Ecological legacies of long-term plant management along the Central Coast of British Columbia

by

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A thesis

presented to the University of Waterloo

in fulfillment of the

thesis requirement for the degree of

Master of Environmental Studies

in

Social and Ecological Sustainability

Waterloo, Ontario, Canada, 2021

AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that this thesis may be made electronically available to the public.

ABSTRACT

Quantifying long-term human impacts to landscapes allows us to understand the ways in which ecosystems respond to constant human pressure and the effects this pressure has on permanently influencing ecological processes and functions. Permanent ecosystem changes due to human activity are described as ecological legacies. As the global population steadily increases and resource demands heighten, understanding how humans drive ecosystems can contribute to the effective development of strategies that protect sensitive species and manage resource landscapes responsibly. Many modern management techniques have devastating ecological consequences, resulting in species endangerment and extinction, habitat fragmentation, and the loss of ancient cultural landscapes similar to that of the Great Bear Rainforest of British Columbia (BC). Here, the Coastal Indigenous peoples of BC have been modifying the temperate rainforests to increase food sources for hundreds, in some cases, thousands of years, enhancing the biotic potential of the Pacific Northwest ecosystem through complex, sustainable methods of management. Since before colonization, Indigenous landscape management along the Pacific Northwest Coast has supported and enhanced ecological processes and functions, proving to be significantly less destructive than management techniques practiced by commercial industries today. Though discrete in nature, ecological and Indigenous methodologies can be used to uncover the legacies of these sustainable management systems, detectable in the present-day composition of plant communities, fire occurrence patterns, and local habitat structure. As modern resource management encroaches on coastal rainforests, these ecological legacies become increasingly threatened. Localized field surveys that identify present-day distributions and spatial boundaries of edible and economic plants, as well as highlight habitat and phenotypic characteristics can help protect and uphold cultural landscapes and valued species.

The objective of this study was to collect ecological data on the distribution, community composition, ecological niche, abundance, and species richness of culturally valued plants on a set of historic islands in the Great Bear Rainforest. The overarching goal of this study is to assess if the legacy effects of long-term Indigenous management still persist in these ecological variables today and collect data on the habitat, community composition, and phenotypic traits associated with large populations of edible species. Our goal is also to determine which sections of coastline surveyed in our study hold the greatest overall cultural significance and identify populations of edible plants that may have been subject to high human management. All field research was carried out in collaboration with Indigenous community and council members. One if the goals for this collaboration was to bridge the gap between western and Indigenous knowledge and identify components that led to meaningful relationships, stronger research, and the ability to exhibit “two-eyed seeing”.

From the results of our study, we can conclude that the landscape surrounding all sampled sites holds high cultural and economic value, with higher richness and abundance of culturally valued species around places with known long-term human presence. Additionally, almost all of the plants identified in this study have some known management technique associated with them, with the highest managed plants subject to 11 unique and complex strategies. We believe our results are legacies of these management techniques traditionally utilized for thousands of years to increase productivity and richness of edible and economic plants. Data of this type will complement existing Indigenous Knowledge on the current location and spatial distribution of culturally important plants to support local Nations as they implement ecosystem-based-management strategies within their territories. In addition to the ecological data collected, pathways to work collaboratively with a diverse team of researchers who embody different ways of knowing were also uncovered. These included building trust, establishing respect, honoring diversity, communicating openly, and possessing cultural awareness. Our hope is that other research teams will reflect upon our experiences and use them as a path to guide their own knowledge collaborations.

Keywords: Ecological legacies, Indigenous management, culturally valued species, northern rice root, Pacific crab apple, estuarine root garden

ACKNOWLEDGMENTS

Though this thesis was written in solidarity, there were a great number of people who facilitated its completion.

I would like to begin by acknowledging the Heiltsuk and Wuikinuxv First Nations whose traditional land and management practices this study encompasses. Thank you for allowing me to explore your traditional methods of plant harvesting and making me feel welcome in your traditional territories. Thank you hugely to Christina and Eric and the Hakai Institute who facilitated the fieldwork portion of this thesis by providing food, shelter, and resources to myself and my field team and to the Hakai staff who offset the island fever with humor, encouragement, and companionship.

Megan Humchitt of the Heiltsuk First Nation worked tirelessly by my side for nearly 50 consecutive days in the field to collect the precious data that this thesis is built around. Thank you for standing by my side during two months of challenging fieldwork and for sharing your wisdom, insight, and knowledge with me on Indigenous plant uses, harvesting techniques, and your traditional territory. Additionally, thank you to Jennifer Walkus of the Wuikinuxv First Nation and Michael Vegh of the Heiltsuk First Nation who joined Megan and I for numerus days in the field and offered a wealth of traditional and local knowledge, as well as many laughs and great times. Your friendship alone was worth the months of hard work.

Thank you to my lab-mates, Kyle Schang and Sara Wickham and my Waterloo roommate, Angela Ross. Kyle, your constant encouragement and unwavering mental support meant everything to me during this process. Sara, aside from my friend you have evolved into my mentor. Thank you for your guidance and sharing with me your own experiences that helped me learn and grow. Angela, you were the person who made Waterloo into a home for me. Thank you for always being the one I could confide in, for providing me with relief outside my thesis, and listening to me practice many academic presentations in our living room.

Thank you to my parents, Rick and Emelia and my brother, Aaron who were massive supports throughout this process. You three have been there for me through thick and thin, always making me feel like I could do whatever I set my mind to and giving me momentum when I needed it most. Thank you also to my doctors, therapists, and specialists who supported, encouraged, and cheered me on through 12 long months of recovery.

Lastly, I would like to give an overwhelming thank you to my supervisor, Andrew Trant, my thesis committee, and the staff within the School of Environment, Resource and Sustainability at the University of Waterloo. Andrew, you provided me with the opportunities, knowledge, and resources that facilitated the completion of this thesis. Working with you and the rest of the SERS staff has been such a pleasure. You have expanded my skillset and knowledge base and given me countless invaluable experiences that will stay with me for my lifetime. Maren Oelbermann and Darcy Mathews, thank you for your role as members of my thesis committee and thank you Simon Courtenay for your contribution as my external reader. You all went above and beyond to offer your support when I needed it most and were always there to answer my questions and provide me with help and expertise. Finally, I extend heartfelt thanks to you, Nancy Turner whose wisdom and knowledge on the beautiful plants and management techniques of the Pacific Northwest was invaluable to the development of the data sets and indexes within this document.

This thesis would not be what it is without the people, First Nations, and Institutes mentioned above. I am overwhelmed with gratitude and appreciation for you all. From the bottom of my heart, thank you! Giáxsixa! Gianakaci!

DEDICATION

To Megan and Jen. I'll forever treasure our time together spent laughing in the sunshine amidst the beauty of your homelands. These days, our friendship, your knowledge, I am so grateful for.

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PREFACE

May 2017. After two years of work in the Cayman Islands I had decided to switch oceans. Swapping the warm, tropical waters of the Caribbean for those of the wild and untamed Pacific Northwest. Three flights, two van rides, and a boat trip later I stepped onto the shores of Calvert Island, territory of the Heiltsuk and Wuikinuxv First Nations. I was among one of a handful of scientists conducting research through the Hakai Institute, humbled to be granted the honor to carry out western scientific methodologies alongside Indigenous community and council members of both Nations. Within me lies a deep-rooted belief that the collaboration of western science and Indigenous Knowledge has enormous power to aid in ecological sustainability and if done correctly, contribute to reconciliation. I wanted to choose a topic that was equally relevant to both the local environment and the Nations. In order to do this however, I first had to better understand the people, the cultures, and the ecology of the coastline I was working on.

After a week on Calvert, to encourage research inspiration, my supervisor, Andrew Trant told me to "go sit in the forest and let the trees speak". The next day he left back to Waterloo, leaving me with a boat and a guy named Kyle. Kyle turned out to be cool and the trees did speak to me, but they didn't tell me enough. Thankfully, a woman, named Jennifer Walkus did. Jen was a book of knowledge, willing and eager to share stories about plants, animals, rocks, her culture, and her people. She was from Rivers Inlet and a member of the Wuikinuxv First Nation, also a member of their council. One afternoon we were cruising across the waters of Kwakshua Channel. Jen and I were locked in an engaging conversation. I was curious about her people's relationship with the surrounding forest's plants. How did they use them? Did they care for them? Which species held the highest cultural value? It was then that she showed me my first estuarine root garden and told me about Fritillaria camschatcensis. That summer I also met Megan Humchitt, a fiery Heiltsuk woman from the nearby community of Bella Bella, also a council member. Radiating strength yet softness, Megan instantly felt like a sister. Within minutes of our meeting she invited me down to the beach. We spent the night around a fire, with her husband, Simon and their dog, Salty, oblivious to the adventures that would unfold the following summer.

May 2018. I stepped off the plane in Bella Bella. Familiar faces from the Hakai Institute greeted me and I was loaded into a big white van. The year prior I was excited to see the landscape. This year I was excited to see my friends. Megan greeted me at the dock. A few months earlier we'd been chatting on social media and it became transparent who my fieldwork collaborator had to be. Not only was Megan eager to assist with fieldwork and engage in knowledge collaboration, but we had formed a meaningful relationship the summer prior and I knew we'd be the perfect team. We stepped off Bella's dock onto a boat headed for the Hakai Institute on Calvert Island. The next two months were a chaotic adventure, otherwise known as exploratory ecology. We meticulously surveyed over 60 kilometers of coastline by boat, bushwhacked rainforests so thick you couldn't see a meter in front of you, canoed through ocean swell, endured heavy rain, and overcame countless mishaps. Oh yah, we also collected a boat load of data. Jen would often join us, as well as a guy named Mike Vegh. Mike grew up around Vancouver but Heiltsuk blood ran through his body. The four of us would laugh so hard some days my "abs" were regularly sore, elated by the stunning scenery and the rich cultural history that vibrated through the landscape. You could feel the people of the past in the wind, the trees, the air, the soil. We were grateful to be there. At the end of our time together Megan came to me with a request to go out into the field one last time before we left. This time it was not to collect data but to harvest root plants! Her Auntie wanted some to cook up and eat. We excitedly chose the garden we wanted to harvest from and paid it a visit one final time. That chosen garden happened to be the very first root garden Jen had showed me the summer earlier. Talk about coming full circle.

This document is a synthesize of the data, the mishaps, and all the adventures in between from the 2017 and 2018 field seasons. It is a compilations of stories derived from generational knowledge about the people and cultures of the Pacific Northwest and about the plants that sustained them for time immeasurable. Furthermore, it is a story about a diverse team of researchers working together to bridge the gap between different ways of knowing and successfully doing just that. Though a required piece of work for a graduate degree, to me this thesis is so much more.

INTRODUCTION

Throughout time humans have interacted with Earth's natural systems for life-sustaining purposes. It is widely recognized that these interactions have had a significant impact on shaping and changing the surface of the earth as it is today (McLaren, 2018). Though humans have forever had some level of influence on landscape processes and functions, this influence has intensified with technological advancements and heightened resource demands due to overpopulation (Matson, 1997). Today, humans have such an effect on Earth's processes that there is no driver of ecological, geological, biophysical, hydro-spherical, and atmospheric change more powerful than humans themselves (McLaren, 2018; Harden et al., 2013). It is estimated that nearly 75% of Earth's ice-free surfaces have been influenced to some extent by human kind (Ellis & Ramenkutty, 2008). Human dependency on resource landscapes will only increase with the growing population, threatening the integrity of critical ecosystem and, in turn, threatening biological and cultural diversity (Watson et al., 2016). As this happens, the need for alternative solutions to manage resources and landscapes sustainably becomes more urgent than ever (Watson et al., 2016). Quantifying how long-term human pressures have shaped and changed landscapes over time, collaborating with Indigenous knowledge holders, and collecting current field data on culturally and ecologically valued species can contribute to this matter (Benner et al. 2019; Turner & Berkes, 2006).

The Pacific Northwest Coast encompasses the stretch of coastline between California and Alaska. Humans have occupied this stretch of coastline for millennia, with some of the oldest evidence of human presence in North America recently uncovered here (McLaren, et al., 2018; McLaren, Rahemtulla, & Fedje, 2015; McLaren et al., 2014). Not only have people existed in the Pacific Northwest before colonization, but they have been managing the marine and forest ecosystems using complex methods of management long before western agricultural methods were introduced (Turner, Deur, & Lepofsky, 2013; Mathews & Turner, 2017; Deur et al., 2013). Management techniques, such as clam gardens and root gardens, extended the ecological niche of culturally important, edible species, naturally increasing their productivity and resulting in higher yields (Jackley, Gardner, Djunaedi, & Salomon, 2016; Deur, 2000; Smith et al., 2019). Though there is no clear documentation of how long estuarine root gardens have been utilized for, clam garden presence has been dated back 3500 years (Smith et al., 2019). Fish traps were another marine management technique used by people in the Pacific Northwest (Moss, 2012; Jackley, et al., 2016; Langdon, 2006). These circular stone structure constructed in the intertidal environment retained fish as the tied ebbed and flowed, allowing for an easy harvest by people (Deur & Turner, 2011; Moss, 2012; Langdon, 2006). Ecological and anthropological research combined with Indigenous Knowledge confirms that legacies of human presence and management continue to persist in coastal ecosystems today (e.g., Fisher et al., 2019; Hoffman, Lertzman, & Starzomski, 2017; Jackley et al., 2016; Trant et al., 2016). As threats from modern development and resource extraction grow, documenting these ancient landscapes and the species within becomes urgent (Benner et al., 2019; Turner, Deur, & Lepofsky, 2013). Current knowledge and data on cultural plants, their distributions, abundances, and ecological environments become increasingly valuable for Indigenous Nations as they regain control over their traditional territories (Benner et al., 2019) considering the current locations and spatial extent of many culturally valued species has become unknown as a result of logging and industrial development transforming traditional ecosystems (Benner et al., 2019; Turner, Deur, & Lepofsky, 2013). Due to increasing human pressures, climate change included, there is a growing urgency to identify and document the current location of culturally valued species and places of management before modern human pressures make this impossible (Turner, Deur, & Lepofsky, 2013; Reid et al., 2014; Routson et al., 2012). Observational field data on the presence, distribution, and ecology of culturally valued species is identified as a step to reach this goal, and will provide benefits for Indigenous Nations, ecologists, archeologists, and forest managers alike (Benner, et al., 2019; Briggs et al., 2006, Turner, Deur, & Lepofsky, 2013; Franklin, Potts, Frelich, Cowling, & Marean, 2015; Lepofsky & Lertzman, 2008; Lopez-Arevalo, Gallina, Landgrave, Martinez-Meyer, & Munoz-Villers, 2011; Pesek et al., 2009; Ziembicki, Woinarski, & Mackey, 2013). The objective of this study is to quantify ecological data on the occurrence, richness, and distribution of culturally important plant species in the Great Bear Rainforest of British Columbia to complement existing Indigenous Knowledge of Coastal First Nations people. The overarching questions this research will address are 1) How have long-term human management practices influence present-day plant communities in the Great Bear Rainforest? 2) Which areas of coastline contain the highest abundance and richness of cultural species? We hypothesize that there will be differences in species richness and culturally valued plants between sites of human habitation and sites free of known human presence with higher richness on sites of human habitation.

1. LITERATURE REVIEW

The following literature review highlights issues surrounding modern landscape management and identifies alternative, sustainable methods that are supported by a wide base of long-term, generational knowledge. These alternative methodologies were developed over hundreds, some thousands of years by the Indigenous people of the Pacific Northwest coast. This review discusses the impacts these methods and this type of research could have for sustainable resource management, upholding Indigenous culture, enhancing western science, aiding in cultural food security, and contributing to reconciliation.

1.1 RESOURCE MANAGEMENT

Due to the intense demand to maximize food production to support the growing human population, over-harvesting, environmental degradation and habitat fragmentation are realities of modern-day resource management systems (Turner & Berkes, 2006). How to sustainably support the current population of humans, while assuring future generations receive similar opportunities become increasingly difficult with time. The urgency to increase the production of economically important plants has resulted in agricultural practices that are degrading and destructive to the environment. Many modern-day resource and landscape management practices threaten biodiversity and challenge ecosystem integrity and resilience, all the while, increasingly exceeding the planet's ecological limits (Turner & Berkes, 2006). While modern resource management has enabled humans to increase the production of economically valued resources, these management systems threaten natural waterways, forest function, biodiversity, air quality, and climate to name a few (Foley et al., 2005; Hoekstra et al., 2005). These consequences come not only at the cost of the environment but at a human cost as well (Cunsolo & Ellis, 2018). Ecological grief is a term that has been given to those experiencing sadness or the sense of loss due to the elimination or destruction of an ecosystem (Cunsolo & Ellis, 2018). This grief is experienced by Indigenous people not only on an ecological level but also on a cultural level as they watch cultural keystone species, which provide unique contributions to their cultural identity, economic systems, ceremonies, and traditions (Garibaldi & Turner, 2104), disappear before their eyes (Garibaldi & Turner, 2014). Since Indigenous culture is tightly woven into environmental entities, a loss in ecological biodiversity often means a loss in cultural diversity (Garibaldi & Turner, 2014). As the present-day human footprint grows, it is more important than ever that cultural values are considered in landscape management and planning to not only protect traditional ecosystems and species but to also uphold cultural diversity and well-being (Garibaldi & Turner, 2014).

1.1.1 LEGACY EFFECTS

It is widely accepted that natural resource management on both small and large scales is one of the most influential drivers of ecological change (Ellis & Ramankutty, 2008). The definition of a natural resource varies depending on the context to which it is being used (World Trade Report, 2010). However, the word "natural", refers to a good that comes from nature and the word "resource" refers to a good that is useful to humans. So, at the core its definition, natural resource refers to anything that is not human made but serves a human benefit (World Trade Report, 2010). Though characterized by the fact that they exist naturally, most natural resources require some form of human modification to be useful i.e. wood or crude oil (World Trade Report, 2010). In modern cases, heavy machinery is often involved in the extraction of natural resources, however this is not a requirement within the definition. This report discusses natural resources in relation to Indigenous stewardship. Considering that, the definition of a natural resource within the context of this paper when Indigenous stewardship is discussed is "a natural good providing benefits to the sustenance of coastal Indigenous peoples and cultures that does not require modern equipment to extract or modify".

The repetitive manipulation of earth's natural resources through long-term human management has profoundly shaped present-day ecosystems, resulting in inherent "ecological legacies" that influence the Earth's natural process and functions. These changes can also be referred to as "legacy effects" (Moorhead, et al., 1999). Ecological legacies can be defined as the "carryover, or memory, of the system with regard to past [anthropogenic] events" (Moorhead et al., 1999). Modern techniques such as chemical dispersion, land clearing, resource harvesting, and the manipulation of fire regimes and climate are examples of human-driven disturbances that have resulted in ecological legacies throughout time (Moorhead et al., 1999; Hoffman, Gavin, & Starzomski, 2016; Hoffman, Lertzman, & Starzomski, 2017; Vogt et al., 1997; Wallin, Swanson, & Marks, 1994). These ecological legacies, imprinted into the ecosystem, influence how the system shifts and responds to future disturbances (White & Pickett, 1885; Johnstone et al., 2016; Hoffman, Trant, Nijland, & Starzomski, 2018). Many landscapes globally cannot be comprehensively understood without considering these ecological legacies (Vogt et al., 1997). Legacies can drive changes to plant communities (Deur & Turner, 2011; Moorhead et al., 1999; Vogt et al., 1997), succession patterns (Deur & Turner, 2011; Kirkman et al., 1996), fire occurrence (Hoffman, Lertzman, & Starzomski, 2017; Hoffman, Gavin, & Starzomski, 2016), forest structure

(Trant et al., 2016; Wallin, Swanson, & Marks, 1994), and biodiversity (Deur & Turner, 2011; Montoya et al., 2020), while largely contributing to the extinction of up to 12,000 of Earth's plant and animal species each year (Avise, Hubbell, & Ayala, 2008).

Though the negative environmental effects of plant management have intensified with the advancements of technology, humans have long been managing economically important plants for edible, medicinal, and resource purposes. Though oral history, documented Indigenous knowledge, and scientific studies confirm that Indigenous management techniques on the Pacific Northwest Coast pre-date colonization, it is unclear exactly long these complex techniques have been utilized for as human habitation did not necessarily equal human resource management (Turner & Berkes, 2006; Deur & Turner, 2011; Deur, 2002). Historically, landscape management on the Pacific Northwest coast of BC was carried out differently, exercising sustainable methods by using innovative ways to naturally enhance important ecological characteristics without compromising the integrity of the entire system (Turner & Berkes, 2006). Though these practices left very light footprints, research indicates that the ecological legacies of long-term plant management can be detected in the ecology of ancient landscapes today (Deur & Turner, 2011). Hoffman et al. (2016) explored this phenomenon on a set of islands in the Great Bear Rainforest of British Columbia that has been susceptible to human management for hundreds, if not thousands of years (Deur, 2000; Moss, 2012). Their study concluded that human resource management played a large role in driving fire occurrences in this region of BC and that these ecological legacies play a role in driving forest structure patterns today (Hoffman et al., 2016).

1.1.2 HABITATION ON THE CENTRAL COAST

To the untrained eye, the Great Bear Rainforest of BC appears untouched and undisturbed by human activities, however, this is far from reality. Within these pristine temperate rainforests lies a deep-rooted history of human habitation (Deur, 2002; Dyck et al., 2020; Lepofsky & Lertzman, 2008; McLaren et al., 2014). This landscape has been home to Central Coast First Nations peoples for at least 13,000 years, encompassing 25 culturally distinct Indigenous groups (McLaren et al., 2018; Price, Roburn, & Mackinnon, 2009). Ecological legacies of human presence dating long before colonization can be detected in these forests making this section of the Central Coast anthropologically unique and incredibly significant (Benner et al. 2019). During the last ice age, the majority of the Central Coast experienced massive sea-level changes. The fluctuating volume of ice on the continent's mainland resulted in shifts to the outer and inner coastlines due to isostatic change; outer coastlines refer to coastlines bordering the open ocean and inner coastlines refer to those near or directly bordering the mainland (McLaren et al., 2014). The outer coastline experienced sea levels 150 m below what sea level is today and parts of the mainland coast experienced sea levels nearly 200 m above present-day (McLaren et al., 2014). The outer islands of the Central Coast, where my research takes place, however, were on what McLaren et al., (2014) termed a "hinge", meaning they were not affected by the isostatic shift and therefore sea level has remained relatively constant for the last 12,000 years (Dyck, 2020). Since sea level has remained relatively unchanged over this time, present-day archeologists have been able to uncover some of the oldest signs of human presence in North America including a footprint dating around 13,000 years before present (McLaren et al., 2018). Indigenous Knowledge and present-day archeological records document many areas along the Pacific Northwest Coast as being intensively managed by people to naturally increase the productivity of marine and coastal species prior to colonization (Deur & Turner, 2011; Turner, 2014a; Turner 2014b). Though human presence has been dated back to 13,000 years, it is unclear exactly how long culturally valued species have been managed. Sites of human presence and management will henceforth be referred to as habitation sites. Habitation sites are distinct due to the presence of a shell midden, an accumulation of cultural materials, compostable debris, and marine detritus built up over hundreds or thousands of years by the people living there, as well as more recent evidence of human resource management such as bark-stripped cedars, and high abundances of culturally managed species (McLaren, 2013; Trant et al. 2016). Deep ties to the landscape resulting from intensive resource and landscape management were missed and discredited by early colonialists and remained largely unknown to most non-Indigenous peoples due to the inaccurate depiction of these sophisticated techniques in scholarly literature and Western education (Deur, 2002).

1.1.3 HISTORICAL BACKGROUND

European settlers ignorantly assumed that there was no need for landscape or resource management along the Pacific Northwest coast, presumptuously concluding that food from the ocean and terrestrial sources was plentiful and easily accessible (Deur 2000; Deur et al., 2013; Turner, 2014). This theory transferred across disciplines and resulted in the inaccurate depiction of Coastal First Nations societies in scholarly literature for decades (Deur, 2000). As well, the argument of a non-agricultural society was used in court to disregard Indigenous land rights, forcing them out of their homes and onto reserves (Deur, 2000; Deur, 2002). The minimal acknowledgment that was given to Indigenous management referred to these systems as irrational, inefficient, and ineffective (Deur, 2002, p. 115-121). This perception was similar to the way that many other forms of agriculture in parts of Asia and Africa were perceived in scholarly literature throughout the 1900's (Deur, 2002). Because of this, the sophisticated techniques used to manage and harvest traditional root and forest gardens have received little to no attention from Western science until lately (Deur, 2002, p. 120-121). Towards the end of the 20th century, Douglas Deur (2000 & 2002) published papers revealing the complex landscape management practices Indigenous societies have been using long before colonization. Many of these practices utilizing similar techniques as the agricultural systems colonialists took credit for introducing to the West (Deur, 2000; Deur, 2002). Deur (2000) dated estuarine root gardens back to the pre-contact era, providing ecological evidence to support Indigenous Knowledge, that humans have been managing landscapes using sophisticated techniques long before European settlement. This research dismantles the over simplified and mischaracterized classification of hunter and gatherer societies, revealing that although hunting and gathering was practiced, substantial complexity and diversity existed within Indigenous food systems and economies (Lepofsky & Lertzman, 2008; Deur, 2000; Deur & Turner, 2011).

1.2 PLANT MANAGEMENT

The Indigenous people of the Pacific Northwest have been masters at utilizing their coastal ecosystem in a way that enhanced and upheld the ecological integrity of the system as a whole (Deur & Turner, 2011; Turner, Deur, & Lepofsky, 2013). The importance of resource conservation and sustainability is understood and valued by coastal Indigenous cultures (Turner, 2014). These values form the foundation for how culturally valued plants have been managed and harvested within communities (Deur & Turner, 2011; Turner 2014). Unlike modern-day agriculture techniques, coastal Indigenous cultures consider overall environmental health as an indicator of sustainable plant production (Deur et al., 2013). Careful consideration has been applied to developing innovative ways to naturally increase the production of culturally important species, while also increasing ecosystem functions and structure (Deur & Tuner, 2011). The plants managed by Pacific Northwest cultures fit into three primary categories: trees, shrubs, and herbaceous perennials (Turner, Deur, & Lepofsky, 2013). In some cases, ten or more different methods were used to manage a single species (Deur & Turner, 2011). Each species within these categories provided different cultural value, based on four categories: food, smoking, materials, and medicine (Deur & Turner, 2011).

Indigenous plant management provides much more than pure sustenance for coastal societies (Deur & Turner, 2011). It holds deep social, economic, and cultural value (Deur & Turner, 2011). Historically, it was not uncommon for chiefs to display their yearly harvest at ceremonies and celebrations, which at times were held to give thanks to the plants themselves. Certain plant species were used as forms of currency, to be traded between different Nations and gifted on special occasions (Deur & Turner, 2011). It was these sophisticated management regimes that formed the foundation for the complex social structures of Northwest Indigenous cultures which baffled colonialists when they first arrived (Turner, Deur, & Lepofsky, 2013; Deur & Turner; 2011). Since it was agreed upon amongst

European scholars at the time that agriculture was a key component to the formation of socially complex societies, colonialists were perplexed when they observed complex social systems but not traditional agricultural practices (Deur & Turner, 2011). Agriculture contributes to the development of sophisticated societies through plot ownership, status divisions, task designations, and responsibility accountability, all of which were evident amongst Pacific Northwest cultures but not the agriculture itself (Turner, Deur, & Lepofsky, 2014; Deur & Turner, 2014). Little did they know they were observing some of the very first affluent cultures on Earth and that the management of coastal landscapes had a whole lot to do with it (Deur & Turner, 2011).

1.2.1 MANAGED TREES

The culturally important trees used by Central Coast First Nations peoples contributed to their sophisticated lifestyles and allowed them to develop complex resource and landscape management techniques. Western redcedar (*Thuja plicata*), western hemlock (*Tsuga heterophylla*), Sitka spruce (*Picea sitchensis*), red alder (*Alnus rubra*), shore pine (*Pinus contorta*), and Pacific yew (*Taxus brevifolia*) were vital to Indigenous communities, gifting them wood to sculpt cultivation tools, fish hooks, canoes, homes, and even clothing out of (Deur & Turner, 2011; Turner, 2014; Zahn, Palmer & Turner, 2018; Deur, & Lepofsky, 2013). Pacific crabapple0 (*Malus fusca*) were also highly valued, providing people with fresh fruit throughout the summer months, hard wood for tools, and bark that could be used for medicinal purposes (Turner, Deur, & Lepofsky, 2013). Techniques used to manage these important tree species included transplanting trees from far away distances to increase accessibility and to introduce culturally significant species into areas where they did not naturally grow (Deur & Turner, 2011; Turner, 2014b; Turner, 2014b). It was a common practice to establish groves of trees, also known as forest gardens, to increase the abundance of species that were most significant to people (Deur & Turner, 2011; Turner, 2014a; Turner, 2014b). Selective harvesting, as well as rotational and partial harvesting, were common management techniques (Deur & Turner, 2011; Turner, 2014a; Turner, 2014b; Turner, Deur, & Lepofsky, 2013). Selective and rotational harvesting was practiced to uphold the integrity of valued populations by only harvesting from individuals and rotating the trees or gardens harvested from so that individuals or populations never faced degradation. Partial harvesting ensured individual species were not killed when harvesting occurred as this meant only a portion of the tree was taken for resource use instead of the entire tree. An example of this harvesting technique is bark stripping, where an incision is made near the base of the tree and a panel of wood is pulled off upwards along the trunk (Deur & Turner, 2011; Turner, 2014a; Turner, 2014b). The number of times a tree could be harvested in this way was limited to ensure that the tree could still survive even while providing people with a life-sustaining resource. The ecological legacies of these harvesting methods are still detectable in temperate rainforests of BC (Deur & Turner, 2011; Turner, 2014a; Turner, 2014b; Turner, Deur, & Lepofsky, 2013).

1.2.3 MANAGED SHRUBS

A diversity of shrub species also provided important economic value to First Nations peoples along the Central Coast of BC, who depended upon them for medicinal and edible purposes as well as for their scent improving qualities. Berry-producing shrubs that were valued the most by Indigenous cultures included salal (*Gaultheria shallon*), red huckleberry (*Vaccinium* *parvifolium*), salmonberry (*Rubus spectabilis*), oval-leaved blueberry (*Vaccinium ovalifolium*), and thimbleberry (*Rubus parviflorus*). Other shrubs that were utilized by people included false lily of the valley (*Maianthemum dilatatum*), false azalea (*Menziesia ferruginea*), black gooseberry (*Ribes lacustre*), bearberry honeysuckle (*Lonicera involucrata*), sweetgale (*Myrica gale*), and crowberry (*Empetrum nigrum*). Many of these plants had edible berries, providing people with essential vitamins and nutrients. Others could not be eaten as their berries were poisonous, though sometimes parts of the plant could still be used for medicinal purposes. Sweet-smelling plants like that of sweetgale were used as incense in dwellings (Turner, 2014). Indigenous Knowledge suggests that berries and shrubs were transplanted into groves to increase abundance and accessibility to communities (Deur & Turner, 2011; Turner, 2014; Turner, Deur, & Lepofsky, 2013). Often a diversity of shrub species requiring the same ecological niche would be planted together to make the management of the species easier (Deur & Turner, 2011; Turner, 2014). Patches of edible shrubs were outline and defined and ownership of these different patches was established (Turner & Deur, 2011). The discovery of highly-concentrated patches of culturally preferred plants in known traditional collection areas is said to be present-day legacies of these management techniques (Turner, 1988). Fire was also used as a plant management tool along the Pacific Northwest. Indigenous Knowledge suggests that intensive burns were conducted every few years to increase shrub and berry production as well as eliminate unwanted species (Lepofsky & Lertzman, 2008; Deur & Turner, 2011). Patches of managed shrub were fertilized with charcoal fires as well as clamshells and marine detritus to enhance soil chemistry and nutrients (Deur & Turner, 2014).

1.2.3 MANAGED HERBACEOUS PERENNIALS

A large variety of herbaceous perennials also served as critical resources to Central Coastal First Nations peoples. The root-producing perennials, northern rice root (*Fritillaria camschatcensis*), Pacific silverweed (*Potentilla anserina*), and springbank clover (*Trifolium wormskioldii*) were especially important in Indigenous societies, as they were the main source of dietary starch until replaced by the potato after colonization (Turner, Deur & Lepofsky, 2013). They were a more reliable food source than ocean animals and there are ethnographic reports of root plants saving communities during times of famine (Deur & Turner 2011). Some of the other culturally valued herbaceous perennials included Labrador tea (*Rhododendron groenlandicum*), fireweed (*Chamaenerion angustifolium*), and Pacific-hemlock parsley (*Conioselinum pacificum*). A variety of ferns were also used for cultural purposes including licorice fern (*Polypodium glycyrrhiza*), bracken fern (*Pteridium aquilinum*), and deer fern (*Blechnum spicant*). Multiple cropping, meaning planting more than one culturally important species together, was a technique used to manage herbaceous perennials. Other than the accumulation of herbaceous perennials as a means of easy access and select other techniques used to eliminate unwanted species or consolidate patches, there was little need for extensive cultivation (Deur & Turner, 2011). This was not the case for the species growing in the estuarine zone, however. The edible plants growing in the estuarine zone, from the high-water line to the edge of the forest, were subject to the highest number of management techniques and were also some of the most important and celebrated species on the Pacific Northwest coast (Deur & Turner, 2011). The discussion below highlights the cultural values and management techniques associated with these plants.

1.3 THE ESTUARINE ZONE

The estuarine salt marsh of the Pacific Northwest is said to be one of the most ecologically productive zones in the world (Deur, 2000). Here, plants receive the maximum amount of energy with a minimal amount of stress, resulting in optimal growing conditions. This zone is located high enough above the intertidal to receive only occasional saltwater inundation during times of the year when tides are at their highest. This periodic inundation of ocean water is key to the success of the plants living here, as the salt eliminates competition from terrestrial plants but is not plentiful enough to support marine species (Deur, 2000; Mathews & Turner, 2017). Marine detritus from the ocean is added to the soil during inundation periods, allowing the plants here to receive an abundance of nutrients with minimal energy output (Deur, 2002). Without management, this productive zone is relatively small, and the soil is very compact, making it almost impossible to remove rhizomes intact (Deur, 2000; Deur, 2002). Using innovative cultivation techniques, the First Nations peoples of the Pacific Northwest were able to eliminate these barriers and "in the process, harness the tremendous biotic output of one of the world's most productive terrestrial ecosystems, the mid-latitude estuarine salt marsh, in a way that has few parallels elsewhere in the world" (Deur, 2000, p. 169).

1.3.1 ESTUARINE ROOT GARDEN

The management of estuarine plants in the Great Bear Rainforest has been given little attention by Western science but Indigenous Knowledge, as well as archeological and ecological findings from coastal regions farther south, indicate that root plants were carefully managed and harvested by Indigenous people in what are known as estuarine root gardens (Deur & Turner, 2011). An estuarine root garden is a plot of cultivated soil located directly above the intertidal zone, or in an estuarine salt marsh nurturing culturally valued edible root species including northern rice root (*Fritillaria camschatcensis*), Pacific silverweed (*Potentilla anserina*), and springbank clover (*Trifolium wormskioldii*). There is evidence that some of the largest gardens, located mainly around Vancouver Island, stretched nearly 10 acres in size (Deur & Turner, 2011). These large gardens were traditionally owned by a clan and then plots of edible plants within the garden's extent were assigned to individuals or families to oversee the management. It is undeniable that without intensive human cultivation, these estuarine gardens could never have achieved the large harvests reported by ethnographic sources (Deur & Turner, 2011). Ecological legacies of estuarine root gardens still exist in present-day ecosystems, nurturing abundances of edible root plants. These gardens demonstrate that human management practices do not have to result in detrimental legacies to overall ecosystem health and highlight techniques that work with the natural environment instead of trying to control it in unnatural ways (Turner, 2014).

1.3.2 ESTUARINE CULTIVATION AND MANAGEMENT

In some areas along the Pacific Northwest coast, to maximize root production within estuarine salt marshes, people strategically extended this fertile zone outwards, closer to the high tide line (Turner, Deur & Lepofsky, 2013). They did this by piling up rocks to form walls in circular or crescent shapes and then filling the beds with newly made soil. These rock walls provided more than just structural support for the gardens. They also captured marine detritus as the tide flowed and ebbed, maximizing the organic matter retained in the bed (Lepofsky & Lertzman, 2008). This organic matter, along with other natural forms of fertilizer like shells and charcoal, was routinely pounded into the garden soil using hard sticks of wood, such as yew and crabapple (Deur, 2002). This rigorous procedure fertilized the estuarine soil and increased garden biomass, continually extending the ecological niche of edible rhizomes over time (Figure 1, Mathews & Turner, 2017; Turner et al., 2013). North of Vancouver Island, estuarine salt marshes become smaller in size. It is unknown if this technique was used in locations like the Great Bear Rainforest as there are no documented sites with evidence of rock wall structures. Root gardens here were likely cultivated in different ecological conditions, possibly using alternative methods, and trade with communities farther south may have been necessary to attain large quantities of edible roots (Deur & Turner, 2011).

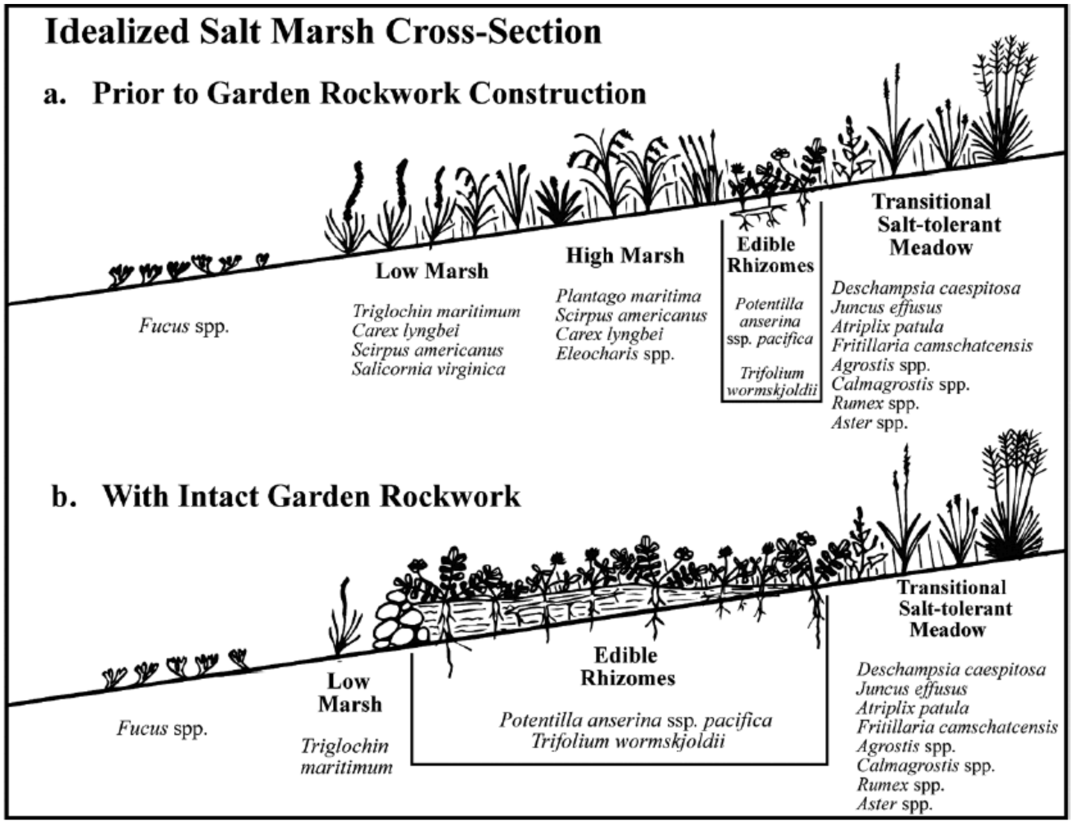


FIGURE 1. Expanding the ecological niche of edible root plants by building up rock walls

and increasing soil biomass with marine detritus within estuarine gardens (Deur, 2000, p. 174).

Sticks of hard yew and crabapple wood were used to aerate and till the soil, loosening the particles and increasing porosity (Deur & Turner, 2011). Manageable soil was an important characteristic of estuarine root gardens; without constant cultivation, it was near impossible to remove rhizomes intact from unmanaged salt marsh soils (Deur, 2002; Deur & Turner, 2011). Chief Kwaxsistala Adam Dick of the Tsawatainuk First Nation reports that for Indigenous Nations like the Kwakwaka'wakw, keeping the soil soft and porous was crucial (Deur, 2000). Chief Kwaxsistala also says that in some communities, breaking the roots during harvest was greatly looked down upon and almost seen as shameful (Deur, 2000). Elements of soil structure, including porosity and particle size were also influenced and altered as a result of traditional cultivation practices (Deur & Turner, 2011, Turner, 2014a; Turner, 2014b). Indigenous Knowledge reveals that it was necessary to annually 'turn the sod', 'churn it up' or 'fluff it up' as a means to influence soil structure (Deur & Turner, 2011; Deur, 2000). First Nations societies understood that creating an amorphous, texturally diverse soil would increase soil fertility and maximize root production (Deur & Turner, 2011).

Deur (2000) collected soil samples from inside and outside estuarine garden sites on the West Coast of Vancouver Island to test if these traditional soil management practices persisted in soil chemistry and structure today. Deur (2000) also dated estuarine gardens using radiocarbon dating. Soil from within estuarine root gardens had nearly twice the levels of nitrogen and phosphorous available and also had detectable differences in soil structure and texture, compared to soils from outside the estuarine root garden (Deur, 2000). Lloyd (2011), a master's student of Deur's, ran laboratory tests on the impact of soil cultivation on

Pacific silverweed (*Potentilla anserina*) and found a significant increase in plant productivity but a decrease in bulb size. This was not what they hypothesized, initially expecting to see increases in bulb size. They note that their results were most likely influenced by a small sample size and the methodologies used (Lloyd, 2011). Additional soil analyses on other estuarine garden sites have been deemed necessary to determine if soil management techniques persist elsewhere along the Pacific Northwest Coast (Lepofsky & Lertzman, 2008).

Aside from cultivating the soil, edible rhizomes were managed carefully to increase production and accessibility (Mathews & Turner, 2017). Once the garden beds were constructed, non-edible plants were removed and rhizomes, like Pacific silverweed, springbank clover, and Northern rice root were transplanted into the garden (Mathews & Turner, 2017). Sometimes species were transplanted from far away as a result of trade among Indigenous Nations. Root plants were also known to be given as gifts (Deur & Turner, 2011; Turner, 2014a). Species range expansion via humans was so influential in these coastal ecosystems that in some areas of the Pacific Northwest, certain species of edible plants did not exist until introduced by people (Deur & Turner, 2011). It is suspected that efforts to increase the accessibility and productivity of rhizome populations could still be noticeable in their distributions along the Pacific Northwest coast today (Lepofsky & Lertzman, 2008).

Weeding of estuarine root gardens was rigorous and occurred often to maximize space for edible root plants and prevent encroachment of unwanted species (Deur & Turner, 2011). To optimize bulb size, propagules with desirable characteristics were replanted and transplanted from garden to garden (Deur, 2002; Lepofsky & Lertzman, 2008). Indigenous peoples also used selective harvesting methods to obtain desired traits and collected seeds from the biggest and strongest plants to repopulate the gardens the following year (Lepofsky & Lertzman, 2008; Mathews & Turner 2017). These long-term modifications could persist in the genetic structure of past-managed root plant communities today (Lepofsky & Lertzman, 2008). It is hypothesized that lower genetic diversity would be present within tended populations (Lepofsky & Lertzman, 2008), similarly to commercially managed species today, such as apples (Routson et al., 2012). This theory has yet to be tested. Phenotypic changes to bulb size may also still be visible, with the expectation of homogenization between plant bulbs in managed gardens (Lepofsky & Lertzman, 2008). Kramer (2000) tested this hypothesis with camas bulbs (*Camassia* spp.) growing in gardens in the Willamette Valley of Oregon and found no significant trends in bulb sizes, though only a small sample size was studied.

1.4 CONCLUSION

It is conclusively established that plant and landscape management has been occurring for far longer than Europeans have occupied the Pacific Northwest (Deur, 2000; Deur & Turner, 2011). Instead of causing environmental harm, these early forms of management used innovative ways to support and uphold ecological integrity and resilience, resulting in systems where species diversity, richness, and productivity were enhanced (Deur, 2000; Deur & Turner, 2011; Turner, 2014a; Turner, 2014b). Much of the current documentation on traditional plant management encompasses the Pacific Northwest as a whole (Deur & Turner, 2011). Unless individual cultures are listed, we cannot assume that all management techniques were used by all Pacific Northwest cultures (Deur & Turner, 2011). To determine which techniques were utilized in which regions, localized ecological studies on plant communities that incorporate Indigenous Knowledge are necessary (Deur & Turner, 2011).

Data on the current location of cultural keystone species becomes increasingly critical as ancient landscapes face unprecedented changes due to climate change (Routson, 2012; Ried et al., 2014), resource extraction (Benner et al., 2019; Turner, Deur, & Lepofsky), and industrial development (Benner et al., 2019; Price et al., 2009; Turner, Deur, & Lepofsky, 2013). These changes threaten both ecological biodiversity and cultural diversity (Garibaldi & Turner, 2004). As lack of data on the current location of culturally valued plant species and their habitat contributes to the challenges local Indigenous Nations face to make informed decisions regarding the management of their territories, observational data from localized field surveys is a proposed method to help fill in these gaps (Benner et al., 2019; Lepofsky & Lertzman, 2008). Research of this nature will also benefit landscape and forest ecologists, historians, archaeologists and conservationists alike (Lepofsky & Lertzman, 2008). Furthermore, data on the local habitat, phenotypic characteristics, and community composition of present-day populations of edible plants like northern rice root will contribute to the protection and reclamation of culturally valued species (Zox & Gold, 2009).

1.5 RESEARCH OBJECTIVES

This study will complement existing Indigenous Knowledge on culturally valued plant species, the traditional techniques used to manage them, and present-day locations and ecological characteristics on a set of islands in Wuikinuxv and Heiltsuk territory, in the Great Bear Rainforest of British Columbia. All field research was carried out in collaboration with Indigenous community members and council member. The goal for this collaboration was to bridge the gap between Indigenous Knowledge and western science and ensure methods and protocols were carried out in a way that honored both Indigenous and western knowledge. It is our hope that highlighting the factors that led to our success will encourage the same within other teams that embody two different ways of knowing. These topics were explored through two complementary studies: *Plant Management* and *Estuarine Root Plants*.

1.5.1 PLANT MANAGEMENT

The Plant Management study explores the current distribution, richness, abundance, associated management techniques and known cultural value of herbaceous perennials, shrubs, and trees, through the following four questions:

1. **How does species richness differ between control and habitation sites?** Given, a pre-colonial history of resource management on and around human habitation sites, including the use of multiple techniques that accumulated valued plants around places where humans lived, as well as techniques that enhanced soil nutrients and biomass, we hypothesize that overall, species richness will be higher on human habitation sites in comparison to control sites.
2. **How does species richness differ between individual plots on control and habitation sites?** Given, a pre-colonial history of resource management on and around human habitation sites that removed non-valued plant species via burning, weeding, and vegetation clearing from localized areas to increase select species of value and form forest, herb and berry gardens, we hypothesize that species richness within individual plots will be lower on habitation sites compared to control sites.
3. **Which areas of coastline hold the highest overall cultural value?** We hypothesize that resource management techniques have resulted in higher richness's of culturally valued species and culturally managed species around habitation sites, thus greater

overall cultural value will be associated with sites with known long-term human presence.

4. **Is there a higher abundance of Pacific crabapple trees located around sites with known human habitation?** Given the importance of Pacific crabapple to Coastal First Nations peoples, we hypothesize finding them in groves on sites associated with long-term human presence and management. We thus predict higher Pacific crabapple abundances on and around habitation sites.

1.5.2 ESTUARINE ROOT PLANTS

To address specific research questions related to management of estuarine root plants, we ask the following three questions:

1. **What ecological characteristics are associated with populations of edible root species?** We hypothesize that the largest patches of edible root species will be associated with habitation sites, freshwater streams, and locally elevated to prevent constant saltwater inundation.
2. **What are the physical traits of northern rice root?** We hypothesize that plant management techniques may have resulted in altered growing conditions and potentially drove the selection of different plant traits and thus predict that sustained management results in taller plants high flowers numbers.
3. **What is the community composition within patches of edible root species?** We hypothesize that the community composition of edible root populations will consist of multiple species of edible root plants and an assortment of other herbaceous perennials and sedges.

2. MATERIALS AND METHODS

2.1 SITE DESCRIPTION

Data collection for this study was based out of the Hakai Institute throughout the months of May and June of 2018 in the Great Bear Rainforest of BC, within the Hakai Lúxvbálís Conservancy. The field sites in this study lie within the territories of the Wuikinuxv and Heiltsuk First Nations. The Great Bear Rainforest encompasses 25 culturally distinct Indigenous groups and around 22,000 people; half of whom are of Indigenous ancestry (Price, Roburn, & Mackinnon, 2009). This area of BC is globally significant as 25% of the world's coastal temperate rainforest remains here (Green, 2007).

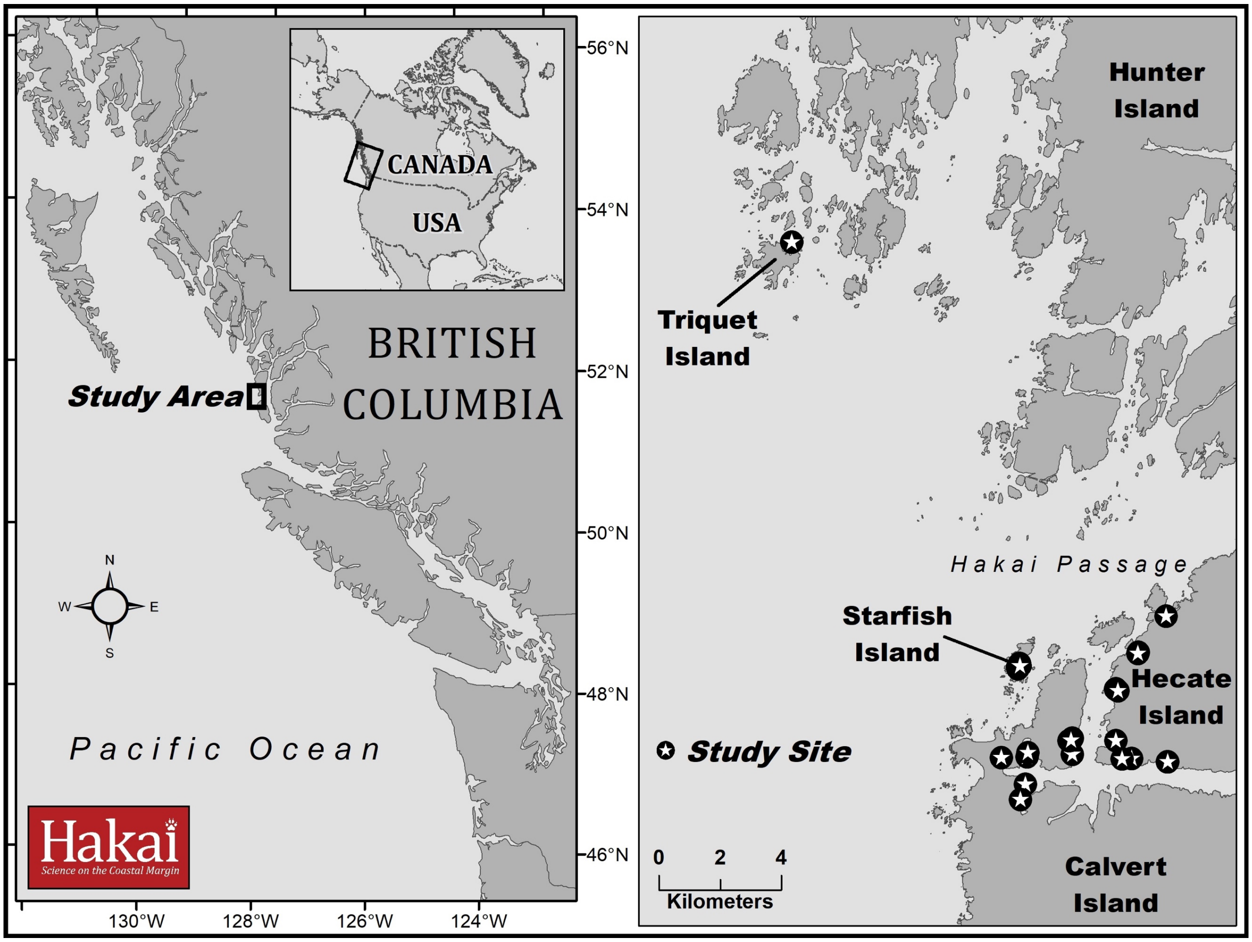


FIGURE 2. Map of the study area within British Columbia (left). Location of all study sites and islands that data was collected on during both studies is displayed on the right. Study sites are indicated by white stars. Map made by Keith Holmes – Hakai Institute.

Cool summers, and mild winters are climatic characteristics of this region. Heavy precipitation promotes temperate rainforest growth, with 3-4 meters of rain falling annually (Price, Roburn & MacKinnon, 2009). The region lies within the Coastal Western Hemlock Bio-geoclimatic Zone (CWH vh2) with all field sites in this study located within the hyper-maritime subzone (Klinka, Pojar, & Meidinger, 1991). Field sites span across Calvert, Hecate, Starfish, and Triquet Islands. The forests on these islands are composed predominantly of western redcedar, Sitka spruce, and western hemlock. Pacific yew, mountain hemlock (*Tsuga martensiana*), Pacific crabapple, and yellow-cedar (*Cupressus* *nootkatensis*) also grow here, though in lower abundance. The forest understory is coated in a thick layer of salal. Other characteristic species inhabiting the understory include false azalea, deer fern, step moss (*Hylocomium splendens* Hedw.), and lanky moss (*Rhytidiadelphus loreus* Hedw). A diverse number of berry-producing shrubs can also be found here, including red huckleberry, oval-leaved blueberry, black gooseberry, and salmonberry. Edible root plants growing in the estuarine zone include Pacific silverweed, springbank clover, and northern rice root. An assortment of smaller aquatic plants can also be found here such as sea-milk wort (G*laux maritima*), as well as a variety of rushes, sedges, and grasses. The data presented in this thesis focus on plant species growing in the estuarine environment as well as species found growing 5 meters into the forest.

2.2 FIELD METHODS

2.2.1 PLANT MANAGEMENT

To test the ecological legacy effects of human habitation on present-day distribution, abundance, and community composition of culturally valued species traditionally harvested and managed by Coastal Indigenous people, we collected presence/absence data of all estuarine and shoreline plant species at five control sites and five habitation sites. The habitation sites used in this study were previously documented by archeologists with the support of the local Indigenous Nations as sites intensely occupied and managed by Indigenous people up until colonization (McLaren, 2013). Habitation sites are distinguishable by the presence of a shell midden: an accumulation of compostable debris and marine detritus built up over millennia by people residing there, as well as evidence of resource management such as bark-stripped cedars and fire-scarred trees. The five control sites were selected where no visible evidence of human habitation or resource management was noticeable or documented, these sites are free of shell midden, distinguishable gardens, clam gardens, bark-stripped trees, housing structures, fish traps, and canoe slides, all common characteristics of habitation sites. Ecological and geomorphological features were also considered when choosing control sites, such as proximity to streams, slope, aspect, and the presence of an estuarine zone in attempt to keep ecological conditions similar between control and habitation sites.

Different habitation sites were used for different purposes. Some were defensive sites, villages, or designated resource management areas (site). We recognized that the different uses of habitation site would have impacted the ecology of the system, influencing plant communities and habitat structure. Because our sample included only five habitation sites, this study concentrated on the general impact of long-term human presence rather than the impact generated from specific site use. The commonality between all five habitation sites being that humans spent extensive periods of time over hundreds or thousands of years modifying the environment in various ways through a plethora of daily activities. These activities have the potential to influence present-day habitat structure, ecosystem functions, and soil chemistry, which all could influence the results of this study. In the field soil samples were attempted but the decision was made not to go ahead with sampling efforts as culturally appropriate methods were determined to be needed. The collection of soil samples from habitation sites would be a strong addition to future research on the distribution, abundance, and biodiversity of plant communities if methods reflected cultural practices adequately.

Presence/absence data were collected along transects running parallel to the shoreline at each site. Multiple factors were considered when determining the placement of transects.

Intact forest canopies in the zonal forest result in deeply shaded understory, making it challenging for partial-shade or full-sun plants to grow. However, the amount of light reaching the understory increases towards the water. Many of the shrub and herbaceous plant species that were valuable to Central Coast First Nations peoples require some sun and are outcompeted by western redcedar, western hemlock, and salal that dominate the zonal forest. Additionally, Indigenous Knowledge and past scientific research on Indigenous plant management confirm that specific management practices, like root gardens and forest gardens, were concentrated to the estuarine zone and forest-edge (Deur & Turner, 2011). For these reasons, transects were placed parallel to the shoreline to maximize estuarine zone and forest-edge plant species. Transect length was set to a maximum of 300 m, though most transects were shorter due to impassible shoreline conditions such as cliffs or large boulders. Sites varied in the number of plots sampled at each due to ecological constraints, with data collected in 106 plots on habitation sites and 54 plots on control sites. Along each transect, 2 m-wide plots were set-up every 10 m, perpendicular to the shoreline, extending from the high-tide line, across the estuarine zone and 5 m into the forest. All plant species and cultural features (e.g. bark-stripped and burnt trees) were identified within each plot. A UTM location was taken with a Garmin handheld GPS at the high-tide line of each plot, distinguished by the barnacle line. Using previously collected LiDAR data for this study region, shoreline slope (in degrees) and aspect were calculated. For the sake of this study, the length of the estuarine zone within plots was recorded using the high-tide line and the start of woody vegetation as boundaries. Though the upper end of this boundary does not receive regular saltwater inundation like some salt marsh environments, high levels of salt still exist here due to ocean spray, storms, and flooding that occurs during peak tidal cycles. These conditions make this boundary a habitable environment for estuarine salt marsh plants like that of northern rice root (*Fritillaria camschatcensis*), Pacific silverweed (*Potentilla anserina*), and springbank clover (*Trifolium wormskioldii*). Soil salinity and soil temperature were measured at three equally spaced locations in each plot using a Spectrum EC 450 meter. For consistency purposes, the EC probe was inserted into the soil 9 cm when possible, however the presence of rock below the soil surface influenced this depth in some plots.

To test the ecological legacies of human habitation on the abundance of Pacific crabapple, the location and abundance of crabapple trees along all transects were recorded. This was done by surveying each transect on foot and recording the position of all visible Pacific crabapple trees from the edge of the shoreline. In locations with a high abundance of Pacific crabapple, the number of individual trees was recorded, and one GPS point was taken for the entire grove.

2.2.2 ESTUARINE ROOT PLANTS

Fieldwork to investigate the current landscape distribution and ecological characteristics associated with culturally valued species of root plants began by surveying portions of the coastline along Calvert, Hecate, Starfish and Triquet Islands by boat and foot to identify large patches of edible root plants. Patches containing a minimum of 4 or more northern rice root plants were identified as well as any patch with two or more edible root species (springbank clover, silverweed, and northern rice root). For each patch, we recorded the length and width of the patch, presence of a nearby freshwater source, and the location of the plot centre using a Garmin handheld GPS unit. Using previously collected LiDAR data for this study region, shoreline slope (in degrees) and aspect were calculated. Once patches of edible root plants were identified, data on species composition and soil depth were collected. Data on other cultural features in the vicinity of each site was also gathered as Indigenous Knowledge and archeological reports note that it was common for management of various kinds to occur in close proximity (Deur & Turner, 2011; Deur; 2002). A 10-minute non-exhaustive, opportunistic survey was conducted to record data on bark-stripped trees, fire-scarred trees, Pacific yew trees, and Pacific crabapple trees in an attempt to connect each patch of root plants to other displays of other cultural modifications and two of the most valued tree species, utilized not just for food but also to carve gardening and cultivation tools out of. One survey was conducted for each patch of plants unless two or more patches were within 10 m of each other. In those cases, one survey was conducted for multiple sites. To gather data on species composition, quadrat sampling along a transect running through the middle of each patch of root plants, parallel to the water, was conducted. Three quadrats were assessed within each patch, except for sites less than three meters long, in these cases only two quadrats were used. Percent cover of all species was calculated for each quadrat. Methods were also developed to collect soil samples from each plot of culturally important species. A transect was ran across the garden and three equally distributed samples were attempted using a soil auger. Our team quickly realized that removing samples from the strips of estuarine soil, thick with culturally important species had to be rethought. The modern scientific methods traditionally employed to collect soil were invasive and destructive to the plants and the cultural landscape. Furthermore, they did not reflect Indigenous methodologies surrounding how these plants were traditionally handled and cared for. Methods were revised and instead, soil depth was measured in the middle of each patch by inserting a thin metal measuring probe into the ground until contact with the bedrock below was made. For the patches containing northern rice root, the number of individual plants in each patch and their number of buds or flowers were counted. Additionally, the height of each northern rice root plant was measured.

2.4 STATISTICAL AND ANALYTICAL METHODS

2.4.1 PLANT MANAGEMENT

Species Richness Across Sites

To examine differences in species richness between site type (habitation or control), we used generalized linear models (GLM) with a Poisson distribution to accommodate the error structure associated with count data. Species richness at each site was calculated by totaling the number of unique plant species. The explanatory variables using in the initial model were: site type, average soil salinity, transect length, estuarine length and aspect. In order to select the variables that best explained the difference in species richness between habitation and control sites, we used a backward stepwise regression model (Zhang, 2016). This method is an effective way to compare all possible combinations of explanatory variables to determine the simplest final model (Zhang, 2016). Stepwise regression is based on Akaike Information Criteria (AIC) and continually removes explanatory variables from the model that increase the overall model AIC score. The model stops when removing additional variables will result in an increase in the model's AIC score, leaving the explanatory variables that will result in the simplest final model. Backwards stepwise regression accounts for collinearity and removes correlated variables. In all statistical models, we were interested in the effect of site type (control or habitation) on the dependent variable, therefore this variable is included in all final models and is not included in the stepwise regression. To understand species richness at each site in more detail, the percentage of plots that each species occurred in was calculated. Since transect lengths were not equal across sites, converting species abundance into a percentage allowed this variable to be considered more equally between sites. Forty-eight logistic regression were tested in R (R Core Team, 2014) to identify significant differences between individual species found in plots on control and habitation sites. *Site* was the single variable included in final models. Additionally, species found on all control sites, all habitation sites, and all study sites were recorded.

Species Richness Within Plots

To examine differences in species richness between plots, we used generalized linear models (GLM) with a Poisson distribution to accommodate the error structure associated with count data. Species richness was calculated by totaling the number of unique plant species found within each plot. The explanatory variables included in the initial model were site type, average soil salinity, transect length, estuarine length and aspect. Model selection was performed using a backwards stepwise regression, as described in the previous section. In all statistical models, we were interested in the effect of site type (control or habitation) on the dependent variable, therefore this variable is included in all final models and is not included in the stepwise regression.

Distribution of Culturally Important Plants

To understand the distribution of culturally important plant species, we determined a Cultural index and a Management Index value for each species. The Cultural Index ranged from 0 to 5 stars, with no known significant assigned zero stars to plants of the highest importance to Coastal First Nations peoples assigned five stars. This Cultural Index was originally developed and used in Fisher et al. (2019) in consultation with ethnobotanist Nancy Turner and further expanded on for this study. This index is based on multiple factors including how many names exist for a specific species in Coastal First Nations languages, how dependent people where on the species, the number of different known uses for the species, such as edible, medicinal and/or resource purposes, and how important theses uses contributed to people's way of life and cultural traditions. It is important to acknowledge that these index values are not a representation of the value held specifically by Heiltsuk and Wuikinuxv cultures but instead the cultures of the Pacific Northwest. After each plant species was assigned an index value, the number of species in each star category was calculated (0, 1, 2, 3, 4, 5). Next, the number of each plants within each index value was calculated for every single plot along all transects. A separate Poisson regression was built for each index value to test the effect of the independent variables on influencing their distribution and presence. The explanatory variables used in the initial models were *site type, average soil salinity, transect length, estuarine length and aspect*. The final model was determined using a backward stepwise regression. In all statistical models, we were interested in the effect of site type (control or habitation) on the dependent variable, therefore this variable is included in all final models.

Further contextualization of culturally important plant species was needed to include the plant species that required the most care and attention in regard to management efforts and cultivation techniques and to better understand where concentrations of potentially managed species lie. To do this we further analyzed the data in five cultural layers: Cultural Index Species, Top Managed Species, trees, shrubs, and herbs. For each layer, species abundance was calculated at each site, along with the overall mean of species found across habitation sites and control sites and put arranged in a table. The data used to calculate the abundance of Cultural Index Species at each site was taken from the Cultural Index developed in part with N. Turner for J. Fisher's thesis and extended for this study. This layer included the 42-plant species with an index rating from 1-5. The sums of cultural trees, shrubs, and herbs were calculated using the same data set that contained only culturally valued species. Aquatic plants that did not fit into these three management categories were excluded from this analysis regardless of their cultural value. The cultural tree layer included 8 species, the cultural shrub layer included 15 species, and the cultural herb layer included 17 species. To calculate the abundance of 'top managed species' a new index was built called the 'management index'. Some plant species used by Central Coastal First Nations grew plentifully in the environment without management and though these plants still held massive economic and cultural value, fewer innovative techniques were needed to produce high yields. For example, though a plant with a cultural index rating of 5 indicates it was used for many life-sustaining and cultural purposes, it does not necessary mean that it required intense management and care by humans.

Much of what is known today by Western science about traditional management techniques is attributed broadly to the Pacific Northwest as a whole, referring to the stretch of coastline from California all the way up to Alaska (Deur & Turner, 2011). It is important to acknowledge that each Indigenous culture would have used slightly different management techniques, based on the environment they existed in as well as their unique cultural values and we cannot assume that all techniques discussed in this paper were being used by the cultures within the Great Bear Rainforest or other specific coastal cultures on the Pacific Northwest (Deur & Turner, 2011). Further investigation of local ecosystem characteristics and data on cultural plant management that is region-specific is needed in order to confidently attribute management techniques to certain traditional territories and cultures (Deur & Turner, 2011). To assess the plants, present in the Great Bear Rainforest that potentially received heavy human management by local Indigenous cultures, a Management Index was developed in collaboration with Nancy Turner. Twenty known traditional plant management techniques were selected and the number of techniques that applied to each plant were tallied. These plant management techniques were: burned, partially harvested (i.e. bark strip), fully harvested, cleaned, pruned, transplanted, owned, replanted, cleared, managed patch, designated grove, designated garden, weeded, selective harvesting, tended, cultivated/tilled, lopped, green shoots cut for regeneration, berries or seeds scattered, and fertilized (Deur & Turner, 2011; Turner, 2014a; Turner, 2014b). Management Index values ranged from 0 to 11, as no plant in this study had greater than 11 known management techniques. A Management Index rating of 0 means that according to traditional knowledge that species had no known management techniques or was managed so minimally that it is not of importance. A Management Index rating of 11, means there are at least 11 known traditional techniques that could have been used to maintain that species for human purposes. The plants included in this layer were only the top managed species, who had an index rating of 5 or greater. Twelve plants were included in this layer.

Distribution and Abundance of Pacific Crabapple

To investigate the abundance of Pacific crabapple trees, count data of the number of individual crabapple trees at each site were analyzed using a GLM with a Poisson distribution. The explanatory variables used in the initial model were site type, average soil salinity, transect length, estuarine length and aspect. The final model was determined using a backward stepwise regression. In all statistical models, we were interested in the effect of site type (control or habitation) on the dependent variable, therefore this variable is included in all final models and is not included in the stepwise regression.

Pacific crabapple abundance data, along with data from two cultural layers in the cultural value table: 'Cultural Valued Species' and 'Top Managed Species' was consolidated onto a map to identify cultural hot-spots along the coastlines surveyed in this study. This map was created in collaboration with Keith Holmes from the Hakai Institute in ESRI Arc GIS 10.6.1. The background data (LiDAR elevation model) was collected by Hakai in 2012, 2014, and 2017.

2.4.2 ESTUARINE ROOT PLANTS

Site Characteristics

An array of ecological characteristics for each patch of edible root species was used to understand growth extent and common ecological characteristics. A number of ecological and site parameters were consolidated. These parameters were taken from data collected in the field on the length and width of each patch of edible plant species, soil depth, stream presence, and closest habitation site. Additionally, for the study sites that contained northern rice root, the number of plants at each site was calculated. Presence of the other edible root species, springbank clover and Pacific silverweed was also stated in the table for each study site. The mean length, width, soil depth, and number of rice root plants were calculated for all sites in this study and indicated in the table along with standard errors.

Data collected from opportunistic surveys conducted behind each patch of edible plant species were used to analyse additional presence of cultural evidence and highly culturally valued tree species. The number of culturally modified trees (CMTs), Pacific crabapple trees, Pacific yew trees, and fire-scarred trees were in the vicinity of each plot of edible plant species included in our study were included. These data was consolidated into a table for visual analysis and displayed on a map, along with rice root population data to highlight areas of cultural importance and further understand how each site in our study may have been used and managed by humans. This map was created in collaboration with Keith Holmes from the Hakai Institute in ESRI Arc GIS 10.6.1. The background data (LiDAR elevation model) was collected by Hakai in 2012, 2014, and 2017.

Phenotypic Traits

To observe trends in phenotypic traits amongst northern rice root plants, data collected on northern rice root height and the number of buds or flowers found on each individual northern rice root plant at each site were analysed. For each site, mean northern rice root height was calculated, as well as the mean plant height over all study sites. A box and whisker plot was created to visually compare rice root height between each study site. A second box and whisker plot was used compare the number of buds or flowers found on each plant at each site. Box and whisker plots were used in order to uncover the greatest detail within the datasets, allowing us to compare means, medians, and modes and identify sites containing outliers.

Community Composition

For each patch of edible root species within our study, we assessed the community composition of other plant species growing within the measurements of the patch. Percent cover data collected in the field was used to calculate the mean percent cover of each plant species across all three quadrats, or two quadrats for those plots < 2 m in length. From these data, we were able to determine the dominate plant species at each study site. The names of the top three species at each site were arranged in a table to compare similarities and differences in community composition between study sites. The mean percent cover of the three edible species: northern rice root, springbank clover, and Pacific silverweed was also calculated.

3. RESULTS

3.1 PLANT MANAGEMENT

Species Richness Across Sites

The final Poisson distribution GLM model to test species richness across all 10 sites identified site type (p= 0.032**) and slope (p=0.057*) as statistically significant variables on 5 habitation sites and 5 control sites. Species richness was higher on and around human habitation sites. Overall, 48 species were identified in 160 plots along ten transects at 10 sites (Table A1). Thirty-three species were identified on control sites and 48 species were identified on habitation sites. Transects were different lengths at each site due to structural differences in the shorelines, with the average transect length being longer on habitation sites (mean=186 m +- 45 SE) than on control sites (mean= 98 m +- 23.53 SE). The mean species richness on control sites was 19 and mean species richness on habitation sites was 29 (Table 1). No one site contained all 48 species. Fifteen plant species identified on habitation sites were not found on control sites (Table A3). There were no species identified on control sites that did not occur on habitation sites.

Eight species occurred on all 10 sites and three species occurred on all habitation sites but not all controls (Table A2). No species occurred on all controls that did not occur on all habitations. Seven species occurred on one single site and six species occurred on only two sites. Ten species were significantly different between site types (Table 2).

TABLE 1. Species richness for plants growing on control and habitation sites. Standard error is given as 'SE'. Codes for habitation sites in parentheses refer to Borden codes.

Site	Site Species Richness
Control 1	20
Control 2	17
Control 3	10
Control 4	21
Control 5	25
All Control Sites	***18.60 +- 2.5 SE***
Habitation 1 (EjTa4)	40
Habitation 2 (EjTa13)	20
Habitation 3 (EjTa19)	28
Habitation 4 (EjTa15)	33
Habitation 5 (EjTa14)	22
All Habitation Sites	***28.60 +- 3.66 SE***

TABLE 2. P-value output for generalized linear model with Poisson distribution for species who exhibited significant differences between control and habitation site and the percentage of plots each species was found in on each site type. 106 plots were sampled on habitation sites and 54 plots were sampled on control sites. Lengths were different due to impassible shoreline conditions. To account for this difference, occurrence is converted into a percentage in the table below.

Species	P-value	% Habitation Plots	% Control plots
Western hemlock	0.00425	60.40%	83.80%
Deer fern	0.0493	25.50%	40.70%
Pacific hemlock parsley	0.0572	21.70%	9.30%
False azalea	0.00159	66%	91%
Thimble berry	0.0466	13.20%	1.90%
Oval-leaved blueberry	0.06408	63.20%	77.80%
Crow berry	0.0442	22.60%	9.30%
Bunchberry	0.000147	24.50%	55.60%
Sea milk wort	0.0116	9.30%	27.40%
Small bed straw	0.00287	1%	18.50%

The final Poisson regression used to statistically test differences in species richness across study sites included *estuarine length*, *aspect, slope,* and *site type* as the explanatory variables. Site type was the only variable that was significant at influencing species richness at site level with more species occurring overall on habitation sites (p = 0.032; Table 3).

TABLE 3. Statistical results for species richness across sites. Variables and output values from the final glm with a Poisson distribution to assess overall species richness at site level. Significance codes are: ** = p < 0.05; * = p < 0.10.

Independent Variable	Final Model Variables	Parameter Estimate	Confidence Interval	P-value
Species richness	**Site Type** (habitation)	0.325	0.152	0.032**
	Estuarine Length	0.060	0.038	0.110
	Aspect	0.002	0.002	0.110
	Slope	-0.041	0.021	0.057*

For the 48 species identified across all 10 sites, 30 species occurred more frequently in plots on habitation sites and 18 species occurred more frequently in plots on control sites (Table A2). Salal was the only species that occurred in all habitation site plots, and nearly all (98.1%) control site plots. The other dominant plant species, occurring in a minimum of 50% of plots on habitation and control sites were western redcedar, western hemlock, false lily of the valley, and oval-leaved blueberry. Bunchberry also occurred in over 50% of plots on control sites and silverweed occurred in over 50% of plots on habitation sites. The 15 species that occurred in plots on habitation sites but not control sites include bracken fern, licorice fern, Alaskan blueberry (*Vaccinium alaskaense*), red columbine (*Aquilegia formosa*), black gooseberry, Pacific yew, springbank clover, fireweed, sweet-scented bedstraw (*Galium trifolorum*), Pacific water parsley, dwarf blueberry (*Vaccinium caespitosum*), twinflower (*Linnaea borealis)*, wild strawberry (*Fragaria virginiana*), coastal strawberry (*Fragaria chiloensis*), and sea asparagus (*Salicornia virginica*) (Table A3).

Species Richness within Plots

Species richness within plots ranged from 4-20 species (mean= 9.84 +- 1.51 SE) in control plots and 3-16 species (mean= 9.23 +- 0.34 SE) in habitation plots (Table 4). Species richness in plots fluctuated less between habitation sites than it did between individual control sites. This difference was not found to be significant in the final Poisson distributed GLM model. 'Slope' was the only significant variable to influence species richness within individual plots (p = 0.006) (Table 5).

TABLE 4. Mean species richness within individual plots. Mean number of species found within individual plots on each site as well as the mean for each site type (control/habitation). Codes for habitation sites in parentheses refer to Borden codes.

Site	Mean Species Per Plot
Control 1	8.64 +- 0.47 SE
Control 2	8.5 +- 0.65 SE
Control 3	6.06 +- 0.25 SE
Control 4	11 +- 0.46 SE
Control 5	15 +- 0.95 SE
All Control Sites	*9.84 +- 1.51 SE*
Habitation 1 (EjTa4)	10.43 +- 0.49 SE
Habitation 2 (EjTa13)	9.11 +- 0.74
Habitation 3 (EjTa19)	8.69 +- 0.68 SE
Habitation 4 (EjTa15)	9.77 +- 0.43 SE
Habitation 5 (EjTa14)	7.27 +- 0.71 SE
All Habitation Sites	*9.23 +- 0.34 SE*

TABLE 5. Statistical results from the Poisson regression analyzing species richness within plots. Output values and variables from the final glm with a Poisson distribution. Significance codes are: ** = $p < 0.05$, * = $p < 0.10$.

Independent Variable	**Final Model Variables**	**Parameter Estimate**	**Confidence Interval**	**P-value**
Species richness	Site Type	0.005	0.056	0.922
	Slope	-0.013	0.005	0.006 **
	Aspect	0.0005	0.0003	0.121

The box and whisker plot indicates less variance between species richness within individual plots along each transect at habitation sites as compared to control sites. Mean species richness within plots on control site ranged from 7.27 (SE= +- 0.71) to 10.43 (SE= +- 0.49) in comparison to control sites which ranged in means from 6.06 (SE= +- 0.25) to 15 (SE= +- 0.95)(Figure 3). A mean species richness of 15, found on control site 5 was the highest species richness mean per plot than any other site. Habitation site 2 (EjTa13) has the largest interquartile range, indicating the highest variation in the number of species identified within plots along the transect at this site.

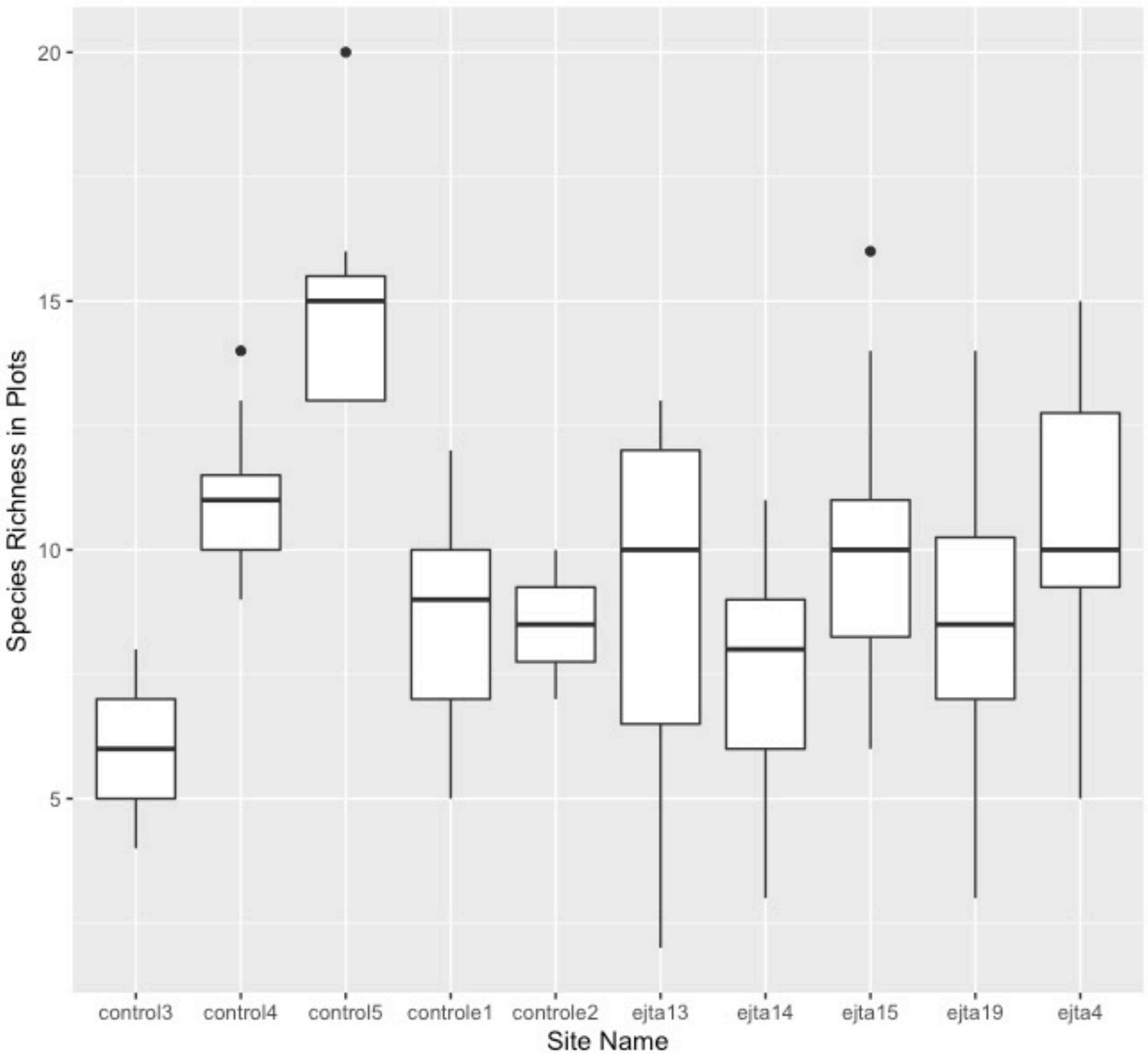


FIGURE 3. Species richness within plots. Box and whisker plot of species richness within all sample plots along each transect at each site. Each box represents the extent of the data's interquartile range, with a median line running through the middle of the box, the whiskers on either side indicating the minimum and maximum of the data set, and outliers as points outside the extent of the whiskers. Borden codes used to indicate habitation sites.

Distribution of Culturally Important Plants

Forty-two of the 48 plant species (87%) identified along all transects held a cultural index rating between 1-5 (Table A4). All 42 of these Cultural Index species were identified on at least one habitation site with 27 identified on controls. Western redcedar was the only plant assigned a 5-star cultural rating. Thirteen species were given a 4-star rating, 13 species were given a 3-star rating, 10 species were given a 2-star rating, five species were given a 1-star rating, and six species had no known cultural value. The results from the final Poisson regression to test cultural species richness within individual plots on control and habitation site did not determine the differences observed to be significant (Table 6). Estuarine length was significant within the 3-starred index group ($p = 0.017$) and salinity nearly significant within the no-star plants ($p = 0.7755$.). This index rating contained two of the three estuarine root plants. The only species which holds a five-star cultural index rating, western redcedar, occurred in greater abundance on control sites than habitation sites. However, as discussed above, western redcedar was one of the most abundant species overall so the fact that it is found in a greater abundance on control sites makes sense as these sites have not had any these more abundant species removed to make way for less abundant tree species that still hold cultural value. Species of trees that hold a 4-star rating included Pacific crabapple, Pacific yew, red alder, and Sitka spruce whose occurrence was all higher on habitation sites. The 5-star and 4-star species make up a higher composition of the plant species found on control sites compared to habitation sites. As the species in these categories are amongst the most common across this entire study, as well as contain some of the most characteristic tree species of the Great Bear Rainforest, such as western redcedar, it is not surprising they would be abundant on these sites, never having been subject to removal for human use or landscape management. Four-star species richness was higher on habitation sites with Alaskan blueberry, and Pacific yew only identified at this site-type. Three, two, and one-star species make up more community composition on habitation sites. These species are amongst some of the least abundant across all transects. Habitation sites also exhibited higher richness within these index levels, with 13 species within these indexes occurring solely on habitation sites. The plant species that were not assigned a cultural index value made up 18% of plant species on control sites and 13% of species on habitation sites.

TABLE 6. Statistical results for cultural index assessment. Variables and output values from the glm with a Poisson distribution ran to assess species richness within plots. Significance codes are: ** = $p < 0.05$; * = $p < 0.10$.

Independent Variable	Final Model Variables	Parameter Estimate	Confidence Interval	P-value
0-star	Site Type	-0.055	0.192	0.775
	Salinity	-0.195	0.100	0.052*
	Estuarine Length	-0.050	0.031	0.108
	Slope	-0.025	0.017	0.133
1-star	Site Type	-0.170	0.282	0.547
	Slope	-0.039	0.026	0.138
2-star	Site Type	0.0779	0.134	0.561
3-star	Site Type	0.029	0.117	0.806
	Aspect	0.0009	0.0006	0.163
	Estuarine Length	0.042	0.0176	0.017**
	Slope	-0.027	0.011	0.119
4-star	Site type	0.013	0.088	0.879
5-star	Site type	-0.1089	0.185	0.556

By broadening our cultural analysis of each study site to include data on highly managed species and the three culturally-managed plant categories: trees, shrubs, and herbs (Table 7), we were able to observe the data in different cultural layers and further understand where cultural species exist, and which sites contained high abundances of species known to be highly managed. Observationally, habitation sites had higher abundance of plant species in all five cultural layers: Cultural Index Species, Top Managed Species, Cultural trees, Cultural shrubs, and Cultural herbs. Control and habitation sites saw the most similarities in the cultural tree category with means of 4.0 (SE = +-0.55) and 5.40 (SE = +-0.668) respectively.

TABLE 7. Cultural layers table displaying the sum of plant species holding different forms of cultural value at each site. “Cultural index species” indicates the total number of plant species found on each site that held a cultural index value *(table A4)* between 1-5 stars. “Top managed species” indicate the richness of species ranked 5 or higher on the management index *(table A5),* meaning they were managed using a minimum of 5 traditional management techniques. “Cultural trees” indicates the richness of tree species with known cultural value. “Cultural shrubs” indicates the richness of shrub species with known culture value. “Cultural herbs” indicates the richness of herb species with known cultural value. This category also includes aquatic plants growing in the estuarine zone that have known cultural uses and were managed in similar ways to herbs in the same environment.

Site	Cultural Index Species	Top Managed Species	Cultural Trees	Cultural Shrubs	Cultural Herbs
Control 1	19	5	6	6	7
Control 2	15	5	4	5	6
Control 3	9	2	4	4	1
Control 4	16	5	3	6	7
Control 5	20	6	3	8	9
All Control Sites	*15.80 +- 1.93 SE*	*4.60 +- 0.69 SE*	*4.0 +- 0.55 SE*	*5.80 +- 0.66 SE*	*6.0+- 1.34 SE*
Habitation 1 (EjTa4)	37	11	8	14	12
Habitation 2 (EjTa13)	19	5	5	9	5
Habitation 3 (EjTa19)	24	6	5	9	10
Habitation 4 (EjTa15)	27	10	5	9	11
Habitation 5 (EjTa14)	20	7	4	6	10
All Habitation Sites	*25.40 +- 3.23 SE*	*7.80 +- 1.16 SE*	*5.40 +- 0.68 SE*	*9.40 +- 1.29 SE*	*9.60 +- 1.21 SE*

Observationally, Habitation 1 (EjTa 4) had the highest sums across all five cultural layers, containing 37 of the 42 Cultural Index species, 11 of the 12 top-managed species, all 8 cultural trees, 14 of the 15 cultural shrubs, and 12 of the 17 cultural herbs. This was also the only site that had 100% of the species in a single layer present (8/8 cultural tree species).

Distribution and Abundance of Pacific crabapple

Our results show that the abundance of Pacific crabapple trees is higher on or near human habitation sites. Out of the 10 sites sampled, Pacific crabapple was identified on only two control sites and four habitation sites (Figure 4). The mean number of Pacific crabapple trees found on control sites was 16, compared to a mean of 44 trees on habitation sites. The final GLM with a Poisson distribution determined the abundance of Pacific crabapples to be best explained by site type and slope (Table 8; Figure 4).

Two habitation sites contained over 70 individual Pacific crabapple trees. The highest abundance of crabapples found on a single control site was 26. Results indicated that on habitation sites, a person had the potential to encounter up to 55% more crabapple trees than on control sites. On the most abundant habitation site (Habitation 3/EjTa19) 5.2 crabapple trees were encountered every ~10 m, in comparison to 2 trees every ~10 m on the most abundant control site (Control 1; Figure 5).

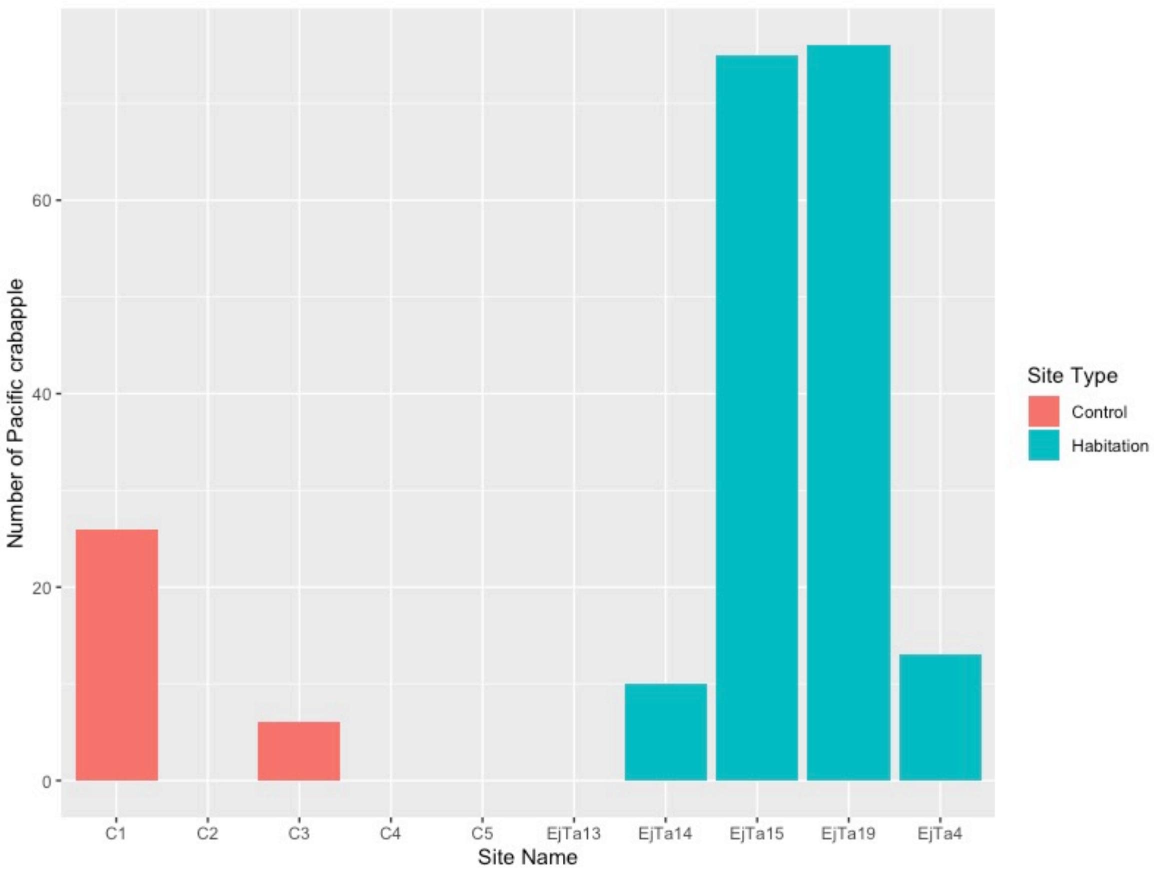


FIGURE 4. Abundance of Pacific crabapple at each control site (c1-c5) and habitation site (EjTa13, EjTa14, EjTa15, EjTa19, EjTa4).

TABLE 8. Final statistical output results analyzing Pacific crabapple abundance. Variables and output values from the final glm with a Poisson distribution to assess species richness within plots. (***) highly significant variable.

Independent Variable	Final Model Variables	Estimate value	Confidence interval	P-value
Crabapple abundance	Site Type (habitation)	0.644	0.194	1.30e-12 ***
	Slope	-0.044	0.009	1.15e-06 ***

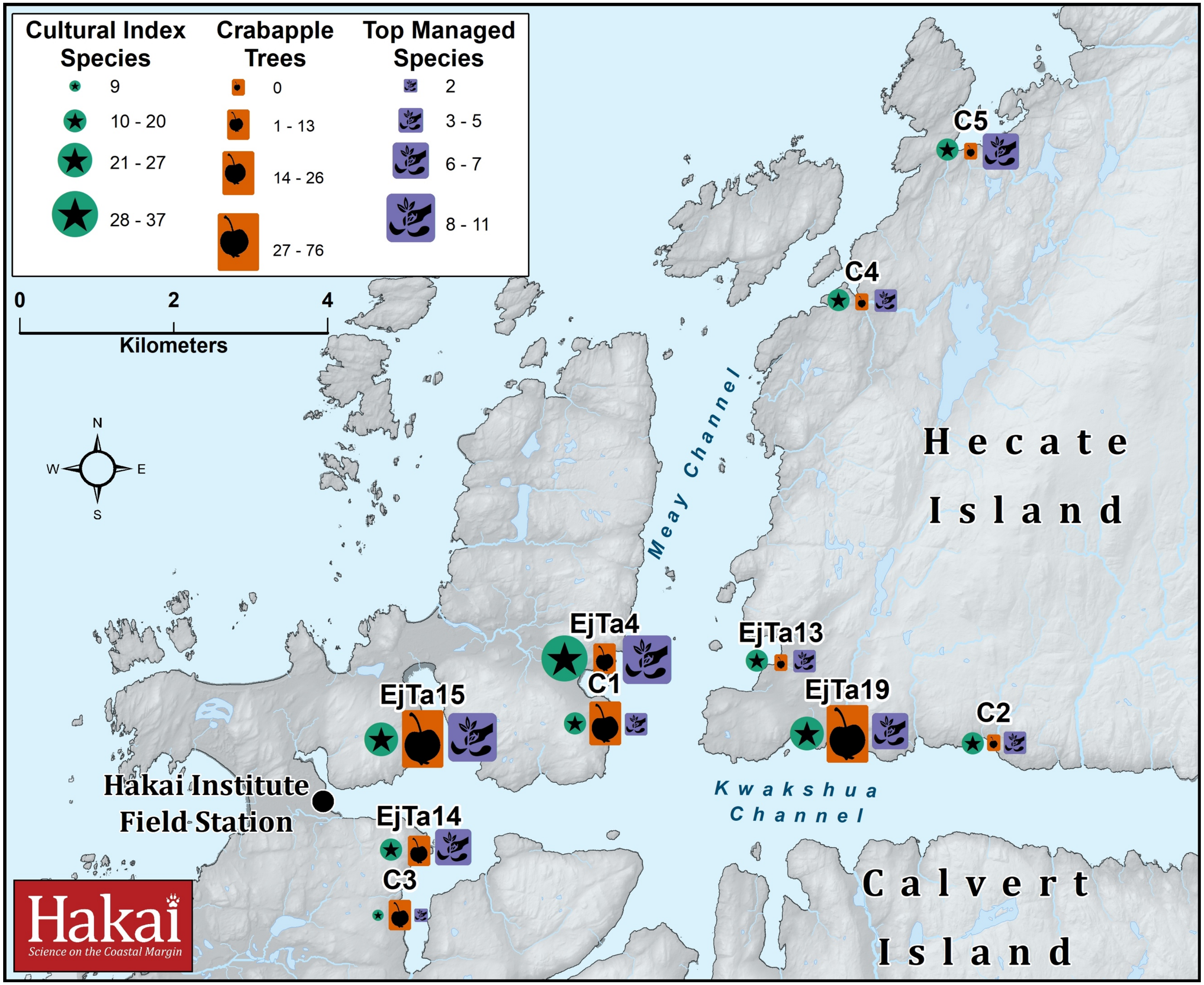


FIGURE 5. Map displaying the distribution of two cultural layers from the cultural value table: ‘Cultural Index Species’ and ‘Top Managed Species’, as well as the abundance of Pacific crabapple at each site.

3.2 ESTUARINE ROOT PLANTS

Site Characteristics of Edible Root Species

All patches of edible root species except for one that were used in this study were on or around a known human habitation site (Table 9). Though search-efforts were unbiased, the design of this study is not sufficient to conclude that habitation is driving the presence of large patches of edible root species, we therefore treat habitation as a notable factor. Site length ranged from 2.1 m to 15.7 m in length, with a mean patch length of 5.04 m +- 0.78 SE. Width of patches ranged from 0.7 m wide to 5.7 m, with a mean width of 2.72 m +- 0.38 SE. Soil depth ranged from 15 - 36 cm, with a mean depth of 22.71 cm +- 1.93 SE. Sites that containing the edible plant northern rice root, had as few as four plants within the plot or as many as 213. The mean number of northern rice root plants found on sites containing rice root was equal to 67.06 plants +- 17.49 SE. Four out of the 17 sites had presence of a stream running within 10 m of the patch of edible root species.

At all 17 sites we observed presence of species that fell into at least one of the four categories in our cultural plant-related survey (CMT's, fire-scars, and the culturally valued species, Pacific yew and Pacific crabapple). The total number of identifications per site ranged from 2-28 (mean= 12.79 +- 1.96 SE). Seven sites had less than 10 features identified on them, six sites had more than 10, and two sites had more than 20. The least abundant feature that we observed across all sites was fire-scarred trees, identified on 3 out of the 17 sites. The most abundant feature was CMT. Pacific crabapple was identified as the first and second highest abundant feature at an individual site, with 28 trees identified on site 12, and 16 on site 11 (Figure 6; Table 10).

TABLE 9. Site characteristics for patches of edible root plants.

Site	Closest Habitation Site	Length (m)	Width (m)	Soil depth (cm)	Number of Rice Root Plants	Stream (Yes/No)	Other Edible Root Species Present
1	EjTa1	7.5	1.6	34	108	N	NA
2	EjTa13	5.3	1.1	31	157	N	NA
3	EjTa19	8.1	5.2	17	15	Y	*Potentilla anserina*
4	EjTa4	9.5	4.8	21	0	Y	*Potentilla anserina* and *Trifolium wormskioldii*
5	EjTa4	2.8	1.3	10	19	N	NA
6	EjTa19	3.6	2.4	23	4	Y	*Potentilla anserina*
7	EkTa2	4.4	3.2	31	16	N	*Potentilla anserina*
8	EkTa2	7.1	4.4	26	0	N	*Potentilla anserina*
9	EkTa2	2.7	1.7	17	76	N	NA
10	EkTa38	15.7	2.4	17	197	N	NA
11	EkTa38	5.4	3.7	15	0	N	*Potentilla anserina* and *Trifolium wormskioldii*
12	Ektb9	5.3	1.1	15	64	N	NA
13	EjTa15	2.1	0.7	17	6	N	NA
14	EkTa38	5	2.2	30	45	N	NA
15	EkTa38	5.1	5.7	16	143	N	NA
16	EkTa38	5.5	1.5	30	77	N	NA
17	None known	3.8	3.2	36	213	Y	NA
Mean	**NA**	**5.04 +- 0.78 SE**	**2.72 +- 0.38 SE**	**22.71 +- 1.93 SE**	**67.06 +- 17.49 SE**	**NA**	**NA**

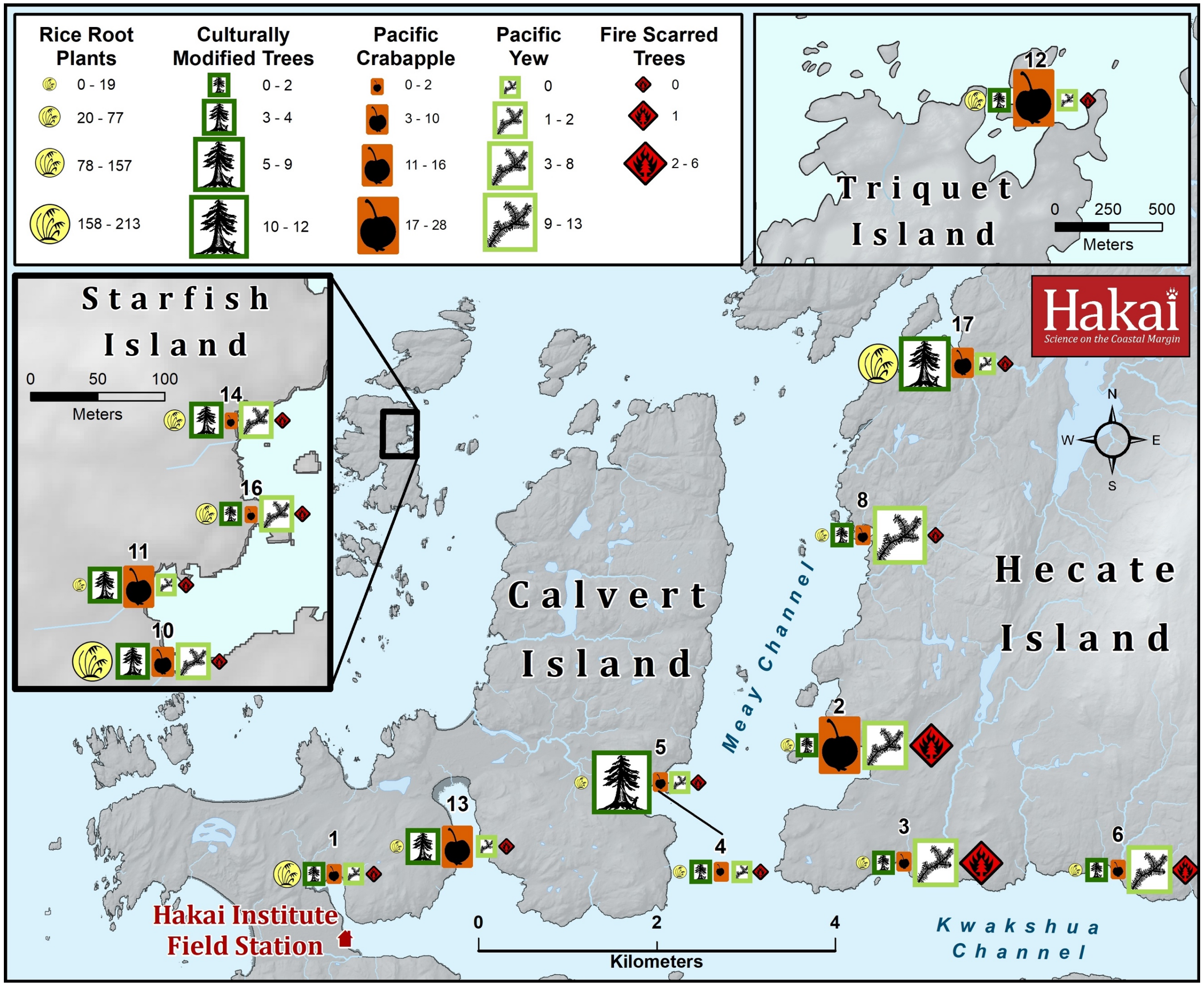


FIGURE 6. Cultural plant-related map. This map displays the abundances of some of the most valued cultural plants including Pacific crabapple, Pacific yew, and northern rice root, as well as evidence of fire-scarred trees and culturally managed trees (cmt). From this map areas of significant cultural value can be identified.

TABLE 10. Presence of CMT's, fire-scars, and cultural trees. Results are from a 10-minute opportunistic field survey to gather data on signs of cultural modification, including culturally modified trees (CMT) and fire-scarred trees, as well as the locations of Pacific yew and Pacific crabapple, both of high cultural importance. A single survey was conducted for multiple populations within a 10-meter range.

Site	**Culturally Modified Tree**	**Pacific crabapple**	**Pacific Yew**	**Fire-Scarred Trees**	**Total**
1	2	0	0	0	**2**
2	9	0	10	1	**20**
3	2	2	8	6	**18**
4	2	0	6	0	**8**
5	12	0	0	0	**12**
6	1	0	7	1	**9**
7, 8 & 9	1	1	13	0	**15**
10	3	9	2	0	**14**
11	4	16	0	0	**20**
12	0	28	0	0	**28**
13	4	10	0	0	**14**
14	3	0	1	0	**4**
15 & 16	1	0	2	0	**3**
17	7	5	0	0	**12**
All sites	*3.64 +- 0.92 SE*	*5.07 +- 2.21 SE*	*3.5 +- 1.18 SE*	*0.57 +- 0.43 SE*	*12.79 +- 1.96 SE*

Phenotypic Characteristics of Northern Rice Root

The mean northern rice root height across the 14 sites containing a minimum of five northern rice root plants was 31.43 cm +- 3.92 SE. The site with the lowest height average was site 12, with a mean height of 18.77 cm +- 1.20 SE. Site 17 had the highest northern rice root height, with a mean height of 69.33 cm +- 1.57 SE. Site 14 had the lowest average height with a mean of 20.56 cm +- 1.27 (Table 11).

<u>TABLE 11.</u> Mean northern rice root height found at each study site that contained a minimum of 4 northern rice root plants as well as across all sites. 'NA' is put as a place holder for sites that did not contain northern rice root.

Site	Mean Rice Root Height
1	31.75 +- 1.03 SE
2	23.14 +- 0.79 SE
3	24.40 +- 1.62 SE
4	NA
5	49.79 +- 2.52 SE
6	20.75 +- 3.17 SE
7	32.13 +- 2.99 SE
8	NA
9	27.37 +- 1.17 SE
10	21.93 +- 0.61 SE
11	NA
12	18.77 +- 1.20 SE
13	49.50 +- 2.85 SE
14	20.56 +- 1.27 SE
15	26.12 +- 0.96 SE
16	24.56 +- 1.34 SE
17	69.31 +- 1.57 SE
All sites	**31.43 +- 3.92 SE**

Northern rice root heights were fairly consistent across the majority of sites and within individual patches (Figure 7). That said, sites 5, 13, and 17 stand out as being different in mean plant height in comparison to the other sites. The rest of the sites have lower means and similar interquartile ranges. Site 17 had the tallest rice root plants. In comparison, sites 3, 6, and 13 have small overall heights and small interquartile ranges indicating less variation in plant height between individuals at these sites. Sites 2, 7, 10, 15, and 16 have outliers taller than the rest of the individuals. The majority of sites have a mean northern rice root flower and/or bud presence near 0, with the exception of sites 1, 5, 13, 9, and 17 (Figure 7). Site 5's data contains the greatest variance, with a range of 0-7 buds and/or flowers present on the individual rice root plants surveyed there. Aside from a few outliers, most of the of the individual northern rice root plants identified on sites 3, 14, 15, and 16 had no buds or flowers present. One particular outlier on site 17 stood out from all the others with 9 flowers present. Two individuals on site 5 had the next highest sums, with a total of seven flowers present.

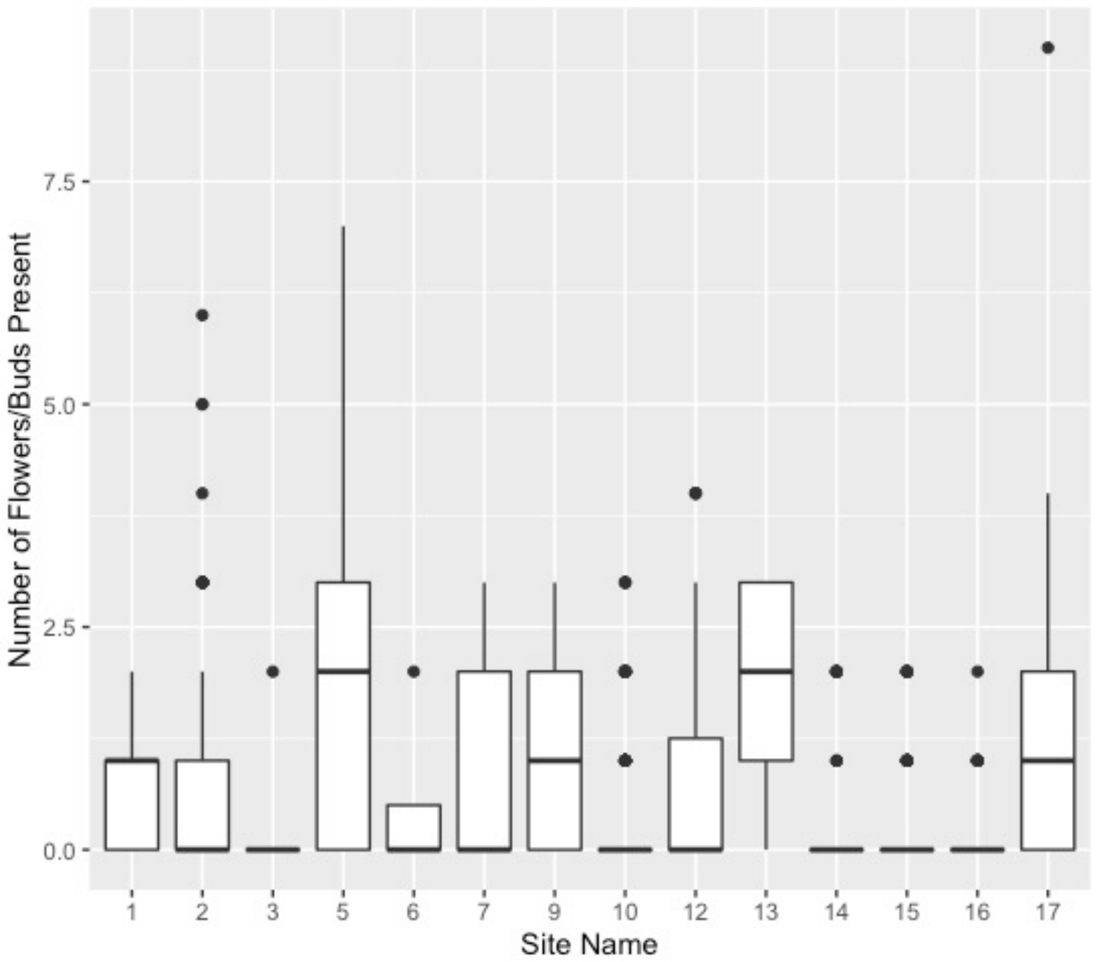


FIGURE 7. Box and whisker plot displaying the number of flowers or buds found on each individual northern rice root plant at each study site. Each box represents the interquartile range, with a median line running through the middle of the box, the whiskers on either side indicating the minimum and maximum of the data set, and outliers as points outside the extent of the whiskers. Sites 4, 8, & 11 are not represented in the plot as there was no rice root present at these sites. The results below do not distinguish between buds and flowers; they are treated as one variable to account for buds that would have bloomed into flowers by the end of the study.

Community Composition

The top plant species that dominated community composition across all 17 field sites were, from highest percent cover to lowest: Northern rice root, Baltic rush (*Juncus balticus*), and false lily of the valley (Table 12). Other species that dominated at a minimum of three sites included salal, pacific silverweed, and American dune grass.

TABLE 12. Community composition within patches of edible root species. Top three species found in each patch of edible root species are listed in order from most abundant ('dominant species 1') to least abundant ('dominant species 3'). The percent cover of each edible root species (rice root, silverweed, and springbank clover) is also displayed. This data is the mean across the two or three quadrats that data was collected in at each garden. 'SE' refers to the standard error of the mean.

Site	**Dominant Species #1**	**Dominant Species #2**	**Dominant Species #3**	**Northern Rice Root Cover (%)**	**Pacific Silverweed Cover (%)**	**Springbank Clover Cover (%)**
1	Salal *Gaultheria shallon*	Sweet gale *Myrica gale*	Large-headed sedge *Carex macrocephala*	9 +- 4.50 SE	0	0
2	Northern rice root *Fritillaria camschatcensis*	Salal *Gaultheria shallon*	Crow berry *Empetrum nigrum*	30 +- 10.41 SE	0	0
3	Pacific silverweed *Potentilla anserine*	Baltic rush *Juncus balticus*	False lily of the valley *Maianthemum dilatatum*	0	28 +- 18.99 SE	0
4	Alaskan plantain *Vaccinium alaskaense*	Baltic rush *Juncus balticus*	Pacific silverweed *Potentilla anserine*	0	22 +- 41.0 SE	0
5	Common vetch *Vicia sativa*	Red huckleberry *Vaccinium parvifolium*	Northern rice root *Fritillaria camschatcensis*	23 +- 22.50 SE	0	0
6	Baltic rush *Juncus balticus*	Pacific silverweed *Potentilla anserine*	Alaskan plantain Vaccinium alaskaense	0	20 +- 7.64 SE	0
7	False lily of the valley *Maianthemum dilatatum*	Baltic rush *Juncus balticus*	Pacific silverweed *Potentilla anserine*	8 +- 6.01 SE	9 +- 5.81 SE	0
8	Pacific silverweed *Potentilla anserine*	Baltic rush *Juncus balticus*	American dune grass *Leymus mollis*	0	55 +- 12.58 SE	0

9	Salal *Gaultheria shallon*	Northern rice root *Fritillaria camschatcensis*	False lily of the valley *Maianthemum dilatatum*	28 +- 17.5 SE	0	0
10	Northern rice root *Fritillaria camschatcensis*	Several-flowered sedge *Carex pluriflora*	Salal *Gaultheria shallon*	18 +- 6.01 SE	0	0
11	Springbank clover *Trifolium wormskioldii*	Pacific silverweed *Potentilla anserine*	False lily of the valley *Maianthemum dilatatum*	0	10 +- 5.0 SE	63 +- 8.82 SE
12	Golden short-capsuled moss *Brachythecium frigidum*	Star flower false Solomon's seal *Smilacina stellate*	Northern rice root *Fritillaria camschatcensis*	9 +- 4.70 SE	0	0
13	American Dune Grass *Leymus mollis*	Large-headed sedge *Carex macrocephala*	Northern rice root *Fritillaria camschatcensis*	13 +- 2.50 SE	0	0
14	Crow berry *Empetrum nigrum*	Common sundew *Drosera rotundifolia*	Several-flowered sedge *Carex pluriflora*	5 +- 2.89 SE	0	0
15	Northern rice root *Fritillaria camschatcensis*	Salal *Gaultheria shallon*	Several-flowered sedge *Carex pluriflora*	22 +- 4.41 SE	0	0
16	Salal *Gaultheria shallon*	Northern rice root *Fritillaria camschatcensis*	Step moss *Hylocomium splendens*	14 +- 5.67 SE	0	0
17	Northern rice root *Fritillaria camschatcensis*	Salal *Gaultheria shallon*	American Dune Grass *Leymus mollis*	69.33 +- 14.62	0	0

4. DISCUSSION

4.1 PLANT MANAGEMENT

Our results indicate a significantly higher number of species on and around human habitation sites, with 15 plant species found only on sites with past human presence. As well, there was significant differences in Pacific crabapple abundances between habitation and control sites, with higher numbers of Pacific crabapple found on sites with long term human presence. Based on our results complementing existing documented Indigenous Knowledge on the plant management systems of the Pacific Northwest, we can conclude that the sections of coastline that data was collected from during this study hold a wealth of economic, ecological, and culturally value. This study reinforces the inherent importance and value of these temperate rainforest ecosystems past the monetary value that many modern harvesting companies focus solely on. Additionally, it highlights the possible management techniques that each species has been influenced by before colonialist arrived in this part of North America. Though this study does not investigate the exact length of time these techniques have been utilized for, it adds to the body of literature that identifies differences between plant communities on and around habitation sites and those growing on sites free of human presence, strengthening the argument that these systems are presently driven by long-term human presence to some degree. It is likely the results of this study are legacies of long-term human presence and plant and landscape management. These results emphasize how pertinent it is to consider long-term human impacts when undertaking research in historic landscapes. If human-landscape interactions are not considered in landscape management, critical drivers of ecological change can be missed and the cultural importance of a landscape can be overseen, risking the loss of valued ecosystems and cultural legacies (Fisher et al., 2019).

The ecological data collected during this study accurately reflects the existing Indigenous Knowledge on Indigenous plant management techniques utilized by Pacific Northwest Indigenous cultures pre-colonization. Additionally, these results parallel the conclusions made by other researchers, Indigenous and non-Indigenous, who have carried out scientific studies on eco-cultural legacies within the Great Bear Rainforest and elsewhere along the Pacific Northwest Coast. As previously stated, it is relatively undocumented as to which specific Pacific Northwest cultures were utilizing which management strategies (Deur & Turner, 2011). Documenting this knowledge can benefit Indigenous Nations who are currently implementing ecosystem-based-management plans within their territories (Price et al., 2009) as well as their Western-based collaborators, including forest ecologists (Lepofsky & Lertzman, 2008). Discussed below is a more in-depth look into how the results of this study reflect Indigenous techniques used to manage cultural species prior to colonization and support other documented work on the ecology of cultural landscapes.

4.1.1 SPECIES RICHNESS

Occurrence data collected on local plant species across five documented habitation sites and five control sites with similar ecological characteristics, highlight how the Great Bear Rainforest landscape has been influenced by long term human presence. Our results show significant differences in community composition between areas free of human habitation and areas known to be occupied and managed by people pre-colonization, with greater overall species richness on habitation sites, including the presence of 15 species not found on controls. These results reflect the findings of other studies documenting human ecological legacies in the Great Bear Rainforest and around the world. Fisher et al. (2019) attributed elevated species richness and abundance within forest plant communities on and around habitation sites in the Great Bear Rainforest to legacies driven by past human management. Within individual quadrats, however, Fisher et al. (2019) did not find significant differences in species richness between habitation and control sites. These results mimic the results of our Plant Management study that revealed higher species richness overall on habitation sites but no significant differences within individual plots. Both studies identified numerous species unique to habitation sites that were not found on controls (Fisher et al., 2019). Also, in the Great Bear Rainforest, Trant et al. (2016) documented enhanced productivity of forest canopy cover on habitation sites, linking his findings to ecological legacies of long-term human presence and management (Trant et al., 2016). Studies outside the extent of the Great Bear Rainforest have similarly linked long-term human presence and prolonged resource management to elevated species abundance and richness (Cook-Patton et al., 2014; Vanderplank, Mata, & Ezcurra, 2014), changes in forest community structure (Cook-Patton et al., 2014), higher occurrences of culturally important species (Levis et al., 2018), and species range expansion (Levis et al., 2018; Routson, 2012).

Trant et al. (2016) and Fisher et al. (2019), respectively, discuss enhancements to soil nutrients and chemistry via the addition of organic matter as a major driver of forest productivity (Trant et al., 2016) and species richness (Fisher et al., 2019). Shell middens, a characteristic of habitation sites, are confirmed to have soils that are rich in nutrients compared to sites that are uninhabited and contain higher levels of marine-derived nutrients (Fisher et al., 2019). The influx of marine nutrients is attributed to the build-up of compostable debris around village sites over time, which included animal bones, shells, and marine detritus (Fisher et al., 2019). Furthermore, Indigenous Knowledge confirms that people were adding marine detritus, shells, and charcoal to forest and herb gardens to extend the ecological niche and enhance productivity (Deur & Turner, 2011; Turner, Deur, & Lepofsky, 2013). These legacies are likely contributing to the enhancement of soil on habitation sites and, in turn, enhancing the richness and productivity of the plant species identified in our study on habitation sites (Deur & Turner, 2011; Turner, Deur, & Lepofsky, 2013).

4.1.2 CULTURAL SPECIES

Overall, habitation sites held more cultural significance than controls, with mean sums for all five cultural layers higher on habitation sites. The number of culturally valued species identified on habitation sites was 42 with 27 identified on controls. Though overall, the five habitation sites contained more species across the entirety of each transect than the 5 control sites, when species richness within individual plots (106 on habitation sites and 56 on control sites) was tested no significant differences between cultural index levels was detected. Though fifteen cultural species were observed in habitation plots and absent from control plots, this difference may not have shown up statistically due to the rare occurrence of these 15 species. If a greater sample size was surveyed, plot-level detail uncovering the significance of rare-occurring species may be able to be detected. Studies around the world have documented the accumulation of culturally valued species around sites which humans inhabited (Levis et al., 2018). The Amazon Rainforest contains a history of human management (Levis et al., 2018) similar to ancient landscapes in North America, with intensive plant management occurring for periods greater than most other places on earth (citation). Levis et al. (2018) identified higher concentrations of species with cultural value on sites with known long-term human management. Fisher et al. (2019) used a similar index to the one used in this study to analyze the cultural value of the species in their study. Results indicated higher richness of culturally valued species on habitation sites compared to control sites.

The cultural species richness findings in this study are likely influenced by the techniques listed for each plant under the management table. These techniques were: burned, partially harvested (i.e., bark strip), fully harvested, cleaned, pruned, transplanted, owned, replanted, cleared, managed patch, designated grove, designated garden, weeded, selective harvesting, tended, cultivated/tilled, lopped, green shoots cut for regeneration, berries or seeds scattered, and fertilized (Deur & Turner, 2011; Turner, 2014a; Turner, 2014b). Unlike modern management, each of these techniques boosted and enhanced overall ecosystem health, while naturally increasing productivity and abundance of cultural keystone species (Turner, 2014a). Burning was used to clear land and increase ecosystem productivity (Lepofsky & Lertzman, 2008; Deur & Turner, 2011). This land was then used for the creation of forest, shrub, and herb gardens, which housed a diversity of cultural berries, shrubs, and herbaceous perennials (Deur & Turner, 2011). In some cases, people cultivated plots of land to increase the ecological niche of valuable species, widening the extent to which they could grow. Findings from studies conducted along Vancouver Island document stretches of coastline acres long dedicated to the cultivation of edible root species (Deur et al., 2013). Other studies document large groves of cultural trees and berries (Turner, 2005; Turner, Deur, & Lepofsky, 2013). Traditional knowledge indicates that most often, people ensured to increase the production of multiple species within the same area as the benefits of multi-cropping were understood (Deur & Turner, 2011; Deur 2002; Lepofsky & Lertzman, 2008). This technique contributed to enhanced species richness on and around habitation sites (Deur & Turner, 2011; Turner, 2014b) and could be one of the ecological legacies driving the species richness results in this study. Transplanting and seeding would have also resulted in enhanced species richness as these techniques were used to increase the number of culturally valued species around human habitation sites (Deur & Turner, 2011; Lepofsky & Lertzman 2008; Turner, 2014a).

The 15 species that were not identified on control sites were some of the lowest-occurring, least abundant species study-wide. Since control sites have not been subject to human management practices that clear forests, expand niches, and enrich soils specifically to accumulate desired species in areas where they do not grow naturally or plentifully, it is no wonder these sites are dominated by common, characteristic species of the Great Bear, like salal and Western redcedar. Additionally, the traditions of trading and gifting desirable species between families and Nations up and down the coast would have meant that species from afar ended up in areas where they did not necessarily grow naturally or plentifully (Deur, Turner, & Lepofsky, 2013; Deur & Turner, 2011). These practices are reflected in the occurrence of the least-common overall species being identified more often on habitation sites. Community composition on control sites was largely dominated by species that occurred regularly in all plots along all transects and that are characteristic species of the Central Coast ecosystem. Control sites had fewer species that occurred in only 1-5% of plots overall. Since species were not regularly introduced into these areas and the environment, continuously manipulated to stimulate productivity and growth of less common or non-native species, it is to be expected these lower abundant species would be found less frequently or absent from control sites. Additionally, the domination of the more common coastal plant species for millennia due to lack of human modification would mean that less-common species would have trouble establishing themselves there today. Since habitation sites have been free of continuous human management post colonialization, sum 300 years ago, it is unsurprising that the more uncommon species that may have been brought to habitation sites by people, whether from far away or somewhere in the local landscape, do not occur often. Once people were forced to vacate these islands, after colonialization, the landscape would have slowly begun to change (Fisher et al., 2019). Since the techniques developed to cultivated plants were so sustainable, working with the natural system instead of causing detriment, the legacies of these techniques are light. However, richness, productivity, and habitat were rigorously enhanced for such long periods, that they can still be noticed, even after 300 years. This study emphasizes the gentle yet persistent nature of human ecological legacies in this part of the Pacific Northwest.

The cultural table displaying the sums of species within five cultural layers gives us a more detailed view of how species richness at each site relates to long-term human management and Indigenous values. From these data, we can begin to understand which management techniques may be influencing landscapes and identify areas of high value to local people. A Management Index rating of 0 does not mean that these plants were not valued to some degree or harvested in a casual sense but it does mean that current Indigenous Knowledge does not noticeably reflect their value in existing vocabulary or oral history. Even techniques such as ‘partially or fully harvested’ were regimented and complex, with strict schedules and thoughtful considerations around environmental conditions, cultural values, location, and species (Deur & Turner, 2011). We believe that the legacies from the techniques identified in this management index largely influence the richness of cultural species found on habitation sites today. Several strategies were attributed to the elevated richness of plant species around habitation sites that were similar to the ones discussed in this study and identified by Pacific Northwest Indigenous Knowledge, including burning, weeding, conservation and enhancement of valued species, seed dispersion, transplanting, selecting for desirable phenotypic characteristics, and soil cultivation and fertilization.

Identifying sites with hot spots of culturally valued species, culturally managed species, and species within the three primary management categories: trees, shrubs, and herbs contribute to our overall understanding of the richness of culturally associated species within our study extent and highlights the areas of land that may be the most influenced by ecological legacies of long-term human management. Maps like the ones built for this study are examples of methods landscape and resource managers can use to account for cultural value and adequately consider Indigenous Knowledge in their planning. Furthermore, "incorporating local values into the climate change planning process in a structured way and effectively using local knowledge not only improves the identification of priority actions for climate change adaptation but also supports successful implementation." (Reid et al., 2014) From maps like these, areas of forest housing lower cultural value can be determined and targeted for resource harvesting to reduce cultural impact. Large patches of culturally valued plants can also be protected more easily when their exact locations are known and identified. Additionally, understanding the sums of these 5 cultural layers gives us insight into the legacies that could be influencing different areas of coastline in the Great Bear Rainforest. From this, we can make more informed conclusions about how human management could be influencing present-day landscape structure directly around habitation sites.

"Village and campsites and their immediate vicinities were intensely modified by humans" (Deur & Turner 2011, p. 145). This made standardizing transect length across all sites difficult due to the lack of long stretches of accessible coastline, free from human presence to use for controls. These site characteristics associated with human habitation sites are most probably legacies of human landscape manipulation throughout time and can offer additional insight into how the ecology of this landscape has been influenced by humans, plant communities included. The characteristics of habitation sites in the Great Bear Rainforest emphasize the conscious, meticulous thinking that went into choosing places of human habitation on this part of the coast; ones with long stretching, gently sloping shorelines, protected from the open ocean, often with large marshy intertidal flats out front or nearby, and a wide estuarine buffer binding the terrestrial and marine environments. Contributing to site accessibility and walkability would have been the many known management techniques identified for most plant species in this study. Burning, clearing, and weeding were all common techniques used to develop and maintain forest gardens, root gardens, herb gardens, and berry patches (Deur & Turner, 2011; Turner, 2014a; Turner, 2014b). At the core of these techniques was the goal of reducing or eliminating certain forest vegetation to improve productivity, richness, and abundance of culturally valued species while extending and enhancing their ecological niche (Turner, Deur, & Lepofsky; Deur & Turner, 2011). It was well-known that many shrub and berry species thrived in clear, open spaces where competition for light was lower (Deur & Turner, 2011). As well, some studies document human habitation sites that are now herb-dominated, as a result of these management practices (Deur & Turner, 2011). Additionally, the technique of clearing rocks from the intertidal and estuarine environments to form canoe runs (Deur, 2000), build fish traps (Moss, 2012), extend clam gardens (Jackley et al., 2016), and outline plots of edible species (Turner, 2016), would also have improved the accessibility of these sites.

In some coastal settlements, large trees were removed from habitation sites to make room for dwellings and provide wood for people, rocks were taken from the shoreline and piled into structures, and vegetation was cleared to extend the boundaries of the village (Turner, Deur, Lepofsky, 2013). Cut tree-stumps also made the perfect foundation for growing species such as red huckleberry, salal, and blueberry (Deur & Turner, 2011). The impact of thousands of footsteps over time would also have influenced the landscape, encouraging species that do well in high-impact environments (Deur & Turner, 2011). All of these techniques would inevitably have affected the structure of the forest and the land. Present-day characteristics of the habitation sites in this study are likely influenced by these human management legacies. Furthermore, the build-up of shell midden over time has resulted in structurally distinct shorelines with sloping, soft-soiled banks gentle enough to climb up. Unlike control sites, the forest on these middens is not completely unpassable, making the deeper rainforest behind accessible. On sites free of human habitation, the banks are unclimbable with thick, overgrown vegetation. This is yet another example of how human legacies persist in the Great Bear ecosystem today, influencing the structure of the landscape around habitation sites.

4.1.3 PACIFIC CRABAPPLE ABUNDANCE

Significantly higher densities of Pacific crabapple were identified on habitation sites, compared to control sites. Pacific crabapple is known for its cultural value (Cultural Index = 4) not only in providing people with edible fruit to eat but also wood for tools, and bark possessing medicinal properties (Turner, Deur, & Lepofsky, 2013). The Management Index built for this study gave this plant an index rating of 6, indicating that at least six management techniques were used by Pacific Northwest cultures to increase its abundance, accessibility to human habitation, and resource yields (Table A5). The six techniques associated with this species are: partially harvested (i.e. bark stripped, select limbs cut, fruit harvested), pruned, traded, transplanted, or gifted, owned, tended to, and lopped. In some Northwest coast cultures, this species was accumulated into groves to be more closely maintained by people. There are even accounts along the BC coast of pegs being placed into the ground to set clear spatial boundaries and borders around distinct groves (Turner, Deur, & Lepofsky, 2013). The collection and analysis of occurrence data via local field studies around habitation sites in the Great Bear Rainforest, leads us to believe that Pacific crabapple was most likely subject to human management on some of the known habitation sites immediately surrounding Calvert Island.

Our results showed significant differences between Pacific crabapple abundance on control sites and habitation sites. Other studies have documented similarly high abundances of Pacific crabapple around human habitation sites in the Pacific Northwest (Armstrong, 2017; Turner, Deur, & Lepofsky, 2013). Armstrong (2017) identified Pacific crabapple as being one of the key indicator species of human habitation on her study sites around Vancouver Island. Turner, Deur, and Lepofsky (2013) recorded dozens of Pacific crabapple trees in their study on the abandon Indigenous settlement, Robintown, located north of Terrace BC. Also identified here were the ecological legacies of techniques used to manage Pacific crabapple, including pruning and cutting the tops of the trees so fruit was more accessible (Turner, Deur, & Lepofsky, 2013)

Out of the five control sites where data were collected, only two contained Pacific crabapple, whereas four out of five of the habitation sites had Pacific crabapple trees growing plentifully on and around them. Out of those four habitation sites, two of them contained over 70 individual Pacific crabapple trees, compared to the highest abundance found on control sites which was 26. Densities varied across habitation sites. The fact that crabapple abundance is not uniform across every single habitation site, in some ways, further emphasizes human management interferences on sites where it is. If we consider that environmental characteristics on each habitation site are very similar from an ecological standpoint, all sites should support similar abundances of Pacific crabapple trees if they were occurring naturally, without human influences. The fact that they are lacking or missing from certain habitation sites could indicate that they were purposefully not accumulated in these spots and that the sites that do house large crabapple densities were designated more for this type of species management.

Identifying the presence of such an abundance of Pacific crabapples on these sites leads to the discussion surrounding where the species came from and who brought it here. There are several species of wild apples (Malus spp.) native to continents around the world, North America being one of them (Routson et al., 2012; Williams, 1982). However, *Malus fusca* has been genetically linked not to native species in North America, but instead to species native to central Asia and China (Routson et al., 2012; Williams, 1982). All current documentation suggests links between the transplanting of *M. fusca* into the Pacific Northwest and the migration of the first people to travel across the Bering Strait during the Late Pleistocene Epoch some 10,000 years ago (Routson et al., 2012; Williams, 1982).

Since the expansion of this species range after being transplanted to North America would have originated from a very localized source, genetic homogenization is expected. Routson et al. (2012) genetically identified over 200 Pacific crabapple trees from Alaska along the Pacific Northwest coastline to California, and confirmed that this was, in fact, true. With the knowledge that present-day commercial crabapple populations are seeing decreased levels of genetic diversity due to human management (Routson et al., 2012), we propose that genetic homogenization of Pacific crabapples could also be a legacy of long-term human management. If present-day commercial apple populations in North America can see genetic homogenization after a mere few hundred years of intensive human modification, then presumably repetitive manipulation over thousands of years would have done the same thing.

Suggestions surround the spread of Pacific crabapple after it made contact with North American soil are wide and varying, including an assortment of ecological factors and as well, the idea that humans would have also contributed to the movement of this species (Routson et al., 2012). If this species was transplanted here intentionally by people, it is more than likely that it held some form of cultural value in its native ecosystems of Central Asia and China. Based on the data presented in the cultural and management index tables indicating a high cultural value (Cultural Index = 4) and a high number of associated management techniques (Management Index = 6) for Pacific crabapple, we present the hypothesis that human movement could be more significant at expanding this species range than originally speculated, however the extent and design of this study is not able to make conclusions on this hypothesis. Traditional knowledge highlights the importance of Pacific crabapple not only for edible purposes but also for the making of tools and medicinal uses (Deur & Turner, 2011; Turner, 2014a). It was also known to be traded, transplanted, and gifted between people and Nations up and down the coast (Deur & Turner, 2011). Considering these Indigenous management techniques and the high cultural value, human transportation may be one of the top drivers of this species range expansion.

4.2 ESTUARINE ROOT PLANTS

A total of 17 patches of culturally important plant species were observed and documented in this study. Except for Site 17, all sites were spatially distributed on or around documented sites with long-term human presence. A study conducted in Washington State on the ecology of northern rice root populations and associated soil characteristics noted that northern rice root thrives in soils that are high in organic matter and nutrients (Zox & Gold, 2009). We know from Fisher et al. (2019) that human habitation sites in the Great Bear Rainforest have elevated soil nutrient characteristics than soils free from human influence. As well, we know that species on these sites have benefited from these nutrients, like that of Western redcedar whose productivity on islands in the Great Bear Rainforest is enhanced by the presence of shell middens (Trant et al., 2016). With rich soils, habitation sites would presumably make ideal growing conditions for northern rice root, and the large population sizes and tall individuals that exist here make these patches easy to locate.

The data collected from cultural plant-related surveys near each patch of edible root plants offered observational insight into the additional ways each site may be affected by long-term human presence. CMTs were observed on all sites, confirming past human management of these forests. The presence of large populations of northern rice root, as well as the other edible root species, Pacific silverweed, and springbank clover, adds to the cultural significance of these sites. This enables us to better understand the other potential management techniques that could be influencing the local habitat. In some parts of the Pacific Northwest, northern rice root is listed as a sensitive species with noticeably declining population sizes in recent years (Zox & Gold, 2009). Warming temperatures are predicted to have a negative impact on the success of rice root populations (Zox & Gold, 2009). With climate change and modern resource development encroaching, identifying the current distribution of this cultural keystone species and other edible root plants is urgent (Benner et al. 2019; Turner & Berkes, 2006). Most of the literature that exists in the Pacific Northwest on northern rice root is ethnobotanical oriented (Zox & Gold, 2009). Understanding the habitat, distribution, and phenotypic characteristics of local populations can aid in the protection and restoration efforts of this culturally valued species (Zox & Gold, 2009). Discussed below is a detailed look into the results of the Estuarine Root Plant study.

4.2.1 SITE CHARACTERISTICS & QUALITATIVE OBSERVATIONS

Northern rice root grows in a variety of ecological conditions (Zox & Gold, 2009; Matsuura, 1935). The two main eco-types being the upper-tidal environment and the subalpine environment (Zox & Gold, 2009; Matsuura, 1935). The upper-tidal environment that Zox and Gold (2009) identified patches of northern rice root in during their 5-year study extends from the forest edge, through the estuarine salt marsh, stopping at the high tide line or line where woody debris piles up (Zox & Gold, 2009). In this study, northern rice root populations were constricted to a band about 30 cm wide (Zox & Gold, 2009). Along Vancouver Island, Deur et al. (2013) noted the presence of northern rice root in cultivated gardens located in the estuarine salt marsh environment. He notes that the extent of some patches of northern rice root here stretch for acres (Deur et al., 2013). Indigenous Knowledge and other estuarine root garden studies in the Pacific Northwest note the presence of rock walls that were built up to extend the ecological niche of edible root plants, increase soil biomass, and maximize marine detritus retention (Deur, 2000; Turner, Deur & Lepofsky, 2013). In our study, patches of northern rice root were identified in the upper-tidal zone, in bands ranging from 70 cm to 5.7 m wide (mean= 2.72 m +- 0.38 SE) and 2.1 m to 17.7 m long (mean= 5.04 m +- 0.78 SE). During our field research, we did not document evidence of rock wall formations, like that of managed northern rice root gardens farther south (Deur et al., 2013), though it is valuable to note that the patch of northern rice root at EjTa13 did have rocks present along the edges of the patch growing there and soil depth here was observationally higher (31 cm) than the overall site mean (mean= 22.71 +- 1.93 SE).

Zox and Gold (2009) noted that plots of northern rice root identified during their study were often locally elevated. They hypothesize that this may be to limit saltwater inundation and increase snowmelt (Zox & Gold, 2009). This characteristic was similar to the structural habitat associated with the northern rice root populations in our Estuarine Root Plant study. Most plots of northern rice root were located on plateaus of granite covered by herbaceous vegetation or on raised beds of woody debris (Figure 8).

FIGURE 8. Megan and Alana harvest northern rice root for Megan's Auntie from a locally elevated plot at site 2 (EjTa13) on raised rock bed.

As snow is not characteristic of the Great Bear Rainforest, the species here would most likely be found raised above sea level to regulate saltwater inundation. Zox and Gold (2009) note that varying levels of salt are harder on this species than the actual amount of salt they are exposed to. This could contribute to the success of the plants at site 17, which were located the farthest from the ocean, on a marshy outcropping jutting out into the middle of a steady flowing, freshwater stream that had to be ford to access the patch. This site would have received the benefits from the freshwater environment it was immersed in and likely have experienced the lowest fluctuation in saltwater inundation, considering that the ocean could not be seen when standing at the site. Elevation and distance from the high tide line were not calculated in this study but these variables could deliver insight into the success of the plants in the Great Bear ecosystem.

Sites that contained more than one patch of edible root species included EjTa4, EkTa2, and EkTa38. At EjTa4 two patches of root plants were found, one containing 19 individual northern rice root plants and the other containing both Pacific silverweed and springbank clover. At EkTa2, three patches of root plants were found, one containing Pacific silverweed, another containing 16 rice roots as well as Pacific silverweed, and the third containing 76 northern rice root plants. At EjTa38, five patches of edible root plants were identified. The first containing 197 northern rice root individuals, the second housing a thick layer of springbank clover and Pacific silverweed, the third with 45 northern rice root, the fourth with 143 northern rice root, and the fifth with 77 northern rice root. The presence of large populations of northern rice root on the same habitation site along with the identification of other cultural plants, CMTs, and fire-scarred trees gives us ecological insight into how this coastline may have been managed and the resources here utilized. These species and features highlight the long-standing cultural importance and value this landscape encompasses. From the map displaying this data, we can identify areas of coastline that would be most impacted if eliminated by climate change or modern resource management. This map is an example of a method that could be used to determine the cultural and ecological hotspots in other areas of the coast to ensure the protection of these areas and the species they encompass in the face of unprecedented changes.

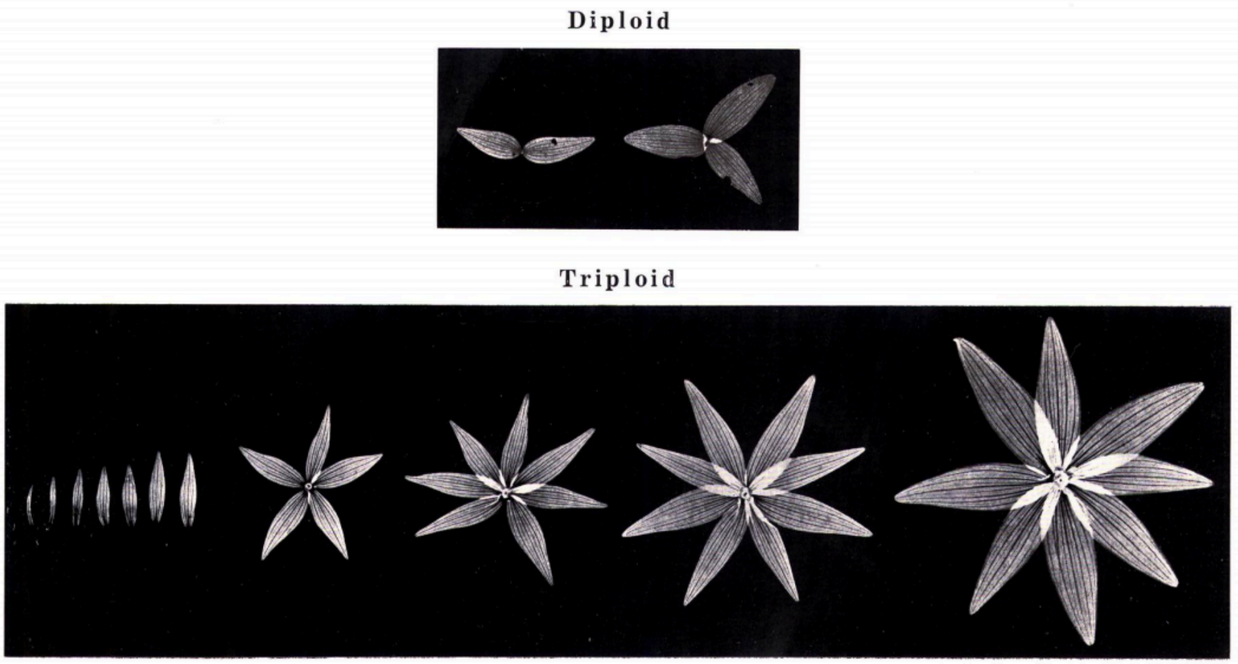
The data from the cultural plant-related surveys conducted behind each edible root patch allowed us to identify other cultural features and important plants within the immediate vicinity of each site. Doing this allows us to understand how each site may have been utilized by people in more detail. The most abundant category across all sites was CMT. They are identifiable by the distinctive marks and grooves left in the tree after modification. CMTs include bark-stripped trees, with long strips of wood, often meters in length missing from their trunks (Lepofsky & Lertzman, 2008). CMT occurrence was documented on 100% of sites. Currently, there is no presence of habitation documented on or around Site 17, the presence of CMTs on this habitation site demonstrates the movement of people throughout this landscape. The map displaying data from this study highlights the cultural significance of site 17 in more ways than just the presence of CMTs, with the largest and tallest patch of northern rice root existing here, as well as the rice root plant containing the greatest number of flowers (9). Additionally, 6 Pacific crabapple trees were present at this site. Site 6 (EjTa 19) was the only site that had species present from all four categories. Site 6 also contained 75% of the fire-scarred trees surveyed across the 17 sites. Fire-scarred trees refer to any species that have burn marks present. Hoffman et al. (2016) found a strong correlation between habitation sites and fire scar occurrence on the islands our study sites lie on, linking the presence of fire evidence to humans. This allows us to confidently associate fire-scarred trees with human presence. All three of the edible roots that this study identified were linked to burning techniques (see Table A5). The fact that the majority of fire-scarred trees occurred on Site 6 further leads us to believe that these scars are most likely not the result of a fire that spread across the entire coastline, but are instead, legacies of localized human presence.

4.2.2 PHENOTYPIC CHARACTERISTICS

Northern rice root exists in three unique life stages, distinguishable by each individual's leaves and flowers (Yonezawa et al., 2000). The three life stages are single-leaf/ non-flowering (SL), multi-leaf/ non-flowering (ML), multi-leaf flowering (ML) (Yonezawa et al., 2000). The number of flowers that a plant possesses as well as its height directly relates to its age, with older plants having more flowers and a taller stature (Matsuura, 1935). Over Zox and Gold's (2009) 5-year study the majority of the plants encountered were in the single-leaf stage. Though our study did not record leaf numbers for each plant, most populations had a mean flower and bulb count of 0, indicating the plants here were in one of the first two non-flowering life stages. These results highlight the importance of including non-flowering individuals in studies on northern rice root in the Great Bear Rainforest instead of only including large, flowering individuals like that of many past studies in the Pacific Northwest (Zox & Gold, 2009). In our study, rare individuals had a bud and/or flower count of 5 to 9. Rare individuals in Zox & Gold's (2009) study had flower counts between 5 to 7. Other field guides list rare individuals having flower numbers up to 8 (Camp, Gamon, & Arnett, 2011). This data highlights the rarity of the individual with 9 flowers found on site 17 in our study.

Northern rice root typically grows between 20 to 60 cm tall (Camp, Gamon, & Arnett, 2011). In our study, the mean plant height across all 17 sites was 31.43 cm +- 3.92 SE. The largest single population of rice root, containing 213 individuals at site 17 also contained the tallest plants, with plants averaging 69 cm in height. Zox and Gold (2009) found plants in their 5-year study to be between 10-60 cm tall. Site 17 once again exhibits characteristics that seem rare for this species from what other studies and current literature have recorded.

Genetic research on northern rice root populations in Japan identified two different karyo-ecotypes, meaning that populations in that area exhibited different genetic characteristics based on the ecosystem they were growing in (Matsuura, 1935). The two genetic types are diploid, found in sub-alpine environments and triploid found closer to sea level, typically in marshy, low-lying conditions, or at the edges of the intertidal environment (Matsuura, 1935). Diploid individuals are small in stature with fewer leaves (2-3) compared to triploid individuals which are much taller and contain whirls of 4 to 8 leaves depending on maturity (Matsuura, 1935). The individuals identified in our study possess the characteristics of the triploid karyo-ecotype, both in height and leaf structure as well as match the described ecological conditions (see Figures 10 & 11).



T. Akemine photo.

H. MATSUURA: On Karyo-ecotypes of *Fritillaria camschatcensis* (L.) KER-GAWLER.

FIGURE 9. Diploid northern rice root (top) and Triploid northern rice root (bottom) leaf arrangements (Matsuura, 1935).

FIGURE 10. Northern rice root plant in the Great Bear Rainforest with whirls of 5 leaves that resemble the Triploid structure in Figure 9.

One of the main differences between diploid and triploid populations is that the triploid has developed the capacity to reproduce asexually through its bulbs (Matsuura, 1935), meaning that offspring will be identical clones of their parent (Zox & Gold, 2009). This would have been a key component to the success of managing this species since after people harvested the plant and collected the starchy, edible nodules, the remaining bulb was replanted back into the ground (Deur & Turner, 2011). Nodules from the strongest and tallest plants were also replanted to populate estuarine root gardens with individuals that honed desirable characteristics (Deur & Turner, 2011). Data collection on sub-alpine populations of northern rice root in the Great Bear Rainforest and genetic research comparing the two populations in these different environments is necessary to confirm if two distinct karyo-ecotypes existed in this area of the Pacific Northwest. Understanding genetic differences in populations of northern rice root can assist with the conservation of this species and its habitat (Matsuura, 1935)

4.2.3 COMMUNITY COMPOSITION

No site contained all three edible root species, however Sites 3, 6, 7, and 8 contained both northern rice root and Pacific silverweed, and Sites 4 and 11 contained Pacific silverweed and springbank clover. Other studies also note the presence of more than one species of edible root plants growing together within the same patch (Deur, 2000; McLaren, 2013; Zox & Gold, 2009). Sites that had a minimum of 20% northern rice root cover saw community composition dominated by salal, false lily of the valley, crowberry, common vetch, red huckleberry, several-flowered sedge, and American dune grass. Zox and Gold (2009) identified Pacific crabapple on sites with northern rice root, noting that this was not surprising as this species is characteristic of nutrient-rich soils, similar to northern rice root.

Our cultural plant-related survey around each patch of rice root identified Pacific crabapple on 7 of the 17 sites. As this study was non-exhaustive, Pacific crabapple is likely present on many of the other sites. Community composition at sites that contained a minimum of 20% silverweed cover was dominated by Baltic rush, false lily of the valley, Alaskan plantain, and America dune grass. At sites where springbank clover cover was a minimum of 20%, community composition was dominated by silverweed and false lily of the valley. See Table 8 for a list of the top three dominant species at each site and the associated percent cover of the three edible root plants: northern rice root, silverweed, and springbank clover in the respective patches.

Springbank clover shared high cultural status with plants like that of the other two edible roots (rice root and silverweed), as well as cedar, and Pacific crabapple. The fact that this species was not found on any other site in this entire study or in any plots surveyed in the previous Plant Management study is notable. The two areas that springbank clover was identified were immediately in front of habitation sites. Zox & Gold (2009) identified springbank clover as another edible plant within the patches of northern rice root that they surveyed. In this study, springbank clover was only identified within patches with silverweed. The patch of Springbank clover in front of EkTa38 was also identified in an archeological survey of this area (McLaren, 2013). It was one of the first cultural identifications that lead to the discovery of this habitation site (McLaren, 2013). The community composition portion of this study calculated the mean percent cover of springbank here to be 63 % (SE= +-8.82). The only other species identified across the entire community composition survey that had a percent cover comparable to this was a patch of rice root on Site 17 whose mean cover was 69 % (SE= +-14.62). The rarity, location, and density of springbank clover lead to the conclusion that the presence of this plant in these locations is likely the legacy of long-term Indigenous management. It is evident that the ecology of the Great Bear Rainforest has the potential to support springbank clover, but that it does not have the large spatial extent of the other root plants across the coastlines explored for this study. It is a probable hypothesis that this species was traded, gifted, or transplanted from other areas farther south. Genetic comparisons between plants at these two sites and plants farther south would open up further discussion about the origin of this species and its range expansion to this area of the Pacific Northwest.

4.3 KNOWLEDGE COLLABORATION

4.3.1 COMPONENTS OF SUCCESS

The combination of Indigenous and western knowledge can be a powerful way to comprehensively understand ecological systems (Turner, 2005; Turner, 2014a; Turner & Berkes, 2006; Fisher et al., 2019; Martin, Roy, Diemont, & Ferguson, 2010; Martinez, 2010; Reid et al., 2020). At the same time this collaboration can support the longevity of Indigenous cultures and methodologies, still well and alive today (Martin, Roy, Diemont, & Ferguson, 2010; Martinez, 2010; Reid et al., 2020). Furthermore, bridging the gap between these two different ways of knowing can be a movement towards reconciliation if carried out mindfully (Reid et al., 2020). A study in the Western Solomon Islands (Aswani, & Hamilton, 2004) used Indigenous knowledge to design and plan its research on bumphead parrotfish. This not only ensured the topic was current and relevant to local Indigenous people but also contributed to more precise and focused management strategies, supported by Indigenous observations over time (Aswani, & Hamilton, 2004). A recent study (Ried et al., 2020) on the collaboration of western and Indigenous Knowledge for enhanced fisheries management highlights the concept of "two eyed seeing" (*Etuaptmumk* in Mi'kmaw), a term originating within Mi'kmaw culture. Two eyed seeing honors both western and Indigenous ways of knowing, making room for their respective ideologies and considering them equally (Ried et al., 2020). This is opposed to the idea that Indigenous knowledge should be integrated into western thinking to benefit scientific research, for integration can often end up being another form of assimilation (Ried et al., 2020). Two eyed seeing means that neither way of knowing overrides or outweighs the other. Instead, the collaboration provides support and balance, while appreciating the other's differences (Ried et al., 2020). Like a pair of eyes, though one can see without the other, together they are stronger and capable of interpreting the world more vividly. Two eyed seeing was present within our team of researchers and research collaborators and led not only to a stronger study, but also meaningful interpersonal relationships. The following discussion identifies some of the key components that contributed to our team's success in the field and allowed us to more easily accomplish two eyed seeing.

In order for any scientific team to perform effectively, strong working relationships between team members is critical (Bennett & Gadlin, 2012; Cheruvelil et al., 2014). In their study on effectively forming an interdisciplinary scientific research team, Bennett and Gadlin (2012) identified trust as the number one most important component of success. Bennett and Gadlin (2012) highlight the ways in which trust between partners can result in a high-performing, smooth functioning team by allowing all participants to feel safe and comfortable to speak openly and work through disagreements (Bennett & Gadlin, 2012). Another study by Cheruvelil et al., (2014) discusses the benefits of diversity and collaboration within science, highlighting the value of multiple ways of thinking and how they can contribute to stronger research studies. Like Bennett and Gadlin's study (2012), Cheruvelil et al. (2014) also indicates trust as absolutely critical, emphasizing that if trust is not present, a team will likely fail. The study highlights the value of different perspectives and knowledge and the power they have on research (Cheruvelil et al., 2014). They argue that teams that embody diversity can produce better quality work than solo researchers who lack alternative perspectives and input (Cheruvelil et al., 2014). For our team, trust and diversity were among the contributing factors that facilitated productive teamwork and two eyed seeing. Additionally, cultural awareness, openness, communication, and respect were also key.

When people come together from different backgrounds, with different ideologies, and alternative ways of knowing, there can be disagreements on the way forward, including the methods used and the type of data collected (Bennett & Gadlin, 2012; Cheruvelil et al., 2014). Layer that with a dark history of colonization, residential schools, displacement, and violence and establishing newfound trust becomes that much more critical. One of the ways in which trust was established between our team was by spending time with each other outside of the work itself. Sharing stories, life experiences, traumas, joys, and family history uncovered commonalities between team members, building deep meaningful relationships and in the process establishing trust. Facilitating positive experiences through shared hobbies also built trust and strengthened connection. Additionally, Indigenous and western collaborators within our team built a relationship prior to carrying out research together. This further contributed to the success of the collaboration as trust and respect were already initiated before challenging decisions and hard work had to be carried out.

In addition to trust, clarity, communication, and openness also allowed our team to work well together. During our time in the field, when soil collection methods were determined to be invasive and destructive to the cultural landscape, sampling efforts were halted, and methods were changed to only gather soil depth measurements instead. These types of modifications emerged from good communication and an open mindset among participants and resulted in research that reflected the local culture and upheld the integrity of the landscape, while also gathering relevant ecology data. What we learnt was that clearly laying out how methods will be carried out can allow room for alternative input and the confirmation that both Indigenous and western participants are satisfied. As a western scientist, accepting and being mindful of when western methodologies are not culturally appropriate is pertinent. It should be understood that data collection is important but collecting that data in a way that supports and upholds Indigenous cultures and ideologies overrides that importance. If this cannot be done, sampling should be halted, revised and revisited until all collaborators agree upon a way forward. Strong, consistent communication between team members will ensure that concerns are addressed, and ecological and cultural factors are considered equally.

Lastly, a key component to the success of our team's collaboration was respect. Respect for each other's cultures and respect for each other's ways of knowing. As a modern scientist, it is valuable to go into the field understanding culturally appropriate ways of interacting with the land and the people. This should be done by increasing one's knowledge through reading and research on the specific cultures whose territories encompass the work. Furthermore, connecting with collaborators through casual conversation to get to know one another before the work begins can also contribute to cultural awareness and understanding for everyone involved. Making an effort to connect on a more personal level will not only establish trust but also build meaningful relationships.

4.3.2 CULTURALLY APPROPRIATE METHODOLOGY

While collecting data in cultural landscapes, on culturally important resources, or with Indigenous collaborators, ensuring that scientific methods and protocols are culturally reflective can uphold both the local ecosystem (Martin et al., 2010) and the local cultures (Martin et al., 2010; Kurtz, 2013). Kurtz (2013) used Indigenous methodologies during a doctoral study that encompassed Indigenous participants. By using traditional methods of communication, Kurtz (2013) was able to create a safe, trusting environment that honored the participants and their culture. The combination of these two different ways of knowing can contribute to the longevity of methods that have been used by humans to naturally uphold the environment and its people for hundreds of years and be an ally in the fight towards reconciliation (Reid, et al., 2020). Martin et al. (2010) discuss the differences in perception between western thinkers and Indigenous thinkers, highlighting the disconnect western societies often have from their environment in comparison to Indigenous cultures whose identity is embedded in the living ecosystem around them. Collaborations between these two ways of knowing could ensure that this philosophical ideology is reflected in western scientific research, in turn, upholding cultural methods and ecological sustainability (Martin et al., 2010). Martinez (2010) discusses the long-term, generational time-span that Indigenous knowledge encompasses. They emphasize how western knowledge is greatly lacking in comparable depth and highlight the value such long-term knowledge could bring to western research development (Martinez, 2010).

While our team was conducting fieldwork the importance of developing culturally appropriate methodology was highlighted during soil collection. Initially we attempted to collect three samples from each garden with a metal soil auger in the month of May, while the plants were nearing full bloom. This method quickly proved to be invasive to the garden and the culturally important plants growing there. While it is true that the plants in estuarine gardens have grown accustom to human contact and arguably thrive better with human interference, the ways in which they were handled by Indigenous people were different. Wooden tools and human hands were employed to manage the tough estuarine soil (Deur, 2000; Deur & Turner, 2011; Turner, 2014a; Turner 2014b), not large, powerful metal tools used by most modern scientists today. As well, the time of year that estuarine garden soil was traditionally worked was in the fall, post-harvest (Deur, 2000; Lepofsky, & Lertzman, 2008; Turner, 2014a). Once the edible plants were removed from the gardens, the soil was churned with added nutrients from the marine and terrestrial environments, unwanted shrubs were removed, and the plots were weeded. The garden was then repopulated with bulbs saved from the harvest (Deur, 2000; Deur & Turner, 2011). These techniques not only upheld the plants and their habitat but enhanced them. Building Indigenous methods like these into modern scientific fieldwork would allow for sustainable data collection while reviving the now unmaintained estuarine root gardens left abandoned after colonization resulted in the death and displacement of the people who once managed them.

5. CONCLUSION AND RECOMMENDATIONS

5.1 SUMMARY AND GENERAL CONCLUSIONS

Ecosystems around the world have been shaped and changed by long-term human management (Gemerden, Han Olff, Parren, & Bongers, 2003; Levis et al., 2018; Willis, Gillson, Brncic, 2004). Ecological quantification of these legacies can allow for a better understanding of what drives present-day ecosystem processes and functions (Fisher et al., 2019). This study demonstrates how Indigenous Knowledge and Western science can complement each other to do just this and highlights how, without the consideration of long-term human legacies and local cultures, drivers of environmental change can be overlooked. A comprehensive understanding of how humans influence and drive ecosystem patterns will aid in making predictions on the trajectory of ecologically and culturally important species and landscapes. Identifying cultural hot-spots and mapping the current distribution of culturally valued species can assist in ongoing ecosystem-based-management efforts being implemented along the Pacific Northwest Coast today (Price et al., 2009). Indigenous Nations can face unique challenges when managing their local territories as it is crucial to adequately consider the ecological and human environments, as well as the cultural (Price et al., 2009; Benner et al., 2019). Due to colonial resource harvesting, the environmental baselines and spatial boundaries of cultural plants have shifted making it increasingly difficult to identify areas with high abundances of valued species (Benner et al., 2019). Additionally, current data that considers both ecological value and cultural value is overwhelmingly lacking (Benner et al., 2019).

To effectively consider and complement Indigenous Knowledge and cultural values in scientific research past site use, cultural history, and relevant present-day issues should be addressed by ecologists and other western scientists alike (Fisher et al., 2019; Reid et al., 2020). Scientific studies should involve Indigenous collaborators and Knowledge during research design, method design, fieldwork, and data interpretation whenever possible. This will ensure that the research, methods, and results are appropriate for both the local habitat and the local cultures and contribute to reconciliation efforts (Reid et al., 2020). This inclusive process can also introduce western scientists to alternative methodologies that uphold ecological integrity and embody multiple philosophical approaches, while being supported by long-term, generational knowledge (Martin et al., 2010; Reid et al., 2020; Martinez, 2010). In order to ensure knowledge is complemented properly and considered appropriately, Indigenous partners, including community members, tribal council members, and knowledge holders should be involved on as many levels as possible and two eyed seeing collaboration, as opposed to knowledge integration should be established. Building trust and mutual respect through engaging conversations, common interests, and positive experiences were ways that two eyed seeing was strengthened within our research team, contributing to a successful collaboration between western and Indigenous knowledge and forming meaningful, lasting relationships between all research participants.

Not only can the collaboration of western and Indigenous Knowledge strengthen scientific research, but as Earth enters into a time of global environmental crisis due to modern resource management and extraction, Indigenous management systems that have stood the test of time can be guides in how to respectfully work with nature (Turner & Berkes, 2006; Martinez, 2010). Understanding historic techniques that naturally supported and enhanced ecological integrity and resilience, like those developed by the Indigenous cultures of the Pacific Northwest, can be a pathway for achieving modern-day resource management that ensures enough or even, more valued resources for future generations. Indigenous landscape management can provide insight into the sustainable production of local foods and ecological research can highlight current habitat characteristics and ecological conditions necessary for these plants to thrive. Additionally, gaining a more comprehensive understanding of the characteristics that define the ecological habitat of culturally valued plants, as well as acquiring data on the locations of large populations and rare individuals can aid in conservation strategies and contribute to reclamation efforts. In turn, these efforts can be used to enhance food security within Indigenous communities and support the longevity of cultural plants that remain highly valued by Indigenous coastal cultures and peoples today.

5.2 LIMITATIONS

Ecological and temporal constraints resulted in limitations to both studies conducted for this thesis, though these constraints did not result in the quality of the data between sites. The main limitation in both studies was the morphology of the shoreline the data was collected along and the vast amount of land the research encompassed. In the first study on general plant management, this prevented us from being able to sample along transects of equal lengths at all 10 sites. Large cliffs, lack of estuarine presence, and unpassable rainforest sections resulted in a variance in transect length, with shorter transects being sampled on control sites. The massive area of coastline that this study assessed is subject to the open ocean and unfavorable weather conditions. This, along with the size and speed of our boat, made us unable to fully search the extent of each island to find control sites the same length as habitation sites, however, we are not confident that sections of coastline the same extent as habitation sites, free of human influence, even exist. In the second study, study area extent was the most significant hurdle as environmental conditions made it unsafe to search certain sections of coastline for patches of edible root species. Additionally, the single-season timeline for this research limited the amount of data that could be collected. That said, the two months spent at the Hakai Institute allowed for an exceptionally large amount of data to be collected. With additional field time or a larger team, however, stem counts within plots could have been recorded and more data could have been collected on more sites.

5.3 SUGGESTIONS FOR FUTURE RESEARCH

There remains a large gap in the documentation of the ecological legacies of Indigenous plant management within the Great Bear Rainforest, as well as other areas along the Pacific Northwest Coast that could be filled by current ecological data coupled with local Indigenous Knowledge. Additional documentation of management techniques specific to local cultures within the Great Bear Rainforest, as well as data collection of present-day occurrences, distributions, abundances, and communities of culturally valued plant populations would provide more detail into the concepts discussed within this study. This would further uncover how the ecological legacies of Indigenous plant management persist in the Great Bear landscape today and highlight additional areas of high cultural and ecological value. This section discusses possibilities for future research and hypothesizes what this additional data could lead to.

Recording the number of stems for each species in individual plots along each transect would give a more detailed look into how traditional management strategies persist within individual populations and allow the researcher to explore species abundance at the plot level. We hypothesize that although species richness is not significantly different between control and habitation sites, species abundance would be significantly higher on habitation sites. This is hypothesized because the techniques of increasing the nutrients, niche, and abundance of select species of plants in root, herb, and forest gardens would have resulted in elevated abundances of these species around human habitation areas. Collecting abundance data at the plot level, in the form of stem counts would be one way to explore if legacies of these management techniques exist today. Stem count data would also allow researchers to further identify management 'hot spots' that demonstrate high biodiversity of culturally valuable species. From these data, root, herb, and forest gardens could be identified, adding to the existing documented inventory of these areas and those that are presently known by local Indigenous people.

Collecting soil samples from estuarine root garden plots would uncover greater detail on the habitat of estuarine root plants and the ecological conditions they thrive best in. In addition, this data could uncover the legacy effects of increasing soil nutrients by adding marine detritus and charcoal to estuarine gardens. Other researchers, including Deur (2000) and Hoffman (2016) have tested soil associated with habitation sites and sites of plant management and their results revealed higher levels of nutrients contained in these soils. In order to collect data of this type from estuarine root gardens, culturally appropriate methodology needs to be used. This should be done by working alongside Indigenous Knowledge holders to ensure methods and protocols reflect the local culture and environment adequately. An alternative way to collect soil samples that would uphold cultural methodologies and integrity when working in estuarine root gardens could be to first remove the edible roots from the ground before sampling, use smaller and less invasive tools such as hand tools or wooden tools when appropriate, carry out fieldwork during a time of year when soil in the gardens would traditionally be modified, churn the soil to encourage plant growth as done regularly in Indigenous management, add natural fertilizer to the soil such as shells or marine detritus, and lastly, re-populate the gardens with the bulbs that were removed. If kept healthy, edible root gardens could be continually harvested from in the future and contribute to the longevity of these methods and food sources.

To further explore the ecological legacies of human presence on plant communities, longer transects could be sampled at each field site. This would lead to additional understanding on how site use effects plant distribution. Extending transects farther past habitation sites would allow the researcher to observe if the chances of encountering culturally important plant species decreased as a person moves away from the habitation site. Genetic analysis could also be used to uncover legacies of past management. From the genetic analysis, it may be possible to determine where culturally valuable species were transplanted from, considering the exchange of economically valuable species between different Pacific Northwest Coast Nations may have resulted in genetic homogenization of populations of plants in different locations.

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APPENDIX

PLANT MANAGEMENT

TABLE A1. Table of all species found across all 10 study sites with the species code used in the field, followed by the species common name, and scientific name.

Borden Codes	Common Name	Scientific Name
PLMA	Alaskan plantain	*Plantago macrocarpa*
VAAL	Alaskan Blueberry	*Vaccinium alaskaense*
LOIN	Bearberry honey suckle Black twinberry	*Lonicera involucrata*
RILA	Black gooseberry	*Ribes lacustre*
PTAQ	Bracken fern	*Pteridium aquilinum*
FRCH	Coastal strawberry	*Fragaria chiloensis*
VISA	Common vetch	*Vicia sativa*
EMNI	Crow berry	*Empetrum nigrum*
BLSP	Deer fern	*Blechnum spicant*
VACA	Dwarf blueberry	*Vaccinium caespitosum*
COCA	Dwarf dogwood bunchberry	*Cornus unalaschkensis*
MEFE	False azalea	*Menziesia ferruginea*
MADA	False lily of the valley	*Maianthemum dilatatum*
ROWI	Fireweed	*Chamaenerion angustifolium*
ARHI	Hairy rock crest	*Angelica lucida* *Arabis hirsute*
LEGR	Labrador tea	*Rhododendron groenlandicum*
POGL	Licorice fern	*polypodium glycyrrhiza*
TSME	Mountain hemlock	*Tsuga mertensiana*
FRCA	Northern rice root	*Fritillaria camschatcensis*
TRBO	Northern starflower	*Trientalis borealis*
VAOV	Oval-leaved blueberry	*Vaccinium ovalifolium*
MAFU	Pacific crabapple	*Malus fusca*
ARAN	Pacific silver weed	*Argentina anserina/* *Potentilla anserina*
OESA	Pacific water parsley	*Oenanthe sarmentosa*

TABR	Pacific yew	*Taxus brevifolia*
COPA	Pacific-hemlock parsley	*Conioselinum pacificum*
PRAL	Rattlesnake root	*Prenanthes alata*
ALRU	Red alder	*Alnus rubra*
THPL	Western redcedar	*Thuja plicata*
AQFO	Red columbine	*Aquilegia formosa*
VAPA	Red huckleberry	*Vaccinium parvifolium*
GASH	Salal	*Gaultheria shallon*
RUSP	Salmonberry	*Rubus spectabilis*
SAVI	Sea asparagus	*Salicornia virginica*
LYMA	Sea milkwort	*Glaux maritima*
ANLU	Sea-Watch	*Angelica lucida*
PICO	Shore pine	*Pinus contorta*
PISI	Sitka Spruce	*Picea sitchensis*
LYAM	Skunk cabbage	*Lysichiton americanus*
GATRD	Small bedstraw	*Galium trifidum*
TRWO	Springbank clover	*Trifolium wormskioldii*
SMST	Star-flowered false Solomon's seal	*Maianthemum stellatum* *Smilacina stellate*
MYGA	Sweet Gale	*Myrica gale*
GATR	Sweet-scented bedstraw	*Galium trifolorum*
RUPA	Thimbleberry	*Rubus parviflorus*
LIBO	Twinflower	*Linnaea borealis*
TSHE	Western hemlock	*Tsuga heterophylla*
FRVI	Wild strawberry	*Fragaria virginiana*

TABLE A2. Percent of the plots that each species occurred in on habitation and control sites.

Species	**Occurrence in control plots (%)**	**Occurrence in habitation plots (%)**
*Vaccinium alaskaense; A*laskan blueberry (VAAL)	0	14.2
Plantago macrocarpa; Alaskan plantain (PLMA)	14.8	20.9
Lonicera involucrate; bearberry honeysuckle (LOIN)	0	1
Ribes lacustre; black gooseberry (RILA)	0	6.6
Pteridium aquilinum; bracken fern (PTAQ)	0	16.9
Cornus unalaschkensis; bunchberry (COCA)	55.6	24.5
Fragaria chiloensis; coastal strawberry (FRCH)	0	1
Vicia sativa; common vetch (VISA)	3.7	21.7
Empetrum nigrum; crow berry (EMNI)	9.3	22.6
Blechnum spicant; deer fern (blsp)	40.7	25.5
Vaccinium caespitosum; dwarf blueberry (VACA)	0	1
Menziesia ferruginea; false azalea (MEFE)	91	66
Maianthemum dilatatum; false lily of the valley (MADA)	76	73
Chamaenerion angustifolium; fireweed (ROWI)	0	3.8
Angelica lucida/Arabis hirsute; hairy rock crest (ARHI)	22.2	23.6
Rhododendron groenlandicum; Labrador tea (LEGR)	1.9	9.4
polypodium glycyrrhiza; licorice fern (POGL)	11.1	15.1
Tsuga mertensiana; mountain hemlock (TSME)	1.9	1
Fritillaria camschatcensis; northern rice root (FRCA)	3.7	1.9
Trientalis borealis; northern starflower (TRAR)	5.6	2.8
Vaccinium ovalifolium; oval-leaved blueberry (VAOV)	77.8	63.2
Malus fusca; Pacific crabapple (MAFU)	5.6	8.5
Argentina anserina/Potentilla anserine; Pacific silverweed (ARAN)	46.3	53.8
Oenanthe sarmentosa; Pacific water parsley (OESA)	0	1.9
Taxus brevifolia; Pacific yew (TABR)	0	6.6
Conioselinum pacificum; Pacific-hemlock parsley (COPA)	9.3	21.7
Prenanthes alata; rattle snake root (PRAL)	18.5	7.5
Alnus rubra; red alder (ALRU)	18.5	28.3
Thuja plicata; redcedar (THPL)	85.2	76.4
Aquilegia Formosa; red columbine (AQFO)	0	11.3
Vaccinium parvifolium; red huckleberry (VAPA)	27.8	30.2
Gaultheria shallon; salal (GASH)	98.1	100

Rubus spectabilis; salmonberry (RUSP)	3.7	1.9
Salicornia virginica; sea asparagus (SAVI)	0	1
Glaux maritima; sea milkwort (LYMA)	9.3	27.4
Angelica lucida; sea watch (ANLU)	26	22.6
Pinus contorta; shore pine (PICO)	3.7	2.8
Picea sitchensis; Sitka spruce (PISI)	24.1	31.1
Lysichiton americanus; skunk cabbage (LYAM)	11.1	1
Galium trifidum; small bedstraw (GATRD)	18.5	1
Trifolium wormskioldii; springbank clover (TRWO)	0	3.8
Maianthemum stellatum/Smilacina stellate; star-flowered false Solomon's seal (SMST)	3.7	2.8
Myrica gale; sweet gale (MYGA)	7.4	2.8
Galium triflorum; sweet-scented bedstraw (GATR)	0	1.9
Rubus parviflorus; thimble berry (RUPA)	1.9	13.2
Linnaea borealis; twin flower (LIBO)	0	1
Tsuga heterophylla; western hemlock (TSHE)	83.3	60.4
Fragaria virginiana; wild strawberry (FRVI)	0	1

TABLE A3. List of species found solely on habitation sites and the percentage of plots each species occurred in.

Habitation Site Species	**Occurrence in control plots (%)**	**Occurrence in habitation plots (%)**
*Vaccinium alaskaense; A*laskan blueberry (VAAL)	0	14.2
Lonicera involucrate; bearberry honeysuckle (LOIN)	0	1
Ribes lacustre; black gooseberry (RILA)	0	6.6
Pteridium aquilinum; bracken fern (PTAQ)	0	16.9
Fragaria chiloensis; coastal strawberry (FRCH)	0	1
Vaccinium caespitosum; dwarf blueberry (VACA)	0	1
Chamaenerion angustifolium; fireweed (ROWI)	0	3.8
Oenanthe sarmentosa; Pacific water parsley (OESA)	0	1.9
Taxus brevifolia; Pacific yew (TABR)	0	6.6
Aquilegia Formosa; red columbine (AQFO)	0	11.3
Salicornia virginica; sea asparagus (savi)	0	1
Trifolium wormskioldii; springbank clover (TRWO)	0	3.8
Galium triflorum; sweet-scented bedstraw (GATR)	0	1.9
Linnaea borealis; twin flower (LIBO)	0	1
Fragaria virginiana; wild strawberry (FRVI)	0	1

TABLE A4. Cultural index rating for all 48 plant species identified in this study. This table is arranged from highest to lowest index plants. Table includes species common name, scientific name and cultural index rating from most culturally important (5 stars) to least culturally important (no stars). It is recognized that this table is not a representation of the value held specifically by Heiltsuk and Wuikinuxv cultures but Indigenous cultures of the Pacific Northwest.

Common Name	Scientific Name	Cultural Index
Five Stars		
Western redcedar	*Thuja plicata*	*****
Four Stars		
Alaskan blueberry	*Vaccinium alaskaense*	****
Northern rice root	*Fritillaria camschatcensis*	****
Oval-leaved blueberry	*Vaccinium ovalifolium*	****
Pacific crabapple	*Malus fusca*	****
Pacific yew	*Taxus brevifolia*	****
Red alder	*Alnus rubra*	****
Red huckleberry	*Vaccinium parvifolium*	****
Salal	*Gaultheria shallon*	****
Salmonberry	*Rubus spectabilis*	****
Sitka spruce	*Picea sitchensis*	****
Skunk cabbage	*Lysichiton americanus*	****
Thimbleberry	*Rubus parviflorus*	****
Western hemlock	*Tsuga heterophylla*	****
Three Stars		
Bracken fern	*Pteridium aquilinum*	***
Coastal strawberry	*Fragaria chiloensis*	***
Dwarf blueberry	*Vaccinium caespitosum*	***
Dwarf dogwood bunchberry	*Cornus unalaschkensis*	***
False lily of the valley	*Maianthemum dilatatum*	***
Fireweed	*Chamaenerion angustifolium*	***
Labrador tea	*Rhododendron groenlandicum*	***
Licorice fern	*polypodium glycyrrhiza*	***
Pacific silver weed	*Argentina anserina/Potentilla anserina*	***
Pacific-hemlock parsley	*Conioselinum pacificum*	**(***)
Shore pine	*Pinus contorta*	***
Springbank clover	*Trifolium wormskioldii*	***
Wild strawberry	*Fragaria virginiana*	***

Two Stars		
Bearberry honey suckle Black twinberry	*Lonicera involucrata*	**
Black gooseberry	*Ribes lacustre*	**
Crow berry	*Empetrum nigrum*	**
Deer fern	*Blechnum spicant*	**
False azalea	*Menziesia ferruginea*	**
Mountain hemlock	*Tsuga mertensiana*	**
Pacific water parsley	*Oenanthe sarmentosa*	**
Red columbine	*Aquilegia formosa*	**
Sea asparagus	*Salicornia virginica*	**
Sea milkwort	*Glaux maritima*	**

One Star		
Sea-Watch	*Angelica lucida*	*
Star-flowered false Solomon's seal	*Maianthemum stellatum* *Smilacina stellate*	*
Sweet Gale	*Myrica gale*	*
Sweet-scented bedstraw	*Galium trifolorum*	*
Twinflower	*Linnaea borealis*	*

No stars		
Alaska plantain	*Plantago macrocarpa*	no stars
Common vetch	*Vicia sativa*	no stars
Hairy rock crest	*Angelica lucida* *Arabis hirsute*	no stars
Northern starflower	*Trientalis borealis*	no stars
Rattlesnake root	*Prenanthes alata*	no stars
Small bedstraw	*Galium trifidum*	no stars

TABLE A5. The Management Table lists each plant species identified in this study and the associated known management techniques followed by a species management index rating, which is the sum of the different techniques used to manage each species. Table arranged in alphabetical order by species common name.

Plant Species	Associated Management Techniques	Total
Alaskan plantain	none known	**0**
Alaskan blueberry	burn, fully harvested pruned trading/transplanted/gifted, owned, managed patch, fertilized	**7**
Bearberry	fully harvested, selective harvesting	**2**
Black gooseberry	burn, partially harvested (i.e. bark strip), cleaned, pruned, managed patch	**5**
Bracken fern	fully harvested, owned, clearing	**3**
Bunchberry	fully harvested, pruned	**2**
Coastal strawberry	fully harvested, trading/transplanted/gifted, fertilized	**3**
Common vetch	none known	**0**
Crow berry	fully harvested	**1**
Deer fern	partially harvested (i.e. bark strip), selective harvesting	**2**
Dwarf blueberry	burn, fully harvested, trading/transplanted/gifted, owned, managed patch	**5**
False azalea	partially harvested (i.e. bark strip), selective harvesting	**2**
False lily-of-the-valley	fully harvested, trading/transplanted/gifted	**2**
Fireweed	fully harvested, owned, managed patch	**3**
Hairy rock crest	none known	**0**
Labrador tea	fully harvested, weeded, selective harvested, managed patch	**3**
Licorice fern	partially harvested (i.e. bark strip)	**1**
Mountain hemlock	partially harvested (i.e. bark strip)	**1**
Northern rice root	burn, fully harvested, trading/transplanted/gifted, owned, replanted, recreation of designated gardens, weeded, selective harvested, tended to through seasons, cultivated/tilled, fertilized	**11**
Northern starflower	none known	**0**
Oval-leaf blueberry	burn, fully harvested, pruned, trading/transplanted/gifted, owned, managed patch, berries/seeds scattered	**8**
Pacific crabapple	partially harvested (i.e. bark strip), pruned, trading/transplanted/gifted, owned, tended, lopped	**6**
Pacific hemlock parsley	fully harvested, owned, replanted, managed patch, selective harvesting	**5**
Pacific silverweed	burn, fully harvested, trading/transplanted/gifted owned replanted designated garden weeded selective harvesting tended cultivated/tilled fertilized	**11**

Pacific water parsley	fully harvested, owned, managed patch	**2**
Pacific yew	partially harvested (i.e. bark strip)	**1**
Rattlesnake root	none known	**0**
Red alder	partially harvested (i.e. bark strip)	**1**
Red columbine	partially harvested (i.e. bark strip), berries/seeds scattered	**2**
Red huckleberry	burn, fully harvested, pruned, trading/transplanted/gifted, owned, fertilized	**6**
Salal berry	burn, fully harvested trading/transplanted/gifted owned managed patch	**5**
Salmonberry	partially harvested (i.e. bark strip), pruned, owned, managed patch, green shoots for regeneration	**5**
Sea asparagus	partially harvested (i.e. bark strip)	**1**
Sea milkwort	fully harvested, owned, managed patch	**3**
Sea-Watch	None known	**0**
Shore pine	partially harvested (i.e. bark strip), selective harvesting	**2**
Sitka spruce	partially harvested (i.e. bark strip)	**1**
Skunk-cabbage	fully harvested, managed patch	**2**
Small bedstraw	none known	**0**
Springbank clover	burn, fully harvested, trading/transplanted/gifted, owned, replanted, creation of designated garden, weeded, selective harvested, tend to, cultivated/tilled, fertilized	**11**
Star-flowered false Solomon's seal	burn, partially harvested (i.e. bark strip)	**2**
Sweet gale	partially harvested (i.e. bark strip)	**1**
Sweet-scented bedstraw	none known	**0**
Thimbleberry	burn, partially harvested (i.e. bark strip), green shoots cut for regeneration	**3**
Twinflower	none known	**0**
Western hemlock	partially harvested (i.e. bark strip)	**1**
Western redcedar	partially harvested (i.e. bark strip), trading/transplanted/gifted owned designated grove	**4**
Wild strawberry	burn, partially harvested (i.e. bark strip), cleared, managed patch	**4**