366702923	-0.34239936
RUPA	-0.100192027	-0.238954433	0.089071292	0.22950175
RILA	-0.071514001	-0.182475999	0.061571794	0.06536620
RUSP	-0.117657813	-0.037728931	-0.085847639	-0.08046658
HYSP	0.404282911	-0.088138076	-0.092045906	-0.05986453
KIND	-0.157280719	0.128173923	0.429165932	0.10445859
RHLO	0.242563191	-0.207961900	0.144297601	-0.04194049
SCBO	-0.001590328	0.352847206	0.006427781	-0.30040934
SPHAG	0.212965353	0.097131685	-0.119787673	0.24414481
RHGL	-0.164075003	0.389019213	0.156950616	-0.04404891
DICRAN	0.238330991	0.257176699	-0.039327098	0.16033218
PLUN	-0.055538886	0.364061011	-0.148247697	-0.21596413
HOLU	-0.167407945	0.231548475	0.264867266	0.18949314
LOBA	-0.133936935	0.104763551	0.373949447	0.06339050
RHGR	0.009600556	-0.057081665	-0.027807850	-0.10527468
ALL.BLSP	0.140361225	0.187816651	-0.197860847	0.27358139
LICO	0.049002622	0.208502026	0.091940428	-0.11592720
COAL	0.373522700	0.062303312	0.097654455	-0.09826068
LYAM	0.128340651	0.249978422	-0.028622951	0.35249603
TITR	-0.223180607	-0.143768539	0.119346348	0.23568515
MADI	0.175418603	-0.170770405	0.155264886	0.13841368
LIBO	0.314565894	-0.085402292	0.335341338	0.02639203
Sedge.and.Grass	0.275628181	0.264209356	0.039855774	0.29105064

Figure 22. Species loadings from PCA of species from all layers within the first 36 m of the transect. Species included in analysis are: step moss (HYSP), *Kindbergia* spp. (KIND), lanky moss (RHLO), yellow-ladle liverwort (SCBO), *Sphagnum* spp. (SPHAG), large leafy moss (RHGL), *Dicranum* spp. (DICRA), flat-moss (PLUN), clear moss (HOLU), *Peltigera* spp. (PELTI), Labrador tea (RHGR), deer fern (BLSP), heart-leaved twayblade (LICO), bunchberry (COAL), skunk cabbage (LYAM), three-leaved foamflower (TITR), false lily-of-the-valley (MADI), twinflower (LIBO), sedge and grass sp. (sedge.and.grass), western hemlock (TSHE), western redcedar (THPL), salal (GASH), false azalea (MEFE), red huckleberry (VAPA), thimbleberry (RUPA), black gooseberry (RILA), and salmonberry (RUSP).

	PC1	PC2	PC3	PC4
HYSP	0.4478289	-0.11668547	0.17449755	-0.06358831
KIND	-0.4360782	0.17069054	0.14389354	0.09259340
HOLU	-0.3360775	0.04894722	0.18131985	0.39297546
RHLO	0.2394686	0.04516411	0.71980432	-0.25205248
PLUN	-0.2356089	-0.42505208	-0.19673284	-0.43940421
SCBO	-0.2224004	-0.47175678	0.16803328	-0.39952566
SPHAG	0.2091886	-0.41364302	-0.14269207	0.52950507
RHGL	-0.3898203	-0.37284565	0.05247596	0.15460921
PELTI	-0.3416741	0.19151089	0.41058749	0.08547269
DICRAN	0.1468245	-0.45033213	0.37311429	0.32425422

Figure 23. Species loadings from PCA of the ground layer species for the entire transect distance. Species included in analysis are: step moss (HYSP), *Kindbergia* spp. (KIND), lanky moss (RHLO), yellow-ladle liverwort (SCBO), *Sphagnum* spp. (SPHAG), large leafy moss (RHGL), *Dicranum* spp. (DICRA), flat-moss (PLUN), clear moss (HOLU), and *Peltigera* spp. (PELTI).

	PC1	PC2	PC3	PC4
RHGR	0.20629306	-0.070211935	0.1674806	-0.853244055
ALL.BLSP	0.29175852	0.382539757	-0.4455252	0.205169733
LICO	0.15812760	0.490332805	0.1903091	0.189619675
COAL	0.47680232	-0.103232897	0.2743591	0.195038891
LYAM	0.18851353	0.092567945	-0.5996161	-0.296676042
TITR	-0.34428798	-0.265354934	-0.3533971	0.002990423
MADI	0.09729391	-0.618006237	-0.2411701	0.242430058
LIBO	0.46752839	-0.369770306	0.1916009	0.089885652
Sedge.and.Grass	0.48770368	-0.002544425	-0.2875139	-0.031730007

Figure 24. Species loadings from PCA of the herb layer species for the entire transect distance. Species included in analysis are: Labrador tea (RHGR), deer fern (BLSP), heart-leaved twayblade (LICO), bunchberry (COAL), skunk cabbage (LYAM), three-leaved foamflower (TITR), false lily-of-the-valley (MADI), twinflower (LIBO), and sedge and grass spp. (sedge.and.grass).

	PC1	PC2	PC3	PC4
ALL.TSHE	0.51470765	-0.01067608	0.004444465	0.06844877
ALL.THPL	0.18794658	0.27560297	-0.535452185	-0.72015717
GASH	-0.45297860	-0.20893008	-0.044909855	-0.07189434
ALL.MEFE	0.49247905	0.11941301	0.030251391	-0.03340555
ALL.VAPA	0.46592483	-0.14091098	0.335843106	0.11586533
RUPA	-0.09506246	0.60782874	-0.253645085	0.41571437
RILA	-0.06090165	0.64396994	0.257763466	0.12551784
RUSP	-0.14898009	0.24901569	0.683206219	-0.51807890

Figure 25. Species loadings from PCA of the shrub layer species for the entire transect distance. Species included in analysis are: western hemlock (TSHE), western redcedar (THPL), salal (GASH), false azalea (MEFE), red huckleberry (VAPA), thimbleberry (RUPA), black gooseberry (RILA), and salmonberry (RUSP).

	PC1	PC2	PC3	PC4
ALL.TSHE	-0.21845606	0.10328225	-0.189445806	0.22293998
ALL.THPL	-0.13593143	-0.02323288	-0.079364113	-0.20410291
GASH	0.12961967	-0.11392170	0.374325274	0.17933363
ALL.MEFE	-0.07878961	0.08616721	-0.292909890	0.20380508
ALL.VAPA	-0.05262462	0.09099864	-0.310179937	0.31004834
RUPA	0.07680808	-0.12146401	-0.126221411	-0.29046112
RILA	0.05277263	-0.10488745	-0.106653258	-0.21243448
RUSP	0.09824619	-0.02708980	0.047674290	-0.08225833
RHGR	-0.14643538	-0.01250938	0.077150655	-0.27385112
ALL.BLSP	-0.18029531	0.21991404	0.203140535	-0.15859832
LICO	-0.07662352	0.21230579	0.151561924	0.15902460
COAL	-0.30257696	-0.02117244	-0.062756461	0.20216695
LYAM	-0.13943546	0.13056429	0.088465585	-0.23033197
TITR	0.21274563	-0.01435589	-0.254674930	-0.18458401
MADI	-0.11255275	-0.18733092	-0.331489862	-0.10052176
LIBO	-0.31470205	-0.02153777	-0.292792266	-0.01322453
Sedge.and.Grass	-0.33160488	0.25364873	0.009349256	-0.19781629
HYSP	-0.35901772	-0.17823314	0.016983475	0.23686634
KIND	0.21452935	0.21472787	-0.305246340	-0.14602109
HOLU	0.15802353	0.27522678	-0.093865995	-0.05932622
RHLO	-0.17131112	-0.19598170	-0.240593949	0.02067960
PLUN	0.06345796	0.30683641	0.128015957	0.20663455
SCBO	0.01935436	0.34869142	-0.064771500	0.25044383
SPHAG	-0.32069614	0.17885889	0.090048639	-0.26134812
RHGL	0.12671259	0.47207013	-0.104210737	-0.02513319
PELTI	0.16034404	0.15282263	-0.222174212	-0.10283610
DICRAN	-0.27146121	0.19096821	0.120490292	-0.18276326

Figure 26. Species loadings from PCA of species from all layers for the entire transect distance. Species included in analysis are: step moss (HYSP), *Kindbergia* spp. (KIND), lanky moss (RHLO), yellow-ladle liverwort (SCBO), *Sphagnum* spp. (SPHAG), large leafy moss (RHGL), *Dicranum* spp. (DICRA), flat-moss (PLUN), clear moss (HOLU), *Peltigera* spp. (PELTI), Labrador tea (RHGR), deer fern (BLSP), heart-leaved twayblade (LICO), bunchberry (COAL), skunk cabbage (LYAM), three-leaved foamflower (TITR), false lily-of-the-valley (MADI), twinflower (LIBO), sedge and grass spp. (sedge.and.grass), western hemlock (TSHE), western redcedar (THPL), salal (GASH), false azalea (MEFE), red huckleberry (VAPA), thimbleberry (RUPA), black gooseberry (RILA), and salmonberry (RUSP).

Table 7. Results from the soil nutrient testing from the samples from the habitation sites (within the shell midden zone) and the control sites for all elements analyzed with the standard error for the mean values, and the significance for each test (p-value).

Element	Measurement	Midden		SE	Control		SE	p-value
Al	**mg/Kg**	4425	±	859	4392	±	841	0.987
B	**mg/Kg**	6.63	±	0.889	2.86	±	0.338	<0.05
Ca	**%**	10.3	±	1.93	0.342	±	0.053	<0.05
Cu	**mg/Kg**	10.3	±	3.04	2.07	±	0.249	0.0908
Fe	**mg/Kg**	5692	±	1225	1379	±	268	0.0621
K	**%**	0.055	±	0.005	0.050	±	0.004	0.590
Mg	**%**	0.234	±	0.017	0.189	±	0.021	0.244
Mn	**mg/Kg**	155	±	22.4	35.1	±	6.47	<0.05
Na	**mg/Kg**	1233	±	143	482	±	37.2	<0.05
P	**%**	0.333	±	0.065	0.039	±	0.004	<0.05
S	**%**	0.116	±	0.010	0.129	±	0.012	0.599
Zn	**mg/Kg**	37.1	±	9.06	6.45	±	0.643	<0.05
N	**%**	0.770	±	0.083	0.733	±	0.070	0.827
C	**%**	29.5	±	3.09	39.7	±	3.64	0.170
S*	**%**	0.096	±	0.011	0.151	±	0.014	0.0594
Exch Al	**CMOL+/KG**	0.231	±	0.117	2.41	±	0.530	<0.05
Exch Ca	**CMOL+/KG**	46.6	±	4.31	8.65	±	1.86	<0.05
Exch Fe	**CMOL+/KG**	0.041	±	0.012	0.068	±	0.010	<0.05
Exch K	**CMOL+/KG**	0.465	±	0.081	0.562	±	0.074	0.588
Exch Mg	**CMOL+/KG**	8.75	±	1.23	12.3	±	1.76	0.287
Exch Mn	**CMOL+/KG**	0.049	±	0.013	0.045	±	0.013	0.872
Exch Na	**CMOL+/KG**	1.59	±	0.196	1.42	±	0.002	0.675
CEC	**CMOL+/KG**	57.7	±	4.85	25.4	±	2.78	<0.05
Inorganic C	**%**	5.13	±	0.602	0.645	±	0.079	<0.05
Organic Matter	**%**	48.4	±	5.70	67.7	±	5.92	0.129
pH	**--**	5.47	±	0.252	3.62	±	0.069	<0.05

*performed with combustion elemental analysis

Table 8. The similarity of percentage (SIMPER) results for testing of dissimilarity between the habitation sites (H) and the control sites (C) with stem count data. The primary species that contributed to the dissimilarity are red huckleberry (VAPA), Labrador tea (RHGR), thimbleberry (RUPA), five-leaved bramble (RUPE), salmonberry (RUSP), oval-leaved blueberry (VAOV), skunk cabbage (LYAM), Pacific crab apple (MAFU), and black gooseberry (RILA). The SIMPER results include average abundance of species (Av. Abund.), dissimilarity (Av. Dissim) and standard deviation (Dissim/SD), percent contribution (Contrib. %) and cumulative percent contribution (Cumu. %).

Species	**Av. Abund. (H)**	**Av. Abund. (C)**	**Av. Dissim.**	**Dissim. /SD**	**Contrib.%**	**Cumu. %**
VAPA	15.8	17.4	9.06	1.32	18.1	18.1
RHGR	0.22	6.63	9.05	1.01	18.1	36.3
RUPA	4.78	0	6.78	0.75	13.5	49.8
RUPE	3.38	0	4.92	0.54	9.8	59.7
RUSP	2.56	0.17	3.81	0.83	7.6	67.3
VAOV	1.29	2.97	3.5	1.28	7.0	74.3
LYAM	0.47	2.19	3.32	0.72	6.6	80.9
MAFU	1.52	1.26	3.08	1.02	6.2	87.1
RILA	1.99	0	2.82	0.71	5.6	92.7