

Recognition and revitalization of ecocultural landscapes: Indigenous plant management
throughout space and time

by

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Author Declaration

This thesis consists of material all of which I authored or co-authored: see Statement of Contributions included in the thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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

Statement of Contributions

Sara Wickham was the sole author for Chapters 1 and 5, which were written under the supervision of Dr. Andrew Trant and were not written for publication.

This thesis consists in part of three manuscripts written for publication. Chapters 2, 3, and 4 were co-authored. The following outlines my contributions and that of each of the authors. I also provide the publication status of each chapter. Due to this structure, there is some redundancy between chapters (especially when providing definitions or when describing study regions). There are also changes in first person singular vs. first person plural (I/we phrasing) reflecting contributions of others when relevant. Any or all mistakes are mine and mine alone. Exceptions to sole authorship of the material are as follows:

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SW developed the concept of the work, compiled the data, conducted the analysis, and prepared the manuscript for publication. AT contributed to data collection and comments and edits to manuscript. CA contributed to the concept and provided edits and advice on the manuscript.

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Abstract

Indigenous Peoples of coastal British Columbia have co-evolved with the temperate rainforest ecosystems of the Pacific Northwest for millennia, cultivating ecocultural landscapes through sophisticated plant management practices grounded in relational worldviews. This thesis explores the historical and ongoing role of Indigenous plant stewardship in shaping biodiversity, ecosystem function, and cultural resilience. Drawing on ecological, archaeological, and ethnobotanical data—as well as community-engaged research with Indigenous Nations—this work highlights the diversity of management systems, from clam gardens to orchards of Pacific crabapple (*Malus fusca*). Recognizing the negative effects colonial disruptions have had on these systems, I examine how Indigenous-led restoration revitalizes both degraded landscapes and intergenerational knowledge systems and outline the potential for Indigenous-led restoration to influence broader conservation and social justice goals. Through an interdisciplinary, collaborative approach, this research contributes to the recognition, recovery, and renewal of ecocultural landscapes in an effort to support Indigenous sovereignty and self-determination through land stewardship.

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Table of Contents

Examining Committee.....	ii
Author's Declaration.....	iii
Statement of Contributions.....	iv
Abstract.....	ix
Acknowledgements.....	x
List of Figures.....	xv
List of Tables.....	xix
List of Abbreviations.....	xxi
Statement of Positionality.....	xxii
Chapter 1. Introduction.....	1
1.1 Thesis structure.....	12
Chapter 2. Legacies of ancient forest gardening along the Pacific Northwest coast highlights broad spatial and cultural variability.....	16
Overview.....	16
2.1 Introduction.....	17
2.2 Methods.....	23
2.2.1 Study regions.....	23
2.2.2 Site selection.....	26
2.2.3 Surveys.....	27
2.2.4 Dendrochronology.....	30
2.2.5 Statistical analysis.....	30
2.3 Results.....	31
2.4 Discussion.....	37
2.4.1 Plant composition.....	38
2.4.2 Habitat and regional variability.....	39
2.4.3 Pacific crabapple.....	42
2.4.4 Archaeological features.....	44
2.4.5 Limitations.....	45
2.5.6 Significance of orchards and forest gardening.....	46
2.5 Conclusion.....	48
Chapter 3. Incorporating place-based values into ecological restoration.....	49
Overview.....	49
3.1 Introduction.....	50
3.2 Place-based values.....	54
3.3 Place-based values support biodiverse, productive ecosystems.....	55
3.3.1 Anthropogenic landscape burning in Garry oak ecosystems.....	57
3.3.2 Clam gardens and shell middens.....	59
3.4 Examples of Place-based Values in Restoration Efforts.....	63
3.4.1 Wuikinuxv Lhènnx̓ (Crabapple) Project.....	63
3.4.2 Hul'q'umi'num' and <u>WSÁNEĆ</u> clam garden restoration in the Gulf Islands National Park Reserve.....	66
3.5 Discussion.....	70
3.5.1 Reconsidering the 'reference' and how to measure success.....	70
3.5.2 Indigenous inclusion and colonialism.....	73

3.6 Conclusion.....	76
Chapter 4. Indigenous-led restoration of a culturally important plant: The Wuikinuxv Lhènnx̓ (Crabapple) Project.....	79
Overview.....	79
4.1 Introduction.....	80
4.2 Methods.....	83
4.2.1 Study area.....	83
4.2.2 Pacific crabapple.....	86
4.2.3 Site selection.....	87
4.2.4 Restoration treatments.....	88
4.2.5 Monitoring.....	90
4.2.6 Data analysis.....	90
4.2.7 Community engagement.....	93
4.3 Results.....	96
4.3.1 Restoration treatments.....	96
4.3.2 Community engagement.....	106
4.4 Discussion.....	107
4.4.1 Early ecological outcomes.....	107
4.4.2 Potential outcomes for bears.....	111
4.4.3 Cultural outcomes.....	113
4.5 Conclusion.....	115
Chapter 5. General conclusion.....	117
5.1 Overview of results and emergent themes.....	117
5.2 Barriers and opportunities to conserving and accessing ecocultural landscapes.....	119
5.3 Working in community.....	125
Literature Cited.....	132
Appendix A Supplementary material for Chapter 2.....	172
Appendix B Supplementary material for Chapter 4.....	176
Appendix C Sample reading list.....	180

List of Figures

Figure 2.1 (A) The pomes of *Malus fusca* (Pacific crabapple). These small, tart apples are an important traditional food for coastal Indigenous people. (B) Pictures of two different forms of crabapple trees observed across the Central Coast and Discovery Islands, BC. Monumental tree form of crabapple. The monumental forms are large and have classic tree-like forms and arranged in orchard-like stands. (C) Volunteer tree form of crabapple. The volunteer form is small and shrubby. 22

Figure 2.2 A map of coastal British Columbia, Canada, showing the general regions of the Discovery Islands and the Central Coast. These two regions are where the study sites in the research are located. Map courtesy of Will McInnes/Hakai Institute. 25

Figure 2.3. Non-metric dimensional scaling (NMDS) of sites across regions, habitats, and site types. Each point corresponds to a site. The habitats are denoted by the point's shape (see legend) and each point has the region displayed next to it (CC = Central Coast, DI = Discovery Islands). Points that are closer together are more similar than those that are further apart. The pink polygon encompasses forest garden sites, and the blue polygon encompasses low-intensity sites..... 34

Figure 2.4 A coastal forest garden in an estuary habitat on the Central Coast. Crabapple trees, both monumental and volunteer form, can be seen in the background. Yarrow and silverweed are abundant in the foreground. 41

Figure 3.1 Examples of ecosystem associated with Indigenous management: (A) Cowichan Garry Oak Preserve in WSÁNEĆ territory, South Vancouver Island, British Columbia (BC; photo courtesy Kelly Fretwell), (B) clam gardens in WSÁNEĆ territory, Gulf Islands National Park Reserve, BC (photo courtesy Iain Robert Reid), (C) crabapple orchard in Wuikinuxv territory, Central Coast, BC.....	62
---	----

Figure 3.2 Map of coastal British Columbia showing the approximate location of the lhənn̓x (crabapple) orchards in Wuikinuxv territory and the clam gardens in the Gulf Islands National Park Reserve located in Coast Salish territory. Map courtesy of Will McInnes/Hakai Institute.....	69
--	----

Figure 4.1 Approximate location of Wuikinuxv Territory in British Columbia, Canada. Map courtesy Will McInnes/Hakai Institute.	85
---	----

Figure 4.2 (A) Pacific crabapple (<i>Malus fusca</i>) blossoms, (B) ripe fruits, (C) the monumental tree form of Pacific crabapple. It is tall, with a central trunk and classic tree form, and has moss and/or lichens on its trunk and branches. (D) Volunteer form of Pacific crabapple. It is shorter, shrubbier, and has multiple stems.	88
--	----

Figure 4.3 (A) Author BO pruning a volunteer crabapple tree. (B) Elementary school students harvest licorice ferns from the moss removed from a monumental crabapple tree. (C) Fish used to fertilize a volunteer crabapple tree. (D) Author BO count jars of crabapple jelly made by the Wuikinuxv Guardians for community members.....	95
--	----

Figure 4.4 Boxplots of fruit per tree and dry fruit weight over the years and with restoration treatments. (A) Total fruit per tree over five different years. Total fruit differed significantly between 2020 and 2021 (a; $p = 6.7\text{e-}05$) between 2020 and 2022 (b; $p = 0.0144$), between 2020 and 2023 (c; $p = 1.4\text{e-}12$), between 2021 and 2022 (d; $p = 0.0072$), 2021 and 2023 (e; $p = 6.7\text{e-}05$) and between 2022 and 2023 (f; $p = 1.4\text{e-}12$), as indicated by letters above respective plots. (B) Dry weight of fruit over three years. Dry weight did not differ significantly between 2021 and 2022. Dry weight differed significantly between 2021 and 2023 (a; $p = 1.1\text{e-}05$) and between 2022 and 2023 (b; $p = 4.8\text{e-}06$), as indicated by the letters above respected plots. Boxplots show median value (solid horizontal line), upper and lower quartiles (box), and maximum and minimum values recorded (whiskers)..... 97

Figure 4.5 Fruit dry weight as a function of the significant terms from the top models. (A) the sum of precipitation from January 1st to September 1st (Table 2 & 5), (B) if the tree had restoration treatments applied to it or if it was a control (Table 2 & 5). Blue line in top plots is the regression line and grey shading represents the 95% confidence interval. Boxplot shows median value (solid horizontal line), upper and lower quartiles (box), and maximum and minimum values recorded (whiskers). 103

Figure 4.6 Probability of crabapple fruit presence as a function of the significant terms from the top model. (A) total amount of fruit as a function of Growing Degree Days (GDD) (Table 3 & Table 5), (B) percent of the tree that was recorded as dead (Table 3 & 5), and (C) the interaction of growing degree days and precipitation (Table 3 & 5). Lines in plots represent the regression line and grey shading represents the 95% confidence interval..... 104

Figure 4.7 Total fruit amount as a function of the significant terms from the top models. (A) total amount of fruit as a function of Growing Degree Days (GDD) (Table 4 & 5), (B) percent of the tree that was recorded as dead (Table 4 & 5), and (C) if the tree had restoration treatments applied to it or if it was a control (Table 4 & 5). Lines in top plots represent the regression line and grey shading represents the 95% confidence interval. Boxplot shows median value (solid horizontal line), upper and lower quartiles (box), and maximum and minimum values recorded (whiskers)..... 105

Figure 4.8 The bears of Wuikinuxv Territory. (A) A black bear eating crabapple in an estuary (B) A grizzly bear eating crabapple from the same tree 5 days later. (C) A grizzly bear in a riverbank crabapple orchard. (D) A large grizzly bear in an estuary. All photos were taken in the fall, dates are displayed in the top left corner of the photo..... 113

List of Tables

Table 2.1 A description of archaeological terms used to describe features or artifacts that could be found at archaeological sites.....	29
Table 2.2 A list of the archaeological features observed near all 29 surveyed sites. Y = yes, blank = no sightings recorded. * Indicate feature is also listed on RAAD for the site (note that fire scars are not specified on RAAD and may be listed as CMTs or unrecorded)	32
Table 2.3. A list of the culturally important plants observed at forest garden sites throughout the Central Coast and Discovery Islands.....	33
Table 2.4 Indicator species for coastal forest garden and low intensity management sites. Bolded species indicate that they are highly significant site indicators ($p < 0.05$).....	36
Table 3.1 Proposed framework for initiating a place-based values (PBV) approach into restoration planning and implementation. Inspired by Table 2 in Artelle et al. 2018. This framework was built for people considering how to implement place-based values in restoration and to clarify how actions relate to the feature of place-based values.....	77
Table 4.1 Variables used for modeling if restoration treatments, tree attributes, or climatic variables were responsible for affecting the total amount of fruit per tree and the size of the fruit.....	93

Table 4.2 Akaike’s information criterion (AIC) values for all datasets from the top five models to predict fruit dry weight, fruit presence/absence, and total amount of fruit on a tree. All models for all datasets in Supplementary Material (Table S1-3). Δ AIC: difference between the current and best model; AICw: Akaike weight; (*) denotes interaction term. GDD = Growing Degree Days. Best performing models are in **bold** text..... 100

Table 4.3 Coefficient estimate, standard error (SE), and p-value for each term in the top models predicting fruit dry weight (Table 2), fruit presence/absence (Table 3), and total fruit amount (Table 4), as determined by the lowest AIC and highest AICw scores. Coefficient estimates are standardized for the continuous predictor variables (precipitation, GDD). The first (alphabetical) term for categorical variable (restoration type: control) is the reference/baseline for that category. Significant terms are **bold**. GDD = Growing Degree Days. (*) Denotes interaction term... 102

Table 5.1 Schedule I of the Great Bear Rainforest Land Use Order identifies the following Type 1 and Type 2 Indigenous Heritage Features. Type 1 and Type 2 relates to the amount of land that is protected in a “buffer zone” surrounding the feature..... 123

Table 5.2 10 calls to action to natural scientists working in Canada, by Wong et al. 2020. The actions are listed in the first column and any addendum or edits I thought could enhance the calls are listed in the second column..... 127

List of Abbreviations

BC – British Columbia

CMT – Culturally Modified Tree

DBH – Diameter at Breast Height

DFO – Department of Fisheries and Oceans

GBR – Great Bear Rainforest

GDD – Growing Degree Days

HCA – Heritage Conservation Act

IHF – Indigenous Heritage Feature

IK – Indigenous Knowledge

RAAD – Remote Access to Archaeological Data

UNDRIPA – United Nation Declaration on the Right of Indigenous People Act

Statement of Positionality

I am a non-Indigenous person of mixed Swedish and Welsh ancestry and undertaking this research has required me to explore my positionality continually and honestly. First, as a settler Canadian, I acknowledge the genocidal legacies that have enabled my occupation on Indigenous lands. I recognize my part in benefitting from colonialism and these benefits derive from violent, drastic, and intentional impacts to First Nations peoples' connections to their lands and waters. Second, as an ecologist, I am aware of how the racist and fictitious assumptions of the Doctrine of Discovery and *terra nullius* has enabled assertion of colonial control over land and wildlife conservation and management.

For these reasons, this research is inseparable from the political landscape – the communities whose histories and stewardship I discuss experience historical and ongoing trauma at the hands of colonialism. Please note that given my positionality, it is not my intention to speak for Indigenous communities about their traumas and/or their complex and deep histories with the land. Instead, it is my intention to use my privilege to advocate for more inclusive and diverse conservation and management, and to provide examples of and elevate pluralistic research.

Chapter 1. General Introduction

The temperate rainforests in (what is now called) the Pacific Northwest of British Columbia (BC), Canada invoke images of wild abundance — landscapes teeming with drippy wet ferns, salmon leaping from rushing rivers, and salty sea spray-soaked Sitka spruce. The ecological and evolutionary processes that formed these landscapes are well recognized — glacial contributions to valleys and sea level change, volcanic and tectonic formation of mountain ranges, and the adaptation of plants to climate regimes. Another ecological and evolutionary process that is gaining recognition as a contributor to landscape formation is the rich and complex history of the people who have co-evolved with these landscapes. Across coastal BC, Indigenous people have been stewarding the territories they live in for millennia, shaping landscapes through ecosystem management. Indigenous stewardship has played a vital role in structuring and maintaining the function and diversity of broader ecological communities (Cox et al., 2020; McCune et al., 2013). The scope and scale of this stewardship throughout time has left long lasting impressions across the landscape.

One notable stewardship practice that has impressed ecological legacies is plant management. At least 150 plants have been recorded to have been used as either food, medicine, or material and many of these plants were extensively managed to procure them in the quality and quantities that people desired (Kuhnlein & Turner, 1991; Turner, 2014a). Management is broadly defined as a set of skilled actions taken to direct a system toward achieving desired goals and objectives (Lertzman, 2009; Turner, 2014c). However, this definition does not account for the formal and informal social constraints (e.g., politics, spirituality, governance) that interact with management processes to shape actions and outcomes. To better reflect the social dynamics embedded within

resource management, Lertzman (2009) proposes the term “management system” as a concept. A management system is the sum of “actions, goals, and objectives, the process through which they are legitimized by social norms, and the institutions and actors involved in carrying them out” (Lertzman, 2009). Therefore, a management system encompasses two types of management: 1) a diverse array of actions made by people to shape ecological systems and, 2) the governance that guides people’s interactions with ecosystems.

The governance that guides people’s interactions with ecosystems is informed by worldviews. A worldview is a group’s collective high-level perspective as to how they see and interpret the world in all its diversity and complexity (Rousseau & Billingham, 2018). Worldviews transcend individual lifetimes, providing continuity, identity, and a sense of belonging to a particular cultural or societal group (Steinhauer, 2002; Turner, 2014g). They also shape the values, philosophies, and knowledge of a society, which in turn drive the social customs, practices, and policies (Little Bear, 2000). Two types of worldviews are Eurocentric and relational. Eurocentric worldviews put faith in the scientific control and ownership of nature, thus separating humans from the nonhuman world (Cronon, 1996; Mead, 2002). Eurocentric societies possess an objective worldview; subjectivity is not measurable and is therefore not credible (Little Bear, 2000). As physical objects and processes are measurable, they become valuable to the western worldview. This objectivity emphasizes materialism and appropriation (Little Bear, 2000).

In contrast, an Indigenous worldview is relational and assumes all forms of life are interconnected and that the survival of each life form is dependent on the survival of others (Hart, 2010; Henderson, 2000; Kimmerer, 2014b; Salmón, 2000; Turner, 2014g). Humans are

neither above nor below others in the circle of life and all life is sacred (Hart, 2010; Henderson, 2000). Relational or kincentric worldviews centre respect, reciprocity, and responsibility; for example, if you take a living being for your nourishment or health you must do so in a respectful way by not overharvesting and by offering something in exchange (Turner et al., 2022). Another important aspect of a relational worldview is a society's intimate connection to its local environment (Turner & Berkes, 2006). Place-based people who have inhabited a specific landscape for hundreds of generations have ways of life that shaped, and in turn, have been shaped by the land (Artelle et al., 2018). This deep time connection to place breeds a place-based value system, which is formed from a deep knowledge of local ecological limits developed through generations of learning by observation and by trial and error (Artelle et al., 2018). This dynamic knowledge helps to safeguard a society from exceeding ecological limits by informing a value system that guides governance and protocols (Turner & Berkes, 2006). Place-based values are further discussed in Chapter 3.

Most Indigenous societies encompass a relational worldview that evolved in part by being place-based. In fact, the definition of Indigenous invokes relational worldviews and land-based relationships: "Cultures whose worldviews place special significance on the idea of the unification of the humans with the natural world" (Cunningham & Stanley, 2003). Indigenous Peoples have always known that the necessary elements of 'good' environmental stewardship derive from the entire sphere of peoples laws, beliefs and worldviews, including ideological foundations like reciprocity (Whyte et al., 2016). Many Indigenous 'managers' do not see themselves as inherently separate from a managed system, while understanding that respect is due to all parts of that system regardless of its utilitarian value (Greening (La'goot), 2024;

Lertzman, 2009; Turner & Berkes, 2006). Deep time histories, dedication to place, and a lack of human exceptionalism define Indigenous management practices.

Relational, place-based Indigenous plant management created biodiverse and productive landscapes because plants were supremely valuable as food and medicines. Recent isotopic analyses confirm that some people on the northern Northwest Coast of BC (Laxyubm, Ts'msyem) relied on plant foods for up to 60% of their total dietary calories (H. Schwarcz et al., 2023). This is consistent with diets of other ancient populations—maize comprised up to 70% of the diet to population of Mesoamerica and North America (Kennett et al., 2020) and grain plants comprised 50% of diets to people of “the Old World” (Europe during the Age of Exploration) (Zohary et al., 2012). Previous research has highlighted the importance of marine and riverine resources (such as salmon (*Oncorhynchus* spp.), clams, mussels, limpets (Class bivalvia), seals (*Phoca vitulina*), and eulachon (*Thaleichthys pacificus*)) to ancient diets of people from coastal BC (Ames, 2003; Coupland et al., 2010; H. P. Schwarcz et al., 2014). This research underestimated “the tremendous quantitative and qualitative importance of plant foods within the Aboriginal diet” (Turner, Lepofsky, et al., 2013) and we are now beginning to understand how fundamental plants were to survival.

Plants were also invaluable resources for technology and material. Many plants were used for multiple purposes. One famous example of this is the long-lived coniferous tree, western redcedar (*Thuja plicata* Donn ex D. Don). Across many coastal Indigenous communities, western redcedar is spiritually, materially, and culturally significant (Zahn et al., 2018). All parts of the trees are harvested including the bark, roots, inner and outer cambium, branches and

needles (Turner & Loewen, 1998). These materials are used to make canoes, totem poles, house boards and posts, boxes, baskets, mats, blankets, clothing, rope, roofing material, and tinder (Turner, 2014e). Additionally, cedar is consumed for medicinal purposes (decoction for treatment of internal pains, colds, and heart) and it is used as decoration for spiritual and ceremonial purposes (Pojar & MacKinnon, 2004; Turner, 2014a). In all material harvesting cases except for canoes and totems, partial harvesting is employed — only parts of the tree are removed, which keeps the tree alive (Sewid-Smith et al., 1998). Many other plants also had multiple uses and were therefore interwoven into culture through daily use, consumption, and ceremony.

Plant management, whether it be intentional or inadvertent, done over millennia and across many habitats has fundamentally altered the landscapes of BC, creating many iterations of ecocultural landscapes (Armstrong et al., 2024). For example, estuarine root gardens, which are areas of coastal marshland where edible and culturally important plants were grown in the past, are still recognizable today due to their rock terracing and composition of plants (Maurice-Hammond et al., 2023). Management practices for estuarine root gardens include weeding out competing species, working and fertilizing soils, and modifying the gradient and the hydrology of coastal marshlands (Deur, 2002; Deur & Turner, 2005; Maurice-Hammond et al., 2023). These practices have been shown to significantly increase the production of these plants, both in abundance and size (Turner and Kuhnlein 1982). Additionally, the hydrology and soil structure remain fundamentally altered at these sites even centuries after forced abandonment of garden caretakers (Maurice-Hammond et al., 2023). Further examples of how past Indigenous ecosystem

management (specifically clam gardening and cultural burning) has contributed to diverse and productive landscapes are discussed in the Chapter 3.

Another management technique that remains imprinted across landscapes is the practice of forest gardening. Some of the historically managed plant communities in Ts'msyen, Gitksan, Nuu-chah-nulth, and Coast Salish territories have been termed Indigenous forest gardens; herbaceous, understory, and tree and shrub species with nutritional, material, cultural, and/or economic values. They were managed by Indigenous peoples in the past, and they continue to grow adjacent to archeological villages (Armstrong et al., 2021, 2023). Management strategies used to cultivate forest garden plants and soils include, but are not limited to: pruning, fertilizing, tilling, weeding and clearing, burning, transplanting, orcharding, propagating and domestication (Armstrong, 2022; Turner, 2014c). Previous research investigating forest garden sites throughout BC found that they are more biologically and functionally diverse than surrounding conifer forests (Armstrong et al., 2021, 2023).

Unfortunately, in BC, some knowledge and some practice of Indigenous plant management have been diminished or lost due to colonialism. Colonial efforts attempted to replace Indigenous, place-based ways of living with western, centralized approaches through genocidal policies and assimilation (Dick et al., 2022; Simpson, 2014; Turner, Lepofsky, et al., 2013). Additionally, forced displacement removed people from the territories they and their ancestors had co-evolved with for millennia, severing the co-dependant relationship between people and ecosystems. This has caused intergenerational trauma to both human and non-human kin (Dick et al., 2022). Acknowledging the impact that colonialism has had, and continues to assert, on Indigenous

Knowledge systems is a small but crucial step in recovering elements of renewal of Indigenous Knowledge (Simpson, 2004).

Indigenous communities have long remembered forest gardening but it has only recently been recognized by academia and other colonial institutions. It has been argued that the scarcity of studies on forest gardening in northwestern North America is owed to (1) colonial biases from early settlers and successive generations of scholars (Deur & Turner, 2005) and (2) that forest gardening practices leave subtle traces in the archeological, ecological, and palaeoecological record (Armstrong et al., 2021; Lepofsky & Armstrong, 2018; Lepofsky & Lertzman, 2008). As a result, a broad disciplinary and methodological framework has been important in generating a critical, integrative, and inclusive perspective on these land-use histories. Additionally, forest gardening practices (and their outcomes) vary dramatically in scale and scope within and between territories. Biogeoclimatic variability in addition to diverse cultural practices and preferences complicate any kind of generalized model of forest gardening classification and attribution (Armstrong et al., 2023). This diversity highlights the importance of examining these landscapes at various cultural and regional scales and we dedicate Chapter 2 of this thesis to discussing coastal forest gardening as a practice in the context of orcharding Pacific crabapple trees (*Malus fusca* (Raf.) C.K. Schneid).

These diverse and productive landscapes created by Indigenous land management continue to contribute to the resiliency of ecosystems today. However, this is not to romanticize past ways of living and being. Pre-colonization over-harvesting did occur as societies adapted to new places. Upon humans initial arrival to a new region, native flora and fauna may be overexploited,

leading to mass extinctions (Evans & Davis, 2018). This pattern is especially obvious when regarding the human settlement of islands: Australia, New Zealand, Easter Island, The Galapagos, Mauritius, The Hawaiian Islands, and Tasmania all suffered from profound collapses in biodiversity following human immigration (Wehi et al., 2018). The first people to arrive to a place likely have no knowledge, protocols, or connection to it, which can lead to the overexploitation of local flora and fauna. Societies need time to develop a relationship to place before strategies and values that mitigate overharvesting can evolve.

We also know that overharvesting and resource depletion was a factor in BC's ancient times. Spencer Greening's (La'ghoot) (2024) autoethnographic research describes one example of this in an oral history that is well known throughout the Ts'msyen, Gitksan and Nisga'a People of the Pacific Northwest Coast. The oral history in English is called "The Downfall of Temlaxam, the Feast of the Goats or The Retaliation of the Goats" and it recounts how ancient peoples had begun to live in excess, hunting mountain goat (*Oreamnos Americanus*) for sport and entertainment until they were reminded to harvest sustainably and with humility by mati – their mountain goat kin (Greening (La'goot), 2024). Greening (La'ghoot) writes:

"The history describes the historical settlement of Temlaxam, an ancient village that all Ts'msyen communities have ties to today. The people of Temlaxam lived in excess and had lost their humility. Even when they didn't need food they would hunt for sport and entertainment. After a kill, people would make jokes and speak thoughtlessly around the bodies of dead animals, while leaving pieces of carcasses on the mountains they hunted as waste. This was a sign of true disrespect to all animals, and the mati especially. It sent a message to the spirits of the skies and mountains that their bones, meat or hides, aren't worth the effort of carrying home. The story has many details leading up to a climax of

human disregard for mati. They begin capturing the mati for fun and bringing one young mati into the village to keep as a pet, where children learn the carelessness from their parents first-hand and make games out of tormenting the young mati. The story goes on to tell how strange men wearing white cloaks came into the village, inviting the people of Temlaxam to a luulgit in the mountains. Impressed by these men, the royalty, their delegates and noblemen of Temlaxam accept the offer and begin making the trek to a longhouse in the highest peaks of a mountain named Stekyawden. After an intricate performance involving dancing and songs, the hosts of the luulgit in the mountain dramatically turn into mati and dance and stomp on the floor so hard the longhouse collapses. Crumbling mountain tops send the visiting humans falling to their deaths in the steep crags and taluses of Stekyawden. Following this, the mati communicate to a lone survivor that humans may harvest them, but there must be laws, ceremonies and rituals accompanying the harvest. The human survivor is sent off to tell the people remaining in Temlaxam. The protocols for the hunt shared by mati long ago are still practiced today, and the mati's ability to heed warning echoes across the Ts'msyen landscape.”

Greening's (La'ghoot) account demonstrates how “good” stewardship was developed over millennia of trial and error, informed by multiple generations of knowledge and governance.

Understanding how, why, and where past peoples managed landscapes is imperative to help restore current and future stewardship practices. In many cases despite decades, and sometime centuries of human abandonment, the imprint of Indigenous management is still visible (for example – forest, root, and clam gardens) across landscapes that are not urbanized or remain industrially undeveloped. Some Indigenous Nations are returning to these sites to rebuild

relationships to their ancestral territories, and one method some are using to rebuild these relationships is the practice of Indigenous-led ecological restoration.

Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. Ecological restoration aims to move a degraded ecosystem to a trajectory of recovery that allows adaptation to local and global changes, as well as persistence and evolution of its component species (Gann et al., 2019). Restoration, as well as environmental conservation in general (two Eurocentric disciplines), have struggled in the past with making space for alternate worldviews (Evans & Davis, 2018; Grenz & Armstrong, 2023) as they operate within a framework that can be reductionist and detaches humans from nature. However, Indigenous-led ecological restoration offers an opportunity to rectify this as it goes further than applying ecological principles to heal damaged lands, it acknowledges the profound and enduring connection of people to landscapes that have been maintained for millennia (Long & Lake, 2018). This shifts the approach to recognize the importance of culture to practice by considering humans as a functioning, contributing component of ecosystems, not a separate entity. This encourages restoration projects that are informed by deep local and traditional knowledge, are site specific, and are culturally resilient (Lee et al., 2021).

Indigenous-led, place-based restoration projects can impart important lessons to the discipline of restoration in general (for more on this, see Chapter 2). However, perhaps more importantly, Indigenous-led restoration can contribute to Indigenous sovereignty and self-determination through the application of land-based practices (Corntassel & Bryce, 2012). Restoration can be used as a vehicle for the revitalization of traditional practices and governance, while at the same

time it can address and attend to legacies of historical, ecological, and cultural degradation (Kamelamela et al., 2022). The processes of cultural resurgence and ecological restoration are overlapping and simultaneous.

In BC there are many examples of Indigenous Nations restoring landscapes as well as the practices that sustained the landscapes. The Xáxli'p community from St'at'imc Territories of interior BC has been practicing a kincentric model of forest restoration and forestry for over a decade (Diver, 2017). The ǰí'ǰǰy (Katzie) Nation in southwestern BC has returned the practice of x^wqul's (wapato - *Sagittaria latifolia*) cultivation and harvesting through eco-cultural restoration (Lyons et al., 2018). The Wuikinuxv Nation of Rivers Inlet, BC is five years into a lhənnǰ (Pacific crabapple) restoration project, which is also kincentric in nature as it was initiated to provide grizzly bears (*Ursus arctos horribilis*) with a complementary food source to salmon. This project is described in greater detail in Chapter 4 of this thesis.

The conservation and restoration of forest gardens and other ecocultural spaces created by Indigenous management is critically important at this time in history. Most ecocultural spaces, including forest, root, clam, oak-meadow, or berry gardens are not formally protected under Heritage, Endangered Species, or Parks and Protected Areas legislation. Recognition of their existence beyond Indigenous, archaeological, and ethnobotanical circles is somewhat lacking. Due to this, resource extraction and development are unrestrained upon these landscapes. For example, in Southwestern BC, oak-meadow gardens (aka Garry oak ecosystems) were engineered by the Indigenous use of low-intensity fire upon the landscape, principally to increase production of the edible, starchy camas root (*Camassia quamash* and *Camassia leichtlinii*).

However, the range of this practice and this ecosystem overlaps with some of BC's largest urban centres – the Fraser Valley, Victoria, and Nanaimo and land conversion for agricultural, residential, and industrial development has obliterated the extent of oak-meadow gardens (Fuchs, 2001). Less than 5% remains and what remains is still consistently threatened, even though oak-meadow gardens are some of the most biodiverse ecosystems in Canada (Fuchs, 2001), and their cultural importance to Coast Salish people is immense (Corntassel & Bryce, 2012). Conservation of these landscapes at a rate faster than industrial and urban development is critically important; unfortunately the bureaucracy to achieve this is unimaginably complicated, as I explain further in the General Conclusion.

1.1 Thesis Structure

Chapter 1 (the Introduction you are now reading) is dedicated to providing background as to why Indigenous, academic, and other forms of knowledge concerning Indigenous plant management has been muted because of colonization and dominant western worldviews, despite the essential importance of plants to people. The following chapters focus on identifying, understanding, and revitalizing ecocultural plant systems. Using multidisciplinary and collaborative methods, the broad objectives of this thesis are to:

- Identify and understand the management systems that contributed to the formation of co-evolved landscapes across BC.
- Explore how management practices are not homogenous and are influenced by culture, ecology, and geography.
- Reflect on the role restoration can play in creating resilient ecocultural plant and human communities.

Chapters 2, 3, and 4 of this thesis are written in the style of manuscripts. The co-authorship statement preceding this chapter offers details on specific author contributions and publication statuses. Please note that because of this writing style, there is some redundancy between chapters. Additionally, please note that the writing style flips intentionally from “we” in collaborative instances (e.g., Chapters 2, 3, and 4) to “I” in non-collaborative chapters (e.g., the general conclusion).

In Chapter 2 - Legacies of ancient forest gardening along the Pacific Northwest coast highlight broad spatial and cultural variability; we explore the differences and similarities in coastal forest gardens. We focus our research on a forest garden indicator species; Pacific crabapple. We use ecological, archaeological, and dendrochronological data to demonstrate variability in plant stewardship. Our findings facilitate discussion about the complexities of determining legacies in perennial plant management, while also considering how Pacific crabapple stewardship relates to forest gardening and management more broadly.

In Chapter 3 - Incorporating place-based values into ecological restoration; we explore how relational worldviews relate to place-based values, and how place-based values established specific Indigenous practices that influenced productivity and biodiversity in BC (our research draws on historical examples, although we respect that this stewardship is still practiced by Indigenous peoples today). We then discuss how cultivating place-based values in contemporary restoration initiatives could contribute to creating and sustaining diverse and productive ecocultural landscapes that provide reciprocal benefits to humans and non-humans alike.

In Chapter 4 – Indigenous-led restoration of a culturally important plant: The Wuikinuxv Lhènnǎx (Crabapple) Project, we put the theory described in Chapter 3 into practice with an Indigenous restoration project led by the Wuikinuxv Nation. Here we describe the relational goals and traditional methods of restoring lhènnǎx (Pacific crabapple) stewardship and orchards. We use early monitoring records and mixed effect modeling to determine factors that have contributed to changes in crabapple productivity. We describe opportunities created for community members to practice traditional stewardship methods. Finally, we discuss the early ecological and cultural outcomes of a project that incorporates place-based values and cultural planning into restoration work.

In Chapter 5, the general conclusion, I discuss the emergent themes presented through this thesis. I demonstrate the barriers to the conservation, stewardship, restoration, and harvest of ecocultural landscapes and discuss potential opportunities to remove those barriers. Finally, I highlight some of the best practices for doing research in and with Indigenous communities and I discuss some of the specific and personal conduct I prioritized.

The research process for this thesis was built upon principles of community engagement (as per (Adams et al., 2014)), whereby the Nations in which territories this research was conducted on contributed to identifying the scope of the research questions. Data collection was supported and, in some cases, implemented by the Nations. The findings of the research were communicated and, in some cases, applied. As trust was built through this process, our research throughout the thesis shifted to facilitate priorities identified by collaborators in the Wuikinuxv Nation

Stewardship Department. This led to facilitating (in collaboration with the Wuikinuxv Guardians) the work described in Chapter 4.

Chapter 2. Legacies of ancient forest gardening along the Pacific Northwest coast highlight broad spatial and cultural variability

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Overview

In British Columbia, Canada, as in many other parts of the world, past Indigenous management of forests has resulted in relict forest gardens composed of herbaceous, understory, tree, and shrub species with nutritional, material, cultural, and/or economic value that continue to grow adjacent to habitation sites, villages, and archaeological sites. However, recognition of these bioculturally important sites has been lacking in research, consultation, and regulatory contexts. In this research, we assess the plant species composition of forest gardens across habitats and across two broad coastal regions — the Central Coast and the Discovery Islands (Haílzaqv, Wuikinuxv, łohos giji (Klahoose), Homalco, Tla’amin, We Wai kai, We Wai Kum, and K’ómoks territories) — to identify 12 coastal forest garden indicator species. We found differences in forest garden plant communities across habitats and regions. We also incorporate archaeological and dendrological techniques to help better understand the complexity of historical and ancient land-use in the Pacific Northwest, while appreciating the diversity of Indigenous people’s stewardship practice over space and through time. Formal recognition of these sites is needed and has implications for social justice and land management.

2.1 Introduction

Recognition of the longstanding interactions between Indigenous peoples and landscapes has recently enabled a better scholarly understanding of the ecological effects arising from human connections to culturally important places (Kurz et al., 2023; Rick et al., 2022). For example, the composition and structure of some purportedly “wild” plant communities are now recognized as resulting from both biophysical and cultural processes (Abrams & Nowacki, 2008; Coughlan & Nelson, 2018; Feinman & Nicholas, 2020; Odonne et al., 2019; Tulowiecki et al., 2022).

Globally, forest gardening is one of the many strategies that, over centuries and in some cases millennia, have resulted in forested ecosystems managed, maintained, and stewarded by people (e.g., [Ford & Nigh, 2015](#)).

While forest gardens are a broad conceptual term, representing substantial variability across space and time, many are characterized by a predominant presence of small trees and shrubs, particularly perennial fruit and nut species, with herbaceous roots and greens in the understory (e.g., [Perera and Rajapakse 1991](#), [Ford and Nigh 2015](#)). Historical and ancient forest gardens have been documented across Australia and the Neo- and Afro-tropics; however, the management strategies and terminology describing forest garden management differ regionally. For example, in Australia, ancient Aboriginal “food forests”, which inspired the modern permaculture movement (Mollison, 1998), are characterized by perennial management practices, including the use of fire, which resulted in human-modified ecosystems across the continent (Gammage, 2012). In the Brazilian Amazon, the distribution of domesticated plant species, coupled with the management of perennial trees, has been shown to increase plant richness and abundance in forests and around habitation sites (Balée, 2013; Levis et al., 2017). In Morocco, a

65-acre communal forest cultivated for over 2,000 years has been termed an “ancient garden” and is still actively managed by nearby inhabitants (Wallace, 2019).

While the terms (e.g., agroforestry, cultural forests, novel forests, etc.) may differ, similar historical and ancient forest gardening practices have been documented in Belize (Ford & Nigh, 2015), southern India (Nogué et al. 2018), Guinea (Fairhead & Leach, 1996), Hawaii (Lincoln & Ladefoged, 2014) and elsewhere. Many of the plant species in forest gardens globally, although managed, would not be considered “domesticated” under the strict definitions offered in Eurasian agricultural contexts (Lepofsky & Lertzman, 2008). However, in some cases, the structure and function of managed plants in these ecosystems appear to differ significantly from other nearby forested ecosystems (Armstrong et al., 2024).

In what is colonially called British Columbia (BC), Canada, Indigenous peoples have occupied coastal regions since time immemorial (at minimum 14,000 years according to oral histories and archaeological records [McLaren et al. 2015, 2018, Gauvreau et al. 2023]). During this time, people actively managed these landscapes to increase and sustain fish, shellfish, and animal populations (Lepofsky et al., 2015; Morin et al., 2021). Long-term management of these biota on the central and south coast of BC has resulted material legacies observed throughout the region, including clam gardens, stone fish traps and weirs, proprietary boundary markers, and so on (Moss et al., 1990; Toniello et al., 2019; White, 2003). While marine and riverine foods were fundamental components of people’s diets, recent isotopic analyses confirm that some people on the northern Northwest Coast (Laxyuubm, Ts’msyem) relied on plant foods for up to 60% of their total dietary calories (H. Schwarcz et al., 2023). Ethnographic and oral records suggest

people actively managed plants on the coast; however, little is known about the legacies of these practices. Researchers are only beginning to understand that forest garden management and the translocation and stewardship of plant foods likely increased the availability and productivity of berry, nut, and root foods in coastal diets (Armstrong et al., 2023, 2024; J. McDonald, 2005).

Forest gardens have long been recognized by Indigenous communities but have only recently been characterized in scientific literature (Armstrong, 2017; Vanier, 2022). Ethnoecologists, Indigenous scholars, and collaborators working in BC who have highlighted the importance of plant foods and medicines in historical contexts have found that plant communities are significantly different (e.g., composition and structure) at, and/or near, archeological sites compared to areas with less intensive (or less understood) evidence of land-use (Armstrong et al., 2022; Fisher et al., 2019; Lepofsky et al., 2017). Although many ancestral villages and habitation sites have recently been uninhabited due to settler-colonial displacement, disease, and ongoing encroachment, in some cases, remnants of perennial plant management are observed in the assemblage and structure of plants species that continue to grow near such sites, along with unique soil structures, ethnographic/linguistic records, and other data. While some studies have illustrated the impact archaeological middens have on contemporary plant species composition, health, and vigor (Feinman & Nicholas, 2020; Fisher et al., 2019; Hrdlička, 1937; Trant et al., 2016) other research has shown that those plant assemblages can differ significantly from nearby forest gardens, berry plots, and orchards, allowing us to infer that some assemblages are not incidental (Armstrong et al., 2022, 2023).

The survey and identification of plant management legacies across BC are improving (e.g., Lloyd 2011, Lepofsky and Lyons 2013, Turner et al. 2013, Fisher et al. 2019, Armstrong et al. 2021, 2022, 2023, 2024, Lyons et al. 2021, Maurice-Hammond et al. 2023), and previous interdisciplinary research employing archaeological and ecological methods has had success in identifying key features of forest gardens (Armstrong et al., 2022). However, questions regarding the variability, scale, and scope of plant management remain. For example, some forest garden indicator species may be more valuable than others in ascertaining the location and/or timing of stewardship legacies. Pacific crabapple (*Malus fusca*; hereafter referred to as crabapple) is an important food, medicine, and material plant for coastal Indigenous peoples (Turner, 2014a). Crabapples are small deciduous trees or shrubby bushes that bear small, tart pomes in the fall (Klinkenburg, 2020b)(Fig. 2.1A). A wealth of ethnobotanical research documents historical Indigenous cultivation and management of the tree, which is still practiced by some Indigenous communities today (Vanier, 2022; Wickham et al., 2022; Wyllie de Echeverria, 2013). Previous forest garden research in BC identified crabapple as an indicator species of anthropogenically modified ecosystems such as forest gardens and/orchards (Armstrong et al., 2022, 2023).

Crabapple favours growing in moist environments: streambanks, shorelines, estuary fringes, swamps, and bogs at low elevation (Klinkenburg, 2020b). It is therefore a common sight along the shorelines of coastal BC, where local and scientific knowledge recognizes two forms of Pacific crabapple: monumental and volunteer (Fig. 2.1B & C) (Armstrong et al., 2022).

Monumental trees are found growing together in a grove — a pattern noticed in other apple management contexts — and maybe referred to an orchard (Rackham, 2015). Monumental groves were located several metres inland and had conifers encroaching into and shading their

canopy. Monumental trees tend to have large tree-like forms with one central trunk (average DBH >10 in). Some have intensive epiphyte growth, with thick mats of moss on their trunks and branches, and/or long lichens hanging from their branches. Conversely, volunteer trees are smaller (average DBH <10 in) and shrubbier than monumental trees and can have multiple stems. Volunteer trees are more dispersed throughout the landscape, and they tend to grow along shoreline edges or in clearings like estuaries and appear to be younger trees, likely established without human mediation (in bear or bird droppings, washed ashore by lakes/rivers/ocean tides, or dropped/sprouted from neighbouring crabapple trees). Monumental crabapple trees adjacent to archaeological habitation sites were likely stewarded by people in the past and are good indicators of forest gardens in coastal ecosystems (Armstrong et al., 2022).

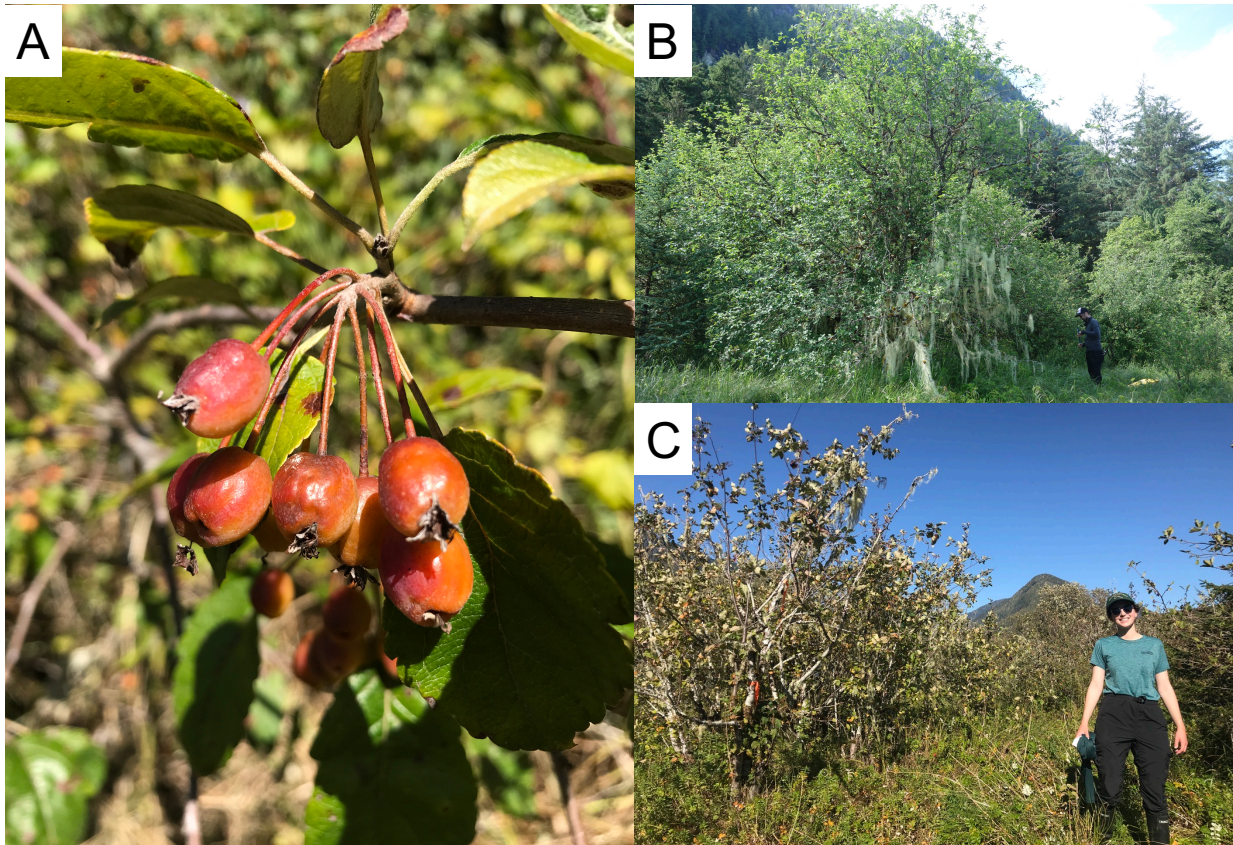


Figure 2.1 (A) The pomes of *Malus fusca* (Pacific crabapple). These small, tart apples are an important traditional food for coastal Indigenous people. (B) Pictures of two different forms of crabapple trees observed across the Central Coast and Discovery Islands, BC. Monumental tree form of crabapple. The monumental forms are large and have classic tree-like forms and arranged in orchard-like stands. (C) Volunteer tree form of crabapple. The volunteer form is small and shrubby.

The objective of this research is to assess plant species composition and archaeological data in forest gardens across coastal BC on a broad scale, between regions, and between habitats. We use dendroecological data to determine if an indicator of forest gardens — monumental crabapple – can be used to infer time of site management. We hypothesize that there will be some overlap in plant species composition, but they will largely differ regionally and between habitats, facilitating discussion about the complexities and characteristics of ascertaining stewardship legacies. We also focus on Pacific crabapple stewardship across both regions to assess how monumental orchards relate to forest gardening more broadly. Recognizing, recording, and describing sites of purported plant management legacies provides opportunities to better understand localized livelihoods and land-use histories; how people connected to, and modified their inhabited landscapes; and supplements the knowledge of people continuing these practices today.

2.2 Methods

2.2.1 Study regions

Data were collected in 2019 from field sites across two study regions: (1) the Central Coast, including Haílzaqv and Wuikinuxv territories, and (2) Discovery Islands, including łohos giji (Klahoose), Homalco, Tla’amin, We Wai kai, We Wai Kum, and K’ómoks territories (Fig. 2.2). The lands and waters of the Central Coast and the Discovery Islands have been extensively managed by Indigenous people for millennia. Indigenous knowledge places people in Haílzaqv and Wuikinuxv (Central Coast) landscapes at the end of the last ice age (at least 14,000 years ago), and this oral history is supported by archaeological evidence (Gauvreau et al., 2023; McLaren et al., 2018). Archaeological evidence indicates that people inhabited the Discovery

Islands at least 13,000 years ago (D. Fedje et al., 2021). There are eight previously reported continuously occupied village sites in the Central Coast study region and many more are recorded in the Discovery Islands (RAAD 2023). The additional presence of thousands of clam gardens, fish traps, canoe pulls, estuarine root gardens, and camp and habitation sites demonstrates how the areas were intensively stewarded and highly populated in the past (McLaren et al. 2015, RAAD 2023).

Both the Central Coast and the Discovery Islands regions are located within the Coastal Western Hemlock biogeoclimatic zone (Meidinger & Pojar, 1991). The Discovery Islands are situated in the Dry Maritime subzone, which is characterized by warm, dry summers and warm winters (mean annual temperature 9.8° C) with moderate amounts of precipitation (mean annual precipitation 498 mm) (averages calculated before 1991; Meidinger & Pojar, 1991). Dry Maritime forests are composed of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco), western hemlock (*Tsuga heterophylla* (Raf.) Sarg.), and western redcedar (*Thuja plicata* Donn ex D. Don) (Meidinger & Pojar, 1991). Salal (*Gaultheria shallon* Pursh), dull Oregon grape (*Berberis nervosa*), and red huckleberry (*Vaccinium parvifolium* Sm.) are typical of the shrub layer (Meidinger & Pojar, 1991).

The Central Coast is part of the wet Hypermartime subzone, which is characterized by cool summers and warm winters, with mean annual temperatures of 7.6 °C, and high amounts of precipitation (mean annual precipitation 1,349 mm, three time more than the Discovery Islands) (averages calculated before 1991; Meidinger & Pojar, 1991). The Hypermartime forests are heterogeneous, but typically represented by mixed stands of western hemlock, western redcedar,

Sitka spruce (*Picea sitchensis* (Bong.) Carrière). Yellow cedar (*Callitropsis nootkatensis* (D. Don) Oerst. Ex D.P. Little), shore pine (*Pinus contorta* Douglas ex Loudon), and mountain hemlock (*Tsuga mertensiana* (Bong.) Carrière) are also locally abundant in outer coastal regions (Meidinger & Pojar, 1991). Shrub layers often consist of Alaskan blueberry (*V. alaskaense* Howell), red huckleberry, salal, and deer fern (*Blechnum spicant*) (Meidinger & Pojar, 1991).

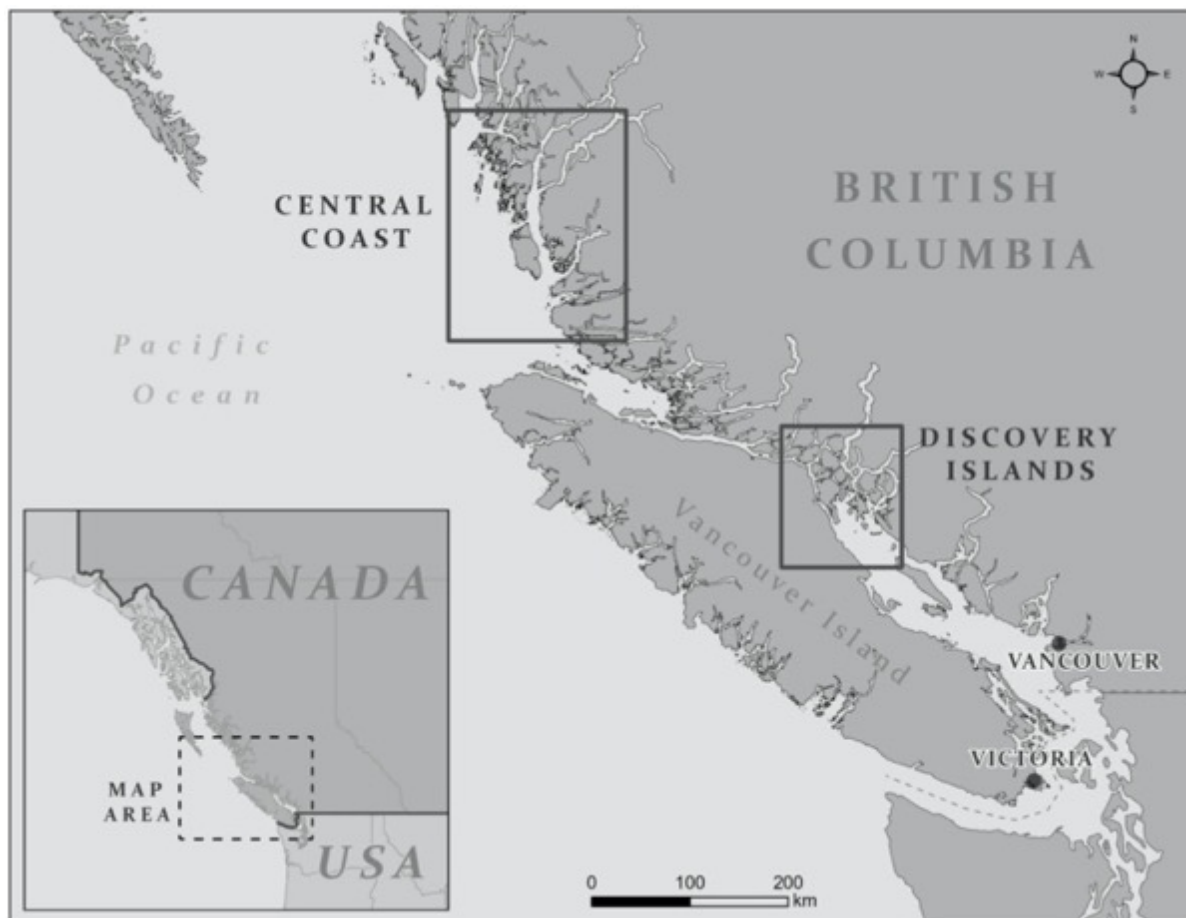


Figure 2.2 A map of coastal British Columbia, Canada, showing the general regions of the Discovery Islands and the Central Coast. These two regions are where the study sites in the research are located. Map courtesy of Will McInnes/Hakai Institute.

2.2.2 Site selection

Effective “control” sites — locations without intensive human modifications, are difficult to determine in this region as Indigenous land-use is extensive at both temporal and landscape scales. To use the paired site approach other studies have considered periphery sites — sites that are periphery to archaeological sites and purported land-use locales and have legacies of less intense use and management but similar environmental characteristics (e.g., habitat, soil type, aspect, slope, etc.) (Armstrong et al., 2023; Fisher et al., 2019; Maurice-Hammond et al., 2023; Reynolds, 2022; Schang et al., 2022). We adopted this approach to test whether plant communities at coastal forest gardens differed significantly from the broader plant community. However, our “control” sites were not periphery to our forest garden sites, instead they were chosen based on the presence of volunteer or monumental crabapple. A lack of monumental crabapple at a site indicates there has been a lower intensity of management, therefore we paired “low intensity” sites against “forest garden” sites.

To identify potential sites, we first targeted Pacific crabapple because much of coastal BC is composed of coniferous forests and so potential Pacific crabapple sites, (which are often located in mixed deciduous forests or along the margins of conifer forests, estuarine, riverine, and island shorelines), can sometimes be distinguished remotely with satellite and aerial imagery (Armstrong et al., 2023). We explored Google Earth imagery for canopy cover characteristic of broadleaf trees with archaeological data downloaded from the Remote Access to Archaeological Data platform ([RAAD 2023](#)). We targeted broadleaf clearings to be within or directly adjacent to (<50 m) the RAAD archaeological site polygon (which is coarse), and as such, we selected clearings within that range. For logistical reasons, we targeted RAAD archaeological sites that

had a portion of their polygon located at the shoreline. In total, 34 potential study sites were identified. All sites included in the study are near to RAAD identified archaeological sites with the potential for higher intensity or frequency of use (e.g., long-term habitation sites or seasonal sites as denoted by archaeological features such as house depressions and clam gardens’, for a full list see Appendix A Table A 2.1).

After an initial survey of the 34 potential sites, we excluded five that had neither archaeological features nor crabapples. We grouped the remaining 29 sites into “forest garden” sites ($n = 16$) or “low-intensity” sites ($n = 12$). Forest garden sites have a minimum of five monumental crabapples. Low intensity sites have either (1) less than five monumental crabapples, (2) only volunteer crabapples or (3) no crabapples at all. We classified each site as an estuary, shoreline, or streambank habitat based on a site’s relative position to the closest body of water.

It should be noted that, (1) not all archaeological sites are recorded and displayed in RAAD and, (2) many sites in RAAD are categorized as “pending” and their data is not yet available or approved by the BC Archaeology Branch. Therefore, more sites likely exist. Only a few archaeological sites had radiocarbon dates associated with them, and as a result of these incomplete records, temporal scales (timing of site occupation) could not be considered in our analyses.

2.2.3 Surveys

We visited all 34 sites identified, 29 of which were surveyed more thoroughly. At these 29 sites, we conducted archaeological and botanical “blitzes,” where one researcher walked through the

study site and recorded the presence and number of visible archaeological features (defined in Table 2.1) and ethnobotanically salient plant species.

A study site was defined as the RAAD archeological polygon and its periphery of up to 50 m (as defined by RAAD as the “buffer zone – indicating areas with high potential for archaeological discovery”). The size of the sites ranged from 286 to 12,616 m² (however, the larger sites included intertidal portions that were not surveyed). The closest sites were located 2 km (Discovery Islands) and 3.3 km (Central Coast) apart in a straight line. The sites furthest apart were a straight-line 42 km (Discovery Islands) and 107 km (Central Coast).

We deemed ethnobotanically salient plants as those used by coastal Indigenous communities for nutritional, material, and/or medicinal purposes (Turner, 1973a, 1973b, 1995; Turner & Bell, 1973, 1973). Plant species were considered culturally important coastal plants if they were listed in Table 5-1, 6-1, or 7-1 of (Turner, 2014a) and their range overlapped with coastal regions. Some culturally important plants that were deemed hyper-abundant or ubiquitous throughout both biogeoclimatically different regions and across habitats were noted but not systematically recorded during surveys (e.g., salal). For a full list of these species see Appendix A Table A 2.2).

Table 2.1 A description of archaeological terms used to describe features or artifacts that could be found at archaeological sites.

Feature/ Site Type	Description	Reference
Shell midden	Heap or soil layer composed of predominantly shellfish fragments created by past coastal Indigenous people.	(Ceci, 1984)
Culturally modified tree (CMT)	Tree that has been altered by Indigenous people as part as their traditional use of forest resources.	(Stryd, 2001)
Fish trap or weir (intertidal)	Rock or wooden obstructions built across a river or tidal waters that fish swim into and can't escape.	(Stewart, 1977)
Clam garden	Human created rock terraces that expand the beach area to make it optimal for clam growth and harvest.	(Augustine & Dearden, 2014)
Canoe run	Section of shoreline in which a laneway has been cleared of rocks and boulders to land canoes and access important landfalls.	(Copp, 2018)
Fire scar	A healing or healed damage to woody vegetation caused by fire. Often visible at the base of a tree, usually triangular in shape.	(Johnson & Gutsell, 1994)
Petroglyph	Rock art made by a reductive (carving, engraving, etc.) processes.	(Bednarik, 1998)
Root garden	Areas of coastal marshland where edible plants are cultivated, some of which are demarcated by plots or terracing.	(<u>Maurice-Hammond et al. 2023</u>)

2.2.4 Dendrochronology

Crabapple tree cores ($n = 27$) were taken from a random selection of crabapple trees across survey sites on the Central Coast (as per BC Parks research permit no. 110279 and with permission from Hailzaqv and Wuikinuxv Nations). We cored a minimum of one and a maximum of three trees at each site. All trees cored had a DBH of >10 in. Due to multiple occurrences of recumbent growing trunks, tree cores were sampled at the base of the trunk with an increment borer. Cores were dried, mounted, sanded, and polished in the lab. To establish minimum ages, annual growth rings were counted with a Velmex sliding stage micrometre (0.001 mm precision), a binocular microscope ($45\times$ magnification) and Measure J2X software (VoorTech Consulting, Holderness, New Hampshire, USA). It should be noted that crabapple growth rings are diffuse-porous and, compared to conifer trees, produce faint and false rings. We overcame these challenges by assigning two analysts to each core and cores were counted more than once by each analyst. The counts were then averaged. Cores that were uncountable were excluded from further analyses ($n = 3$).

2.2.5 Statistical analysis

All analyses were performed in R version 2023.03.0+386 (R Core Team, 2022). To test the variability in plant species composition between regions (Central Coast, Discovery Islands), habitats (streambank, shoreline, estuary), and site types (forest garden, low intensity) we analyzed the relative abundance of each plant species per region/habitat/site type using analysis of similarity (ANOSIM) (Clarke, 1993) in the ‘vegan’ package (Oksanen et al., 2017) with 999 permutations.

To visualize variability in plant species' presence at each site between regions, habitats, and site types, we performed a nonmetric multidimensional scaling (NMDS) analysis with a Bray index using the 'vegan' package. NMDS results were illustrated using the 'ggplot2' package (Wickham, 2016).

To identify which species are found more often in a group than others (indicator species) we used the `multipatt` function in the R package *indicspecies* (De Cáceres & Legendre, 2009) with 999 permutations. We included all plant species abundance data, as well as abundance data of the different tree forms of crabapple (monumental vs. volunteer) and the abundance of cultural features at a site. We ran three tests with different factors: site type (forest garden, low intensity), habitat (streambank, shoreline, estuary), and region (Central Coast, Discovery Islands).

2.3 Results

Of the 29 study sites, 24 had archaeological features recorded (Table 2.2) and to the best of our knowledge (which includes communications with the relevant Nations), none of the sites appeared to be currently stewarded (i.e., actively managed for plant production). However, in Wuikinuxv territories, there is active management of crabapple trees at sites nearby (Wickham et al., 2022) and in other territories, there is forest gardening planned for some sites in the future. Across the 29 study sites, we recorded 20 ethnobotanically salient plant species (that were not ubiquitous throughout the two study regions) (Table 2.3).

Table 2.2 A list of the archaeological features observed near all 29 surveyed sites. Y = yes, blank = no sightings recorded. * Indicate feature is also listed on RAAD for the site (note that fire scars are not specified on RAAD and may be listed as CMTs or unrecorded).

Site	Midden	CMT	Fish trap/weir	Clam garden	Canoe run	Fire scar	Petroglyph
Discovery Islands							
1	Y*			Y*		1	
2	Y*			Y*	3		
3	Y*	1*		Y*			
4	Y*			Y*			
5	Y*		1*	Y*			
6	Y*						
21	Y*			Y*			
22	Y*				2		
23	Y*						
Central Coast							
7		1	1*		2*		
8	Y*		1*		1*	1	
9	Y*	1					
10	Y*	3*					
11	Y*	1*					
12							
13	Y*	1*				2	
14	Y*						
15			1*				
16							
17			2*				
18			2*				
19	Y*						Y*
20	Y	1					
25							
26							
27	Y*					2	
28							
29							

Table 2.3. A list of the culturally important plants observed at forest garden sites throughout the Central Coast and Discovery Islands.

Both regions	Central Coast	Discovery Islands
Yarrow (<i>Achillea millefolium</i>)	Common silverweed (<i>Argentina anserina</i>)	Saskatoon (<i>Amelanchier alnifolia</i>)
Cow-parsnip (<i>Heracleum maximum</i>)	Northern rice root (<i>Fritillaria camschatcensis</i>)	Stinging nettle (<i>Urtica dioica</i>)
Devil's club (<i>Oplopanax horridus</i>)	Pacific yew (<i>Taxus brevifolia</i>)	Bracken fern (<i>Pteridium aquilinum</i>)
Springbank clover (<i>Trifolium wormskioldii</i>)	Red elderberry (<i>Sambucus racemose</i>)	Black gooseberry (<i>Ribes lacustre</i>)
Nootka rose (<i>Rosa nutkana</i>)	Pacific ninebark (<i>Physocarpus capitatus</i>)	
Salmonberry (<i>Rubus spectabilis</i>)	Highbush cranberry (<i>Viburnum edule</i>)	
Thimbleberry (<i>Rubus parviflorus</i>)		
Bitter cherry (<i>Prunus emarginata</i>)		
Sitka columbine (<i>Aquilegia formosa</i>)		
Monumental Crabapple (<i>Malus fusca</i>)		
Volunteer crabapple (<i>Malus fusca</i>)		

The analysis of similarities indicated a significant distinction between plant species composition at different habitats (streambank, shoreline, and estuary) (ANOSIM; factor = habitat, $R = 0.27$, $p = 0.0023$). The analysis of similarities indicated a significant distinction between plant species composition at sites in the Central Coast and the Discovery Island regions (ANOSIM; factor =

region, $R = 0.26$, $p = 0.0042$). The analysis of similarities revealed a significant distinction between plant species composition at forest gardens and low-intensity sites (ANOSIM; factor = site type, $R = 0.14$, $p = 0.002$). The NMDS analyses supported these distinctions, converging with a stress value of > 0.1 in two dimensions (Fig. 2.3). All ANOSIM results reported R values closer to 0 (versus 1), indicating weak to moderate dissimilarities between groups or that environmental factors we have not considered are driving the variability.

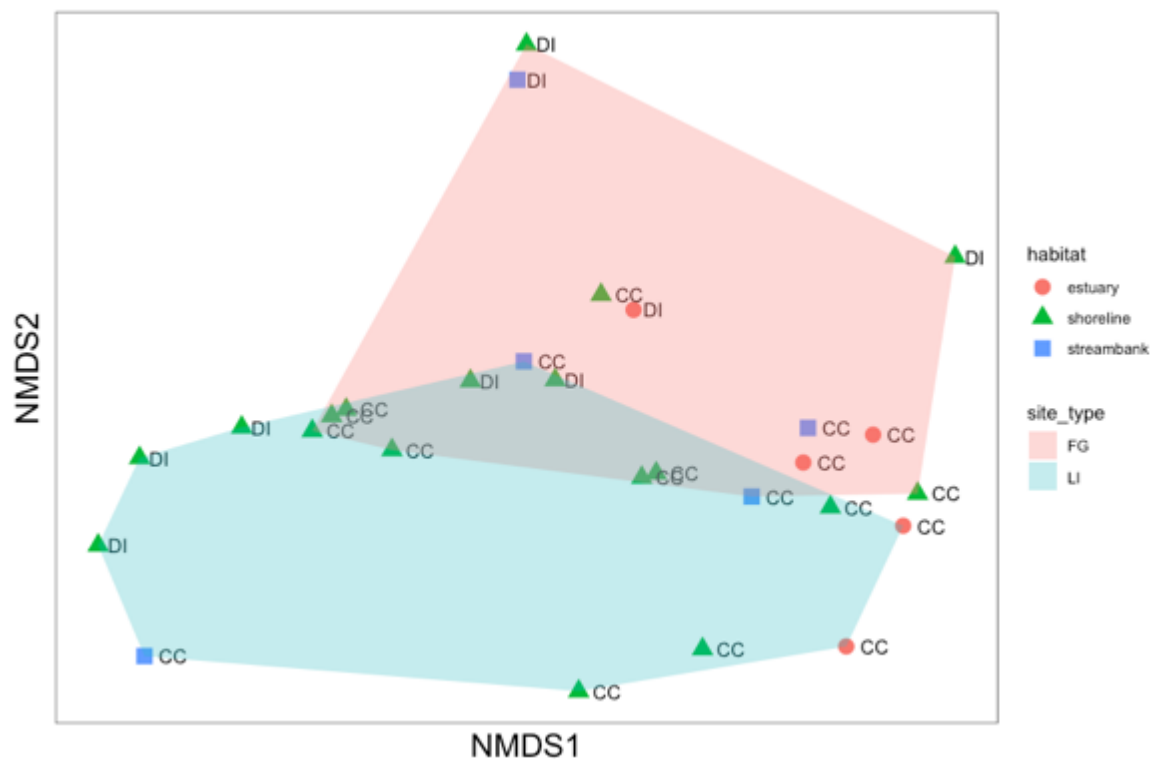


Figure 2.3. Non-metric dimensional scaling (NMDS) of sites across regions, habitats, and site types. Each point corresponds to a site. The habitats are denoted by the point's shape (see legend) and each point has the region displayed next to it (CC = Central Coast, DI = Discovery Islands). Points that are closer together are more similar than those that are further apart. The

pink polygon encompasses forest garden sites, and the blue polygon encompasses low-intensity sites.

Twelve plants were indicators of forest gardens (Table 2.4), with monumental crabapple being a highly significant indicator ($p = 0.001$). Archaeological features were also strong indicators of forest gardens ($p = 0.003$). Eight plants were indicators of low-intensity sites, with volunteer crabapple ($p = 0.011$) being a strong indicator (Table 2.4).

Four plants were identified as indicators of forest gardens in estuary habitats, with springbank clover (*Trifolium wormskioldii*) ($p = 0.006$) as a strong indicator (Appendix A Table A 2.3).

Seven plants were species indicators of forest gardens in shoreline habitats, with no significant species indicators (Appendix A Table A 2.3). Six plants were indicators of streambank habitats, with no significant species indicators (Appendix A Table A 2.3). Crabapple and common cow-parsnip (*Heracleum maximum*) were identified as significant species indicators of forest gardens near the intertidal area, as opposed to a freshwater area such as a streambank (Appendix A Table A 2.3). Eight plants were indicators of the Central Coast region (Appendix A Table A 2.4).

Twelve plants and cultural features were indicators of the Discovery Islands forest gardens with bitter cherry (*Prunus emarginata*) ($p = 0.002$) as a strong indicator (Appendix A Table A 2.4).

Table 2.4 Indicator species for coastal forest garden and low-intensity management sites. **Bolded** species indicate that they are highly significant site indicators ($p < 0.05$).

Site	Species	P-value
Forest Garden	Monumental crabapple (<i>Malus fusca</i>)	0.001
	Bracken fern (<i>Pteridium aquilinum</i>)	0.481
	Pacific yew (<i>Taxus brevifolia</i>)	0.196
	Devils club (<i>Oplopanax horridus</i>)	0.484
	Columbine (<i>Aquilegia formosa</i>)	0.485
	Saskatoon (<i>Amelanchier alnifolia</i>)	1.000
	Stinging nettle (<i>Urtica dioica</i>)	1.000
	Pacific ninebark (<i>Physocarpus capitatus</i>)	1.000
	Black Gooseberry (<i>Ribes lacustre</i>)	1.000
	Thimbleberry (<i>Rubus parviflorus</i>)	1.000
	Cow-parsnip (<i>Heracleum maximum</i>)	0.815
	Bitter cherry (<i>Prunus emarginata</i>)	0.991
Low Intensity	Volunteer crabapple (<i>Malus fusca</i>)	0.021
	Red elderberry (<i>Sambucus racemose</i>)	0.174
	Nootka rose (<i>Rosa nutkana</i>)	0.054
	Highbush cranberry (<i>Viburnum edule</i>)	0.452
	Yarrow (<i>Achillea millefolium</i>)	0.560

	Common silverweed (<i>Argentina anserina</i>)	0.668
	Northern riceroot (<i>Fritillaria camschatcensis</i>)	0.838
	Salmonberry (<i>Rubus spectabilis</i>)	0.896

A total of 27 tree cores representing 27 individual monumental crabapple trees were aged but only three hit piths, therefore the estimated ages are a minimum and the trees could be several years older. Most of the trees ranged from 50–100 years old (Appendix A Fig. A 2.1). The two youngest trees were established 15 years before sampling (they were established by 2004). Only two trees were over 100 years old, one being established at least 101 years from sampling (established in, or prior to, ca. 1918) and the oldest tree was established at least 215 years from sampling (established in, or prior to, ca. 1804) (Appendix A Fig. A 2.1).

2.4 Discussion

Of the 29 sites visited, we categorized 16 of them as forest gardens that were likely stewarded and managed by people. This was based on their proximity to ancient or historical habitation sites, the presence of archaeological features, and the structure and arrangement of monumental apple trees. We identified 12 plants that serve as species indicators of forest gardens in the respective regions. We found that the plant composition and abundance at coastal forest gardens varied regionally and across different habitats. We found that the monumental crabapple trees throughout the Central Coast ranged in minimum age from 15–215 years old, with most trees being 50–100 years old. This research can help aid in the identification of coastal forest gardens

and highlights the diversity apparent in the practices and legacies across different ecological and cultural regions.

2.4.1 Plant composition

The composition of culturally important plants as an indicator of forest gardens is worthy of further discussion. The diversity of indicator plants at mainland sites ($n = 15$) is slightly higher than at coastal sites ($n = 12$). Of the 15 plant species that are indicators of mainland forest gardens (and across a larger area, ~ 900 km) (Armstrong et al. 2023), we recorded three of the same species as indicators of coastal forest garden sites (covering ~ 350 km). These include Pacific crabapple (*Malus fusca*), saskatoon berry (*Amelanchier alnifolia*), and thimbleberry (*Rubus parviflorus*). Mainland forest garden canopy layer indicator trees include Pacific crabapple and beaked hazelnut (*Corylus cornuta*), whereas coastal forest garden canopy layers include Pacific crabapple and bitter cherry (*Prunus emarginata*). Two shrubs recorded as mainland indicators (oval leaf blueberry; *Vaccinium ovalifolium* and black twinberry; *Lonicera involucrata*), were ubiquitous across coastal sites. A further two mainland indicators shrubs, Nootka rose (*Rosa nutkana*) and highbush cranberry (*Viburnum edule*) were found to be indicators of lower intensity coastal sites. There are no overlapping herbaceous indicator species between mainland and coastal forest gardens. Considering the diversity apparent between forest gardens compels further investigation, using multiple lines of evidence (e.g., soil analyses, historic air photos, ethnographic records) to make more robust inferences about indicators of historical and ancient land-use practices.

The frequency and diversity of edible and medicinal plant species at a given site is a compelling and relatively accessible and expedient way of characterizing a potential forest garden. Although attempts to define distinctions between forest gardens are complex and should not be hard-bounded, in some cases, categories could help us to better explain management variability in the region. We propose that many coastal forest garden sites could also be sub-categorized as orchards as they host fewer species of culturally important plants than mainland forest gardens and they are dominated by monumental crabapple. Previous research on crabapple orcharding in Nuu-chah-nulth territory (which is in between our two study regions) also demonstrates this; monumental crabapple was a significant indicator species and plant diversity was lower ($n = 6$) (Armstrong et al., 2022). Orchardling could be categorized as a subset of forest gardening activities, a management strategy within the forest gardening portfolio alongside root gardening and berry cultivation. We therefore use the terms “forest garden” and “orchard” interchangeably throughout the remainder of the manuscript.

2.4.2 Habitat and regional variability

The indicator species for forest gardens had regional and habitat differences. Previous research on forest gardens in British Columbia spread across five degrees of latitude also found regional differentiation between northern and southern sites (Armstrong et al., 2023). Even though all the ethnobotanically salient plants present in our survey are native to both study areas, plant diversity and abundance in the Central Coast and Discovery Islands sites were significantly distinct. While both the Central Coast and Discovery Islands forest gardens are within the same biogeographic zone, their climates are distinct and are further divided into different subzones (Meidinger & Pojar, 1991). The Central Coast is a wetter and slightly cooler climate, while the

Discovery Islands are drier and warmer (Meidinger & Pojar, 1991). The difference in climate likely explains why some species are associated with one region and not the other. For example, saskatoon berry tends to favour drier conditions and, as such, may explain why it is an indicator at the Discovery Islands, and not the Central Coast sites (Klinkenburg 2020).

Similarly, plants' preferences and tolerances reflect their abundance across habitats. Pacific yew, stinging nettle, and bracken fern are some of the indicators of streambank habitats. These three species are commonly found in forest habitats (Klinka et al., 2007). Streambanks tend to have higher canopy cover than both estuaries and shorelines, which could explain why these three plants are indicative of streambank habitats.

However, the variation of species associated with forest garden sites across regions and habitats may also reflect cultural preferences. Springbank clover (*Trifolium wormskioldii*), yarrow (*Achillea millefolium*), and common silverweed (*Argentina anserina*) are indicators of forest gardens in estuary habitats (Fig. 2.4). All are moisture-loving species that grow in estuaries, however, they are also commonly seen along streambanks and shorelines (Fretwell et al., 2013). Since all three of these habitats were ubiquitous throughout both study regions (Pojar & MacKinnon, 2004), these plants' occurrence as estuary indicators could be due to past management preferences. Stewarding estuarine "root gardens" and cultivating these three particular species together is a well-documented management practice (Ames, 2005; Maurice-Hammond et al., 2023), further evidence to support that the appearance of these plants in estuarine forest gardens is due to cultural practice.



Figure 2.4 A coastal forest garden in an estuary habitat on the Central Coast. Crabapple trees, both monumental and volunteer form, can be seen in the background. Yarrow and silverweed are abundant in the foreground.

Spatially, culturally, and ecologically, people's land-use histories and plant stewardship practices should be conceptualized as highly variable. Terms like root gardens, berry patches, and orchards are used under the umbrella of forest gardening to highlight various forms of perennial plant management. However, these practices will vary in different ecological and cultural contexts and are likely to leave equally varied legacies or signatures decades or centuries after such practices have ceased.

2.4.3 *Pacific crabapple*

The association of crabapple with habitation sites is congruent with observations elsewhere in the province — Ts’msyen researchers consider the presence of crabapple trees a tell-tale sign of a campsite or habitation site (Armstrong, C.G., *personal observation*); in the 1980s anthropologist Jim McDonald noted that “wherever the old people camped, there are crabapples” (McDonald 2005, 2003). The association between crabapple and habitation sites is intuitive because of its importance as food, medicine, and material. Some uses for crabapples were ubiquitous across many regions; for example, many coastal people used crabapple wood as digging tools and the small, tart fruits were harvested in the late summer and early fall for food (Turner, 2014a). Other uses, preparation methods, and recipes were more culturally or geographically specific.

On the Central Coast (Haílzaqv and Wuikinuxv territories) and in the northern parts of the Discovery Island range (Kwakwaka’wakw territory) sometimes the fruits would be left on the branches until the first frost, which browned, softened, and sweetened them (Compton, 1993; Turner & Bell, 1973). Because of their acidity, the fruit preserved well; they were either stored raw or cooked and then preserved in fish oil or water (Burton, 2012; Turner, 2014f; Turner & Turner, 2008). Boxes of crabapples were a common trade item, wedding gift and crabapples mixed with eulachon (*Thaleichthys pacificus*) grease were served at feasts and potlatch ceremonies (Kuhnlein & Turner, 1991; Turner & Bell, 1973). In some Haílzaqv and Wuikinuxv stories, crabapples have supernatural qualities (Turner, 2014d), a testament to their cultural significance.

Medicinally, crabapple bark was harvested and boiled as a medicine to treat colds and coughs (Turner, 2014b). In Wuikinuxv territories, hunters chewed the bark as a hunger and/or thirst suppressant (Compton, 1993). As a technology, crabapple tree branches and trunks offered a valuable source of hardwood for fuel and tools (Burton, 2012; Turner, 2014e). In Wuikinuxv territories the wood was used to make spoons because it does not crack in water (Compton, 1993).

Ethnographic evidence of past crabapple management is relatively rich compared to other food plants. The trees were pruned, fertilized, transplanted, and cultivated (Turner, 2014c; Armstrong 2022; Armstrong et al. 2021; Wickham et al., 2022; Wyllie de Echeverria, 2013). In Wuikinuxv territory, Elders have memories of stewarding crabapple trees near the village site of Katit as recently as the 1950s (Wickham et al., 2022). At several sites we visited across the Central Coast, trees appeared to have been pruned so that their trunks were low to the ground, making it easier for people to harvest fruit, a practice that has been described to ethnobotanists in other regions (Wyllie de Echeverria, 2013). Early accounts of merchant and admiralty ships arriving in Nootka Sound (Mowachaht-Muchalaht) and in Port Alberni (čišaaʔath/Tseshaht) territories explicitly note apple “orcharding” of the native crabapple species (Armstrong et al., 2022).

Pacific crabapples have a longer lifespan than most apples, often living for 150 years or more (Arno & Hammerly, R., 2007); one of the trees we cored on the Central Coast was at least 215 years old. Crabapples’ fruiting productivity reduces after the age of 80 years (Arno & Hammerly, R., 2007), which means tree stewardship and cultivation would have most likely taken place before that age. Therefore, the time of active site management could be inferred from a

dendrochronology of a crabapple orchard. However, complicating this is the fact that crabapples actively regenerate through suckering, so orchards may have had many stratified layer of tree ages, instead of one homogenous planting as we see in colonial contexts. Historical ecologists' intending to infer the time of active site management from a crabapple dendrochronology would need to take care to choose a fulsome sample size and incorporate additional methods (i.e., soil sampling) as supplementary evidence.

It should be noted that despite being more dispersed across the landscape, volunteer crabapples are important and relevant for people and animal relations. Their short size makes the entire tree/shrub harvestable for humans, bears, and other animals. Presently, the Wuikinuxv Nation harvests crabapples from volunteer trees located in an estuary because they are shorter and more productive than the monumental trees located close to the Wuikinuxv village of Katit in orchards.

2.4.4 Archaeological features

Based on visual shoreline surveys, shell middens were recorded at every forest garden surveyed in the Discovery Islands, and clam gardens were recorded at all but three sites. We observed shell middens at over half of the surveyed sites on the Central Coast. Augering or soil analysis may reveal middens at more sites. None of the monumental crabapple trees we recorded appeared to grow *on top* of the middens, but rather, they were recorded adjacent to the site or further inland, behind the midden. Further soil sampling is warranted to confirm this observation. The presence of midden is grounds for the protection of a site under the provincial Heritage

Conservation Act, but currently such protections are not granted to forest gardens even if they are located directly above a midden (more below).

Fish traps and weirs were also commonly recorded features at Central Coast forest gardens, with two sites hosting multiple traps or weirs. Salmon (*Oncorhynchus* spp.) are an important coastal food resource; they migrate from the open ocean to their natal stream and rivers, where they are harvested by weir and fish trap technologies. Several species of salmon (such as sockeye, chum, and coho) make the return migration between August and December and many of the forest garden indicator species are harvestable in the fall (e.g., crabapple, all the currants, bitter cherry). From a seasonal harvesting perspective, it makes sense that the forest gardens are arranged near fish traps/weirs as both are available for harvest at the same time.

No archaeological features were recorded at several sites on the Central Coast. Sites 16 and 25 had no RAAD recordings, and there was nothing sited throughout our surveys. Both sites were on islets, connected to a RAAD archaeological site at low tide, which is why they were not discounted from our initial survey. Site 16 hosted relatively large numbers of estuarine root plants; therefore, its sole potential purpose was that of a forest and/or root garden. Two of the other sites with no archaeological recordings were located in estuaries and had archaeological features listed in RAAD. However, we did not observe them.

2.4.5 Limitations

For future research, we consider several limitations that should be addressed. First, we conducted relatively expedient “blitz” botanical surveys rather than structured, systematic plant surveys.

Transect and quadrat sampling would have given us a more refined snapshot of plant diversity, abundance, and edge effects. Second, there was a relative lack of detailed ecological metadata for each site. Site-specific slope, aspect, soil type and soil formation processes, soil moisture, and tree canopy are all important factors when considering a plant's habitat preferences and tolerances. The decision to survey in blitzes was balanced against the number of sites surveyed (n= 34), which, to date, is the largest regional survey for forest gardens in the Pacific Northwest.

Third, there was a lack of ethnographic data. The study spans eight distinct territories, representing multiple languages and language families. While previous work has integrated site-specific ethnographic knowledge and expertise on crabapple management (e.g., Wyllie de Echeverria 2013, Armstrong 2022), and ethnographic data is an incredibly valuable form of knowledge that could complement this research, we forwent hyper-localized inferences for a more regional and broadscale approach. We believe that the emerging patterns will be useful at a local scale as well.

2.4.6 Significance of orchards and forest gardening

Indigenous orcharding can be ancient, historical, contemporary, or a combination of all three. In BC, the Wuikinuxv Nation is still actively managing forest gardens that were originally cultivated by their ancestors (Wickham et al., 2022). Sts'ailes in southwestern BC have developed a forest garden revitalization project on sites that have been aged at over 3,000 years (Vanier, 2022). At a number of forest gardens sites, including in Sts'ailes, Hailzaqv, and Gitselasu (Ts'msyen) territories, historical-ecological research has shown that after the onset of settler colonialism, some communities adopted newly introduced European cultivars (cherry,

apple, plum) into their already productive orchard and forest garden systems (Armstrong, 2022; *Húyat*, n.d.). Contemporary management of these legacy ecosystems demonstrates the continued occupation and connection of Indigenous peoples to the plants and landscapes that sustain them. It also reflects the importance of considering the nuances in how these places are managed throughout space and time.

The recognition of forest gardening can link people to their traditional homelands and can re-awaken traditional land-use practices (Armstrong et al., 2021; Simpson, 2014; Wehi & Lord, 2017). The Indigenous-led reclamation and/or restoration of land-based food systems offer access to intergenerational, place-based opportunities that can connect displaced or younger generations to ancestral traditions and territories (Deloria Jr. & Wildcat, 2001; Grenz & Armstrong, 2023; Joseph et al., 2022; Simpson, 2014). Additionally, forest gardens can aid in reaffirming food sovereignty and healthy nutrition initiatives, which is especially important for remote Indigenous communities (Joseph & Turner, 2020a; Nabhan, 2014; Robin, 2019; Sowerwine et al., 2023).

The survey, identification, and recognition of forest gardens and other relevant food systems (berry plots, orchards, root gardens etc.), although an ancient and ongoing practice, is relatively new for policymakers, regulatory bodies, and consultants across BC. Forest garden and orchard sites are not currently protected under BC heritage conservation laws (unless they are growing directly on top of middens or close enough to other features like cultural depressions; Armstrong et al., 2023). This omission ignores the types of heritage that Indigenous communities consider important (Lepofsky et al., 2020). Archaeological assessments should expand to include plant

management legacies and support a more culturally just approach to archaeological practices (Armstrong et al., 2023). On top of that, forest gardens are also not currently protected under any BC environmental management laws or regulations. Indigenous land-use and ecological values are generally devalued or ignored altogether under environmental management policies, and therefore, formal recognition for forest gardens and orchards may be one avenue for overcoming this egregious gap.

Broadly, this work adds to the growing body of knowledges that challenges the “pristine myth” – the notion that the Americas were once a sparsely populated wilderness, where humans had little or no influence (Denevan, 1992) by demonstrating the subtle yet long-term impacts ancient people had on their lived landscapes.

2.5 Conclusions

We found that coastal forest gardens displayed regionally distinct patterns of plant composition and abundance and can be identified by 12 indicator species, the monumental form of Pacific crabapple being a strong indicator. This research demonstrates the importance of considering regional distinctions in academic research and land management, provides guidance for identifying coastal forest gardens at a broad scale, and facilitates discussion on the intricacies of forest gardening as a land-use practice. While orcharding and forest gardens are relatively new concepts in academic, policy and management circles, Indigenous communities have long been aware of and caring for these landscapes. Formal appreciation of these culturally specific and co-evolved landscapes has implications for social justice, and Indigenous self-determination and sovereignty.

Chapter 3. Incorporating Place-based Values into Ecological Restoration

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Overview

Knowledge of how ecocultural landscapes co-evolved, how they were shaped and maintained by local people, and what processes disturbed the landscape should inform the planning, execution, and significance of restoration projects. Indigenous stewardship has resulted in legacies of diverse and productive ecocultural environments. Often, this stewardship has been guided by place-based values, which are informed by Indigenous Knowledge, beliefs of equal respect for all ecosystem components, and conduct that sustains resource productivity. We propose that cultivating place-based values in restoration initiatives will provide reciprocal benefits by conserving biodiversity and promoting human connections to land. Drawing on lessons from Indigenous Knowledge systems in what is now called British Columbia, Canada, we demonstrate how place-based values directed the stewardship of historical oak-meadow and clam gardens, which created diverse and productive ecosystems that sustained for millennia. Drawing on examples of contemporary restoration projects (crabapple orchards and clam gardens) that utilize place-based values to inform the recovery of ecocultural landscapes, we propose a framework to help initiate a place-based values approach in contemporary restoration design congruent with ethics of inclusion.

3.1 Introduction

Land and seascapes of cultivated and domesticated species have been tended to and utilized by people for centuries, resulting in the co-evolution of unique ecological and cultural (ecocultural) ecosystems (Pfeiffer & Voeks, 2008). However, many Indigenous practices that have created, modified and/or sustained ecocultural systems for millennia have been disrupted by colonialism (Armstrong et al., 2021; Heckenberger et al., 2007; Senos et al., 2006; Trauernicht et al., 2015), and the intrinsic value of biodiversity that is crucial to the cultural fabric of many societies is threatened (Ghilarov, 2000; Kelbessa, 2013). Place-based communities that depend on the biodiversity, productivity, and integrity of their immediate environment are directly and adversely affected by contemporary environmental degradation (Liu et al., 2007; Pfeiffer & Voeks, 2008) and in colonial contexts, this disproportionately affects Indigenous peoples. Furthermore, ecosystems have become distressed in the absence of cultural practices and management that once sustained them (Hoffman et al., 2019, 2021; Senos et al., 2006).

Indigenous Oral Histories and multiple western research disciplines (e.g., archaeology, anthropology, ecology, ethnobiology) have demonstrated how historical Indigenous stewardship has contributed to patterns of productivity and biodiversity at the landscape level (Armstrong et al., 2021; Cox et al., 2020; Hoffman et al., 2021; Schuster et al., 2019; Trant et al., 2016). For example, in South America landscape burning, crop diversification, and the creation of terra preta anthropogenic soils has shaped Amazonian biodiversity (Heckenberger et al., 2007; Levis et al., 2017; Pivello, 2011). In Australia, Aboriginal peoples increased plant production and biodiversity through seed dispersal, soil turnover, burning, and hunting (Bird & Nimmo, 2018; Bowman, 1998; Zeanah et al., 2017). In the absence of Aboriginal practices both plant and

mammal species richness has decreased in the Australian outback (Bowman, 1998). In these and many cases, Indigenous stewardship has contributed to complex and resilient ecosystems that sustained human beings for millennia.

Indigenous groups have considerably different cultures; however, many of them share a notable commonality: place-based value systems. Values are defined as being potential determinants of preferences and attitudes (Lyver et al., 2016), which guide the practices and customs of a social group (Berkes and Turner 2006). Place-based values are reflective of a peoples' intimate connection to their local environment (Berkes & Turner, 2006; Indigenous Peoples, Indigenous Voices Factsheet, 2006). These values are formed from a deep knowledge of local ecological processes developed through generations of learning by observation and by trial and error experimentation (Artelle et al., 2018). Place-based values that guide interactions with the environment can emerge from any community with a long-term relationship to place. However, in this paper, we have chosen to focus on place-based values as they are enacted in examples of Indigenous land and seascape management. Indigenous management can provide us with unique examples of how to create and sustain biodiverse, productive landscapes and seascapes that have co-evolved alongside people for very long-time scales (millennia).

Ecological restoration is another means of shaping, protecting, and conserving biodiversity. The practice of restoration is a process, aimed at supporting the recovery of an ecosystem that has been degraded, damaged or destroyed (Gann et al., 2019) often by industrialized cultures (Senos et al., 2006). Ecological restoration intends to shift degraded environments into a recovery trajectory, supporting the redevelopment and persistence of a native species assemblage, while

still enabling adaptation to local and global changes (Gann et al., 2019). Often, the primary intent of restoration efforts is to regain ecological integrity and resilience, and little acknowledgement of the human landscape is used to drive goals or targets (Hallett et al., 2013).

The inclusion of place-based values has been called for in environmental management, stewardship, and conservation (Artelle et al., 2018; Augustine & Dearden, 2014). In this paper we build off work by Augustine and Dearden (2014) and Artelle et al. (2018) by calling for the inclusion of place-based values into the practice of ecological restoration. In many instances, place-based relationships have been driving factors in increasing ecosystem productivity and biodiversity across local and regional levels (Bird & Nimmo, 2018; Cox et al., 2019; Trant et al., 2016). We propose that to encourage culturally and ecologically relevant, community-engaged restoration projects, place-based values should be incorporated into restoration practice. We define place-based values led restoration as efforts that convey clear, consistent objectives that are informed by inter-generational local knowledge, express aspects of respect to all ecosystem components, and aim to sustain ecosystem biodiversity and productivity. Place-based values led restoration is distinct from terms such as “ecocultural restoration” and “socioecological restoration” in that place-based values led restoration projects are geographically, temporally, and culturally specific to place. Indigenous led restoration is often place-based; however, place-based values led restoration does not have to be Indigenous led.

‘British Columbia (BC), Canada’ is exceptional for its ecocultural diversity. BC contains diverse ecosystems that support some of the last intact wildlife communities found in North America (Shackelford et al., 2017). BC is comprised of Indigenous territories and inhabited by Indigenous

Nations with inherent rights and title to access and harvest land and resources (BC Treaty Commission, 2020). Despite the genocidal attempts of colonialism to assimilate Indigenous peoples and lands, and to extinguish Indigenous rights and title, Indigenous peoples, their laws, cultures, landscapes, and management practices have endured. Indigenous peoples have been present in BC since time immemorial (at least 14,000 years; (McLaren et al., 2015, 2018)) and the potential for land and sea management practices extends back thousands of years. Accordingly, this stewardship has contributed to the unique biodiversity of the province (Turner, 2007).

In this paper we, 1) explore how place-based values established specific Indigenous practices that influenced productivity and biodiversity in BC (our research draws on historical examples, although we respect that this stewardship is still practiced by Indigenous peoples today), and 2) discuss how cultivating place-based values in restoration initiatives can contribute to creating and sustaining diverse and productive ecocultural landscapes that provide reciprocal benefits to humans and non-humans alike. We draw on examples from the literature and from our own experiences. S.B.W. (settler) is a graduate student working with and for the Wuikinuxv Nation on terrestrial ecology and restoration; S.A. (Hul'q'umi'num') is a graduate student, policy advisor, and clam garden restoration practitioner; D.M. (Cree/settler) is an ethnoecologist, archaeologist, and faculty member; A.F. (settler) is the Wuikinuxv Stewardship Director, N.S. (settler) is a restoration ecologist and faculty member; J.W. (Wuikinuxv) is an Indigenous scientist and Wuikinuxv Council member; A.J.T (settler) is a historical ecologist and faculty member.

3.2 Place-based values

A literature review and discussions between co-authors highlighted four important features of place-based value systems:

- 1) *Belief Systems*. Place-based values are grounded within a belief system that promotes respect (Turner & Mathews, 2020). Many Indigenous belief systems ascribe to various versions of relational worldviews, which assume all ecosystems components are related, interconnected, and that the survival and success of each is dependent on the survival, success, and reciprocity of others (Henderson, 2000; Kimmerer, 2014b; Salmón, 2000). Crucial to this belief is that humans are neither above or below others in the circle of life and all life is equally sacred (Atleo, 2011; Henderson, 2000; Tuck & McKenzie, 2015; Wilson, 2008).
- 2) *Knowledge*. Place-based value systems are informed by dynamic, inter-generational or long-term knowledge of place, such as Indigenous Knowledge (IK) or Local Ecological Knowledge (LEK). IK is grounded in spiritual worldviews and cultural values and has emerged from centuries of survival strategies and cultural systems that have sustained Indigenous communities (Simpson, 2004; Smith, 2012) – different systems and bodies of knowledge are held by different Indigenous groups (Kawerak Inc., 2017). IK includes Traditional Ecological Knowledge (TEK)(Kawerak Inc., 2017), which relates to western concepts of ecology and the environment; however, not all definitions of TEK recognize the effects of Indigenous worldviews/values/beliefs on cumulative knowledge systems (Dudgeon & Berkes, 2003; Simpson, 2004). LEK encompasses long-term knowledge of place, including ecosystem processes and how humans have affected these processes. However, LEK does not have to be inter-generational and can be informed by a different

worldview and set of responsibilities than IK (e.g. one that is not relational)(Gann et al., 2019).

- 3) *Conduct*. Place-based values guide principles, protocols, objectives, practices, and rituals that safeguard against exceeding ecological limits now and into the future (Artelle et al., 2018; Turner & Berkes, 2006). This includes the observations, experimentations, and persistent practices that inform Indigenous Knowledge.
- 4) *Attachment to place*. Place-based values are grounded in a connection to a specific land and/or seascape.

Over time, the connections and feedbacks between these, other features of place-based values, and the surrounding environment, shape place-based value systems, place-based peoples, and their environments – resulting in the co-evolution of an ecocultural landscape.

3.3 Place-based values support biodiverse, productive ecosystems

Evidence from multiple forms of knowledge suggests that complex, integrated environmental management systems developed historically by Indigenous peoples contributed to patterns of biodiversity and productivity seen across BC—many of which persist today (e.g., Armstrong et al., 2021; Cox et al., 2019; Fisher et al., 2019; Hoffman et al., 2017). Indigenous management systems are the conscious and skillful application of any combination of methods that sustains or enhances the availability, abundance, diversity, and/or quality of a resource or resource habitat over generations (Turner, 2014c). Indigenous management systems are value-led (Artelle et al., 2018) and in this way, many Indigenous management systems are consistent with the concept of ‘stewardship’ (Lertzman, 2009; Whyte et al., 2016). Stewardship is primarily concerned with the conservation and sustainability of the resource at hand due to values that imply an obligation to

that resource (Lertzman, 2009). While acknowledging that not all Indigenous management is necessarily in line with stewardship (nor does it need to be) in this paper and in the examples we focus on, we will use the terms interchangeably.

Ecocultural land and seascapes created by Indigenous management in BC include (but are not limited to): stone fish trap communities, eelgrass harvesting meadows, seaweed harvesting rocks, estuarine root gardens, crabapple and hazelnut orchards, berry gardens, forest gardens and wapato gardens (Armstrong et al., 2021; Cullis-Suzuki et al., 2015; Hoffmann et al., 2016; Lepofsky et al., 2017; Mathews & Turner, 2017; Turner & Turner, 2008; White, 2003). Place-based values directed the stewardship that sustained these complex and resilient ecosystems for millennia. In this section we describe two additional ecocultural environments: Coast Salish oak-meadow gardens (hereafter referred to as oak-meadow gardens and also known as Garry oak habitats, ecosystems, etc.) and clam gardens (and associated shell middens), in an effort to demonstrate how the features of place-based value systems (beliefs, knowledge, conduct and attachment to place) contribute to shaping the biodiversity and productivity of these environments.

We provide historical examples not to “romanticize” the past (both anthropogenic burning and clam gardening are still practiced today), but to demonstrate some of the ecological consequences of non-western, long-term landscape management, values, and worldviews. Both oak-meadow and clam garden ecosystems are found across large geographical regions and we discuss their stewardship in generalized terms. However, it should be recognized that the

practices and beliefs associated with the stewardship of oak-meadow and clam gardens were far more culturally, spatially, and temporally diverse than we have described in this article.

3.3.1 Anthropogenic landscape burning in oak-meadow gardens

For millennia across southwestern Vancouver Island and adjacent lands, Coast Salish peoples have consistently and expertly employed anthropogenic burning, which has become integral to creating oak-meadow gardens (Figure 1A)(Lake & Christianson, 2019; Pellatt & Gedalof, 2014). A principal motivation for this has been to create habitat that supports the productivity of the nutritionally and economically important root, blue camas (*Camassia quamash* and *Camassia leichtlinii*) (Beckwith, 2004; Storm & Shebitz, 2006; Turner, 1999). Unlike large and destructive wildfires these controlled, low-intensity fires served additional often simultaneous purposes, including increasing the productivity of other culturally important plants such as berries, clearing travel routes, creating fire breaks near habitation sites, accelerating nutrient cycling, and promoting early successional vegetation that attracts more game (Boyd, 1999; Hoffman et al., 2021; Lake & Christianson, 2019; Turner, 2014c).

Coast Salish fire management has been based on leadership and inter-generational knowledge transfer (Turner, 1999). Using fire effectively requires significant local knowledge and expertise, including a fine-tuned understanding of different environmental and climatic indicators specific to a place. Short-term factors informed burns, such as prevailing wind direction, and soil moisture (Turner, 1999). Decadal and longer-term factors that Coast Salish fire managers considered are: planning burning frequency with the intention of reducing fuel loads to lower fire intensity, considering the desired patterns of habitat succession across a landscape, creating

productive ecological edges, and deliberating on plant community health due to long-term weather patterns (Turner, 1999, 2014c). Landscape burning was a sacred ceremonial practice and an art form, informed and guided by cultural protocols and Indigenous laws and were only to be overseen by experts who had life-long training on the subject (Turner, 2014c).

In many cases, burning experts were community or house leaders, who would direct community members on the proper timing and extent of burns (Turner, 2014c). In other cases, the responsibility of burning was carried out by designated stewards. Protocols endowed a responsibility to keep sites properly tended through the use of fire. For example, camas meadows and oak habitats were often burned every year or two. Without fire, these open landscapes would have transitioned to closed canopy forests that yield a relatively low amount of food species (Turner, 2014c). It was recognized that fire was an important factor in maintaining and sustaining habitats that yielded food security. Whether it be by house leaders or designated stewards, fire management was deeply respected and conducted at the optimal times and under appropriate conditions in order to ensure food resources were consistently available (Turner, Deur, et al., 2013).

Mature oak trees sustain little damage when exposed to low intensity fire at moderate intervals (3-5 years) (Hamman et al., 2011; Long et al., 2016). At the ground level, fire consumed moss, leaf litter, dry grasses, shrubs, as well as young trees and seedlings of non-fire adapted species (such as many conifer species) (Hamman et al., 2011). In Coast Salish territories, this created suitable seedbed for fire-adapted species and stimulated the germination of grasses and forbs (Gedalof & Franks, 2019). Fire enabled the development of alternative system states by creating

an open canopy and enabling grass and forb growth that would not be seen in a closed-canopy forest (Pellatt & Gedalof, 2014). Diversity can be increased through the creation of environmental heterogeneity – patches of habitat at multiple ecosystem states spread throughout the landscape (Balée, 2006; Ponisio et al., 2016; Smith & Wishnie, 2000). A diversity of successional stages can attract species that utilize the landscape in different ways and enables the co-existence of many species in a given area (D. W. Bird et al., 2016; Bliege Bird et al., 2018; Fuchs, 2001). Ultimately, low intensity burning at moderate intervals created open Coast Salish oak-meadow garden complexes: highly diverse, forb-dominated communities with a sparse overstory of oak and Douglas-fir (*Pseudotsuga menziesii*) (Pellatt et al., 2015; Pellatt & Gedalof, 2014). At local scales this created one of the most biodiverse terrestrial communities in Canada (Fuchs, 2001) and increased habitat heterogeneity at the landscape level.

3.3.2. Clam gardens

Clams (Phylum Mollusca Class Bivalvia) are a food resource for many coastal Indigenous peoples across BC, important throughout the year and vital in the winter. In the past, clams were eaten raw, steam cooked, or preserved by smoke-drying (Deur et al., 2015; Hul'q'umi'num - Gulf Islands National Park Reserve Committee, 2016; Lepofsky et al., 2015; Salter, 2018). Clam gardens are a system of mariculture constructed by building rock walls or terraces near the lowest intertidal zone of a shoreline (Figure 1B) (Groesbeck et al., 2014; Lepofsky et al., 2015; Smith et al., 2019). These human constructed intertidal rock-walls traps sediment and reduces the slope of beaches, creating both a soft sediment terrace and novel rocky reef habitat that increase the habitat, productivity, and standing stock of native clams (*Saxidomus gigantea*, *Leukoma staminea*, *Clinocardium nuttallii*, *Tresus spp.*, *Macoma spp.*) (Groesbeck et al., 2014;

Hul'qumi'num Treaty Group, 2011; Jackley et al., 2016). Historical coastal peoples from northern Washington up to Southeast Alaska left an extensive record of clam gardens throughout their territories (Smith et al., 2019).

Building, maintaining, tending, and harvesting clam gardens require a wealth of knowledge, which would have been learned over time through observation and experimentation at a specific place (Deur et al., 2015; Hul'q'umi'num - Gulf Islands National Park Reserve Committee, 2016; Olsen & WSÁNEĆ Leadership Council, 2019). To maximize productivity, clam gardens must be positioned at a specific tidal height and the substrate must be aerated and of optimal grain size (Groesbeck et al., 2014; Jackley et al., 2016). The practice of harvesting larger clams and leaving juveniles behind allowed for a proliferation in both size and numbers (Deur et al., 2015; Hul'q'umi'num - Gulf Islands National Park Reserve Committee, 2016).

Conduct around clam garden maintenance and harvesting was tightly controlled to ensure the continuance of this food resource. In Kwakwaka'wakw territories clam gardens were traditionally owned by specific families and harvests were governed by the heads of these families (Deur et al., 2015; Jackley et al., 2016). Rules such as: 1) restricting access to specific harvesting locations, 2) limits on the duration of harvest, and 3) intentional harvest closures to allow for population recovery, were imposed to ensure that clam resources were not overexploited (Deur et al., 2015; Jackley et al., 2016). These guiding principles also displayed an intimate knowledge of clam garden responses to anthropogenic and environmental effects (Deur et al., 2015).

Inherent to beliefs of respect for all life forms, many Indigenous peoples recognize that animals have familial communities (Atleo, 2011). For many Indigenous groups throughout coastal BC, clams are regarded as being relatives in a different form, having families and societies in a similar fashion to humans (Deur et al., 2015). Clam families and societies have abilities and needs, and if clam harvesters were able to ensure that clams had their needs met, it was believed that the clams had the ability to support the needs of humans by presenting themselves abundantly for harvest (Deur et al., 2015). These beliefs guided practices that fostered respect and reciprocity for clams as well as increasing clam biomass and encouraging sustainable harvests.

Clam gardens enhanced clam productivity and also diversified coastal community assemblages (Cox et al., 2019, 2020; Deur et al., 2015). Ecological and archaeological investigations demonstrate higher growth rates, survivorship, densities, and biomass of clams in walled gardens (despite harvesting pressures) as opposed to non-walled beaches of similar tidal height, slope, and substrate (Groesbeck et al., 2014; Jackley et al., 2016; Toniello et al., 2019). Additionally, the in-and-epi faunal communities of clam gardens are distinct from similar mud and sand flat habitats (Cox et al., 2019). These patterns of productivity and diversity persist in community assemblages even though the clam gardens that were studied had not been actively stewarded for over 150 years (Cox et al., 2019; Toniello et al., 2019). Further, the rock wall structures trap sediment and create habitat for a variety of other marine species such as seaweeds, sea cucumbers, crabs, and small fish (Hul'q'umi'num - Gulf Islands National Park Reserve Committee, 2016; Lepofsky & Caldwell, 2013; Olsen & WSÁNEĆ Leadership Council, 2019). In turn, the abundance of clams and their associated faunal communities supported higher trophic

level consumers such as seabirds, river otter, raccoon, and mink, thus increasing local diversity (Deur et al., 2015).



Figure 3.1 Examples of ecosystem associated with Indigenous management: (A) Cowichan Garry Oak Preserve in WSÁNEĆ territory, South Vancouver Island, British Columbia (BC; photo courtesy Kelly Fretwell), (B) clam gardens in WSÁNEĆ territory, Gulf Islands National Park Reserve, BC (photo courtesy Iain Robert Reid), (C) crabapple orchard in Wuikinuxv territory, Central Coast, BC.

3.4 Examples of place-base values in restoration efforts

Across BC, values-led restoration approaches exist in both Indigenous and non-indigenous communities. We have defined place-based values led restoration as efforts that convey clear, consistent objectives that are informed by inter-generational local knowledge, express aspects of respect to all ecosystem components, and aim to sustain ecosystem biodiversity and productivity. The practices that stem from place-based values led restoration should recognize the role humans have played in ecosystem stewardship and serve to further connect people to place. When possible, these restoration efforts should incorporate long-term management and engagement plans. Below, we describe two case studies of contemporary Indigenous restoration:

3.4.1 *Wuikinuxv lhənnx̌ (crabapple) project*

Wuikinuxv territories are located in a remote region on the central coast of BC (Figure 2). The Wuikinuxv village of Katit is the full-time home of ~60 people and a further ~250 Wuikinuxv Nation members are based elsewhere (British Columbia Assembly of First Nations, n.d.), and return throughout the year for seasonal hunting and fishing. In the past crabapple (*Malus fusca*) was an important source of food for humans, bears, and other animals throughout Wuikinuxv territories (J. W. personal observation).

Pacific crabapple is an iconic plant for coastal First Nations; it is named in over 31 languages (Turner, 2014a) and was an important component of historical diets (Turner & Turner, 2008). The fruits of crabapple trees (lhənnx̌ in 'Wuik'ala) were a culturally important food, served and gifted at feasts throughout Wuikinuxv territories (Compton, 1993). They could be eaten fresh, dried, or stored in oil or water (Compton 1993). Crabapple trees were used for multiple purposes:

the hardwood was used for tools such as spoons and digging sticks, the bark was chewed for hunger suppression, and licorice ferns (*Polypodium glycyrrhiza*) and lichens (*Usnea* and *Alectoria*) were collected from crabapple branches and used as medicines and materials (Compton 1993).

Wuikinuxv Elders have recollections of tree management by fertilizing, pruning, and transplanting lhènnǎ trees into groves or orchards (Figure 1C). However, genocidal colonial policies disrupted traditional Wuikinuxv land management practices and lhènnǎ trees have not been stewarded in over 80 years, which may be the reason they no longer fruit. A lack of lhènnǎ has resulted in decreased food resources for wildlife in the territories. Over this same time period, a variety of factors – mostly importantly commercial overfishing – have decimated local salmon stocks (Gresh et al., 2000). Salmon and lhènnǎ fruit are two important food sources for bears (Adams et al., 2017) and their decline has contributed to bears scavenging in the village, increasing potentially dangerous human-bear interactions. Western methods of bear control often resulted in bears being killed by Conservation Officers, which upset Wuikinuxv Nation members (J.W. personal observation/experience).

Beginning in early 2020 the Wuikinuxv Stewardship Department initiated a lhènnǎ re-management project in collaboration with some of the authors of this paper. The intent of this project is to increase productivity of lhènnǎ by restoring historically managed trees and cultivating volunteer trees. The project goals are to provide bears with more food in the form of lhènnǎ at sites throughout Wuikinuxv territory (and in doing so, entice them out of the village), and to reconnect people in the community (especially youth) with harvesting and managing

lhènnǎ trees through participation in restoration and monitoring. In order to achieve these goals, the following objectives have been set: 1) survey existing orchard and volunteer sites throughout Wuikinuxv territories, 2) increase crabapple production using management methods remembered by Elders (e.g., pruning and fertilizing, 3) monitor the survival/production of re-managed trees, 4) monitor the bear consumption of crabapples at restoration sites, and 5) engage and encourage community participation through restoration and harvesting events.

Evidence of place-based values directing the Wuikinuxv lhènnǎ project are identifiable within the goals and objectives of the project. IK has been used to inform survey and restoration sites. Elders have provided inter-generational knowledge to determine which restoration treatments are to be applied to trees. Increasing lhènnǎ production for bear consumption shows respect to animal life forms and monitoring tree survival and lhènnǎ production displays respect for plant life forms. Monitoring also demonstrates conduct that is committed to the sustainability and productivity of lhènnǎ in the long-term. Encouraging community engagement in restoration events recognizes the value of human stewardship and further ensures long-term project sustainability by cultivating new human-environment relationships.

It is worth noting that the re-management of lhènnǎ trees at historical orchards may recreate historical conditions. Although this often a goal for many restoration projects, it is an unintentional by-product in this case. The specific goal of this project (increased lhènnǎ production for bear consumption) is emphasized in the new practice of cultivating volunteer trees, which may create a novel ecosystem.

3.4.2 Hul'q'umi'num' and WSÁNEĆ clam garden restoration in the Gulf Islands National Park Reserve

In southernmost BC lie the Gulf Islands, home of endemic coastal ecosystems, a Mediterranean climate, and within the traditional territory of 19 Coast Salish Indian Bands, including Hul'q'umi'num' and WSÁNEĆ communities. This region is also one of the most densely populated marine areas in Canada with two major urban centers, international shipping routes, commercial fishing industries, marine tourism industry, and over 3 million people (Bodker & Philibert, 2016). Hul'q'umi'num' and WSÁNEĆ peoples have actively stewarded this coastal landscape for millennia, shaping many novel ecosystems including clam gardens. In Coast Salish territory the physical structure of low tide rock wall is supported by a system of beach tending practices including tilling, selective harvesting, garbage removal, and discouraging predators (such as river otters, raccoons, and mink) through monitoring (Deur et al., 2015; Hul'q'umi'num' - Gulf Islands National Park Reserve Committee, 2016; Lepofsky et al., 2015; Olsen & WSÁNEĆ Leadership Council, 2019).

Over 11,000 years of continuously rising sea levels (Fedje & Sumpter, 2009; James et al., 2009) has meant intertidal rock walls – dating to the mid-late Holocene – require continuous maintenance to function as intended (Smith, 2019). Without this maintenance clam garden rock walls become fragmented and intertidal terraces creep below ideal tidal heights for target species. However, clam gardening within Coast Salish territory has been interrupted due to colonial practices, land privatization, pollution, commercial overharvesting (Fediuk & Thom, 2003) and a lack of maintenance (Lepofsky et al., 2015). Many beaches throughout the Gulf Islands currently have low densities of clams (Parks Canada, 2010). Elders state clearly that to bring beaches back

to life, people need to be on the clam gardens, caring for them again (Hul'q'umi'num - Gulf Islands National Park Reserve Committee, 2016; Hul'qumi'num Treaty Group, 2011; Lepofsky et al., 2015; Olsen & WSÁNEĆ Leadership Council, 2019).

Following the guidance of Coast Salish knowledge holders, in 2014 Hul'q'umi'num' and WSÁNEĆ Nations, in collaboration with Parks Canada, began a restoration experiment (led by one of the authors of this paper) to bring people back onto beaches and re-establish ancient human-nature relationships by reintroducing Coast Salish beach tending practices to untended clam gardens (Figure 2). Since 2014, project goals have evolved and now include: 1) ensuring functional densities of all key clam garden species, 2) ensuring food species are safe for human consumption for generations into the future, and 3) building the financial and resource capacity for Coast Salish Nations to lead this work into the future. Each goal includes elements that require ecological restoration, cultural resurgence, policy reform, and strengthened relationships.

These goals not only increase ecosystem health through the maintenance of intertidal productivity and biodiversity, but also provide opportunities for Coast Salish people to reconnect with territory and practices, learn intergenerationally on the land, and improve the way Indigenous knowledge and western science are used together within contemporary resource management. One important element of the work includes training youth in language, culture, and science. Since 2014, this has included intergenerational restoration efforts as well as annual science and culture camps for youth.

All restoration practices come from the people of these places. For instance, Hul'q'umi'num' and WSÁNEĆ knowledge holders emphasize the importance of supporting key species that are missing from untended clam gardens in order to restore the relationships between those ecosystem components (H-GINPR 2016). Restoration practices have been refined through careful observation of changes that occur to habitat structure and condition, shifts in water movement, species characteristics, and ecosystem diversity. Efforts to restore clam gardens are based on a growing understanding of the critical role humans have played, and continue to play, in shaping, maintaining and protecting the landscapes and seascapes we value today.



Figure 3.2 Map of coastal British Columbia showing the approximate location of the lhènnx (crabapple) orchards in Wuikinuxv territory and the clam gardens in the Gulf Islands National Park Reserve located in Coast Salish territory. Map courtesy of Will McInnes/Hakai Institute.

3.5 Discussion

In this paper we have outlined how the enactment of place-based values through Indigenous stewardship has influenced patterns of productivity and biodiversity in order to create an appreciation for the role of place-based values in the evolution of landscapes. We described two contemporary restoration initiatives that have incorporated place-based values into their practices. Incorporating place-based values into restoration efforts provides a critical opportunity to appreciate the potential for humans to shape and sustain future ecosystems. In the discussion, we consider some of the realities of integrating place-based values into restoration work to help inform opportunities moving forward.

In Table 1, we outline how the features of place-based values might translate into questions, restoration action, and have provided examples from the Wuikinuxv lhənn̓x project to help conceptualize the actions. These actions and questions can be applied to urban, rural, and large- or small-scale restoration initiatives as a framework to begin applying place-based values to restoration planning and implementation. The localized and site-specific nature of place-based values make them particularly applicable to restoration planning and design, which is also site-specific (Kimmerer, 2000).

3.5.1 Reconsidering the ‘reference’ and how to measure success

Identifying the place-based values associated with a site can help to understand the past processes that shaped the site. Ecological restoration requires in-depth knowledge about ecosystems and their dynamics, including an environment’s relationship to humans and their societal values, activities, patterns of resource use, and impacts (Uprety et al., 2012). Without the

knowledge of how or why a landscape came to be, restoration projects can produce landscapes without meaning (Allison, 2004). For example, (Olwig, 1995) argues that the restoration of a Danish River from a linear feature to a meandering stream will be done in vain unless the ancient agricultural system that originally created meandering streams is resurrected. A clear understanding of all the processes (environmental and societal) that shaped the landscape being restored is required to avoid ecological impracticality or harm.

Many of the landscapes we seek to preserve were created by millennia of human intervention and their restoration will require sustained human management. For example, continuous and frequent anthropogenic burning created a complex oak-meadow ecosystem, which contains a mosaic of open canopy stands and prairie habitat, and their restoration and recovery will be dependent on a regime of frequent, low-intensity, intentional burning (Pellatt & Gedalof, 2014). This concept of human-sustained ecological restoration diverges from other concepts of restoration that centre human-free visions of resilience. For example, rewilding frameworks aim to “minimize or gradually reduce human interventions” (Perino et al., 2019). However, passive management techniques such as rewilding may not be appropriate for the restoration of landscapes with complex human-environment relationships (McIver & Starr, 2001; Shackelford et al., 2019). Identifying the persistent human influences that shaped landscapes can help to inform the future role of humans in long-term management plans.

Including place-based values in restoration provides a chance to consider how humans and non-humans have used, and will use, the site in question. Recognition that humans can provide beneficial services to ecosystems, and that they are not always the source of environmental

degradation, enables human-led restoration projects to be less focused on bringing back the imagined and static historical state of an ecosystem, and more focused on developing an ecocultural landscape that provides reciprocal benefits to all members of the affected communities (human and non-human) through on-going practice (Armstrong et al., 2021; Lee et al., 2021). Incorporating place-based values into restoration projects could entail the inclusion of introduced species if they are important culturally (Pfeiffer & Voeks, 2008). For example, the herb *Plantago major* was imported to North America during the arrival of European colonists and is now considered naturalized (Kimmerer, 2014a; Mack & Lonsdale, 2001; J. Rousseau, 1966). In the years since its arrival, *P. major* has become an important medicinal plant for many Indigenous communities (Kimmerer, 2014a; Kuhnlein & Turner, 1991; Pfeiffer & Voeks, 2008). Dandelions (*Taraxacum*), Pacific oysters (*Crassostrea gigas*), and potatoes (*Solanum tuberosum*) are further examples of non-native species that have become culturally or economically important to their places of introduction (Jones et al., 2011; Larson et al., 2014; Miossec et al., 2009; Wenstob, 2011). While these species have provided cultural, medicinal, ecological or economic benefits, there can be complex consequences to species introductions. For example, on the islands of Haida Gwaii, non-native Sitka black tailed deer (*Odocoileus hemionus sitkensis*) are an important food source culturally. However, through grazing on the forest understory, they have reduced the diversity of plant and animal communities (Martin et al., 2010). Restoration planning informed by geographically and temporally dynamic place-based values would need to be considerate of all interconnected ecological and cultural ecosystem components when considering the maintenance or removal of species (Augustine & Dearden, 2014).

Utilizing place-based values in restoration also provides the opportunity to revitalize human-environment connections. When restoration work focuses too heavily on technical aspects of projects (e.g., seed density and mixtures, germination trials), the chance to cultivate personal connections with the environment is lost (Higgs, 2003). However, cultural engagement requires multiple efforts, long-term commitments, and thoughtful deliberation (Higgs, 2003).

Incorporating place-based values into restoration planning can provide community members and practitioners the opportunity to collaborate on the design, goals, and objectives of restoration. Active incorporation of these values can also lead to stronger connections between restoration practice and the names and stories associated with places (Gray & Ruck, 2019). These cultural dimensions of the environment highlight our meaningful relationship with the landscape, and further strengthen human connections and attachments to place (Simpson, 2014). Place-based storytelling can provide inter-generational guidance for stewardship (Wehi & Lord, 2017) and provide alternative methods of engagement. Successful engagement is key to sustaining ecological restoration (Higgs, 2003) and can also enhance human well-being (Poe et al., 2016; Rey Benayas et al., 2009).

3.5.2 Indigenous inclusion and colonialism

Colonization introduced an onslaught of disease, epidemics, displacement, and attempted assimilation across the globe (UN General Assembly, 2011). By removing Indigenous peoples from their territories and disrupting embedded relationships to place, colonialism has not only been harmful to human communities, but also to non-human kin (Irlbacher-Fox, 2014; Wildcat, 2009). The early foundational definition of restoration as a recovery of an ecosystem to a self-sustaining state, free from human influence (Society for Ecological Restoration International

Science & Policy Working Group, 2004) erased the historical and enduring role of Indigenous land and seascape stewardship (Dickson-Hoyle et al., 2021). As restoration evolves to a deeper understanding and inclusion of human-ecosystem relationships, critiques of colonialism and/or western science cannot be absent from discussions of climate change and environmental degradation. Without their explicit inclusion, restoration will continue to erase Indigenous relationships to place and fail to address the underlying harmful and unsustainable systems that have led us to a point of climate and environmental crises in the first place (Jimmy et al., 2019).

For non-indigenous practitioners, it is important to recognize that place-based and Indigenous communities hold knowledge about the Earth and other beings differently than western scientists do (Black Elk, 2016; Whyte et al., 2016), and acknowledge that there is an unevenly shared responsibility for creating ecological crises'. In many cases, Indigenous stewardship modified environments and created beneficial ecological legacies, such as shell middens providing nutrient subsidies to forests making vegetation larger, more productive, and more diverse than areas without shell middens (Cook-Patton et al., 2014; Trant et al., 2016). On the other hand, western and/or colonial management practices often transform environments. For example, clearcutting forests, mining, dams, and large-scale agricultural all fundamentally change landscapes, often irreversibly. This erasure of place has ramifications for socioecological integrity but can be actively countered through considerate restoration (Dickson-Hoyle et al., 2021).

With consent and consideration, engaging with Indigenous communities/scientists/restoration practitioners on restoration projects can provide opportunities to support reciprocal benefits for all communities involved (human and non-human) (Lee et al., 2021). However, particular care

should be taken to ensure engagement methods are not extractive (Liboiron, 2021; Trisos et al., 2021). Inclusion should not create burden for Indigenous communities, whose capacities are sometimes limited due to historic and current colonial policies. Intellectual property rights should be protected and sensitive information (such as harvest locations) should not be made public (Trisos et al., 2021). Indigenous knowledge and expertise should be paid for, in a manner equal to how a professional or academic expert would be paid (Liboiron, 2021). When envisioning long-term projects involving cross-cultural collaborations, all parties should commit to developing stamina, flexibility, and humility (Jimmy et al., 2019). This will increase capacity to sustain relationships to humans with other ways of knowing, which will ultimately create better relationships to the land for all involved (Jimmy et al., 2019).

Unfortunately, Indigenous Knowledge is often considered subjective evidence, only acceptable when supported by western science (Liboiron, 2021). This methodology maintains the supposed superiority of western science over Indigenous Knowledge (Liboiron, 2021; Simpson, 2004) and further exacerbates the linked processes of environmental and cultural degradation. However, Indigenous-led restoration can provide opportunities to strengthen movements of reconciliation, decolonization, and Indigenous self-determination (Dickson-Hoyle et al., 2021). Restoration and monitoring can demonstrate Indigenous continuity in territorial occupation that can help assert rights and access to traditionally managed lands (Armstrong & Veteto, 2015), and provide evidence for Treaty negotiations (in countries such as Canada). Restoring “relationships of mutual obligation between land and people” and considering people as beneficial components of functioning ecosystems can disrupt western and/or colonial beliefs of land as property and resource (Burow et al., 2018). Encouraging human facilitated ecosystem recovery with methods

informed by Indigenous Knowledge can re-awaken traditional land use practices and connect younger generations to their ancestral territories and traditions (Simpson, 2014; Wehi & Lord, 2017). Restoration and re-management of particular places that are important for people's lifeways and identities (aka "cultural keystone places") can provide opportunities for land-based teaching and learning and contribute to the integrity and resilience of Indigenous communities (Cuerrier et al., 2015; Deloria Jr. & Wildcat, 2001; Simpson, 2014).

3.6 Conclusion

The formation of place-based values is circular: restoration practice is one method of spending time on a landscape that leads to the formation of beliefs, knowledge, and rituals, which accumulate into place-based values (Berkes & Turner, 2006). These acquired values guide a dynamic, co-evolving relationship with place and inform future generations on respectful, sustained relationships with their surroundings (Artelle et al., 2018). The contemporary movement and settlement of people around the world may seem like a barrier to the formation of place-based values. However, this globalization can be responded to by learning from and being respectful of the knowledge, laws, and protocols of the place-based people at a given location (Frid, 2020; Kimmerer, 2014a). Creating space for Indigenous led restoration practice to re-claim stewardship roles will be vital to support the well-being and cultural identity of Indigenous peoples and aid in processes of decolonization and Indigenous self-determination (Dickson-Hoyle et al., 2021; Simpson, 2014).

Table 3.1 Proposed framework for initiating a place-based values (PBV) approach into restoration planning and implementation.

Inspired by Table 2 in Artelle et al. 2018. This framework was built for people considering how to implement place-based values in restoration and to clarify how actions relate to the feature of place-based values.

PBV Feature	Action	Questions	Examples from the Wuikinuxv Lhènnx Project
Knowledge, Belief System, Attachment to place	Identify knowledge holders.	Who are the people already associated with this place? Who carries the knowledge of this place and this system? Who will be associated with this place and who will be the knowledge holders of the future? Is any knowledge sensitive?	Determined via Stewardship Committee meeting and discussions, conversations with Elders, and community members.
Knowledge, Belief System, Attachment to place	Identify the values associated with the place.	Which ecosystem services should be prioritized? Cultural/spiritual priorities?	Determined as above: care for place and engage youth in the project so they can re-learn traditional practice.
Belief System	Identify values that should/could be associated with place.	(Especially if there are none identified in step 2)	Determined as above: provide food for other species.
Knowledge, Belief System	Decide on which values should be prioritized.	Whose privilege is it to decide this? Who holds decision-making authority? Whose decision-making authority will require support to be equitably included?	Stewardship committee identified youth engagement and food provisions for bears as priorities. Stewardship Committee and Councils privilege to decide this as they permit access to land throughout Wuikinuxv territories.
Conduct, Knowledge	Translate values into objectives.	Do these objectives ultimately foster social-ecological resilience?	Objectives determined based on priorities and goals.
Conduct	Translate objectives into practice.	Are there already practices in place? What are their effects?	No practices currently in place, only memories of past practices.
Conduct	Enforce/encourage practices.	Evaluate how to best do this: Laws? Policy? Cultural protocol?	Requested five years of funding to create a small work team dedicated to fulfilling objectives.
Knowledge	Share efforts, educate.	Are all community members informed? Do all communities members have an	Work team to engage with Stewardship Committee on a yearly basis and organize school

		opportunity to contribute?	trips to restoration and harvesting sites. Project updates and invitations to join restoration/harvesting events posted on community Facebook page.
Conduct, Knowledge, Attachment to place	Monitor and adapt.	Are the practices and effects benefitting humans and the ecosystem? How can they?	Work team to monitor tree growth, fruiting, and bear visitation on a yearly basis. Adapt treatments based on monitoring data and Stewardship Committee/community feedback.

Chapter 4. Indigenous-led restoration of a culturally important plant: The Wuikinuxv Lhənnx̌ (crabapple) Project

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Overview

This paper examines a Pacific crabapple (*Malus fusca*) restoration project led by the Wuikinuxv First Nation in British Columbia, aimed at reviving traditional orchards to support food sources for bears (*Ursus* spp.). Drawing on Indigenous knowledge and place-based values, the project used traditional stewardship methods such as pruning and fertilizing to increase fruit production and size. The restoration also seeks to reconnect community members, especially youth, with cultural practices that strengthen ecological and cultural resilience. Early findings demonstrate promising ecological benefits and enhanced community engagement, emphasizing the importance of Indigenous-led restoration in fostering ecocultural landscapes and sustaining Indigenous identities.

4.1 Introduction

Ecological restoration is a powerful tool to support the recovery of an ecosystem that has been degraded, damaged, or destroyed (Gann et al., 2019). Restoration projects can involve technical aspects such as reforestation, reintroducing plant and/or animal species that have been extirpated, removing invasive plant species, eliminating harmful substances (e.g. mine tailings), and re-introducing natural processes (e.g. fire, flooding, etc.) (Higgs, 2003; E. S. Higgs, 1997; Senos et al., 2006). Additionally, (re)introducing cultural aspects of restoration (stewardship, cultivation, harvesting, storytelling, naming, etc.) is essential in supporting the long term recovery and resilience of ecosystems and the people embedded within those ecosystems (Higgs, 2003; Poe et al., 2016; Wehi & Lord, 2017).

Integrating place-based values into restoration efforts is one example of a method used to incorporate cultural processes into restoration ecology (Wickham et al 2022). Place-based values guide the practices and customs of a social group, and are reflective of a peoples' intimate connection to their local environment (Berkes & Turner, 2006). These values are formed from a deep knowledge of local ecological limits developed through generations of learning by observation as well as trial and error (Artelle et al., 2018). The Indigenous community of the Wuikinuxv First Nation (Katit, British Columbia) initiated a Pacific crabapple (*Malus fusca* (Raf.) C.K. Schneid.) restoration project that was inspired and guided by Wuikinuxv place-based values.

Indigenous-led, values-led restoration serves many benefits beyond supporting ecosystem recovery. For example, it can reconnect Indigenous People to their current and/or ancestral territories. It can support the revitalization of Indigenous practices (Corntassel & Bryce, 2012;

Kamelamela et al., 2022), and it provides opportunities to increase the capacity of Indigenous communities to shape and lead land stewardship efforts (Kamelamela et al., 2022). Indigenous-led restoration work is not uniform; it varies considerably based on culture and ecologies. However, there are some commonalities. First, Indigenous-led projects place a high value on considering Elders Knowledge, oral histories, the archaeological record, and historical ecological data to make informed decisions with long-term contexts (Grenz & Armstrong, 2023; Hernandez & Vogt, 2020; Lyver et al., 2015). Second, Indigenous-led restoration incorporates cultural practice as an element of restoration, which effectively creates ecocultural landscapes (Lyver et al., 2016; Wehi & Lord, 2017).

Ecocultural landscapes refer to the reciprocal and inseparable link between ecology and culture, and how that link manifests upon the land. Ecocultural landscapes are formed through dynamic relationships between people and non-humans landscape components, which evolve and shape each other throughout time, forming ecocultural identities that complement the perceptible ecological landscapes. One example of an ecocultural landscape is Pacific crabapple orchards in Wuikinuxv territory.

Pacific crabapple (hereafter interchangeably referred to as Pacific crabapple or crabapple) is an iconic plant for coastal First Nations. It is named in over 31 languages (Turner, 2014a) and has over 200 uses recorded in the ethnobotanical record (Wyllie de Echeverria, 2013). It was an important component of historical diets (Turner & Turner, 2008); the fruit could be eaten fresh, dried, or stored in oil or water (Compton 1993). In Wuikinuxv territory the fruits of crabapple trees (lhənn̓x̌ in the Wuikinuxv language of 'Wuikala) were served and gifted at feasts

(Compton, 1993). Crabapple trees were used for multiple purposes: the hardwood was used for tools such as spoons and digging sticks, the bark was chewed for hunger suppression, and licorice ferns (*Polypodium glycyrrhiza*) and lichens (*Usnea* spp. and *Alectoria* spp.) were (and still are) collected from crabapple branches and used as medicines and materials (Compton 1993).

Crabapple is recognized an important source of food for humans, bears, and other animals throughout Wuikinuxv territory. Elders have recollections of crabapple management through fertilizing, pruning, and transplanting trees into groves or orchards near village sites near habitation sites (Wuikinuxv Stewardship Committee 2019). These cultivation practices intensify fruit production and simultaneously support sustainable harvesting (Deur, 2002). However, settler-colonial policies of displacement, genocide, and assimilation disrupted traditional Wuikinuxv land management practices and as a direct result of this, crabapple trees have not been stewarded in over 80 years.

Concurrently, factors such as commercial overfishing and climate change have reduced local salmon stocks (Brown, 2011; Gresh et al., 2000). Salmon and crabapple are two important food sources for grizzly and black bears (*Ursus arctos horribilis* and *Ursus americanus*) (Adams et al., 2017; Comberti et al., 2015) and they are both harvestable in the fall when the bears are undergoing hyperphagia – intensive foraging prior to winter and then entering a state of winter lethargy with no feeding (Nelson et al., 1983). The Wuikinuxv values of náanakila guide the Nation to “watch over someone and look ahead for them; to be a guardian or a protector” (Adams et al., 2021). To look ahead for the grizzly bears the Wuikinuxv Nation has decided to restore crabapple production to provide a food resource for their neighbouring bear populations.

A restoration project was initiated early 2020 by author JW and the Wuikinuxv Stewardship Department (with full support of elected Chief and Council), who then solicited academic partners to help facilitate the work (authors SW, AT). The project goals and objectives were co-developed with the Wuikinuxv Stewardship Department, academics, and the Wuikinuxv Stewardship Committee – a volunteer group of community members, Elders, and Hereditary leaders (including author PJ) who guide Stewardship Department decisions. The restoration treatments, monitoring, and community engagement work were performed by the Wuikinuxv Guardians (authors BO, AN, GC, WH, PJ), a Wuikinuxv ethnobotanist (author AW), and an academic (author SW).

The goals of the project are to: 1) increase crabapple productivity in Wuikinuxv Territory, 2) to provide more food for bears, and 3) reconnect community members (especially children) to traditional practices on the land. Traditional methods remembered by Elders and Knowledge holders were used to complete restoration objectives. In this paper we examine if restoration treatments contributed to a change in crabapple fruit production and size. We also describe opportunities created for community members to access crabapple sites and traditional stewardship. We then discuss the early ecological and cultural outcomes of a project that incorporates place-based values and cultural planning into restoration work.

4.2 Methods

4.2.1 Study area

Wuikinuxv Territory (aka Owikeno or Rivers Inlet) is located on the Central Coast of what is colonially called British Columbia (Fig. 4.1). The territory encompasses open ocean, exposed

islands, mountainous fjord and river valleys, mountain tops, and glaciers. From sea level up to 900 m, the territory is classified in the Coastal Western Hemlock (CWH) biogeoclimatic zone (Pojar, Klinka, Demarchi, 1991). This zone is characterized by cool summers and warm winters with a mean annual precipitation of 2,228 mm and a mean annual temperature of 8 °C (Meidinger & Pojar, 1991). Characteristic flora species of this zone include western hemlock (*Tsuga heterophylla*), western redcedar (*Thuja plicata*), Sitka spruce (*Picea sitchensis*), salal (*Gaultheria shallon*), Alaskan blueberry (*Vaccinium ovalifolium*), red huckleberry (*Vaccinium parvifolium*), deer fern (*Struthiopteris spican*), *Rhytidiadelphus loreus*, *Hylocomium splendens*, and *Kindbergia oregana* (Green & Klinka 1991).



Figure 4.1 Approximate location of Wuikinuxv Territory in British Columbia, Canada. Map courtesy of Will McInnes/Hakai Institute.

4.2.2 Pacific crabapple

Pacific crabapples are small deciduous trees or shrubby bushes that reach 2 – 12 metres tall and are western North America’s only native apple species. In the spring they produce white or pink fragrant blossoms (~2 cm across) in clusters of 5 – 12 at the end of branches (Fig. 4.2A).

Crabapples are self-incompatible, requiring cross pollination from *Malus* trees via insect pollination for fruit set (only *Malus fusca* is present at restoration sites) (Burns & Stanley, 2022). The pollinated blossoms become yellow or reddish small (~10 – 15mm) edible apples (Fig 4.2B), which fruit from August – October (Pojar & MacKinnon, 2004). Crabapple is found in coastal areas west of the Cascade and Coast mountain ranges from Alaska to California, and favours growing in moist to wet open forests, streambanks, shorelines, estuary fringes, swamps, and bogs at low elevation (Klinkenburg, 2020b). Crabapple trees can tolerate standing freshwater and ocean spray (Klinka et al., 2007).

Crabapples are high in carbohydrates, fibre, and vitamins (especially Vitamin C and calcium) (Kuhnlein & Turner, 1991). Their nutritional profile makes them complementary to the proteins in salmon, both of which are harvestable in the early fall. Bears supplement protein diets with fruit as a strategy to increase their energy metabolism (Rode & Robbins, 2000). Other animals such as birds, squirrels, mice, rabbits, deer, and foxes also eat the fruit. Crabapple leaves are colloquially known as “deer candy” because they are appealing to browsing mammals.

Crabapple blossoms are also important for many pollinator species and crabapple leaves provide habitat for butterfly larva.

4.2.3 Site selection

During conversations with Wuikinuxv Committee members and through initial reconnaissance to several sites, we recognized two forms of crabapple trees in Wuikinuxv territory: 1) monumental trees, and 2) volunteer trees (Fig. 4.2C & D). The monumental trees are older groves of trees often found near old village sites. The groves are several metres inland and have conifers encroaching into them, shading the trees. The monumental trees are large and have thick mats of moss on their trunks and branches, and/or long lichens hanging from their branches. Sometimes these trees are old enough to have been cared for by people in the past and they have been pruned so that their trunks are long and low to the ground. Volunteer trees are small and shrubby. They are younger trees that have grown up without the help of humans. They are opportunistic, dispersed throughout the landscape, and most likely have established by chance (in bear or bird droppings, washed ashore by lakes/rivers/ocean tides, or dropped/sprouted from neighbouring crabapple trees). Volunteer trees are found in clearings like estuaries and along shoreline edges and are easy for humans, bears, deer, and other animals to pick from because the trees are small and short. We hypothesized that the volunteer trees would be more productive than monumental trees.

In total, four locations were selected for restoration and monitoring based on: 1) the presence of both monumental and volunteer crabapple trees, 2) proximity to an old village site, 3) accessibility (e.g., boat or trail access, as there are very few roads), 4) low levels of local forest disturbance such as logging, which can obscure signatures of pre-colonial plant management and, 5) Wuikinuxv Stewardship Committee preference. Two sites are located on the Katit Reservation (>1km from the main village of Katit) and two sites are in surrounding provincial

conservancies. Research in the conservancies was supported by BC Parks under Park Use Permit No. 110279.

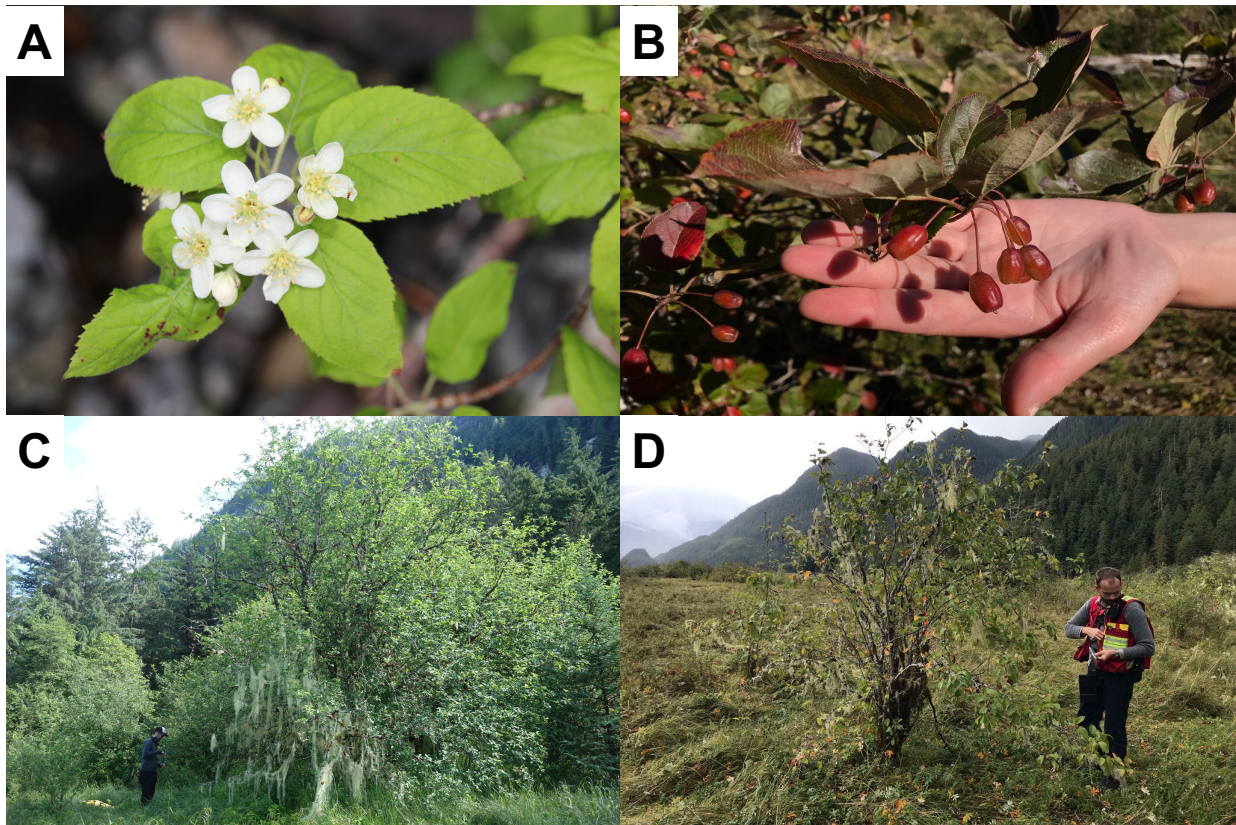


Figure 4.2 (A) Pacific crabapple (*Malus fusca*) blossoms, (B) ripe fruits, (C) the monumental tree form of Pacific crabapple. It is tall, with a central trunk and classic tree form, and has moss and/or lichens on its trunk and branches. (D) Volunteer form of Pacific crabapple. It is shorter, shrubbier, and has multiple stems.

4.2.4 Restoration treatments

We had two sites at each of the four locations: a monumental site and a volunteer site. At each site we randomly selected ten trees for restoration and monitoring ($n = 80$). Restoration

treatments included: 1) pruning, 2) clearing the trees of moss, 3) fertilizing, and 4) clearing encroaching brush. All methods were suggested by the Wuikinuxv Stewardship Committee.

The first restoration treatments were applied in February 2022. Each tree was pruned of dead, rotten, and diseased branches, based on visual assessment (Fig. 4.3A). Trees were also pruned of root and trunk suckers, branches that crossed/rubbed other branches, branches that grew towards the centre of the tree, or branches that grew downwards. Trees were pruned to a maximum of 30% of initial tree. Trees were also cleared of moss on their trunks and lower limbs, to increase air circulation and discourage rot. Moss was saved and used at a garden in the village of Katit, and licorice ferns were harvested from the moss for tea and medicine (Fig. 4.3B).

Three trees at each site ($n = 24$) were randomly selected to have fertilizer applied to their base and around the “drip zone” (zone of maximal root absorption) (Fig. 4.3C). The fertilizer was marine-derived and came from three sources; 1) sea wrack harvested from the shoreline, 2) freezer-burnt herring or salmon donated by community members, or 3) dead salmon and salmon eggs donated by the Percy Walkus Hatchery (Katit, BC). Seaweed and fish were traditionally used as fertilizer in Wuikinuxv territory. Encroaching brush was cleared around and above each tree to increase the amount of sunlight that reached the crabapple trees’ canopy.

The second round of restoration treatments were applied in February 2023 and followed the same methods as described above. Pruning efforts from 2022 successfully removed dead, diseased, and broken tree limbs so later pruning efforts were focused on “heading cuts”, a method used to

increase fruit production (Kumawat et al., 2022). We treated the same 24 trees with fertilizer in 2023 as we did in 2022.

4.2.5 Monitoring

Pre-treatment monitoring took place in September 2020 and 2021. In 2020/2021 and each subsequent monitoring year after that (2022, 2023) six variables were collected from each tree: number of fruit clusters, average number of fruits per cluster, percent dead, DBH (of up to three stems per tree/shrub), presence of moss/lichens, and stem density. Ten “control” trees (trees that had not had restoration treatments applied to them and were >8m away from restored trees) were incorporated into monitoring surveys in September 2023. We also collected bear scat data and deployed trail cameras to collect data on bear visitation, in order to determine if changes in crabapple productivity and abundance affects changes in bear visitations for future research.

During September monitoring trips, ten random bunches of fruit were picked from a subset of trees that had fruit. The fruit was refrigerated and transported to a lab where they were individually measured for length, width, colour and wet weight. The fruit were then dried at 80 °C for 48 hours in a Thermoscientific Heratherm drying oven. The fruit was then re-weighed, and dry weight was recorded.

4.2.6 Data analysis

All analysis were performed in R version RStudio 2022.07.1+554 (R Core Team, 2022). We first checked variables for extreme outliers by examining percentiles, we removed three outliers (two trees that had died over the course of the project due to a snow loading event in 2022, and one

tree that fruited double the amount of any other tree). Data distribution was examined visually and then confirmed using Shapiro-Wilks tests. We tested for significant differences in fruit production, size, and tree health in 2021 vs. 2023 and in control vs. treatments using one way ANOVA (for homogenous, parametric data) and Tukey post hoc tests or with Kruskal Wallis test and Wilcoxon post hoc tests (non-parametric data) as appropriate.

We used a modelling approach to investigate if the predictor variables affected the size of crabapples fruits (Table 4.1). To analyze the size of fruit dataset, we used a linear mixed effect model with gaussian distribution, site as a random effect, and fruit size as the response variable. We checked for correlated predictor variables, and none were detected. We tested all possible combinations of our predictor variables ($n = 32$) (Appendix B Table B 4.1).

We also used a modelling approach to determine if the same predictor variables affected the total amount of fruit on a tree (Table 4.1). This dataset was zero inflated, so we separated it into two datasets (a presence/absence and a fruit amount dataset) and used hurdle modeling (Zuur et al., 2009). This required two steps. First the data were considered as zero or non-zero to capture the probability of fruit growing on a tree. Second, all zero data points were removed, and a normally distributed dataset was created that captures the amount of fruit on trees, when fruit is present.

To analyze the presence/absence dataset we used a generalized linear model (GLM) with site as a random effect and a binomial distribution (Zuur et al., 2009). To analyze the fruit amount data set we used a linear mixed effect model with gaussian distribution and site as a random effect (prior to modelling the response variable was log transformed to normalize distribution). We

checked for correlated predictor variables and restoration treatments, and tree type were correlated for both the presence/absence and the fruit amount datasets. We removed tree type (monumental vs. volunteer) as we were more interested in learning about the effects of restoration treatments. We then tested all possible combinations of predictor variables ($n = 16$) (Appendix B Tables B 4.2 & 4.3).

Continuous predictor variables for all models were standardized by subtracting the mean and dividing by the standard deviation. All modelling was done in the R package 'lme4' (Bates et al., 2015). We ranked the multiple candidate models generated for each dataset using Akaike's information criterion (AIC) (Burnham & Anderson, 1998) with the package mvMORPH (Clavel et al., 2015). From the top models (within four points of the lowest AIC score) we determined which option best explained the data by calculating the Akaike weight for each model and the proportion of deviance being explained (Burnham et al., 2011). We checked the models for independence and spatial correlation by examining the residuals of the top model.

Table 4.1 Variables used for modeling if restoration treatments, tree attributes, or climatic variables were responsible for affecting the total amount of fruit per tree and the size of the fruit.

Variable name	Type of variable	Type of data	Data source	Description
Amount of fruit per tree	Response	Numerical	Recorded at site	
Dry weight of fruit	Response	Numerical	Recorded in lab	
Restoration treatment	Predictor, fixed	Categorical	Recorded at site	treatment vs. control
Tree type	Predictor, fixed	Categorical	Recorded at site	monumental vs. volunteer
Percent of tree dead	Predictor, fixed	Numerical	Recorded at site	
Growing degree days	Predictor, fixed	Numerical	Daymet database (Thornton et al., 2022)	$((\text{daily } T_{\max} + T_{\min})/2) - \text{crabapple base temp})$ summed from Jan 1 – Sept 1
Precipitation	Predictor, fixed	Numerical	Daymet database (Thornton et al., 2022)	Sum of daily average Jan 1 to Sept 1
Site	Predictor, random	Factor	Recorded in the field	

4.2.7 Community Engagement

The Wuikinuxv Stewardship Committee determined a priority (nested within goal 3 - reconnect community members to traditional practices on the land) would be to involve the school-aged children in the project. During each restoration season the children accompanied us to a site to help prune trees or to spend time at crabapple orchards.

In September 2023 and 2024 the guardians and author SW facilitated community harvesting events. Attempts were made to host these events in 2021 and 2022 but were cancelled due to a COVID outbreak (2021) and unsafe weather (2022 – the harvesting site is only accessible via boat). For the community harvesting event's folks were transported by boat to a location near one of the restoration sites. Permission to harvest at this location was asked for and granted by a Wuikinuxv Elder who has familial tenure over the area. During these events we spent several hours harvesting ripe crabapples. In the days following the harvesting event the Guardian team and SW de-stemmed the crabapples and processed them into jelly or whole fruits preserved in a simple syrup (a Wuikinuxv traditional method) (Fig. 4.3D).



Figure 4.3 (A) Author BO pruning a volunteer crabapple tree. (B) Elementary school students harvest licorice ferns from the moss removed from a monumental crabapple tree. (C) Fish used to fertilize a volunteer crabapple tree. (D) Author BO counts jars of crabapple jelly made by the Wuikinuxv Guardians for community members.

4.3 Results

4.3.2 Restoration treatments

The amount of crabapple fruit per tree was significantly different between years (Kruskal-Wallis chi-squared = 77.91, df = 1, p-value = 2.2e-16) Wilcoxon post hoc test revealed differences between 2020 and 2021 (a; p = 6.7e-05), between 2020 and 2022 (b; p = 0.0144), between 2020 and 2023 (c; p = 1.4e-12), between 2021 and 2022 (d; p = 0.0072), 2021 and 2023 (e; p = 6.7e-05) and between 2022 and 2023 (f; p = 1.4e-12). Notably, the amount of crabapple fruit in 2023 was less than all other years (Fig. 4.4A).

There was a significant difference in the dry weight of crabapple fruit between years (ANOVA, $F_{2,83} = 19.04$, $P = 1.57E-07$). There was no significant differences in dry weight of fruit from 2021 to 2022, however there was a significant difference between 2021 and 2023 (post hoc Tukey test; a; p = 0.0000024) and between 2022 and 2023 (post hoc Tukey test; a; p = 0.0000002) (Fig. 4.4B).

There was a significant difference in the amount of tree that was dead when comparing between trees that had restoration treatments applied to them and control trees, control trees having more dead branches (Kruskal-Wallis chi-squared = 6.3917, df = 1, p = 0.01147) (Appendix B Fig. B 4.1).

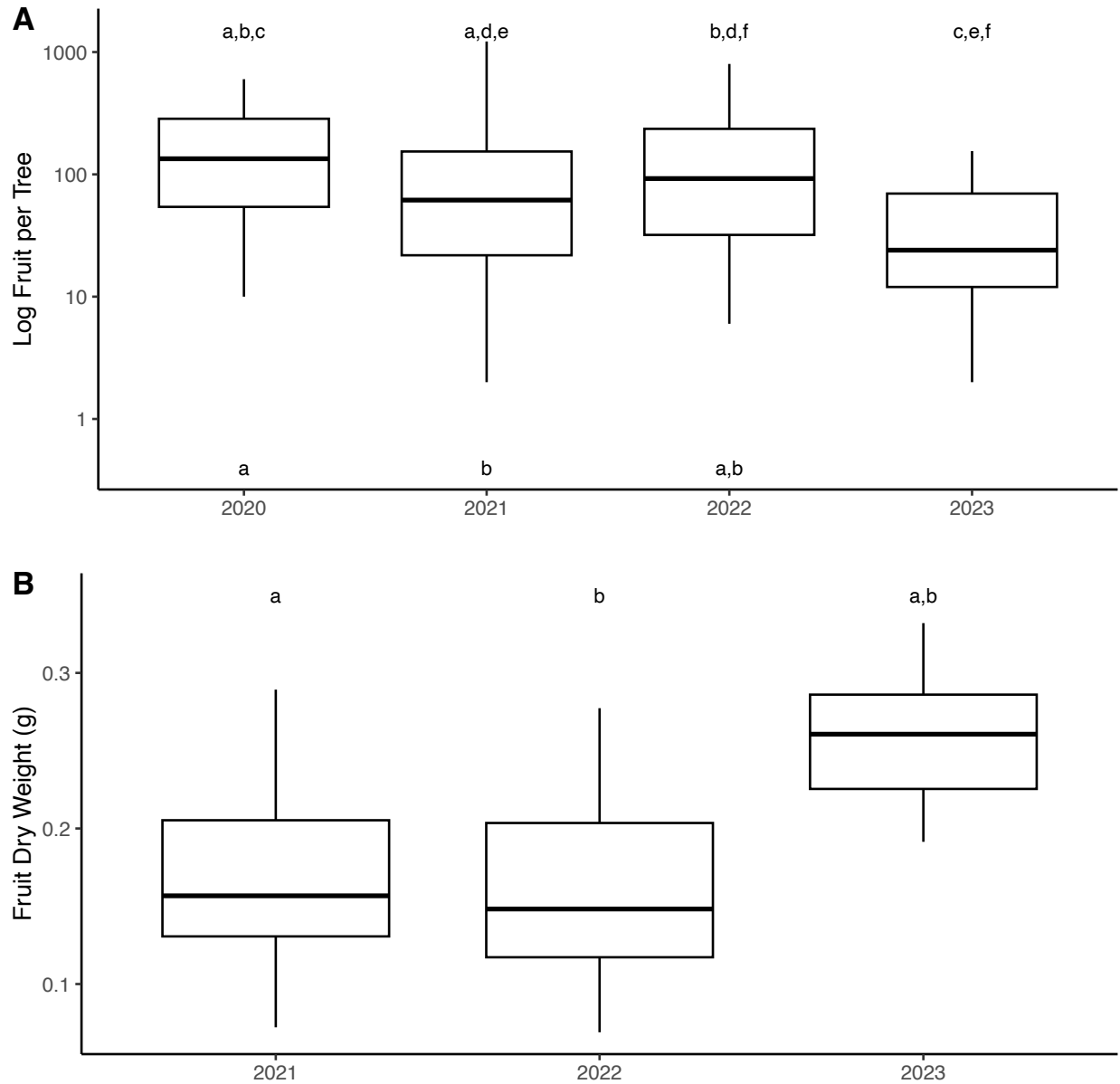


Figure 4.4 Boxplots of fruit per tree and dry fruit weight over the years and with restoration treatments. (A) Total fruit per tree over five different years. Total fruit differed significantly between 2020 and 2021 (a; $p = 6.7\text{e-}05$) between 2020 and 2022 (b; $p = 0.0144$), between 2020 and 2023 (c; $p = 1.4\text{e-}12$), between 2021 and 2022 (d; $p = 0.0072$), 2021 and 2023 (e; $p = 6.7\text{e-}05$) and between 2022 and 2023 (f; $p = 1.4\text{e-}12$), as indicated by letters above respective plots. (B) Dry weight of fruit over three years. Dry weight did not differ significantly between 2021

and 2022. Dry weight differed significantly between 2021 and 2023 (a; $p = 1.1\text{e-}05$) and between 2022 and 2023 (b; $p = 4.8\text{e-}06$), as indicated by the letters above respected plots. Boxplots show median value (solid horizontal line), upper and lower quartiles (box), and maximum and minimum values recorded (whiskers).

In the tests for dry fruit weight, the top model was composed of two variables: precipitation and restoration type: treatment (Table 4.2), both of which had significant associations (Table 4.3). Precipitation had a strong negative influence on fruit size (Fig. 4.5A) and restoration treatments had a strong positive influence on fruit size (Fig. 4.5B).

In tests for the presence/absence of fruit on a tree, the top model was composed of four variables and one interaction term: growing degree days, precipitation, percent dead, restoration type: treatment and growing degree days*precipitation (Table 4.2). Of these, growing degree days, percent dead, and growing degree days*precipitation had significant associations (Table 4.3). Growing degree days had a strong negative influence on fruit presence (Fig. 4.6A), percent dead had a moderate negative influence (Fig. 4.6B), and the interaction of growing degree days and precipitation had a moderate positive influence on fruit presence (Fig. 4.6C).

In the tests for the total amount of fruit recorded on a tree, the top model was composed of three variables: growing degree days, percent dead, and restoration type: treatment (Table 4.2), all of which had significant associations (Table 4.3). Growing degree days had a strong negative influence on the amount of fruit on a tree (Fig 4.7A), percent dead had a moderate negative

influence (Fig. 4.7B), and restoration treatments had a strong negative influence on the amount of fruit on a tree (Fig. 4.7C)

Table 4.2 Akaike's information criterion (AIC) values for all datasets from the top five models to predict fruit dry weight, fruit presence/absence, and total amount of fruit on a tree. All models for all datasets in Supplementary Material (Table S1-3). Δ AIC: difference between the current and best model; AIC_w: Akaike weight; (*) denotes interaction term. GDD = Growing Degree Days. Best performing models are in **bold** text.

Dataset	Model	Variables	Rank	AIC	Δ AIC	AIC _w
Fruit Dry Weight	12	PRECIPITATION + RESTORATION TYPE	1	-227	0	6.20E-01
	24	PRECIPITATION + TREE TYPE + RESTORATION TYPE	2	-226	1.78	2.55E-01
	18	GDD + PRECIPITATION + RESTORATION TYPE	3	-222	5.83	3.37E-02
	2	PRECIPITATION	4	-221	6.79	2.08E-02
	6	GDD + PRECIPITATION	5	-220	7.6	1.39E-02
Fruit Presence / Absence	16	GDD + PRECIPITATION + GDD:PRECIPITATION + % DEAD + RESTORATION TYPE	1	285	0	5.55E-01
	13	GDD + % DEAD + RESTORATION TYPE	2	288	2.53	1.57E-01
	15	GDD + PRECIPITATION + % DEAD + RESTORATION TYPE	3	288	2.73	1.42E-01
	6	GDD + % DEAD	4	290	5.29	3.93E-02
	5	GDD + PRECIPITATION	5	291	5.79	3.06E-02

Total Fruit Amount	13	GDD + % DEAD + RESTORATION TYPE	1	572	0	4.12E-01
	16	GDD + PRECIPITATION + GDD:PRECIPITATION + % DEAD + RESTORATION TYPE	2	573	1.58	1.86E-01
	7	GDD + RESTORATION TYPE	3	574	2.05	1.48E-01
	15	GDD + PRECIPITATION + % DEAD + RESTORATION TYPE	4	575	2.9	9.68E-02
	5	GDD + PRECIPITATION	5	576	4.44	4.48E-02

Table 4.3 Coefficient estimate, standard error (SE), and p-value for each term in the top models predicting fruit dry weight (Table 2), fruit presence/absence (Table 3), and total fruit amount (Table 4), as determined by the lowest AIC and highest AICw scores. Coefficient estimates are standardized for the continuous predictor variables (precipitation, GDD). The first (alphabetical) term for categorical variable (restoration type: control) is the reference/baseline for that category. Significant terms are **bold**. GDD = Growing Degree Days. (*) Denotes interaction term.

Data set and model number	Variable	Estimate	SE	p
Fruit dry weight (m12)	PRECIPITATION	-0.15	0.02	4.97E-11
	RESTORATION TYPE: TREATMENT	-0.13	0.03	6.22E-05
Presence/absence of fruit (m16)	GDD	0.30	0.08	0.000165
	PRECIPITATION	0.63	0.38	0.101861
	PERCENT DEAD	-0.47	0.19	0.012803
	RESTORATION TYPE: TREATMENT	0.12	0.66	0.855993
	GDD*PRECIPITATION	0.12	0.06	0.036404
Total amount of fruit (m13)	GDD	-0.22	0.04	4.12e-08
	PERCENT DEAD	-0.40	0.16	0.01570
	RESTORATION TYPE: TREATMENT	-0.76	0.23	0.00131

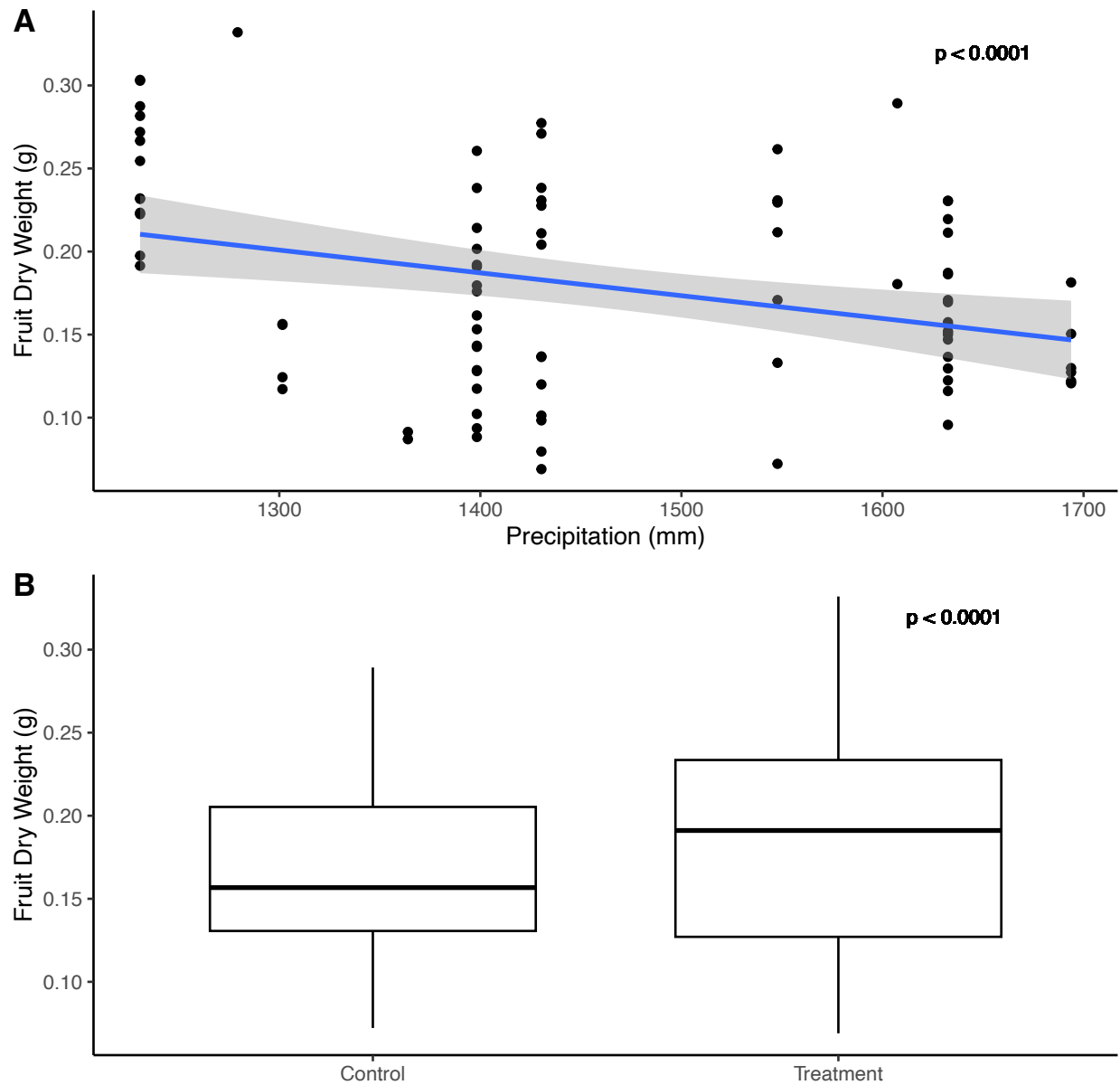


Figure 4.5 Fruit dry weight as a function of the significant terms from the top models. (A) the sum of precipitation from January 1st to September 1st (Table 2 & 5), (B) if the tree had restoration treatments applied to it or if it was a control (Table 2 & 5). Blue line in top plots is the regression line and grey shading represents the 95% confidence interval. Boxplot shows median value (solid horizontal line), upper and lower quartiles (box), and maximum and minimum values recorded (whiskers).

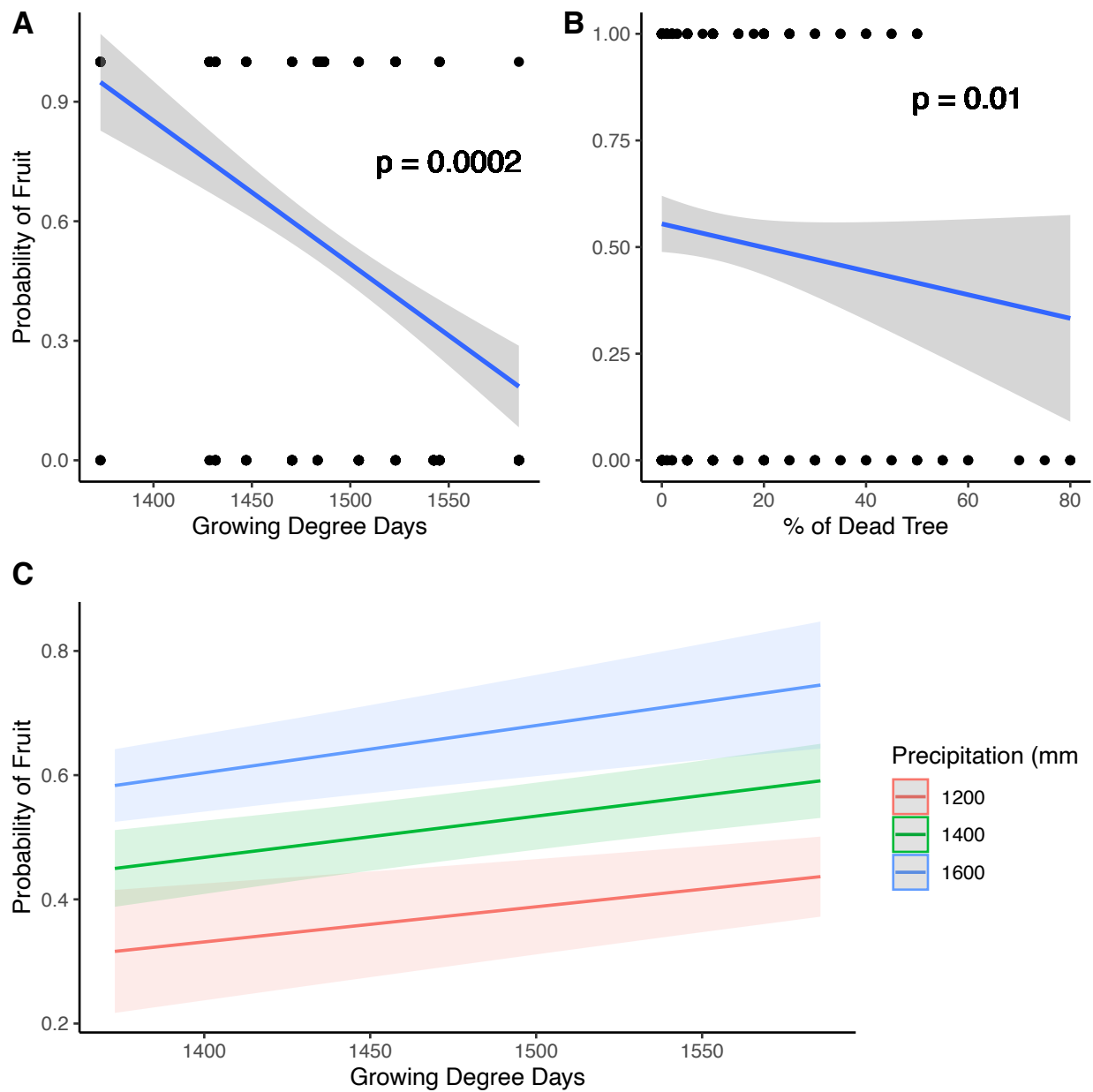


Figure 4.6 Probability of crabapple fruit presence as a function of the significant terms from the top model. (A) total amount of fruit as a function of Growing Degree Days (GDD) (Table 3 & Table 5), (B) percent of the tree that was recorded as dead (Table 3 & 5), and (C) the interaction of growing degree days and precipitation (Table 3 & 5). Lines in plots represent the regression line and grey shading represents the 95% confidence interval.

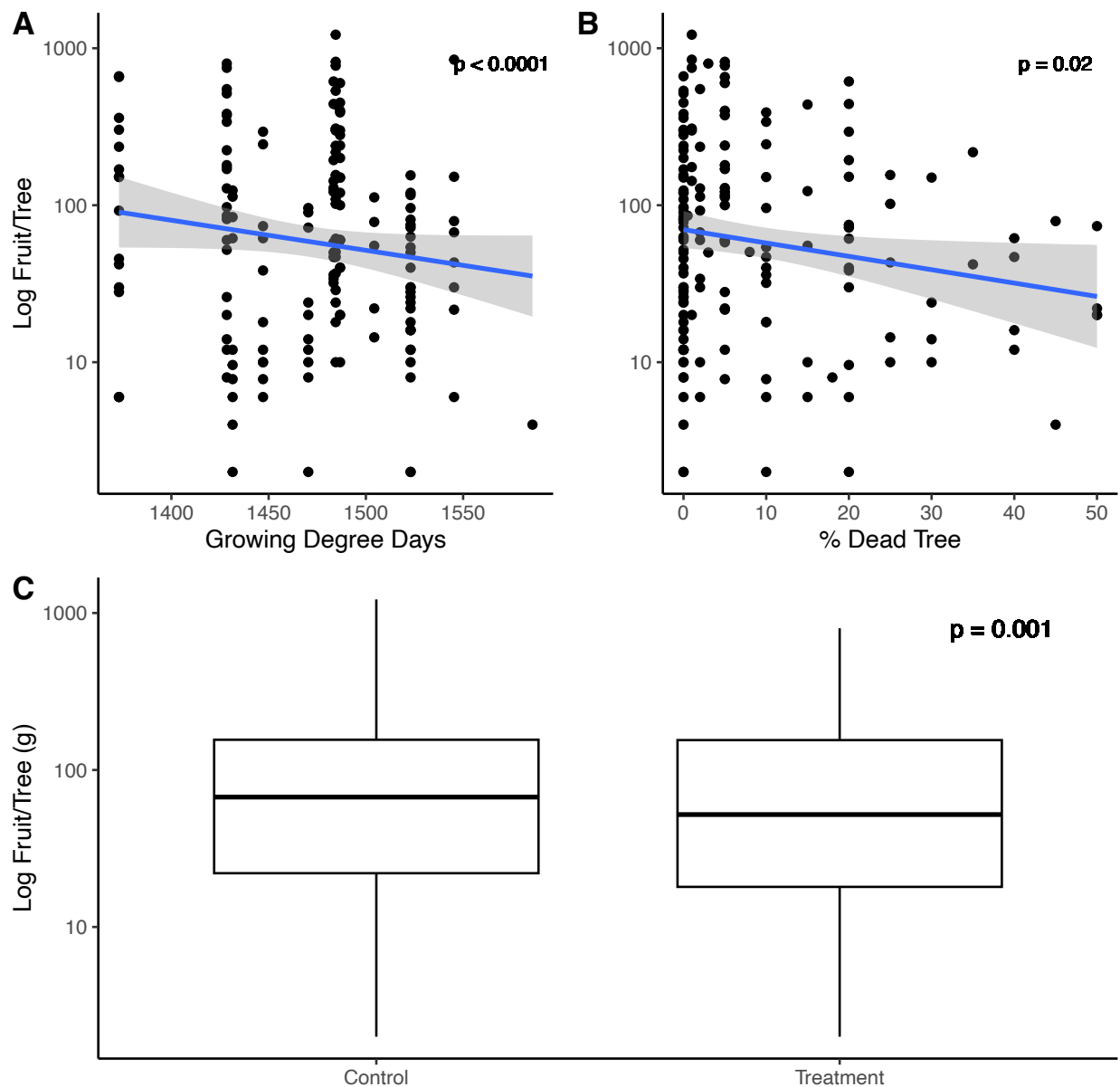


Figure 4.7 Total fruit amount as a function of the significant terms from the top models. (A) total amount of fruit as a function of Growing Degree Days (GDD) (Table 4 & 5), (B) percent of the tree that was recorded as dead (Table 4 & 5), and (C) if the tree had restoration treatments applied to it or if it was a control (Table 4 & 5). Lines in top plots represent the regression line and grey shading represents the 95% confidence interval. Boxplot shows median value (solid

horizontal line), upper and lower quartiles (box), and maximum and minimum values recorded (whiskers).

4.3.2 Community Engagement

Prioritizing spending time with the Elementary School children has resulted in three off-campus trips and is ongoing. Additionally, the authors have led several “plant ID” walks with the school children and have organized cultural knowledge-sharing about plants with a Wuikinuxv ethnobotanist and food sovereigntist (author AW).

The jellies and preserves from the crabapple harvest events were jarred and then distributed to the community. In 2023 we picked 25 pounds of crabapple, which resulted in over 30 jars, enough to ensure all Elders received a jar. In 2024 we picked 40 pounds of crabapple, which resulted in over 80 jars, enough to ensure that every household in the community received 1-2 jars, and extras were distributed to Elders who lived out of the village.

In listening to the wants of the community, but tangential to crabapples, a “Birds of Wuikinuxv” field guide was created by the authors and other academic collaborators. This field guide is pamphlet size and waterproof, making it easy to stash in a pocket, truck dashboard, or boat, facilitating easy access for those spending time on the land. As a thank you to the community from authors SW and AT an “Edible plants of Wuikinuxv Territory” field guide was created. This guide was like the bird guide in that it was small, waterproof and therefore easily packable while on the land. Both pamphlets are free for community members and are stocked at the Band Office in Katit for pick-up as needed.

4.4 Discussion

Early restoration results indicate that there was less fruit on the trees after restoration treatments, but the fruits were larger. Growing degree days, precipitation, the percent of tree that was dead, and if the tree had restoration treatments applied to it, were factors that influenced fruit production. All these factors relate to weather and restoration treatments, and tree type (monumental vs. volunteer) had little influence. The crabapple project provided the community with several opportunities for land-based activities in hard-to-access locations, and it facilitated inter-generational knowledge-sharing through during time spent with the Elementary School children.

4.4.1 Early ecological outcomes

The first goal of this project was to increase crabapple production, as it is a culturally valued species. However, it is not a commercially valuable crop therefore there is not much research on its life history, tolerances and/or preferences (but see Routson et al., 2012; Wyllie de Echeverria, 2013). There is a wealth of research on the closely related domestic apples (*Malus domestica* Borkh.) and for domestic apples, the most important uncontrollable factors in production are 1) dormancy and chilling hours¹, 2) spring/summer temperatures, and 3) precipitation (Flore et al.,

¹ Dormancy is when the tree enters a state of “rest” and nothing grows; this protects the tree by not letting it be forced into growing by warm winter spells, which could kill the tree if preceded by severe cold (Flore et al., 1984). Dormancy is broken when buds are exposed to chilling temperatures for a given amount of time. The precise chilling temperatures for *Malus fusca* are unknown but for domestic apples in BC, temperatures of -2°C to 5.5°C were optimum (Guak & Neilsen, 2013). We checked the temperature data to ensure all trees at all locations in all years had sufficient dormancy/rest and chilling temperatures, which they did (Thornton et al., 2022) therefore we did not include dormancy/chilling temperatures in our models.

1984). Our findings reflected that spring/summer temperatures (growing degree days) and precipitation were also important factors in crabapple size, presence, and production.

The amount of fruit per tree decreased over time, and there was less fruit per tree on trees that had restoration treatments applied to them versus controls. Crabapple, as well as many other fruit-bearing trees, only fruit on branches that are two years or older (Flore et al., 1984). A hard prune of dead, rubbing, or crossing branches was done in the early winter of 2021. In winter 2022, we pruned to encourage fruit production (heading cuts). So, in 2023, many of the newly grown, post-pruning branches would not be older than two years old, and thus would not be producing fruit. Further monitoring in upcoming years will reveal if restoration treatments increase fruit production over the long term as predicted.

The size of the fruit was positively influenced by restoration treatments (Fig. 5B). Agricultural research on closely related domestic apples has demonstrated that pruning will result in fewer but more high-quality flower buds on a tree, which allows for larger fruit growth (Flore et al., 1984; Robinson et al., 2016). Additionally, pruning can improve light penetration, opening up the trees' canopy and allowing more sunshine to reach the fruit, which is crucial for fruit growth (Fallik & Ilic, 2018; Kumawat et al., 2022). However, despite the amount of high-quality blossoms or sunlight on a tree, fruit growth will not take place without pollination (Burns & Stanley, 2022; Klein et al., 2007).

The size of fruit was negatively influenced by rain. Precipitation can reduce fruit size through several mechanisms related to pollination. First, cold, wet, or windy weather makes it difficult

for insect pollinators to fly, effectively reducing the pollination process (Lawson & Rands, 2019). Second, rain can directly damage pollen, washing it out of the receptive stigmas or making it less viable when pollinated (Lawson & Rands, 2019). And lastly, because of these pollination problems, there could be a reduced number of seeds within the crabapples, resulting in smaller fruit size and weight (Weekers et al., 2022). These factors could explain why fruit size is negatively affected by precipitation – the rain could be affecting fruit pollination. This seems especially likely because crabapple trees are otherwise unaffected by too much rain – they are tolerant of standing water, flooding estuaries, and tidal fluxes (Pojar & MacKinnon, 2004). In fact, *Malus fusca* is often used as root stock for *Malus domestica* cultivars in home orchards with wet or poorly drained soils (*Grafting Apples onto Malus Fusca*, 2011; Lee-Mäder, n.d.).

Fewer growing degree days resulted in a higher probability of fruit presence. Fewer growing degree days also resulted in more fruit on a tree. Typically for domestic apples, increases in growing degree days results in increases in overall apple production (Flore et al., 1984; Han et al., 2023). However, increases in growing degree days can also lead to accelerated bud breaks (which can lead to frost risk during late spring freezes) and accelerate fruit time to maturity (which can increase the risk of exposing the fruit to damaging summer heat) (Preston et al., 2024). Damaging summer heat for domestic apples in North America is defined as “days with a maximum temperature of 34°C” (Preston et al., 2024) and according to climate data for the region the maximum temperature across all years (2020-23) was 32°C, therefore summer heat was likely not a factor that affected crabapple presence (Thornton et al., 2022). There were several spring frosts however – mid-March of 2020, 2021, and 2023, and mid-April of 2021 and 2022 (Thornton et al., 2022). Therefore, in Wuikinuxv territory it seems that bud damage due to

spring frosts may play a factor in how growing degree days relate to the presence/absence and amount of fruit on a crabapple tree.

Trees that had a lower amount of dead limbs demonstrated a higher probability of fruit presence and more fruit. Dead limbs can be a source of disease, rot, and pests, which weakens the tree and diverts energy that would otherwise be used for fruit production (Flore et al., 1984). Pruning away dead limbs is one method of safeguarding the trees health. Pruning also has other benefits, that may indirectly increase fruit production; opening up branches to more lights and airflow, maintaining the trees' size and vigour, and improving load-bearing strength (Robinson et al., 2016). Pruning is a well-known, consistently performed practice — and our results clearly demonstrate the benefits of pruning. Future crabapple restoration projects should prioritize pruning as a restoration treatment.

The interaction of more precipitation and more growing degree days increased the probability of fruit presence. This is an interesting influence, as we have already seen that growing degree days demonstrated a strong negative influence on both the probability of fruit being on a tree and the amount of fruit on a tree. Therefore, the effect of growing degree days on fruit presence is moderated by precipitation, and the positive influence on fruit presence is specific to precipitation (Gardner, 2012). Higher amounts of precipitation result in a higher probability of fruit, while higher amounts of rain lead to small fruit size (as discussed above). The mechanism behind this is that while rain disrupts pollination (potentially causing smaller fruit development), it also provides more water overall, which can encourage fruit set and development (Zydlik et al., 2024). The significance of this interaction between precipitation and growing degree days

elegantly demonstrates the complex balance between pollination and water availability and their effect on crabapple fruit outcomes.

4.4.2 Potential outcomes for bears

Early ecological outcomes indicate that the combination of weather and restoration efforts has resulted in fewer, but larger fruits. In the fall, bears will choose food sources that maximize energy intake (Erlenbach et al., 2014; Rode & Robbins, 2000). Larger domestic apples provide bears with a higher caloric density, enabling faster weight gain, and bears will likely select for larger fruits over more abundant small fruit (Koike, 2009). However, domestic apples are considerably larger than crabapples (~150 grams versus ~0.2 grams, respectively), and we only saw an increase of 0.1 grams in crabapple size. Therefore, the targeted selection of larger fruit by bears might not be relevant to crabapples.

Although at first glance, it may not seem like crabapple fruit could be a significant component of bears' diets, especially when protein abundant salmon (*Oncorhynchus* spp.) are readily available in Wuikinuxv territory at the same time of year. However, carbohydrate rich fruit is an extremely important source of nutrients and when given a choice of apple (carbohydrate), salmon (protein), or beef fat (lipid) grizzly bears in captivity selected for mixed diets over protein diets (Erlenbach et al., 2014). Additionally, grizzly bears in the wild have been observed to leave salmon in order to consume fruit, even though energy maximization theory predicts that bears should choose to consume salmon as it is more energetically valuable (Rode & Robbins, 2000). Bears appear to incorporate fruit in their diet for two reasons: (1) gustatory and/or olfactory appeal and, (2) as a method to maximize mass gain per unit of energy spent (Erlenbach et al., 2014; Rode &

Robbins, 2000). Regardless of the reason for incorporating fruit into their diet, crabapple clearly have the potential to significantly contribute to a healthy, tasty, and optimum diet for bears.

One of the main goals of this project was to provide more food for neighboring bears (Fig. 4.8). The Wuikinuxv Stewardship Department carefully selected restoration sites near but not within the village of Katit. The intention of this was to entice the bears to sites of fruit availability and away from potential human-bear conflict zones. This plan was developed with deep local knowledge and is supported by science; previous research found that ripe fruit trees, especially ornamental crabapples (*Malus* spp.), acted as significant attractants for black bears (Lewis et al., 2015). The crabapple project demonstrates one of the many ways the Wuikinuxv Nation is approaching ecosystem management; it is practicing reciprocity by aligning its values to provide sustainable resources for humans and non-humans alike. Another example is seen in the Wuikinuxv bear monitoring program, a project that ran from 2013 – 2020 (Adams, 2019). This project monitored bear population and foraging behaviour in the territory in order to inform the Nation's decision makers on the impact of salmon harvesting on bears (Adams et al., 2021). Currently, the Nation adjusts its fishing efforts yearly in an effort to ensure that bears and other wildlife have their allocation of salmon. Locally driven and executed research, such as the data generated by Wuikinuxv's bear and crabapple projects, is essential in supporting Wuikinuxv Nations place-based and localized decision making, which is founded in respect to non-human kin like bears (e.g., Adams et al., 2021; Housty et al., 2014; Thompson et al., 2019).

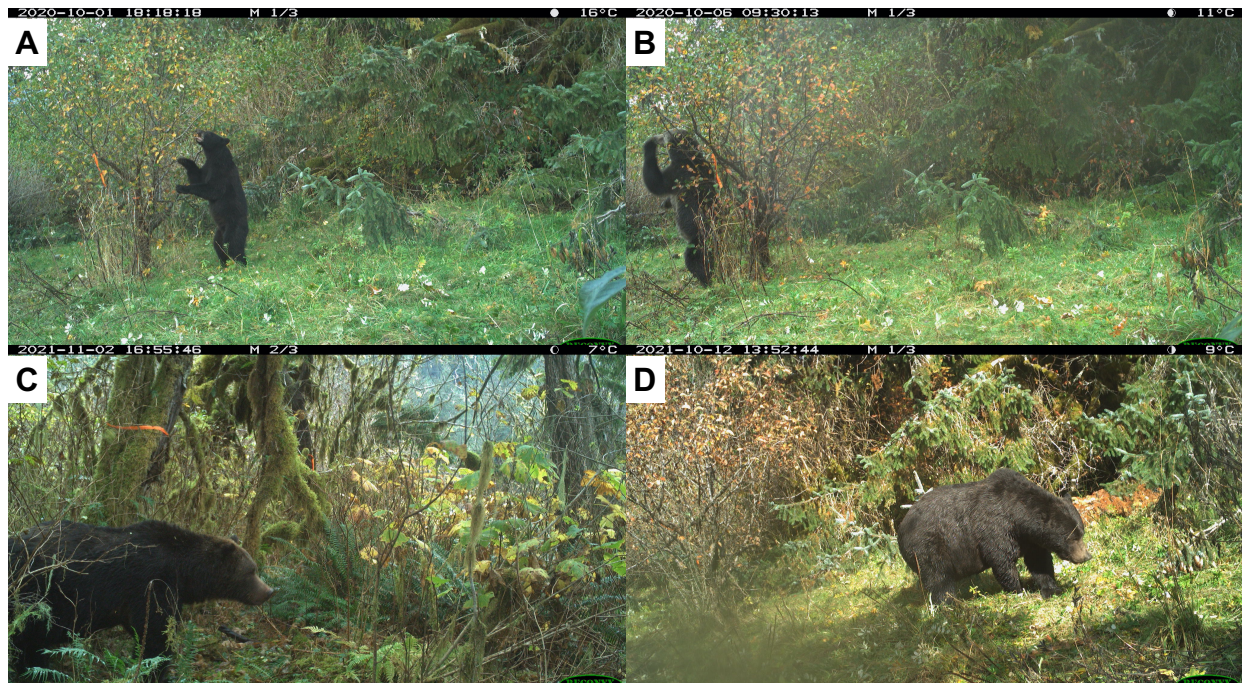


Figure 4.8 The bears of Wuikinuxv Territory. (A) A black bear eating crabapple in an estuary (B) A grizzly bear eating crabapple from the same tree five days later. (C) A grizzly bear in a riverbank crabapple orchard. (D) A large grizzly bear in an estuary. All photos were taken in the fall; dates are displayed in the top left corner of the photo.

4.4.3 Cultural outcomes

Several short-term, tangible benefits were recognized early on in during the crabapple project. First, initial surveys to locate orchards and forest gardens throughout the territory contributed to recording and documenting past land use, which may be useful for the Wuikinuxv Nation to assert land claims. Second, through surveys, restoration, and harvesting events the crabapple project provided travel for Stewardship employees and community members to remote, boat-access only locations with high cultural importance, supporting connections to ancestral and familial landscapes (Kamelamela et al., 2022). And third, although not a direct goal, the project

introduced a traditional food into the pantries of community members, encouraging many people to taste this traditional food for the first time. This contributes to restorative, renewing food traditions and cultural resurgence (Gavenus et al., 2023; Grenz & Armstrong, 2023; Joseph & Turner, 2020b).

Early in the project the Wuikinuxv Stewardship Committee and the Wuikinuxv Stewardship Department highlighted that this work was to be practice-based and not entirely data-driven. Crabapple restoration and harvesting, plant ID walks, and crabapple jarring, jellying and tasting all provided opportunities for intergeneration knowledge transfer, a practice that is often best facilitated during harvesting, food processing, or food sharing (Greening (La'goot), 2024). Haítzaqv scholar Kánílkás Desiree Lawson describes these actions as “future-proofing” a practice; when children are centered during cultural practice this ensures that future generations will be equipped with the knowledge and skills to continue that practice in the future (Lawson, 2024). By including a human element into the project’s goals, the Stewardship Committee and Department ensured that many cultural components were reinforced and future-proofed.

As previously mentioned, crabapple is a valued plant to Indigenous Nations all over coastal BC, and several other Indigenous Nations participate in crabapple stewardship revitalization. However, each project is culturally and ecological distinct. For example, on the islands of Xaayda Gwaay (Haida Gwaii), crabapple trees and crabapple tree recruitment are threatened by beaver (*Castor canadensis leucodontus*) and deer (*Odocoileus hemionus sitkensis*) foraging (Gaston et al., 2008). Both mammals are an introduced species to the islands and their presence has caused transformative vegetative changes (Gaston et al., 2008). The Haida Nation and a local conservancy initiated a crabapple restoration project involving beaver trapping and crabapple

tree fencing (Camire, 2022). In the Gulf Islands National Park of Canada, located in Coast Salish territories, crabapple forest gardens were replaced by colonial practices of domestic apple, plum, and pear orcharding. Currently, and in collaboration with local Nations, parks scientists are working on a project to reintroduce crabapple groves (*B.A. Miller, personal communication*). Other, longer-term, restoration and revitalization projects are also underway in Sts'ailes, Gitselasu, Quw'utsun, Nuchatlaht, and Hul'qumi'num-speaking First Nations territories (McCarthy, 2023; Park & Higgs, 2018; Vanier, 2022). This publication on the Wuikinuxv crabapple project is one of the first comprehensive reports on crabapple stewardship results, though it is early data. Longer-term data should be examined again and endeavors to share crabapple restoration experiences between communities should be prioritized.

More broadly, these projects are some of the many examples of how Indigenous governments are turning their collective efforts toward holistic and de-centralized regional monitoring and management to guide their integrated stewardship of marine and terrestrial species (e.g., Nation-based integrated resource stewardship departments, or similar). In doing so, these Nations are contributing to their Indigenous sovereignty through traditional foods revitalization, through intergeneration and cross-cultural knowledge sharing, and through value driven, land-based practice (Corntassel & Bryce, 2012; Greening (La'goot), 2024; Joseph & Turner, 2020b; Lawson, 2024; Lee et al., 2021; Simpson, 2014).

4.5 Conclusion

Early ecological results indicate that uncontrollable factors of spring/summer temperatures and precipitation are important in influencing crabapple production, but controllable factors such as pruning and fertilizing also have an important influence. The Wuikinuxv crabapple project has

the potential to supply bears with an important complementary food source to salmon in the fall before hibernation. The cultural elements of this restoration project demonstrate the many benefits of restoring ecocultural spaces, and restoration that prioritizes cultural practice can contribute to Indigenous sovereignty.

Chapter 5. General Conclusion

5.1 Overview of results and emergent themes

Broadly, the objective of this thesis was to understand the creation, sustainability, and diversity of ecocultural landscapes (such as forest gardens and crabapple orchards) and then reflect on the role restoration can play in revitalizing these resilient landscapes. Here is a brief overview of our results:

In Chapter 2, we performed a large-scale survey to document the locations of 16 coastal forest gardens. We used data collected from these sites to identify 12 plant species that indicate the presence of a coastal forest garden, and we demonstrated how valuable the monumental form of Pacific crabapple is as a forest garden indicator species. This research highlights the contributions of regional cultural and biogeoclimatic diversity to forest garden assemblages and facilitates discussion on the intricacies of forest gardening as a management strategy.

In Chapter 3 we outline how worldviews inform place-based values, guiding management practices that contribute to biodiverse, productive, and sustainable ecosystems. We provide a framework for incorporating place-based values into contemporary restoration initiatives. We also detail how including Indigenous Knowledge and practice in restoration can contribute to decolonization efforts.

In Chapter 4 we describe the initiation, goals, and methods of an Indigenous-led restoration project: the Wuikinuxv lhènnx̓ (crabapple) project. We report early monitoring results that

indicate that spring and summer temperatures, precipitation, pruning, and fertilizing all influence crabapple production. We conclude that the Wuikinuxv lhènnǎx project has the potential to supply bears with an important complementary food source to salmon in the fall before hibernation and provides the community with opportunities to connect with traditional practices.

Although the scientific methods, frameworks, and results throughout this research vary, underlying themes that emerge throughout. Broadly, this research demonstrates how:

- 1) Different worldviews, values, and ways of knowing guide different scientific, stewardship, and cultural practices.
- 2) Indigenous stewardship has created biodiverse, productive ecocultural landscapes.
- 3) These landscapes are diverse, due to their plant and animal assemblages based on their biogeographical location and due to the diversity of cultural practices that sustain them.
- 4) The cultural practice and ecosystem sustainability of ecocultural landscapes are mutually supportive and co-dependant.
- 5) Formal recognition, along with legislation to conserve ecocultural landscapes, is needed. Failing to do so ignores and devalues Indigenous land use as well as Indigenous cultural and ecological values.
- 6) Stewardship, harvesting, and restoration of ecocultural landscapes can encourage Indigenous resurgence and sovereignty. Enabling support and access to these practices assists in decolonization.

5.2 Barriers and opportunities to conserving and accessing ecocultural landscapes

As discussed throughout this thesis, the conservation, restoration, and accessibility of these landscapes are important for Canada's reconciliation with Indigenous Nations. However, due to lack of legislative protection and layers of complicated bureaucracy, industrial and urban development continue to threaten many of these ecosystems. Even when features such as forest and clam gardens are protected, Indigenous rights around stewardship and harvesting from these landscapes are insensitive or regulated. For example, in Canadian National Parks, forest gardens have blanket protection under the National Parks Act, although no specific legislation formally recognizes them (Legislative Services Branch, 2025). For the general public, the harvest of plants, mushrooms, nuts, berries, or any other natural material is forbidden and can result in fines, eviction, or court orders (Legislative Services Branch, 2025). Indigenous People have been granted permissions to harvest at about half of the 40 National Parks in Canada, although often this requires prior consent from Parks managers (*Can Indigenous Peoples Hunt in National Parks?*, n.d.). Indigenous stewardship and restoration are currently permitted in fewer than five National Parks (*Can Indigenous Peoples Hunt in National Parks?*, n.d.).

Bureaucracy surrounding the protection of and harvest from clam gardens is even more convoluted. Clam gardens are not protected by the National Parks Act because they exist below the high-tide mark. If a registered archaeologist visits the clam garden site and records it as a feature with the Archaeology Branch, then it will be protected under the Heritage Conservation Act (*Heritage Conservation Act*, n.d.). However, once recorded, if a Nation would like to rebuild or restore a rock wall structure, they would have to apply for permission from the Archaeology Branch to "alter or disturb" the feature. Then, a registered archaeologist would have to be onsite

during any restoration or rebuilding activities. This is hard to coordinate for Nations without an archaeologist on staff to coordinate, especially for Nations that are remotely located. Further, any clam garden rock wall rebuilding also requires permissions from Transport Canada, because it is considered building “a structure in navigable waters” (Transport Canada, 2020). And then the harvest of clams is regulated by the Department of Fisheries and Oceans (DFO) and the Fisheries Act. Shellfish harvesting requires a permit and can only be done during regional openings, which is dependent on containment testing, which is limited geographically and temporally (*Canadian Shellfish Sanitation Program*, 2018).

The harvest and/or restoration of ecocultural landscapes is never a given, even on reserve lands. For example, the Pauquachin First Nation, residing on the Coles Bay Reservation, recently began construction on a clam garden in their territory. To initiate this project (which started in 2015), the Pauquachin Nation had to engage with DFO, the Province’s Ministry of Water, Land and Resource Stewardship, the Capital Regional District, the Municipality of North Saanich, and the federal government (*Report on Shellfish Restoration*, n.d.). The administrative burden of such engagement would be immense. At the onset of construction, which should have been a celebratory moment, the popular media cast the project in an unfavorable light, as local, uninformed residents were concerned about construction (Depner, 2025). Adding insult to injury, shellfish harvest has not been possible in Pauquachin territory since 1997 because of pollution in Coles Bay causing shellfish contamination (*Report on Shellfish Restoration*, n.d.). The source of this pollution has been identified as stormwater and septic problems created by the Municipality of North Saanich’s past planning decisions (Depner, 2021). The Municipality of North Saanich did not consult with the Pauquachin First Nation when they planned and permitted infrastructure

related to these sources of pollution, so it is ironic that the Nation had to engage with so many levels of Government to initiate a project on reserve land. Pauquachin Nation maintains that their lack of access to harvest edible shellfish is a treaty violation and a violation of fundamental Aboriginal rights to fish (Depner, 2021).

These examples demonstrate how at any level of land “ownership”, Indigenous People are still restricted from practicing traditional forms of harvest and stewardship and they have little say in the protection or conservation of culturally valuable landscapes. This bureaucratic racism is premised on Canada’s assertion of control over Indigenous People’s lands and resources, which stems from fictions such as the Doctrine of Discovery and *terra nullius* (Borrows, 2015). In the past, legislative and policy initiatives removed Indigenous People from their homelands and criminalized traditional practices in the name of conservation (Binnema & Niemi, 2006). Clearly, this serious and longstanding systemic and institutional racism is unresolved. However, some potentially good changes are being made at the legislative level, facilitated by Canada signing the United Nations Declaration on the Rights of Indigenous Peoples Act (UNDRIPA) into law in 2021 (Government of Canada, 2021). Federal and Provincial institutions are working to implement the declaration in a variety of ways.

Parks Canada is revising the Parks Act to be more culturally sensitive and inclusive. Although it will likely take many years before it is formally adopted, in the interim there is an “Indigenous Stewardship Framework” – a new policy to help reduce barriers to Indigenous harvest and stewardship in National Parks (Parks Canada Agency, 2024). Similarly, the Heritage Conservation Act (HCA) is undergoing revisions through the “Heritage Conservation Act

Transformation Project” to better align with the commitments in DRIPA (*Home - Heritage Conservation Act Transformation Project*, 1641380898). According to a contract advisor on the Transformation Project, the updated HCA is borrowing much of its language in defining cultural features from the Great Bear Rainforest Land Use Order (*B. Deroy, personal communication*).

The Great Bear Rainforest Land Use Order is an Act that was established to protect and manage the Great Bear Rainforest (GBR), which is on the Central Coast of BC in the territories of the Wuikinuxv, Nuxalk, Haílzaqv, Kitasoo/Xai’xais, Metlakatla, Gitxaala, and Gitga’at Nations (Environmental Laws: A Field Guide for BC’s North and Central Coast and Haida Gwaii, 2024).

This legal framework is aimed at balancing ecological integrity with sustainable economic development, but it prioritizes the rights and interests of the Nations within the GBR

(Environmental Laws: A Field Guide for BC’s North and Central Coast and Haida Gwaii, 2024).

The GBR Land Use Order recognizes Indigenous Heritage Features (IHF) as – “an artefact, feature, or site of the general types listed in Schedule I, other than a Contemporary Culturally Modified Tree or a Historical Culturally Modified Tree, that is known, is found, or is identified during First Nation Engagement and is important to the cultural practices, knowledge, or heritage of a First Nation” (see Table 5.1 for Schedule I IHFs) (Mackie et al., 2024). Forest, root, and berry gardens are included in the definition of an IHF and in general, the definition of an IHF is open to interpretation as a Nation sees fit. IHFs must be recorded by an archaeologist, and this almost always happens with the guidance, or at minimum, in the presence of a representative from a Nations Stewardship Department². Once recorded, IHFs are protected from

² Full transparency – (and as some of you may know) over the past three years I have been working with Wuikinuxv, Nuxalk, and Haida Gwaii Stewardship Departments on IHFs as they relate to plants. This work stemmed from teaching content developed by Dr. Chelsey Armstrong to the Nations’ Guardians and then evolved

industry/development at the Nation’s discretion (Mackie et al., 2024). Indigenous stewardship, harvesting, and restoration are not restricted.

Table 5.1 Schedule I of the Great Bear Rainforest Land Use Order identifies the following Type 1 and Type 2 Indigenous Heritage Features. Type 1 and Type 2 relates to the amount of land that is protected in a “buffer zone” surrounding the feature.

Type	Feature	Example
1	Ancestral remains	Burial sites
	Habitation	Villages, campsites, middens
	Rock Art	Petroglyphs, pictographs
	Identified Oral History Sites smaller than 2 hectares	
	Identified Spiritual Sites smaller than 2 hectares	
2	Harvesting and Processing Sites	Fish traps and weirs, clam gardens, plant gardens, quarries for stone and pigments
	Trails	
	Isolated Finds	Beach find artifacts, lost tools

Haida Gwaii has a similar framework under the Haida Gwaii Land Use Objectives Order, however one crucial difference is that archaeologists are not required to record IHFs. Instead, the Haida Nations Heritage and Natural Resource Department certifies its own “cultural features

into facilitating workshops aimed at identifying and prioritizing each Nations’ specific culturally important plant species and plant gardens.

technicians” through a robust training program, and any feature a technician records is afforded protection. Overall, the GBR Land Use Order and the Haida Gwaii Land Use Objectives Order give these nations authority over the protection, stewardship, and harvest of their current and ancestral ecocultural landscapes. Indigenous Nations should all have an inherent authority over their territories to govern, steward, and harvest from the land and waters. This authority comes from a place-based relationship that spans millennia and has shaped the worldview, values, laws, and knowledge into considerate practice.

While we wait (potentially decades) for outdated legislation to be brought up to date with basic human rights, the only solution I feel invested in is continuing to support Indigenous Nations on their paths to resurgence and sovereignty. I support the Nations who are asserting authority over their territory unphased by colonial jurisdictions. I also support Nations that are investing time, energy, and money to assert their authority through land claims and/or other legislation battles. I think the best way to support Indigenous self-determination is to help the nations build capacity. At the individual level, this can be done through a multitude of methods, and levels of expertise, and comfort: as a volunteer (write grants, pull invasive species), employee (is your background in policy, administration, mental or physical health?), researcher, lawyer, educator, funder, donor and through bequeathing (money, land and/or resources). Encouraging other kind, self-aware, non-Indigenous Canadians to also focus their energy on capacity building for the long-term is important. Simply attending rallies or making territorial acknowledgements is no longer sufficient; Indigenous Canadians’ rights have suffered for too long for more tangible action not to be taken.

5.3 Working in community

In the past, power imbalances between academics and Indigenous People have led to appropriation, exploitation, and misinterpretation of Indigenous Knowledge (Simpson, 2001). More recently, the call for academics to do better, coupled with a federal level push for reconciliation, has led to the exposure and dissection of power imbalances. Many papers, reports, frameworks, and guidelines are dedicated to navigating academic engagement with Indigenous communities written from both Indigenous and non-indigenous perspectives (see Appendix C for a sample). What is less written about, from a non-indigenous perspective, is the personal aspects of working in community. Please note that this is not the case from Indigenous perspectives as there are many personal accounts.

I think that personal perspectives are where many non-Indigenous people's curiosity lie, especially those of early career ecological researchers. During academic research presentations, without fail, the number one question I get asked is: How did you form a partnership? Other repeat questions are: How much time do you spend in community? Do you hire local research assistants? For full transparency I spend 20-30 days a year in Wuikinuxv territory, and I don't hire local research assistants because I am basically the help (though I do work closely alongside local community members in the field, which I think is what that question is alluding to). Broadly, what I think these questions are getting at, is how invested in a community should one be? Over-the-top investment into scientific research is perfectly acceptable in academia; however, there is some unspoken assumption that it is unprofessional to be too invested in a community, as it may signal a bias.

Throughout this research I had the great privilege to have the support of several First Nations communities. Additionally, I was honoured to work in service of the Wuikinuxv Nation on the lhènnx̌ project. As a non-Indigenous scholar, working in and with the community of Wuikinuxv helped me appreciate different work and cultural values than what is common in western academic or ecological research settings. Colleagues at Wuikinuxv Stewardship and beyond have indicated it would be of value for me to share my experiences, as it could reduce their workload by providing a template for working in their community. Before I do so, I admit that to a degree I am a biased researcher (and I think that is apparent by reading this general conclusion)³. For me, being a biased researcher means that I choose research projects that are Nation-driven and ideally, applied science (as stated in my positionality statement). It does not mean I will compromise data to fit a narrative.

To help me communicate best practices while working in community, I trust in Wong et al.'s (2020) "10 Calls to Action to natural scientists working in Canada" to succinctly list what I think should be regarded as the baseline of actions that academics should follow when engaging with Indigenous communities (Table 5.2).

³ I also challenge any natural scientists who claim they are unbiased, although that is material for a whole other thesis.

Table 5.2 Ten calls to action to natural scientists working in Canada, by Wong et al. 2020. The actions are listed in the first column and any addendum or edits I thought could enhance the calls are listed in the second column.

Call	Addendum/edit
We call on natural scientists to understand the socio-political landscape around their research sites.	I would remove the word “their”. Research sites are not owned, especially by natural scientists.
We call on natural scientists to recognize that generating knowledge about the land is a goal shared with Indigenous peoples and seek meaningful relationships and possible collaboration for better outcomes for all involved.	
We call on natural scientists to enable knowledge sharing and knowledge co-production.	
We call on natural scientists studying animals to seek out advice from Elders for respectful ways of handling animals.	This could be expanded to include plants and other non-human kin.
We call on natural scientists to provide meaningful opportunities for Indigenous community members, particularly youth, to experience and participate in science.	To participate in *western science. Many who spend time of the land are already practicing Indigenous science.
To decolonize the landscape, we call on Indigenous scientists to incorporate Indigenous place names as permitted.	
We call upon natural scientists and their students to take a course on Indigenous history and rights.	A course should be the baseline, there is also a wealth of academic, fiction, and non-fiction work that can be digested.
We call on funding bodies to change approaches to funding.	
We call on editors of all scientific journals to recognize that publication of research on Indigenous Knowledge and cultural resources require review and permission from the respective Indigenous communities.	Onus should be put on the journals to do the heavy lifting. Hire someone who can present the research in lay terms. Do not transfer the burden of responsibility to nations.
We call on natural scientists and postsecondary research institutions to develop a new vision for conducting natural science: fundamentally	

mainstreaming reconciliation in all aspects of the scientific endeavour, from formulation to completion.	
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Wong et. al's (2020) calls to actions are broad and meant to be applicable across Canada. To supplement these calls to action on a more personal and geographical level, I have listed the conduct that I prioritized while working in Wuikinuxv territory, as I believed it helped in forming a good relationship. My work alongside and for Indigenous communities is by no means perfect, mistakes have been made and will continue to be made, but here are some of things I learned along the way. Please recognize that this conduct is specific to time, place, people, and to a huge extent, privilege. It is described here in good faith.

- 1) First and foremost, take the time to viscerally understand how colonialism has impacted and still impacts Indigenous People today. This repeats what so many others have said before me. I suggest reading Indigenous authors, both fiction and non-fiction. Auto-biogeographical work by Alicia Elliot and Jesse Thistle helped to show me some examples of how the trauma of colonialism manifests in Indigenous People today.
- 2) Be humble; enter the relationship with no ego. Recognize that first and foremost, working in community is not about you, your career, your research, your supervisor, your students, etc. Also, there might not be much interest in your expertise or proposed research if it can't be applied within that territory. Therefore, you may not get to do the research you intend/proposed/have the most expertise in. If you are not 100% onboard with this, then you may want to examine the reasons you want to engage with nations in the first place.

- 3) Be creative with engagement. Many Nations' Government, Lands, or Stewardship departments lack the capacity to respond to smaller-scale, individual projects. Instead, you could reach out to an Elder care centre, language class, or Medicine/harvesting club to do a presentation and ask for guidance or feedback.
- 4) Volunteer your time. Sometimes your expertise is in something that will directly benefit an Indigenous Nation and they will be keen to work with you. But often a level of trust and familiarity needs to be built, and this can be done by volunteering your time and expertise.
- 5) Form friendships! Because there is no good reason not to. Talk to people. Check in with people. Find a common connection. For me this has always been a shared love, awe, and appreciation for the territory. If you don't think community members will remember who you are, don't be afraid to reintroduce yourself. But often, out-of-town visitors who are kind and friendly and return more than once or twice are remembered and appreciated.
- 6) Give money. In Wuikinuxv and other coastal communities, small fundraisers are common events. They help support family members recoup fishing or hunting gear that was stolen, pay for airfare to visit family members off reserve, help pay for medical bills, etc. The fundraisers are often in the form of 50/50 ticket sales, raffles, draws, or Go-Fund Me's. If someone I know organizes a fundraiser I will always contribute.
- 7) Attend cultural events, even if you feel uninvited or out of place. In communities there are often regular cultural events taking place that take many forms: language classes, cedar hat weaving circles, traditional dance practice, community dinners/potlucks, ceremony relating to seasonal harvests (e.g., first fish ceremony), etc. These weekly events and larger, less regular cultural events (such as potlaches or homecomings/burials)

will have no official invitation, just a community wide announcement. I felt awkward about knowing if I was invited to these events or not until a friend said, “you will not be specifically invited, but you will know if you should go or not based on your relationship to the family hosting the event”. So, if you have an important relationship with someone in the host family, you should go. Putting in the effort to attend these events, even if it requires out-of-pocket travel funds will strengthen your relationship to the community.

- 8) Face-to-face time and time in community is the most valuable currency. Even if it makes you feel unproductive because of “wasted time” on travel days or weather setbacks, you are showing respect and interest by being there and you are laying the foundation for a trusting relationship.
- 9) Recognize and deeply respect implicit and explicit cultural practices. There are protocols and permissions involved with harvesting and being on the land, so if your research involves either of these, find out how to proceed respectfully. Also, Indigenous governments operate on traditional protocols. Therefore, they may be open or closed on a different schedule than 9-5 Monday to Friday. For example, if there is a death in the community, many Indigenous Government offices will close out of respect for the grieving family. This means that you must also give space to your Indigenous colleagues, even if you have a funding or publication deadline approaching. Instead, you could email the granting agency or publication, explain the situation, and ask for an extension. This will help normalize cultural sensitivity.
- 10) Disseminate your research in an accessible way. Write lay summaries, make infographic abstracts, write yearly project updates, engage in conversation. Facebook is also a

valuable communication tool for coastal BC communities. Some nations also have newsletters you can submit your summaries or updates to.

- 11) Consider the soft and hard skills that you can take with you into community. Will you be leading workshops or presentations? Perhaps a facilitation course would be helpful. I think trauma-informed training should be required. This is something I didn't do but based on experience I think this would have been an extremely valuable soft skill to learn. Does the community you work in struggle with drugs and alcohol? Perhaps take a Naloxone course. And for fieldwork you will need: first aid and the certifications and experience that will make you feel confident to drive a boat, run a chainsaw, fly a drone, drive a snowmobile, etc. Feeling confident in these skills will make you less of a chore or a liability to the folks you will be working with and can help project efficiency.
- 12) When you are in a small or remote Indigenous community, recognize and respect that the interconnectedness and dependency between community members and different departments is greater than in urban, western settings. Therefore, you have a responsibility to visit and inform as many community members as possible because they are all affected by research in their Territory at some level. In Wuikinuxv the academics and those who work closely with them have created an implicit rule wherein you must organize an activity with the school kids when you are in the village. Another example is that you are expected to do a community presentation on your research when it is finished — a community defense as well as an academic defense. Thank you to Jennifer Walkus, Megan Adams, and Chris Darimont for setting the standards in Wuikinuxv Territory.
- 13) Be generous with time.

To close this thesis, I would like to add another theme or call to action that has emerged throughout the writing of this general conclusion and that is that non-Indigenous people need to invest in growing the capacity of Indigenous Nations. Although colonial institutions are taking small steps towards reconciliation, we cannot rely on them to expunge themselves of the systemic racism that has been pervasive for so long in a timely manner. Our Indigenous colleagues, all Indigenous Canadians, and the lands we all occupy and hold dear deserve more decisive action.

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Appendix A

Table A 2.1 RAAD archeological site typologies that were prioritized for surveys.

Feature	Typology
Habitation	Platform
	Depression
Subsistence	Fish Trap
	Fishing Weir
	Clam Garden
	Shellfish Harvesting
Cultural material	Shell Midden
	Lithics
Transportation	Canoe Skid

Table A 2.2 Plants listed in tables 51, 6-1, 7-1 in Turner (2014) that are considered culturally important but were excluded from our surveys due to their ubiquity in our study region.

Common Name	Latin Family or Species Name
Salal	<i>Gaultheria shallon</i>
Plantains	<i>Plantaginaceae</i>
Giant horsetail	<i>Equisetum telmateia</i>
Lodgepole pine	<i>Pinus contorta</i>
Western redcedar	<i>Thuja plicata</i>
Western hemlock	<i>Tsuga heterophylla</i>
Black twinberry	<i>Lonicera involucrata</i>
Tall oregon grape	<i>Berberis aquifolium</i>
Red huckleberry, oval leaf, and Alaska blueberry	<i>Vaccinium sp.</i>

Table A 2.3 Indicator species for three types of forest garden habitats and one combination of habitats found in proximity of archaeological sites along the coast of British Columbia. **Bolded** species indicate that they are highly significant indicators.

Factor	Species	P-value
Estuary	Springbank clover (<i>Trifolium wormskioldii</i>)	0.006
	Nootka rose (<i>Rosa nutkana</i>)	0.370
	Yarrow (<i>Achillea millefolium</i>)	0.218
	Common silverweed (<i>Argentina anserina</i>)	0.372
Shoreline	Devil's club (<i>Oplopanax horridus</i>)	0.667
	Sitka columbine (<i>Aquilegia formosa</i>)	0.677
	Northern riceroot (<i>Fritillaria camschatcensis</i>)	0.575
	Salmonberry (<i>Rubus spectabilis</i>)	0.635
	Saskatoon (<i>Amelanchier alnifolia</i>)	1.000
	Thimbleberry (<i>Rubus parviflorus</i>)	1.000
	Black gooseberry (<i>Ribes lacustre</i>)	1.000
Streambank	Cultural features	0.078
	Pacific yew (<i>Taxus brevifolia</i>)	0.106
	Stinging nettle (<i>Urtica dioica</i>)	0.393
	Pacific ninebark (<i>Physocarpus capitatus</i>)	0.360
	Bracken fern (<i>Pteridium aquilinum</i>)	0.568
	Bitter cherry (<i>Prunus emarginata</i>)	1.000
Estuary + Shoreline	Total crabapple (<i>Malus fusca</i>)	0.254
	Monumental crabapple (<i>Malus fusca</i>)	0.400
	Volunteer crabapple (<i>Malus fusca</i>)	0.423
	Cow-parsnip (<i>Heracleum maximum</i>)	0.727

Table A4. Indicator species for forest gardens across two regions along the coast of British Columbia. **Bolded** species indicate that they are highly significant indicators.

Factor	Species	P-value
Central Coast	Common silverweed (<i>Argentina anserina</i>)	0.094
	Pacific yew (<i>Taxus brevifolia</i>)	0.340
	Northern riceroot (<i>Fritillaria camschatcensis</i>)	0.645
	Nootka rose (<i>Rosa nutkana</i>)	1.000
	Pacific ninebark (<i>Physocarpus capitatus</i>)	1.000
	Monumental crabapple (<i>Malus fusca</i>)	0.663
	Yarrow (<i>Achillea millefolium</i>)	0.995
	Total crabapple (<i>Malus fusca</i>)	0.895
Discovery Islands	Bitter cherry (<i>Prunus emarginata</i>)	0.008
	Bracken fern (<i>Pteridium aquilinum</i>)	0.057
	Saskatoon (<i>Amelanchier alnifolia</i>)	0.228
	Thimbleberry (<i>Rubus parviflorus</i>)	0.261
	Stinging nettle (<i>Urtica dioica</i>)	0.255
	Black gooseberry (<i>Ribes lacustre</i>)	0.261
	Salmonberry (<i>Rubus spectabilis</i>)	0.261
	Devil's club (<i>Oplopanax horridus</i>)	0.261
	Cultural features	0.498
	Volunteer crabapple (<i>Malus fusca</i>)	0.552
	Cow-parsnip (<i>Heracleum maximum</i>)	1.000
	Springbank clover (<i>Trifolium wormskioldii</i>)	1.000
	Sitka columbine (<i>Aquilegia formosa</i>)	1.000

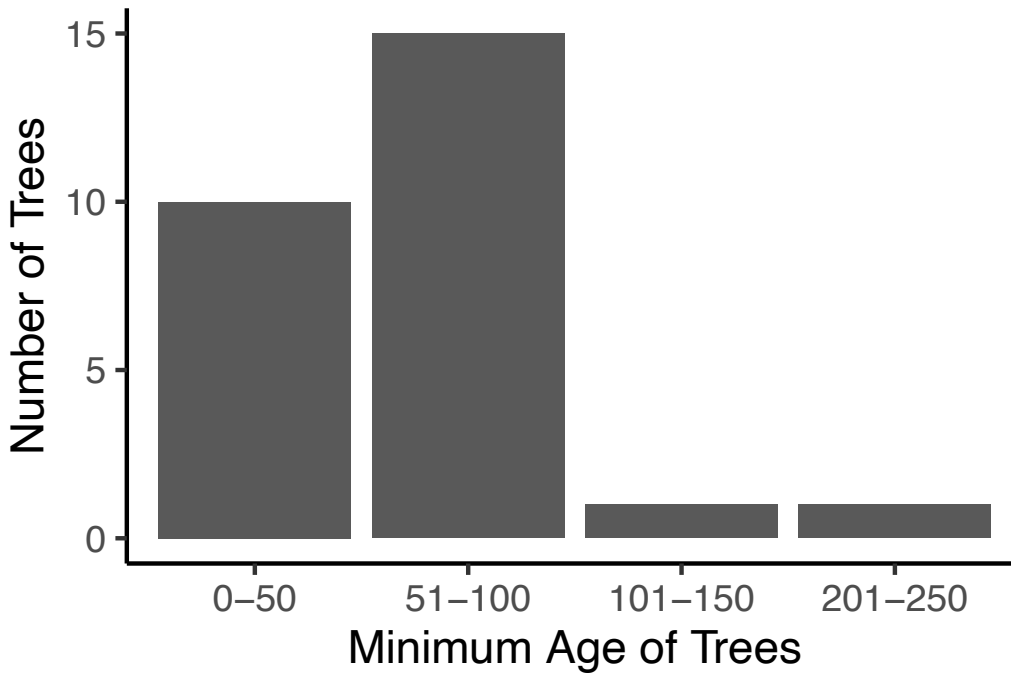


Figure A 2.1 Bar plot displaying the minimum age of crabapple trees dated by dendrochronology and the number of trees of that age.

Appendix B

Table B 4.1 Akaike's information criterion (AIC) values from all models to predict fruit dry weight. Δ AIC: difference between the current and best model; AIC_w: Akaike weight; (*) denotes interaction term. GDD = Growing Degree Days. Best performing models are in **bold** text.

Model	Variables	Rank	AIC	Δ AIC	AIC _w
12	PRECIPITATION + RESTORATION TYPE	1	-227	0	6.20E-01
24	PRECIPITATION + TREE TYPE + RESTORATION TYPE	2	-226	1.78	2.55E-01
18	GDD + PRECIPITATION + RESTORATION TYPE	3	-222	5.83	3.37E-02
2	PRECIPITATION	4	-221	6.79	2.08E-02
6	GDD + PRECIPITATION	5	-220	7.6	1.39E-02
16	GDD + PRECIPITATION + % DEAD	6	-220	7.6	1.39E-02
9	GDD + RESTORATION TYPE	7	-219	8.14	1.06E-02
28	GDD + PRECIPITATION + TREE TYPE + RESTORATION TYPE	8	-219	8.57	8.56E-03
17	GDD + PRECIPITATION + TREE TYPE	9	-218	9.57	5.17E-03
1	GDD	10	-218	9.87	4.45E-03
21	GDD + TREE TYPE + RESTORATION TYPE	11	-217	10.23	3.72E-03
23	PRECIPITATION + % DEAD + RESTORATION TYPE	12	-217	10.86	2.72E-03
11	PRECIPITATION + TREE TYPE	13	-217	10.96	2.59E-03
4	TREE TYPE	14	-216	11.66	1.82E-03
8	GDD + TREE TYPE	15	-215	12.11	1.46E-03
30	PRECIPITATION + % DEAD + TREE TYPE + RESTORATION TYPE	16	-214	13.13	8.75E-04
5	RESTORATION TYPE	17	-213	14.62	4.14E-04
10	PRECIPITATION + % DEAD	18	-211	16.35	1.74E-04
27	GDD + PRECIPITATION + % DEAD + RESTORATION TYPE	19	-210	17.02	1.25E-04
20	GDD + % DEAD + RESTORATION TYPE	20	-209	18.52	5.90E-05
3	% DEAD	21	-208	19.22	4.16E-05
15	TREE TYPE + RESTORATION TYPE	22	-208	19.35	3.89E-05
22	PRECIPITATION + % DEAD + TREE TYPE	23	-208	19.48	3.65E-05
31	GDD + PRECIPITATION + % DEAD + TREE TYPE + RESTORATION TYPE	24	-208	19.84	3.06E-05
26	GDD + PRECIPITATION + % DEAD + TREE TYPE	25	-207	20.52	2.17E-05

29	GDD + % DEAD + TREE TYPE + RESTORATION TYPE	26	-206	21.15	1.58E-05
7	GDD + % DEAD	27	-205	22.31	8.87E-06
13	% DEAD + TREE TYPE	28	-204	23.28	5.45E-06
19	GDD + % DEAD + TREE TYPE	29	-203	24.71	2.68E-06
14	% DEAD + RESTORATION TYPE	30	-202	25.26	2.02E-06
32	GDD + PRECIPITATION + GDD*PRECIPITATION + % DEAD + TREE TYPE + RESTORATION TYPE	31	-199	28.31	4.42E-07
25	% DEAD + TREE TYPE + RESTORATION TYPE	32	-198	29.7	2.20E-07

Table B 4.2 Akaike's Information criterion (AIC) values from candidate models to predict fruit presence/absence. AIC: AIC score; Δ AIC: difference between the current and best model; AICw: Akaike weight; (*) denotes interaction term. GDD = Growing Degree Days. Best performing models are in bold text.

Model	Variables	Rank	AIC	Δ AIC	AICw
16	GDD + PRECIPITATION + GDD:PRECIPITATION + % DEAD + RESTORATION TYPE	1	285	0	5.55E-01
13	GDD + % DEAD + RESTORATION TYPE	2	288	2.53	1.57E-01
15	GDD + PRECIPITATION + % DEAD + RESTORATION TYPE	3	288	2.73	1.42E-01
6	GDD + % DEAD	4	290	5.29	3.93E-02
5	GDD + PRECIPITATION	5	291	5.79	3.06E-02
11	GDD + PRECIPITATION + % DEAD	6	291	5.79	3.06E-02
7	GDD + RESTORATION TYPE	7	292	6.55	2.09E-02
1	GDD	8	292	7.32	1.43E-02
12	GDD + PRECIPITATION + RESTORATION TYPE	9	293	7.78	1.13E-02
14	PRECIPITATION + % DEAD + RESTORATION TYPE	10	306	20.9	1.61E-05
9	PRECIPITATION + RESTORATION TYPE	11	309	24.23	3.03E-06
8	PRECIPITATION + % DEAD	12	325	39.94	0.00E+00
2	PRECIPITATION	13	327	41.67	0.00E+00
3	% DEAD	14	342	56.95	0.00E+00
4	RESTORATION TYPE	15	342	57.09	0.00E+00
10	% DEAD + RESTORATION TYPE	16	344	58.95	0.00E+00

Table B 4.3 Akaike's Information criterion (AIC) values from candidate models to predict the total amount of fruit present on a tree. AIC: AIC score; Δ AIC: difference between the current and best model; AICw: Akaike weight; (*) denotes interaction term. GDD = Growing Degree Days. Best performing models are in bold text.

Model	Variables	Rank	AIC	diff	AICw
13	GDD + % DEAD + RESTORATION TYPE	1	572	0	4.12E-01
16	GDD + PRECIPITATION + GDD:PRECIPITATION + % DEAD + RESTORATION TYPE	2	573	1.58	1.86E-01
7	GDD + RESTORATION TYPE	3	574	2.05	1.48E-01
15	GDD + PRECIPITATION + % DEAD + RESTORATION TYPE	4	575	2.9	9.68E-02
5	GDD + PRECIPITATION	5	576	4.44	4.48E-02
11	GDD + PRECIPITATION + % DEAD	6	576	4.44	4.48E-02
12	GDD + PRECIPITATION + RESTORATION TYPE	7	577	5.02	3.35E-02
1	GDD	8	578	6.23	1.83E-02
6	GDD + % DEAD	9	579	7.07	1.20E-02
14	PRECIPITATION + % DEAD + RESTORATION TYPE	10	583	10.8	1.86E-03
9	PRECIPITATION + RESTORATION TYPE	11	584	11.79	1.13E-03
8	PRECIPITATION + % DEAD	12	585	12.7	7.19E-04
2	PRECIPITATION	13	586	13.94	3.87E-04
3	% DEAD	14	589	17.56	6.33E-05
4	RESTORATION TYPE	15	591	18.99	3.09E-05
10	% DEAD + RESTORATION TYPE	16	592	19.7	2.17E-05

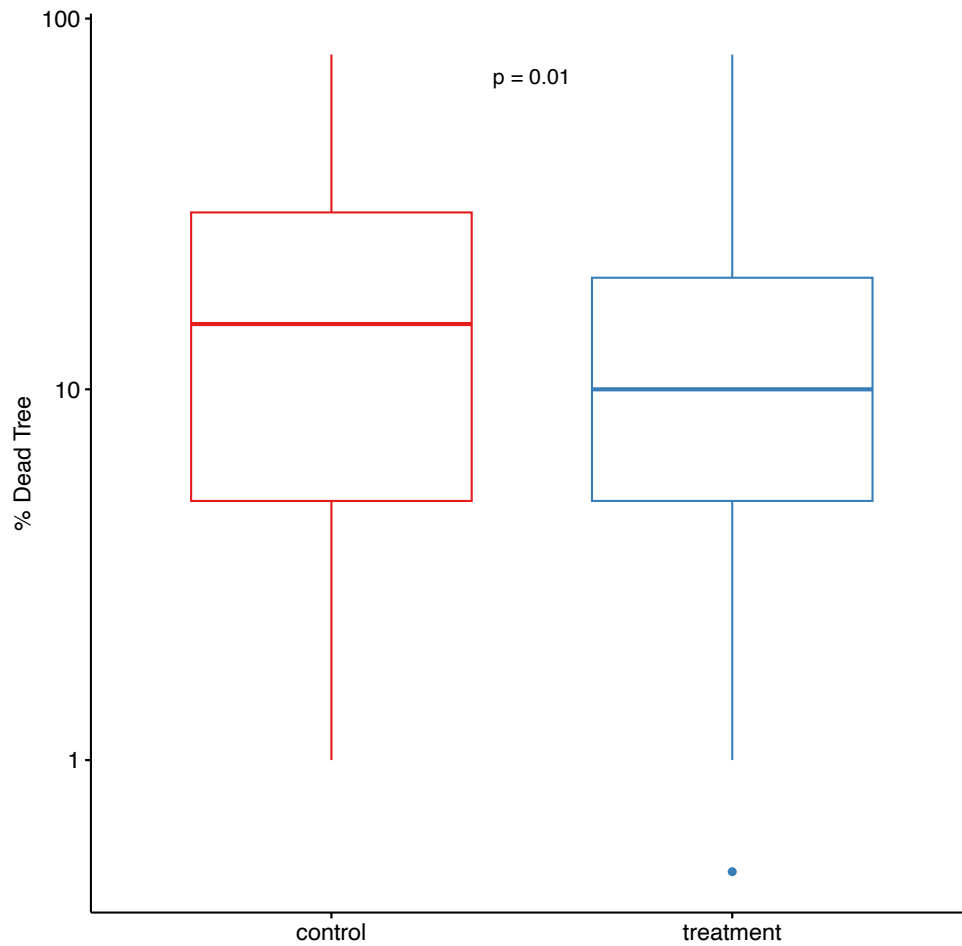


Figure B 4.1 A boxplot of the percent of tree that was recorded dead with restoration treatments (blue) and without (control; red). Boxplots show median value (solid horizontal line), upper and lower quartiles (box), and maximum and minimum values recorded (whiskers). There was a significant difference between restoration and controls.

Appendix C

Below is sample decolonization reading list. This was not assembled by me, it was shared by an anonymous reviewer.

Unsettling Canada	Arthur Manuel
The Reconciliation Manifesto: Recovering the Land, Rebuilding the Economy	Arthur Manuel
Indigenous Writes	Chelsea Vowel
Indigenous Nationhood: Empowering Grassroots Citizens	Pam Palmater
The Winter We Danced: Voices from Past, Future, and Idle No More	The Kino-nda-niimi
Collective Peace, Power, Righteousness: An Indigenous Manifesto	Taiaiake Alfred
Bury My Heart at Wounded Knee	Dee Brown
Medicine Unbundled	Gary Geddes
As We Have Always Done: Indigenous Freedom through Radical Resistance	Leanne Betasamosake Simpson
Red Skin, White Masks: Rejecting the Colonial Politics of Recognition	Glen Sean Coulthard
Unsettling the Settler Within: Indian Residential Schools, Truth Telling	Paulette Regan
Memory Serves	Lee Maracle
My Conversations with Canadians	Lee Maracle
Clearing the Plains: Disease, Politics of Starvation, and Loss of Aboriginal Life	James Daschuk
Restoring the balance: First Nations women, community, and culture	Gail Valaskakis
Maps and Dreams	Hugh Brody
Chaos Inside Thunderstorms	Garry Gottfriedson
In The Rapids: Navigating the Future of First Nations	Ovide Mercredi
We are the Dreamers	Rita Joe
Inconvenient Indian: a Curious Account of Native People in North America	Thomas King
Comparing Mythologies	Tomson Highway
Settler: Identity and Colonialism in 21st Century Canada	Emma Lowman, Adam Barker
Surviving Canada: Indigenous Peoples Celebrate 150 Years of Betrayal	Myra Tait
The right relationship: reimagining the implementation of historical treaties	John Borrows
Returning To the Teachings: Exploring Aboriginal Justice	Rupert Ross
Decolonizing Education: Nourishing the Learning Spirit	Marie Battiste
Alliances: Re/Envisioning Indigenous-non-Indigenous Relationships	Lynne Davis
Critically Sovereign: Indigenous Gender, Sexuality, and Feminist Studies	Joanne Barker
Beyond Settler Time: Temporal Sovereignty and Indigenous Self-Determination	Mark Rifkin
What We Have Learned: Principles of Truth and Reconciliation	Murray Sinclair
Price Paid: The Fight for First Nations Survival	Bev Sellars
500 Years of Indigenous Resistance	Gord Hill
Canada's First Nations: A History of Founding Peoples from Earliest Times	Olive Dickason
As Long as This Land Shall Last: A History of Treaty 8 and 11	Rene Fumoleau

The Fourth World	George Manuel, Michael Posluns
A Narrow Vision: Duncan Campbell Scott and Admin of Indian Affairs In Canada	Brian Titley
Our Elders Understand Our Rights: Exploring Int. Law Re: Indigenous Rights	Sharon Venne
All Our Relations: Native Struggles for Land and Life	Winona LaDuke
The Winona LaDuke Chronicles	Winona LaDuke
First Peoples Law	Bruce McIvor
Whose Land Is It Anyway? A Manual for Decolonization	Peter McFarlane, Nicole Schabus
A Tortured People: The Politics of Colonialism	Howard Adams
Struggle for the Land: Native North American Resistance to Genocide, Ecocide	Ward Churchill
Kill the Indian, Save the Man: The Genocidal Impact of Residential Schools	Ward Churchill
The Imaginary Indian: The Image of the Indian in Canadian Culture	Daniel Francis
Entering the War Zone: A Mohawk Perspective on Resisting Invasions	Donna Goodleaf
In Defense of Mohawk Land: Ethnopolitical Conflict in North America	Linda Pertusati
Accounting for Genocide: Canada's Bureaucratic Assault on Aboriginal Peoples	Dean Neu, Richard Therrien
Gustafsen Lake Under Siege	Janice Switlo
Blood of the Land: The Government and Corporate War Against First Nations	Rex Weyler
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