

Using GIS modelling as a tool to search for late Pleistocene and early Holocene archaeology on  
Quadra Island, British Columbia

by

Colton Vogelaar  
B.A., University of British Columbia, 2015

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of  
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in the Department of Anthropology

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## **Abstract**

The archaeological sites that inform the hypothesized coastal route of entry to the Americas are limited, with fewer than twenty sites older than 11,500 years before present on the Northwest Coast of North America. Late Pleistocene and early Holocene archaeological sites are hard to find in this expansive, remote, and heavily forested area due to the complexity of paleoenvironmental change since the last glacial maximum. The study area for this thesis, Quadra Island, in the Discovery Islands, lies in the middle of a gap in knowledge about this time period. Changes in relative sea level have proven to be especially important for early site location on the coast. Predictive modelling has been used to search for new archaeological sites on the Northwest Coast, and is a basic component of cultural resource management practices in British Columbia. Such quantitative modelling can aid in archaeological site survey, but must be used critically.

This study integrates quantitative and qualitative modelling with a heuristic method to incorporate more humanistic modelling theory and address some critiques of a traditional predictive modelling approach. In this study, quantitative modelling highlighted target areas which were then evaluated by qualitative modelling. A selection of targets were then subjected to focussed archaeological survey to evaluate methodology, results, and search for new sites. This method is important theoretically because modelling is explicitly used only as a tool and does not label the landscape with values of potential. Modelling was applied in two areas of Light Detection and Ranging (LiDAR) data which collectively host more than 4,000 kilometres of potential paleo-coastline. Fifteen new archaeological sites were found during this study, with at least two sites radiocarbon dated to ca. 9,500 calibrated years ago. This methodology could be applied in different archaeological contexts, such as underwater and in different coastal regions. The results of this study have important implications for coastal First Nations and implications for cultural resource management in the province.

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*DILA Approved*

## **Chapter 1: Introduction**

The Northwest Coast of North America is a dynamic place, inhabited by Aboriginal peoples since time immemorial. Archaeological evidence from the late Pleistocene, which can be defined as before 10,000 radiocarbon years ago (ca. 11,500 calendar years ago), is sparse, and comes from 16 sites in an area stretching from the north end of the Alaskan Panhandle to the mouth of the Columbia River (Mackie et al. 2011; see Table 2). More archaeological sites must be found in order to further our understanding of local Northwest Coast culture histories, find more evidence of the first peopling of the Americas, and augment evidence of Aboriginal title to the land.

On the Northwest Coast, the environment has undergone extreme change since the last glacial maximum. One of the most significant of these has been changing relative sea level. Sea levels on the Northwest Coast have ranged from ca. 150 metres below to ca. 200 metres above modern sea level, sometimes contemporaneously (Shugar et al. 2014). Typically, Pleistocene archaeological sites would now be located underwater due to the ca. 120 metre eustatic sea level rise after the last glacial maximum (Peltier and Fairbanks 2006), however, in ice-proximal areas where relative sea level was higher than modern due to isostatic depression, Pleistocene sites are now stranded at various elevations (see Section 2.1.1, starting page 13 for further discussion). Pleistocene-aged archaeology would more likely be discoverable in these now-terrestrial areas versus underwater ones due to access and funding constraints. The study area for this thesis is located around Quadra Island, British Columbia, where relative sea level was higher during the late Pleistocene and early Holocene, making archaeological survey and investigation of the early period more viable.

Archaeological site location and preservation are controlled by complex interactions between environmental, social, and biological processes. Therefore, it is essential to have an understanding of the ancient environment in order to search for sites. To find more sites in specific spatial and temporal contexts, GIS modelling and predictive modelling have been used to aid in site discovery. GIS modelling approaches site reconnaissance from a computational, quantitative view, which can be combined with an archaeologists' own 'mental model', built from knowledge and experience about site location.

This study broadly examines GIS modelling for archaeological site survey on the Northwest Coast of North America. In particular, it uses GIS modelling as a tool to explore aspects of high resolution late Pleistocene – early Holocene paleoecological data to heuristically aid in archaeological site survey. Rather than approach GIS modelling from a completely quantitative point of view, I combine quantitative and qualitative modelling to make predictions about site location. The quantitative modelling variables, namely, coastline complexity and wind fetch, are inspired by a humanistic view of the landscape and aspects of the paleoenvironment that may be important to site location. These variables also incorporate ideas about site survivorship and cultural deposition. Target areas were highlighted by quantitative modelling and were then subjected to qualitative modelling, including human behavioural models, site and landform formation models, and expert judgement. Assessed targets were then selected for focused archaeological survey.

Each new late Pleistocene – early Holocene archaeological site found on the Northwest Coast adds to our knowledge of this poorly known period. This study area lies in a gap in late Pleistocene – early Holocene archaeological knowledge that stretches from Vancouver to the Central Coast of British Columbia (see Figure 13, Page 50). Finding new sites adds to

knowledge in this regional area, contributes to local archaeological culture histories, and supports Aboriginal rights and title cases.

The results of this study suggest that a heuristic and humanistic approach to GIS modelling is a productive avenue for focusing late Pleistocene – early Holocene archaeological survey in the future. Further, this study highlights the potential for important late Pleistocene – early Holocene archaeological sites located in counter-intuitive areas, and suggests this has important implications for cultural resource management (CRM) practices and Aboriginal land, rights, and title cases.

## 1.1 Research Questions

The questions that this study aims to address are as follows:

*Can using GIS modelling as a tool to apply paleoenvironmental knowledge to the current landscape aid in late Pleistocene – early Holocene archaeological site survey?*

The main question of this study addresses the capabilities and practicalities of using GIS modelling as a tool to locate sites. It also addresses whether the methods used in this study are effective for finding late Pleistocene – early Holocene coastal archaeology on the Northwest Coast.

*Can using GIS modelling tools and qualitative modelling together help address some of the downfalls of predictive modelling?*

This question examines the methodology employed in this study. Can quantitative and qualitative modelling be combined in a practical methodology? What can be learned about the processes involved in predictive modelling and what are the potential impacts of model output

and results? This study aims to use high resolution paleoenvironmental knowledge and GIS exploration and application of that knowledge to understand the landscape at a more human scale, incorporating anthropological theory and formation processes.

*What are important factors involved in late Pleistocene – early Holocene coastal site location?*

This question aims to synthesize the results and findings from the literature and from this thesis. This addresses the approaches that are important for finding new early period coastal sites, and the implications this might have for the future.

## 1.2 Chapter Organization

The chapters of this thesis are organized as follows:

Chapter 2 outlines the background and literature review for three main areas of research related to this study: paleoecology, archaeology, and GIS modelling. Within this chapter is the first “false start” section, which narrates some of the future directions, theoretical implications, and breadth of possibilities for graduate study that were explored through the course of this study. Every thesis reflects the changing ideas and emergent insights that come with full immersion in a subject for a period of time. In the same fashion as a false start in a 100 metre sprint, each false start section explores an aspect of study that was keenly jump-started and subsequently jogged off due to realizations about the scope of this study, the time involved, and the methodological and learning process required. However, such false starts served as important platforms for learning and significant examples of the different ways in which this study could be advanced, changed, built on, and succeeded, and therefore, documenting them may prove valuable to future researchers.

In Chapter 3, I move on to discuss the anthropological, archaeological, modelling, and earth sciences theory that informed this study. A critique of GIS modelling is at the core of the methodology used in this thesis. This critique guided the approach to quantitative and qualitative modelling and the use of a heuristic methodology. Further, prior knowledge, insights gained from graduate courses at the University of Victoria, and the perspectives of my supervisory committee influenced the theoretical direction of this study.

Chapter 4 reviews the methods used in this study, from quantitative modelling to qualitative modelling, and archaeological survey. Each method is outlined, with special attention to the quantitative modelling undertaken, so that it could be easily replicable.

Chapter 5 reports on the results of this study—first of the GIS modelling and next of the archaeological survey. The results of GIS modelling are reported in both summary form and in the form of case studies of particular sites. This flows into the results of the archaeological survey, where full archaeological reports will be referenced (e.g., DILA, in prep) that include more detailed information about individual sites and findings.

Chapter 6 evaluates the results of GIS modelling and archaeological survey, putting them into context with each other and the existing literature. Here I discuss the implications of the results, review problems, and start to make conclusions about what this study contributes to the understanding of the early period on Quadra Island.

Chapter 7 makes conclusions about the results of this study and situates them within the broader discipline. This research may have implications for First Nations and cultural resource management in BC. This chapter also discusses the future directions of this research and the potential uses of and ways forward for GIS modelling and late Pleistocene – early Holocene archaeology on the Northwest Coast.

## **Chapter 2: Background and Literature Review**

The many different fields involved in this study necessitates a large background and literature review section, here divided into three main sections: paleoecology, archaeology, and GIS modelling. The main purpose of this chapter is to review the major themes and data that contributed to the understanding of GIS model construction, input, output, and interpretation, and also to review the literature that was incorporated into the quantitative modelling, qualitative modelling, and archaeological survey aspects of this study.

Quadra Island is the largest of the Discovery Islands, located on the inside passage on the coast of British Columbia, west of the BC mainland, and east of Vancouver Island. This thesis was completed as part of the larger Discovery Islands Landscape Archaeology (DILA) project, led by my co-supervisors, Dr. Quentin Mackie and Daryl Fedje. The study area of the DILA project includes all of Quadra Island and parts of the surrounding islands, including the eastern edge of central Vancouver Island (see Figure 1). An important data resource on Quadra Island is Light Detection and Ranging (LiDAR) data flown for the DILA project in 2014 for two areas, detailed in Figure 1. These areas of LiDAR data further focus the study area of the DILA project to north and south Quadra Island LiDAR areas. LiDAR is a technique that produces extremely accurate digital elevation models (DEM) by projecting high frequency laser pulses at the ground and recording their reflection from an accurate, differential global positioning system (DGPS) positioned receiving unit, typically mounted on an aircraft (Carey et al. 2006; Challis et al. 2011; Hesse 2010; Holden et al. 2002). The highly accurate ( $\pm 25$  cm vertical error) DEM is then stripped of vegetation using algorithms that separate data points that return from the ground versus data points that return from vegetation (Devereux et al. 2005; Devereux et al. 2008; Doneus et al. 2008). These data have been revolutionary for archaeology and many other

disciplines, such as forestry. Without the resolution of the LiDAR data, archaeological survey would be much more difficult and primarily field-based rather than quantitative due to issues of scale.

Scales of analysis:

One of the most important themes in this thesis is the idea that scale is important to consider in thinking about the paleoenvironment, especially in its relation to site location. For clarity, different scales are defined here: these are site, local, regional, and continental (see Table 1 below). The site scale includes the submetre resolution of the LiDAR DEM to 1 kilometre. The local-scale comprises 1 kilometre to 30 kilometres, for example, one of the LiDAR swathes. The regional-scale consists of the eastern portion of central Vancouver Island including parts of the Johnstone Strait and the Strait of Georgia, to the mainland, while the continental-scale refers to the Northwest Coast as a whole, and beyond. These scales are not meant as strict boundaries, but rather, qualitatively establish units of analysis to clarify the diversity of data, areas, and scales that are involved in this project.

Table 1: Scales of analysis referred to throughout this thesis.

<b>Scale:</b>	<b>Extent:</b>	<b>Area:</b>	<b>Examples:</b>
Site	Submetre – 1 km	1000 m <sup>2</sup>	Archaeological site boundary; Small Inlet
Local	1 km – 30 km	30,000 m <sup>2</sup>	One LiDAR swath
Regional	30 km – 300 km	30,000,000,000 m <sup>2</sup>	Discovery Islands; eastern Vancouver Island
Continental	300 km – 3000 km	900,000,000,000 m <sup>2</sup>	Northwest Coast; Yakutat Bay to Channel Islands



Figure 1: Location map for Quadra Island and the DILA study area.

## 2.1 Paleoecology

Although the DILA project is an archaeological project, the small number of previously recorded archaeological sites and other data for the early period means that paleoecological proxies play a large role in making inferences about what people would have been doing in this area before 10,000 years ago. Paleoecological investigation is an important aspect of the DILA project and an important source of data for this thesis. Building a more complete paleoecological picture enables a better understanding of the environments that humans would have lived in, and the human-environment interactions that may have taken place, allowing for better archaeological inferences and interpretations; perhaps especially for site location. Because of this, I completed a review of the paleoecology of a large area of the Northwest Coast through the late Pleistocene to the early Holocene. This review can be divided into two main sections: the abiotic environment, including geology, glaciology, and relative sea level change; and the biotic environment, including palynological data for flora, paleontological data for fauna, and finally, what these ancient environments imply for the humans who may also have been on this landscape.

### 2.1.1 Abiotic environment

#### Geology and tectonics:

The Northwest Coast is located along an active subduction zone which makes for complex geology and tectonics. Largely, the coast mountain range, including the Discovery Islands area, is made up of volcanic and metamorphic rock in different terranes that have been accreted to the continent (Cannings et al. 2011). The geology of Quadra Island is largely made up of volcanic and intrusive rocks such as basalt, diorite, and granodiorite, with some

sedimentary rock such as limestone in select areas (see Figure 2 below). These sedimentary areas host some karst caves. An important surficial geological unit is Quadra Sand, which covers the southern-most part of Quadra Island. Quadra Sand is a well sorted fine to coarse grained glacial outwash sand that blankets most of the Georgia depression from Quadra Island, south to Puget Sound, Washington (Clague 1976, 1977). Quadra Sand is overlain by till related to the LGM, and was deposited during the transition from interglacial to glacial conditions at the beginning of the Fraser Glaciation, ca. 30,000 years ago. The underlying geology and knowledge of the geological history contextualizes observations made in the field, and can contribute to our knowledge of site location, formation processes, and raw material used for lithics.

Tectonically, subduction of the Explorer, Juan de Fuca, and Gorda plates beneath the North American plate subjects the region to regular volcanic and seismic activity. Tectonic activity and mega-thrust earthquakes can result in major areas of subsidence and other landscape events such as landslides, slumping, uplift, tsunamis, liquefaction, and downdrops. Some of these events were observed around Quadra Island in 1946, after a 7.1 magnitude earthquake near Courtenay, 40 kilometres southwest away on Vancouver Island (Rogers 1980). The Gulf of Georgia region saw specific cases of downdrop on land and underwater, and many instances of liquefaction as a result of this quake (Rogers, 1980). The regular tectonic activity has proven to be a complicating factor for constructing the sea level history of local areas due to the potential for localized subsidence or other landscape changes. Travis Crowell considered these local tectonic effects in his M.A. thesis (2017) reconstructing local, high resolution sea level history in Kanish and Waiatt Bays on Northern Quadra Island. Crowell found differences in each bay's sea level history despite them being ca. one kilometre apart, due to differences in substrate, compaction, and subsidence (Crowell 2017, 23).

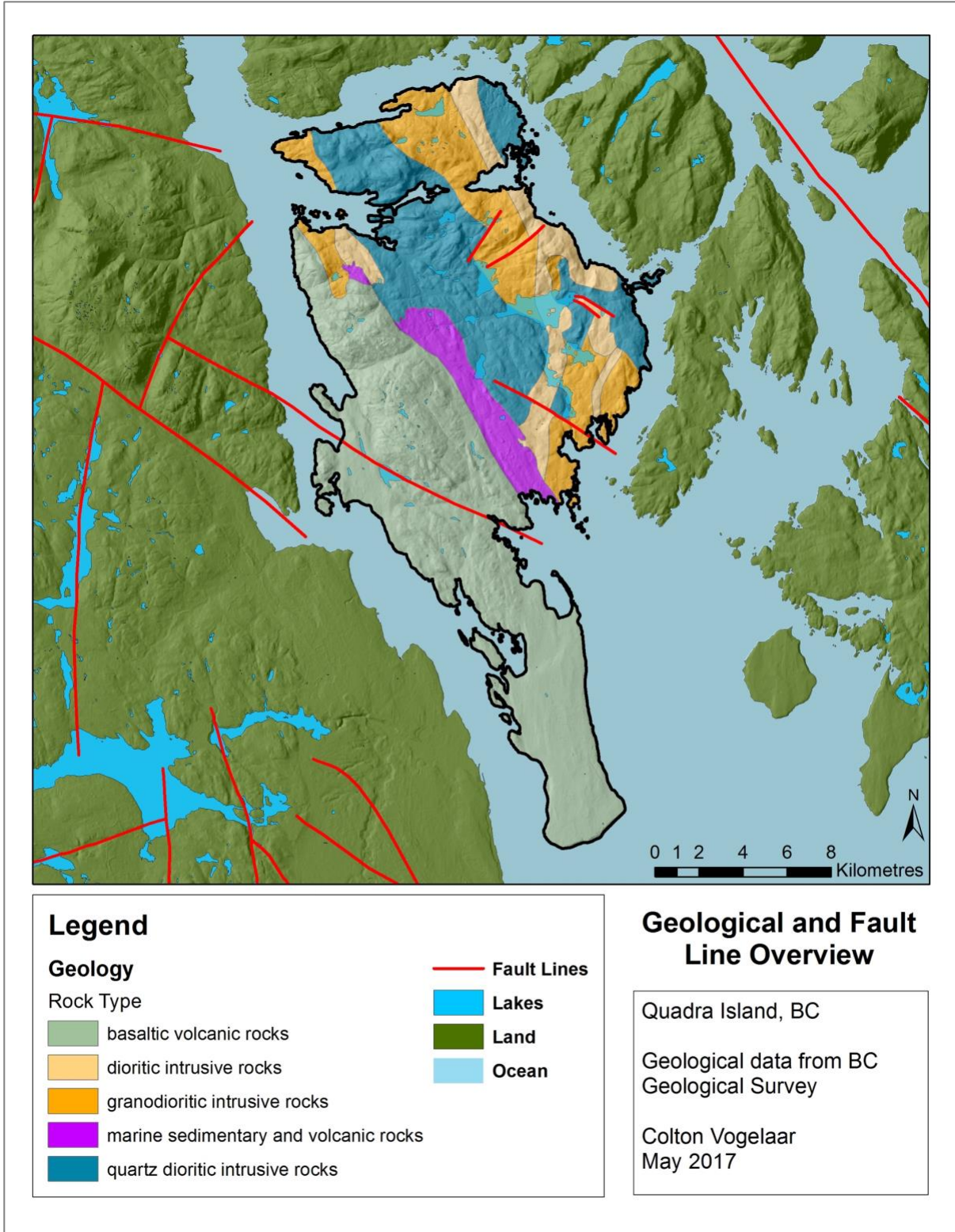


Figure 2: Map of Quadra Island geology and fault lines.

## Glaciology:

The latest period of glaciation in the Pleistocene is locally known as the Fraser Glaciation. Starting around 30,000 years ago, the Fraser Glaciation saw the coalescence of the Cordilleran ice sheet over much of British Columbia (Clague and James 2002). Clague and James (2002) review the history of the Cordilleran ice sheet in southern British Columbia. In

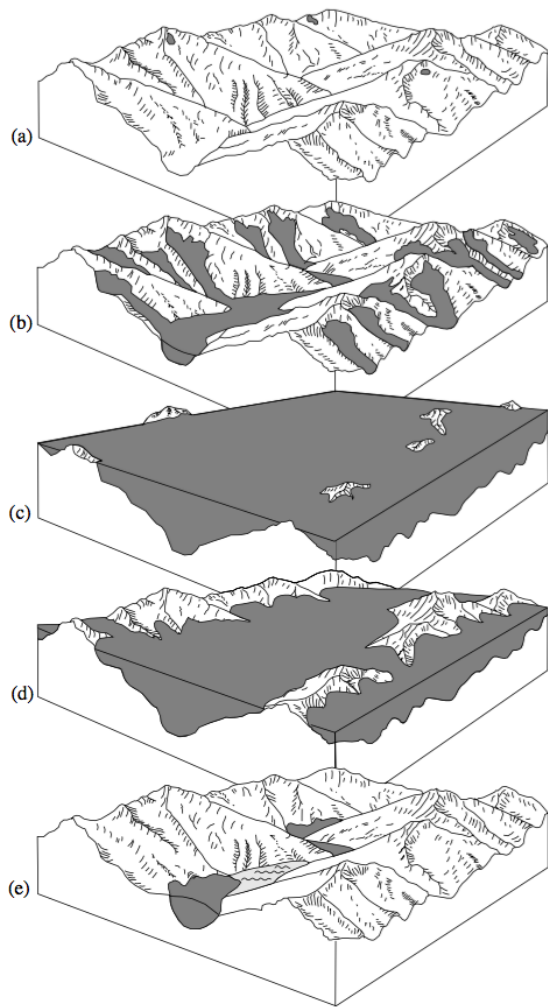


Figure 3: Model of ice sheet growth and decay from Clague and James 2002, 74. a) Beginning of glacial cycle. b) Development of a network of valley glaciers. c) Coalescence of ice sheet. d) Decay of ice sheet by downwasting. e) Residual ice left in valley.

general, ice grew from a network of valley glaciers and piedmont lobes which coalesced to form an ice sheet (Clague and James 2002, 74). The Cordilleran ice sheet reached its maximum thickness and extent around 17,000 – 16,000 years ago (Mood 2015, 6). After the last glacial maximum (LGM), the ice sheet decayed by downwasting, meaning that upland areas were ice-free before adjacent valleys (Clague and James 2002, 74). With more detailed resolution, one would see the overall process of growth and decay interspersed with local periods of advance, stability, and retreat.

In a recent study of the Holocene history of the Franklin Glacier, north of Quadra Island, up Knight Inlet in the Mt. Waddington area, Bryan Mood (2015) shows the complex history

of advance and retreat by dendrochronology of glacially sheared tree stumps at the glacier's margins. Mood (2015) shows that the Franklin glacier expanded at least nine times since 13,000 years ago, with periods of retreat in between periods of advance at 12.8, 6.3, 5.4, 4.6, 4.1, 3.1, 2.4, 1.5, 0.8, and 0.6 thousand years ago. This highlights the complexity of glacial growth and retreat through the study period of this thesis.

Ice would have filled the Strait of Georgia region during the LGM, but was rapidly deglaciated commencing ca. 15,000 years ago, facilitated by calving into the ocean (Clague and James 2002, 74). Most importantly, the weight of the Cordilleran ice sheet on the continental land mass isostatically depressed the continent, meaning relative sea level during the late Pleistocene and early Holocene was higher than modern, even as eustatic levels were lower. Latest Pleistocene and early Holocene glacier activity has proven to be very complex, with small advances and retreats due to climatic fluctuations at regional and global scales (Mood 2015). We can extrapolate this activity to earlier in the late Pleistocene, where small changes in glacial activity could mean micro-shifts in relative sea level and sedimentation due to climate. This complex landscape history means that paleoecological investigation on a regional and local-scale are very important to late Pleistocene – early Holocene archaeological research on the BC coast.

#### Relative sea level:

The major paleoecological research goal of the DILA project is to refine the sea level history of the area. Late Pleistocene coastal archaeological sites around the world are typically now submerged due to the ca. 120 metre eustatic sea level rise that occurred after the end of the last glacial maximum (Bailey and Flemming 2008; Peltier and Fairbanks 2006). However, near areas of major glaciation, the effects of local tectonic factors, isostatic depression, and rebound factors complicate the sea level history (Clague 1983; Clague et al. 1982). Because northern

North America was heavily glaciated during the Pleistocene, the relative sea level history is vastly different at the same time in different places along the coast (see Figure 4, McLaren et al. 2014).

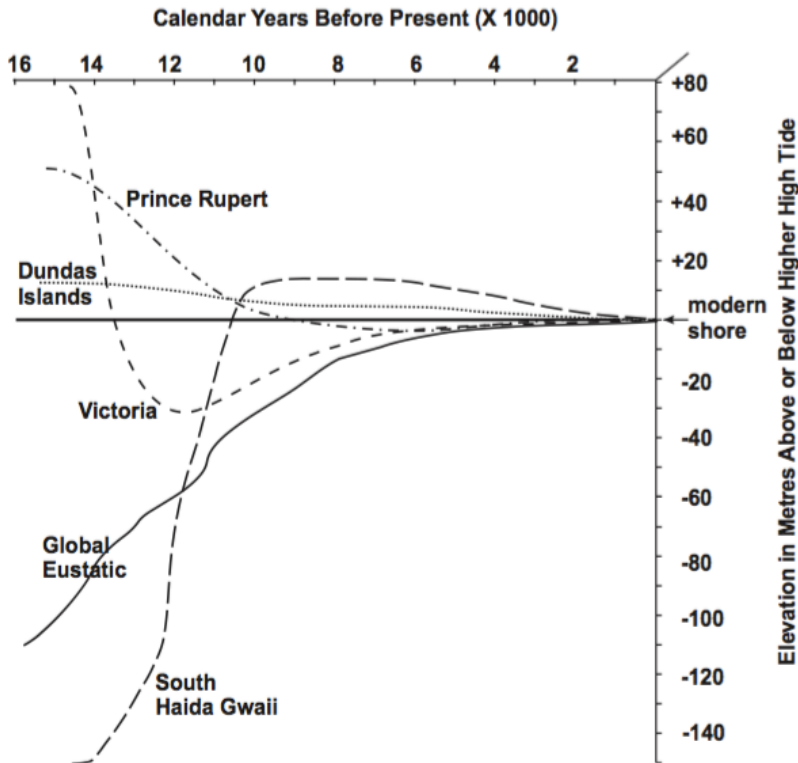


Figure 4: Relative sea level curves for coastal areas of British Columbia (McLaren et al. 2014, 149).

Although sea level history in the Discovery Islands is known at a coarse regional-scale (e.g., James et al. 2005; James et al. 2009), spatial and temporal variation and intricacies are important when dealing with relative sea level variability on a local or sub-regional scale. By coring and column sampling sediments at known elevations and looking for the remains of diatoms as a proxy for water salinity, the DILA project is establishing the local sea level history for Quadra Island at a finer resolution (see Figure 5a) (Fedje et al. 2016; Fedje et al. in prep), leading to a high resolution sea level curve that is localized to the region around Quadra Island (see Figure 5b). The DILA sea level history curve was established from 12 different

paleoecological locations from 195 metres above higher high tide (ahht) to 0.5 metres below hht. Results and elevations from archaeological sites and geological sections also contribute to the sea level history curve, resulting in high resolution spatially and temporally for Quadra Island.

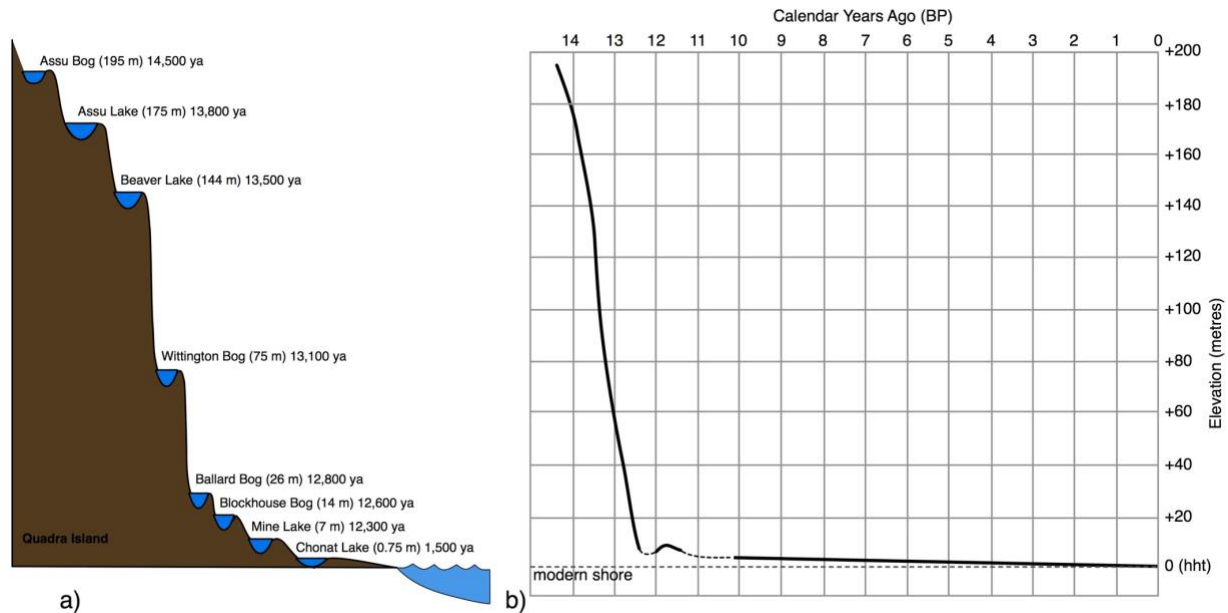


Figure 5: a) Sediment isolation basins cored during paleoecological investigation of the DILA project. b) The resulting sea level curve constructed from marine transition data points and other data (Fedje et al. 2016; Fedje et al. in prep).

The highest late Pleistocene sea level is termed the high stand, and was above 195 metres at ca. 14,500 years ago. After 14,500 years ago, sea level fell very rapidly, at 175 metres ca. 14,500 years ago, at 144 metres ca. 13,500 years ago, 75 metres ca. 13,100 years ago, 26 m ca. 12,800 years ago, 14 metres ca. 12,600 years ago, and 7 metres ca. 12,300 years ago (Fedje et al. in prep). During this time, sea level was falling an average of 8.5 centimetres per year. Around 12,000 years, sea level may have briefly and subtly transgressed. Relative sea level regressed slowly to modern in the next 11,000 years (Fedje et al. in prep). The effects of relative sea level change, in this case, regression, on the landscape can be seen in Figure 6, below. The change from a small broken up archipelago in the late Pleistocene to the current modern shoreline of what is now known as Quadra Island with sea level regression of almost 200 metres is dramatic.

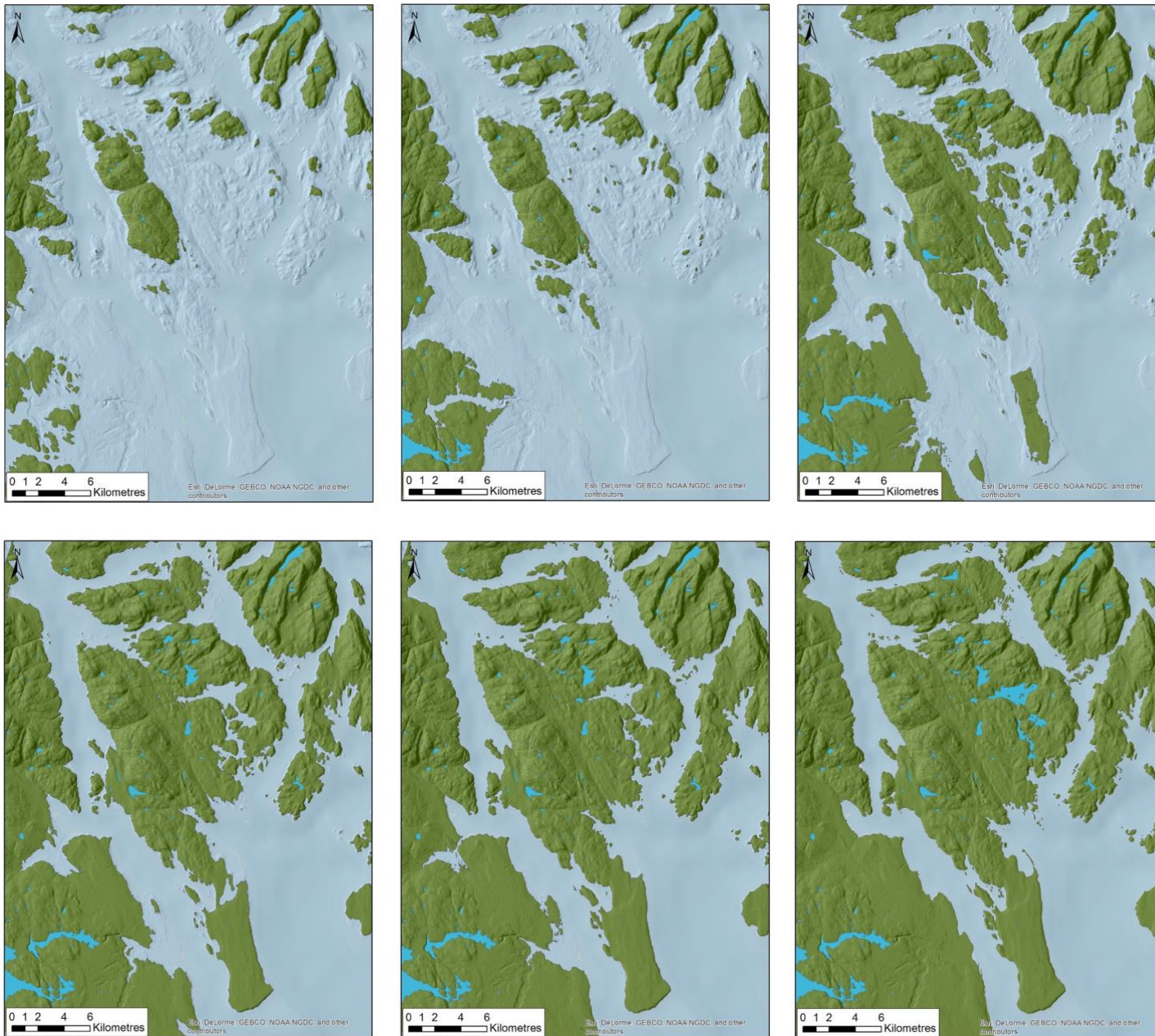


Figure 6: Flooded elevation models of Quadra Island. Top left to top right: Flooded to 195 metres (14,500 ya), flooded to 144 metres (13,500 ya), flooded to 75 metres (13,100 ya). From bottom left to bottom right: Flooded to 30 (12,800 ya), flooded to 14 metres (12,600 ya), and modern sea level.

Tides are also important to sea level history and site location. In the Quadra Island area, tidal range can be as much as 5.3 metres (Government of Canada, 2017). The most important tidal measure for archaeology is higher high water large tide (HHWLT; shortened in this thesis to higher high tide, hht). HHWLT is calculated as an average of the highest high tide from each year of prediction, making it a good measure for the highest possible tide in a given year (Government of Canada 2017). From four tidal stations around the perimeter of Quadra Island, the average HHWLT value is 2.04 metres above mean sea level (Datum CGVD28). When using sea level history data, this intertidal zone elevation data must be taken into account. Therefore, for this thesis and for the DILA project, elevations are typically reported as ahht, because it is more relevant archaeologically to exclude the intertidal zone as a living area.

With this sea level history and understanding of tides, we can better imagine and model the paleoecological history of Quadra Island and focus archaeological survey to places that would have been subaerial during the late Pleistocene and early Holocene. The terminal Pleistocene was a time of dynamic change on the Northwest Coast, where rapidly receding glaciers and regressing sea levels left new terrain to be colonized by plants and animals. Multi-proxy environmental evidence shows that the Younger Dryas climate interval further complicated climate during this period (Fedje et al. 2011 a). Climatic and other environmental evidence from data such as palynology and paleontology help to characterize the environment that humans would have lived in.

### 2.1.2 Biotic environment

An examination of floral and faunal evidence can contribute to a better understanding of local and regional paleoenvironments and their associated ecosystems. This review will explore the biotic environment in the form of floral and faunal data previously reported for the Pacific Northwest Coast of North America, focusing on the time period from ca. 18,200 – 7,800 cal. BP. Time period boundaries for this review have been chosen arbitrarily for data management and research purposes. Focusing on post-glacial time, this time period includes part of the last major glacial period, the Fraser Glaciation, through the terminal Pleistocene, and into the early Holocene. The timing of the last glacial maximum, or LGM, as defined by ice cover, varied locally (Clague et al. 2004), probably occurring earlier in the area of southeast Alaska and Haida Gwaii, and later along the west coast of Vancouver Island (Heaton and Grady 2003; McLaren et al. 2014). Thus, 18,200 cal. BP may include the final part of the LGM in some areas, but is considered post-glacial for the purposes of this review. The time period for this study ends at 7,800 cal. BP because generally, after this period, faunal populations were better established and climate was more stable, although relatively minor sea level fluctuations were still occurring. An assumption of this review is that the presence of top level terrestrial or marine predators and herbivores may have implications for the productivity of an ecosystem overall and that their presence may indicate a landscape that is viable for humans.

This review is meant to inform the understanding of the paleoenvironment around the Discovery Islands, British Columbia, and therefore, will focus on faunal data closest to this area. Major regions included in this review where significant paleontological and archaeological research has been carried out include: Southeast Alaska, Haida Gwaii, different areas of Vancouver Island, and Puget Sound, Washington. Faunal evidence has been split into two

regions, a northern region and a southern region. Both regions are detailed in Figure 7. The Discovery Islands are located in the northern half of the southern region. The northern region includes the area of southeast Alaska and Haida Gwaii and south to the northern tip of Vancouver Island. The southern region includes the area of Vancouver Island, and south to Puget Sound, Washington. I have summarized faunal data in two charts according to region (see Figure 8 and Figure 9). Each chart plots faunal remains by their calibrated BP date, showing the directly radiocarbon dated appearances of each species within the time frame and region. Radiocarbon dates were calibrated with Calib 7.1 software to 2-sigma error BP (Reimer et al. 2013) or published calibrated ranges were used. Importantly, this review did not include fish, shellfish, or bird species due to the scope of this thesis. Fish, shellfish, and birds would have been important and abundant resources on the coast throughout the time period, and were likely a major resource for early coastal peoples. The presence of these resources is elaborated below. Most faunal remains included in this review were directly radiocarbon dated or associated with archaeological strata that were directly radiocarbon dated to within the time period of study. However, it is recognized that there is further evidence that is not necessarily radiocarbon dated, but dated stratigraphically or constrained within a range of radiocarbon dates. This review does not exhaustively include every single dated faunal element, but rather, has used the literature to capture most of the directly dated paleontological and archaeological fauna that have been radiocarbon dated to older than 7,800 cal. BP.

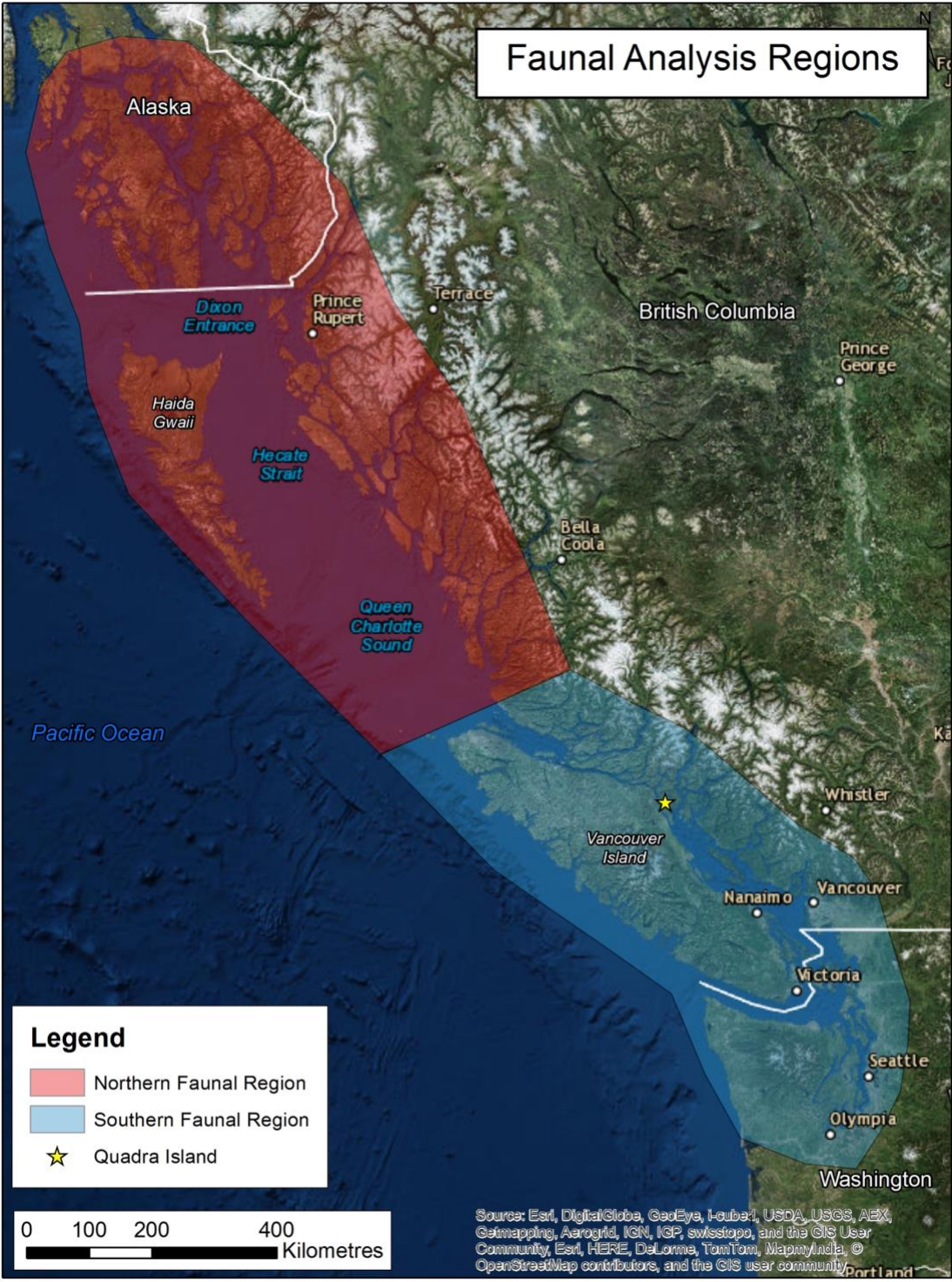


Figure 7: Location map of northern and southern faunal analysis regions.

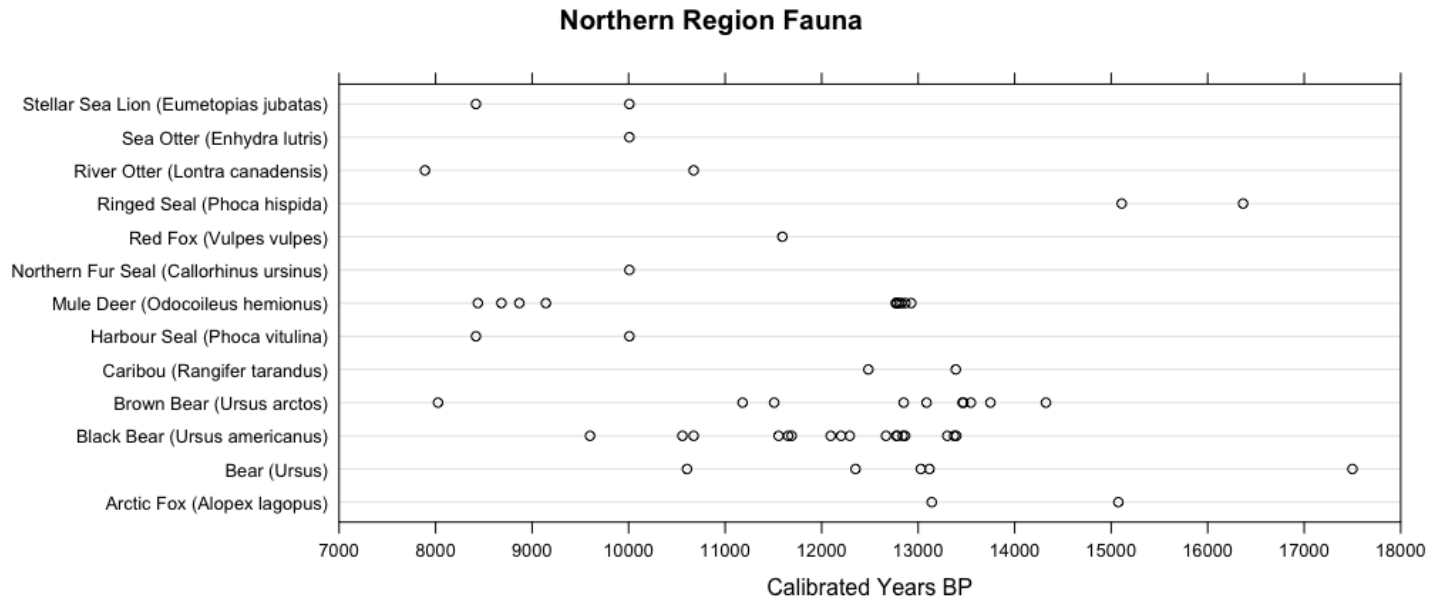


Figure 8: Faunal data collected for the northern region excluding fish, shellfish, and birds. Includes data from: Cannon 1996; Fedje et al. 2001; Fedje et al. 2011a; Heaton and Grady 2003; Ramsey et al. 2004; and Wigen 2005.

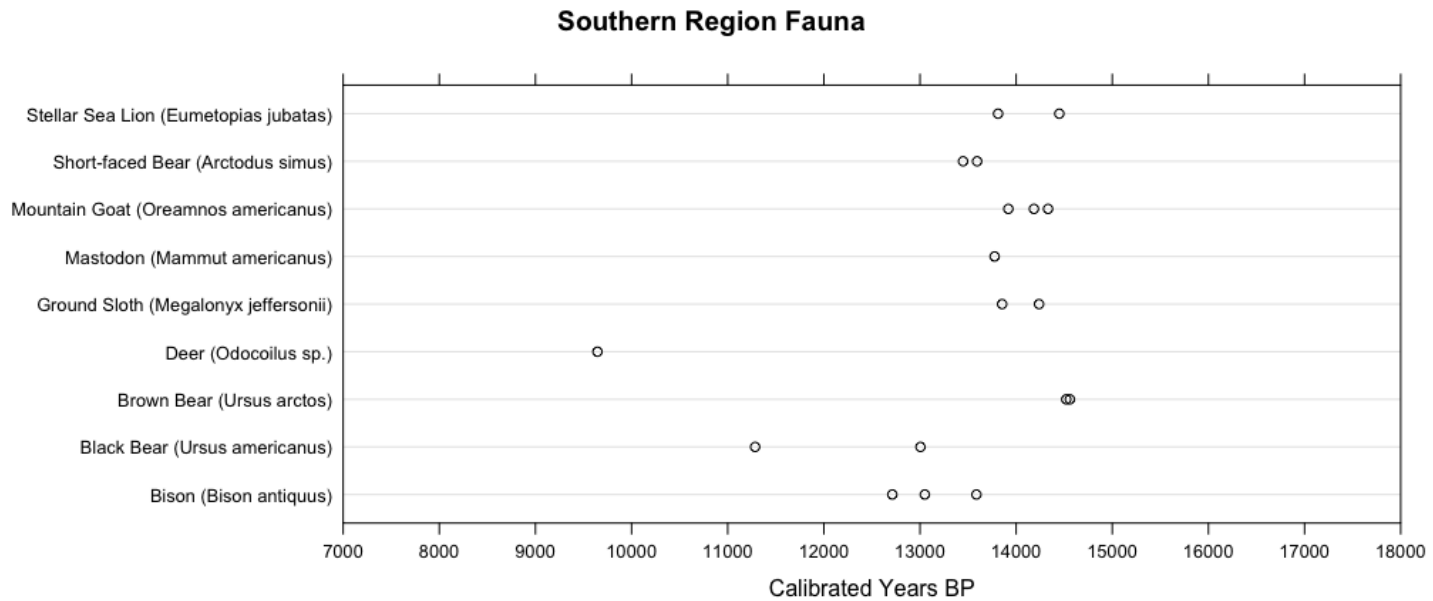


Figure 9: Faunal data collected for the southern region excluding fish, shellfish, and birds. Includes data from: Al-Suwaidi et al. 2006; Gustafson et al. 1979; Harington et al. 2004; Kenady et al. 2011; Nagorsen et al. 1995; Nagorsen and Keddie 2000; Steffen and McLaren 2008; Waters et al. 2011a; Wilson et al. 2009.

Understanding the presence and absence of different fauna throughout time can contribute to our understanding of the environment and landscape that people lived in along the coast during the early post-glacial period. This view can also inform predictive modelling in the Discovery Islands, specifically modelling for early post-glacial sites.

Faunal evidence has typically been found in cave deposits in karst terrain areas of the coast, or in archaeological contexts. Certain conditions are required for fossil preservation, with karst cave deposits typically having the right conditions for preservation. There are two main ways in which faunal material is deposited in caves. Firstly, animals and sediment can fall into a cave through accidents, natural traps, or collapse (Steffen and McLaren 2008). Secondly, carnivores may use the cave as a den or shelter, dragging in meals or using the cave for hibernation, with natural mortality adding carnivore bones (Heaton and Grady 2003, 19). Caves are also attractive places for humans (e.g., for hunting) (McLaren et al. 2005). Preservation of faunal material in karst caves is then supported by karst water chemistry, fluvial or colluvial sedimentation, and typically protected circumstances inside caves.

Like the archaeological record and other records of the past, late Pleistocene–early Holocene faunal evidence is fragmentary. The most abundant faunal evidence for this period is of medium to large vertebrate species presumably because of their larger, robust bones. Therefore, reviewing the faunal evidence does not give us a complete picture of the past, but a partial one. However, understanding these biases and combining faunal evidence with other lines of inquiry can give us a better understanding of the past environment, climate, post-glacial life, and human view of the landscape.

Fish and shellfish would have been abundant and reliable marine resources throughout the late Pleistocene and early Holocene. A wide variety of fish and shellfish species have been

documented both paleontologically and archaeologically along the Pacific Northwest Coast for the early period (e.g., Fedje et al. 2011a; Heaton and Grady 2003; Hetherington and Reid 2003; Roy et al. 1995; Steffen 2006; Wigen 2005). Evidence of rapid recolonization of inland, salt water, and fresh water areas after glaciation (Halfmann et al. 2015) suggests that fish and shellfish could have been utilized by humans throughout the study period, and species compositions have not substantially changed throughout the time period. Therefore, this analysis has not included fish or shellfish based on this assumption, and the increased scope of including fish and shellfish in this review.

Similarly, evidence suggests that migratory birds and local birds were exploited during the time period in question (Heaton and Grady 2003; Heaton 2007, Wigen 2005), however, birds have been excluded from this review due to the scope of this thesis, the variety of species and number of elements identified. Birds would have been an abundant and important resource for late Pleistocene – early Holocene people on the Northwest Coast. However, unlike fish and shellfish, the species present on the coast in the late Pleistocene and early Holocene versus today have likely changed due to climatic shifts and habitat location changes. Madonna Moss and Jon Erlandson (2013) make the case for abundant migratory bird habitat on the coast in late Pleistocene – early Holocene times due to ice sheet coverage at their present-day nesting and breeding grounds in the arctic and the cooler, wetter, climate supporting more wetlands than the present.

They further suggest that crescents, an early period lithic tool type could have been specifically used as a projectile point for hunting birds. Crescents are part of the Western Stemmed Tradition of the American west, and have been found in areas of California, the Great Basin, Oregon, and as far north as central Washington (Moss and Erlandson 2013, 177), with

some perhaps further north in BC. If crescents were used as bird hunting points, this may suggest that bird resources could have been a very important resource for late Pleistocene – early Holocene people. Elsewhere in the Americas, researchers have suggested that migratory birds were a staple resource, and that some early period site distributions may be understood as hunters tracking such birds (Dincauze and Jacobson 2001). Additionally, migratory birds could have indicated to humans that southward resources existed beyond the horizon (Fiedel 2007).

Recognizing that the fragmentary nature of the late Pleistocene—early Holocene vertebrate faunal record on the Northwest Coast limits interpretation, faunal data interpreted in conjunction with paleoenvironmental analyses, such as palynological analysis, can be a useful indicator of the productivity and habitat of past environments. Broadly, palynological evidence for the coastal plain area show a succession of herb tundra, to pine forest, to more complex coniferous forests with dominant species changing according to climate.

In a synthesis of pollen evidence from different cores around Vancouver Island and the Fraser Valley, Brown and Hebda (2002) show that post-glacial vegetation in the southern coastal plain region broadly consisted of pine dominated forest, followed by pine–spruce–fir–hemlock, succeeded by Douglas-fir–alder–bracken, and next, western hemlock–spruce–fir (Brown and Hebda 2002). At Bear Cove Bog, Port Hardy, on the northeast of Vancouver Island, pollen from core samples is divided into four distinct zones (three of which fall within the time period of this review) (Hebda 1983). The earliest zone identified by Hebda (1), starting around 14,000 BP and continuing to about 11,500 BP, is dominated first by lodgepole pine (*Pinus contorta*) (Hebda 1983, 3183). Lodgepole pine rapidly colonize and reproduce on immature soils—being one of the first trees to invade new territory—typical of a recently deglaciated environment (Heusser 1983, 876). Hebda (1983, 3183) states that pine and other indicator species suggest a cooler and

slightly drier environment, with bracken fern (*Pteridium aquilinum*) spores suggesting relatively open vegetation. Alder (*Alnus*) lags slightly behind pine, but is still an important forest tree during this period (Hebda 1983, 3183). The next zone (2), from 11,500–8,000 BP, is characterized by spruce (*Picea*) and hemlock (*Tsuga*) displacing pine but not alder, suggesting a more humid environment (Hebda 1983, 3184). Lastly, the third zone (3), 8,000–7,000 BP, suggests a Holocene warm interval with the arrival of Douglas-fir (*Pseudotsuga*), where Douglas-fir and Sitka spruce (*Picea sitchensis*) were probably the dominate forest trees (Hebda 1983, 3185). Similarly, Lacourse (2005) defines three chrono-zones between 14,900 cal. BP and 8,630 cal. BP in her pollen analysis of a core from Misty Lake, on northern Vancouver Island. Zone M-1 is defined by high values of lodgepole pine, with ferns, grasses, and sedges playing minor roles (Lacourse 2005, 109). A larger diversity of species is represented in Zone M-2, with red alder, spruce, and hemlock constituting significant percentages (Lacourse 2005, 112). Lastly, Zone M-3 encompasses the maximums of spruce and red alder, with increases in western hemlock (Lacourse 2005, 112).

Notable in these findings is the typical absence of western redcedar (*Thuja plicata*) during this time period, except in the most southerly areas. Hebda and Mathewes (1984, 712) describe cedar moving from the south up into the area around Bear Cove, on northeast Vancouver Island, around 6,000 years ago, and only becoming more dominant by 4,000 years ago. This is significant as western redcedar is an extremely important cultural resource from the later Holocene to today, but is absent during this study period.

On the north coast on Haida Gwaii, palynological evidence suggests an earlier deglaciation. The earliest evidence for vegetation in this area is at Cape Ball, on north east Graham Island, with rushes (*Juncus*) herbs (e.g., *Caryophyllaceae*, *Rumex*) pondweed

(*Potamogeton filiformis*) and algae (*Chara*) in laminated sand and clay sediments at ca. 18,000 cal. BP (Warner et al. 1982). Paleoecological evidence from the continental shelf off the east coast of Haida Gwaii indicates that the shelf was subaerially exposed during the late Pleistocene (Lacourse et al. 2005). Palynological evidence from this region indicates herb tundra dominated by sedges after deglaciation at ca. 16,600 cal. BP (13,750 <sup>14</sup>C years BP), followed by dwarf shrub tundra after ca. 16,200 cal. BP (13,500 <sup>14</sup>C years BP) (Lacourse et al. 2005). Subsequently, increasing Pteridophytes (including ferns) in a lodgepole pine (*Pinus contorta*) forest at ca. 15,500 cal. BP (13,000 <sup>14</sup>C years BP), changed to co-dominant pine–alder forest with developing spruce by ca. 13,300 cal. BP (11,500 <sup>14</sup>C years BP) (Lacourse et al. 2005). This evidence indicates that areas around Haida Gwaii may have been ice-free earlier than areas in the southern region, but would have been a tundra-like environment. Studying a core from Hippa Island, Haida Gwaii, J. Michelle Delepine (2011) and Terri Lacourse and colleagues (2012) found tundra-like herb vegetation from ca. 14,000 to 13,230 cal. BP including sedges (*Cyperaceae*), mugworts (*Artemisia*), and willow (*Salix*). A transition to open pine woodland occurred ca. 13,000 cal. BP and is followed by increases in alder and spruce (Delepine 2011; Lacourse et al. 2012). During the Younger Dryas, there is a decrease in pine and a minor increase in ferns and herbs (Delepine 2011). Subsequently, there was a sharp change in vegetation from pine, alder, and sedges to spruce, hemlock, and skunk cabbage (*Lysichiton americanus*) (Delepine 2011). Despite documented climate changes in other areas, this vegetation community was relatively stable until an increase in cypress (*Cupressaceae*) and cedar (*Thuja plicata*) around 6,000 cal. BP (Delepine 2011; Lacourse et al. 2012).

In this review, I have focused on the vegetation variation through time on a north – south axis, however, there was likely variation through time on an east – west axis as well, which could

have an impact on areas at a regional and local-scale, such as Quadra Island. To account for or discuss these possibilities is outside the scope of this thesis, however, it would make for interesting future work on the Northwest Coast.

This dynamic time period is characterized by complex, changing climate and subsequent vegetational responses, along with deglaciation, Younger Dryas cooling and other climatic oscillations, and Holocene warming—which all occur in a relatively short period of time (Pellatt et al. 2002). These climatic fluctuations are characterized in the palynological evidence from cores along the coast. Most importantly, this evidence highlights the relationships between plant, animal, and human communities, along with both local-scale paleoenvironmental reconstructions, and larger scale processes of plant succession in newly deglaciated environments.

What do these faunal and paleoecological data say together? In the northern region, ringed seal (*Phoca hispida*), indicates still significant amounts of sea ice earlier than ca. 16,000 cal. BP (see Figure 8) at Shuká Káa (49-PET-408; On Your Knees Cave) in Southeast Alaska (Heaton and Grady 2003). From the faunal data, the first hint at deglaciation, or a paleoecological refugium, is a bear bone from K1 Cave, Haida Gwaii, dated to ca. 17,500 cal. BP with a semi-marine diet ( $14,390 \pm 70$   $^{14}\text{C}$  years BP) (Ramsey et al. 2004). Sea level and palynological evidence dates a herb tundra coastal plain in Hecate Strait at ca. 16,000 cal. BP (13,750  $^{14}\text{C}$  years BP) (Lacourse et al. 2005). Presence of Arctic fox (*Vulpes lagopus*) suggests a climate still cool after deglaciation. The early presence of both harbour seal and northern sea lion is significant for the area, as their present-day ranges can extend from California to Southern parts of Alaska, and may indicate more ice-free areas to the north and south.

Perhaps one of the most important inferences that can be made from certain faunal evidence is the keystone species inference. An ecosystem must be developed in order to support certain large keystone species, meaning that a range of assumptions can be made about lower trophic levels, prey species, and other resources on the basis of keystone evidence. Bears are a good example of a keystone species fauna, and in the northern region were present ca. 16,400 cal. BP, and constituted a significant population by ca. 14,300 cal. BP.

In the southern region, early evidence for Stellar Sea Lion (*Eumetopias jubatas*) has significant implications as a keystone predator. One found near Courtenay, British Columbia, was dated to 14,034 – 13,575 cal. BP (12,720 ± 70, 380 ± 50 marine res.) and one on Bowen Island, British Columbia, was dated to 14,944 – 14,063 cal. BP (13,180 ± 90, 410 ± 40 marine res.). The locations of these finds suggest ice-free marine areas on the inner east coast of Vancouver Island at this time, which is especially significant for Quadra Island, situated on the northern edge of this inner coastal plain.

Other data for the southern region show that by ca. 13,800 cal. BP (12,000 <sup>14</sup>C years BP), the northern Vancouver Island environment at Pellucidar Cave, in the Nimpkish Valley, could support three different species of bear (brown, black, and short-faced) indicating abundant terrestrial resources at least locally (Steffen and McLaren 2008). Significantly, this area may have been ice-free as early as ca. 16,000 cal. BP with radiocarbon dates on willow leaf and barnacle (Stafford and Christensen 2011). The habitat and resources necessary to support a large, omnivorous mammal such as a bear could be extended as evidence that humans could have exploited the same environments.

Broadly, there is greater evidence for large grazing species in the southern region of the coast, including multiple finds of bison, a ground sloth, and a mastodon. This may suggest a

greater availability of flat grassland plain environments in this region. In the northern region, glaciers and fluctuating sea level may have prevented large grazers from moving up the coast during this time period, and/or this evidence may now be underwater, especially in the Hecate Strait region. Some of the large mammal evidence is associated with humans. In Sequim, Washington, mastodon remains are associated with a possible bone point embedded in a rib bone (Waters et al. 2011a). This evidence, along with a possible bison butchery on the San Juan Islands (Kenady et al. 2011; Wilson et al. 2009), suggest that humans were present in this coastal plain zone by ca. 13,800 years ago. Quadra Island is situated along the edge a coastal plain that probably extended down to the Puget Sound area in Washington, while being cut by glacial melt channels and rivers such as the Fraser. The remnants of this plain still exist on eastern Vancouver Island north of Nanaimo, with potential paleoshorelines present going downslope from ca. 150 metres to the current sea level (Q. Mackie pers. comm. 2017). This was probably a much different environment compared to that along the west coast of Vancouver Island, which is more rugged topographically. Similarly, the west coast of Haida Gwaii, and both the Cascade and Coast mountains on the mainland would have offered quite different environments.

Complicating the varied post-glacial environments along the Northwest Coast is the Younger Dryas and other climatic episodes. In the northern hemisphere, the Younger Dryas is a period of generally cooler and drier climate. However, this has been shown to vary regionally and locally, where for example, climate in Southeast Alaska was cooler and drier, but climate in the southern region of Haida Gwaii was cooler and wetter (Fedje et al. 2011a, 454). These complicating factors are important to consider when interpreting a fragmentary faunal record, and extrapolating paleoecological information to larger regions, as these small differences can mean changes to archaeological site location on a site, local, and regional-scale.

The floral and faunal evidence reviewed here is useful for further understanding the paleoenvironment, both local and regional. Especially when used in conjunction with other lines of evidence, a review of faunal evidence can have important insights. Understanding the paleoenvironment at a high resolution and local-scale is very important for finding archaeological sites from this period. At local-scales of tens of kilometres or less, there can be strikingly different local environments that can mean major differences in site location. Further, there are substantial parts of the early post-glacial coastal plain that are not currently drowned, including the margins of the Salish Sea, areas of the Central Coast, and others that have a high potential for early archaeological sites. Increasingly, interdisciplinary projects examining multivariate lines of evidence are important for furthering our understanding of the dynamic paleoenvironments of the Northwest Coast.

The resolution of individual pieces of paleoecological evidence is very local, and regional-scale analyses require very significant amounts of work. Despite this, the future of paleoecological research on the Northwest Coast is promising, with recent work such as Letham and colleagues (2016) in Prince Rupert Harbour analysing the relative sea level history of the area. There is also potential for new techniques to contribute to analyses, such as sporomiella in cores (Mathewes et al. 2015) and eDNA (Willerslev et al. 2003). Evidence from the DILA project on Quadra Island is being compiled; these data will help fill the major gap in knowledge on the Northwest Coast.

## 2.2 Archaeology

Archaeological evidence is a foundational aspect of this study which provides an avenue to relate GIS modelling and archaeological results to the wider continental area, contributing to dialogues about the peopling of the Americas and late Pleistocene – early Holocene culture histories. This study also contributes to smaller-scale discussions about patterns, patchiness, and gaps in knowledge in the wider archaeological record of North America. The most contested area of North American archaeology is that pertaining to the earliest sites and the peopling of the Americas.

### 2.2.1 Continental-scale early period coastal archaeology

This thesis focusses on archaeological sites on the Northwest Coast of North America that date to greater than 7,000 calendar years before present. In reviewing these sites, I have focussed on how sites were found, along with their modern and paleolandscape settings. Additionally, I have noted significant artifacts, ecofacts including fauna, and features that are present. Radiocarbon dates have been reported as published if calibrated years before present (cal. BP) were used. Where radiocarbon years with standard deviation in age (e.g.,  $12,340 \pm 30$ ) were published, dates have been calibrated using Calib 7.1 software to 2-sigma error BP (Reimer et al. 2013). If radiocarbon dates were published without errors (e.g., 12,340  $^{14}\text{C}$  years), I have calibrated them with a 50-year standard deviation and generalized the date range to the nearest 100 years, preceded by a tilde (~) symbol. Marine reservoir use is noted where applicable.

The archaeological study area is overviewed in Figure 10, below. It runs from Yakutat Bay in SE Alaska to the Channel Islands, California. The study area includes many of the oldest sites in North America, but focusses only on those that are coastal. This excludes many old sites

in the interior of North America, some of which are important to the story of the first peopling of the Americas. Table 2 lists most of the archaeological sites covered in the study area that are older than 7,000 cal. BP. The table is most comprehensive for the BC coast and some sites in the continental USA are excluded due to issues of scope (e.g., some sites from Erlandson 1994). The earliest widely accepted site that has been included is Paisley Caves, Oregon, with an oldest date range of 14903 – 14262 cal. BP (Jenkins et al. 2012). This site is also the furthest from the coast, about 300 km, in south central Oregon. Although this site is much further inland than other sites included in the review, it is still included because it is one of the oldest sites in North America nearest the study area. The youngest site in this review is EdSn-35, a shell midden with a single radiocarbon date of ca. 6,500 cal. BP. Although it is not older than 7,000 cal. BP, it is included because it is one of the oldest sites that is near to Quadra Island, on Farquaharson Island in the Broughton Archipelago. The second youngest site is Kasta, Haida Gwaii, with an oldest date of 7000 – 6700 cal. BP (Fladmark 1986). The lower date boundary of 7000 cal. BP was arbitrarily chosen to include the sites most relevant to the late Pleistocene–Holocene transition but also to limit the number of sites relative to the scope of this thesis. Table 2 also notes how each site was found, its landform and general setting, and whether it was found on an island or the continent.

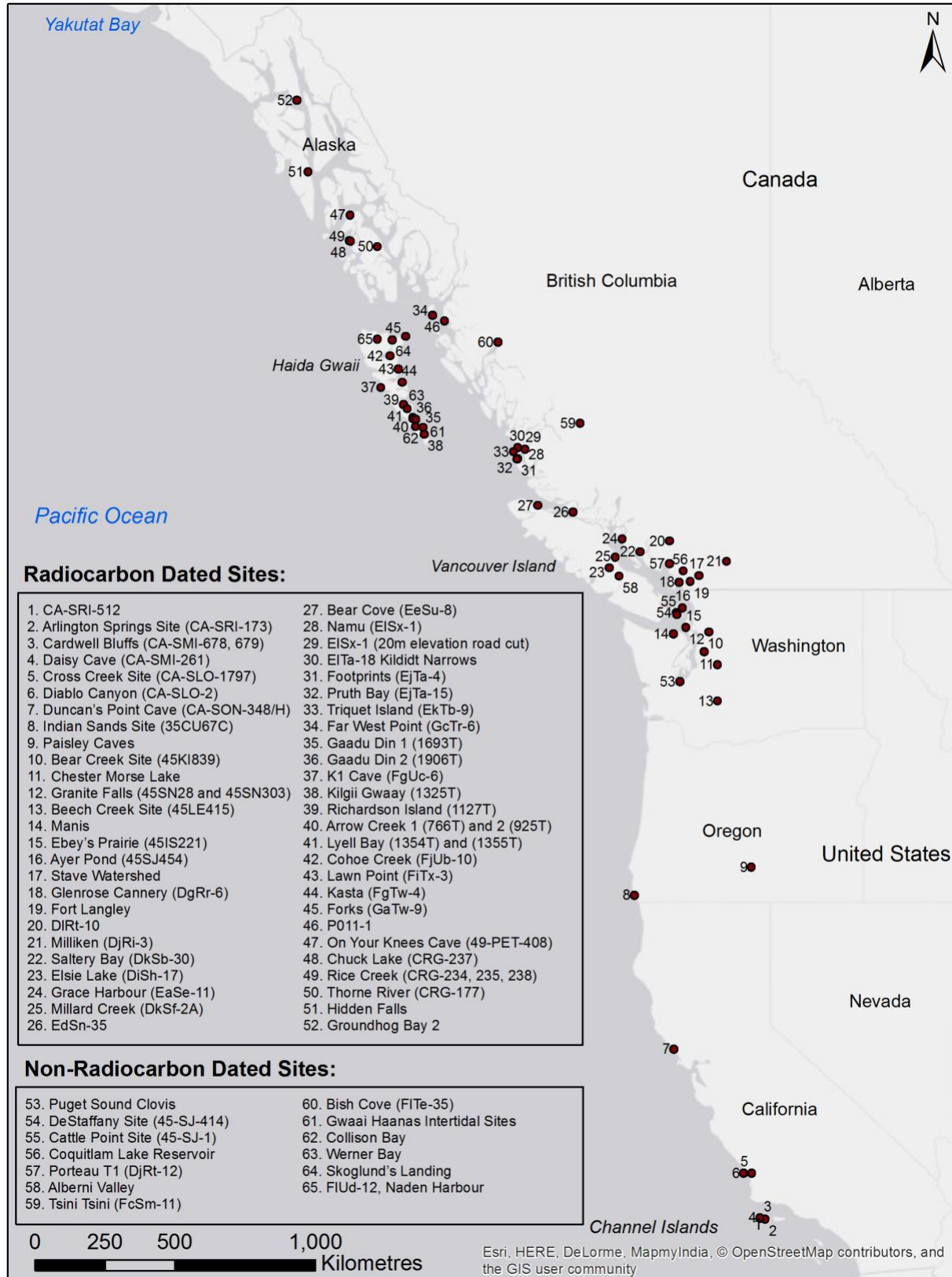


Figure 10: Overview map of radiocarbon dated sites over 7,000 cal. BP in Table 2.

Table 2: Radiocarbon dated archaeological sites in the study area.

Name	Location	Calibrated Date (as published, or 2 sigma, Calib 7.1)	Radiocarbon Date (if published without error, <sup>14</sup> C)	How it was found	Landform and paleosetting	Cont. or Isl.?	References
CA-SRI-512	Santa Rosa Island, Channel Islands, California	11,960 – 11,760 cal BP	10,155 ± 30	Predictive model?	Terrace. Upland site 75m above paleo sea level, 5 to 7 km away from coast.	I	Erlandson et al. 2011.
Arlington Springs Site (CA-SRI-173)	Santa Rosa Island, Channel Islands, California	13,013 – 12,709 cal BP	10,960 ± 80 (human bone, no marine res. applied)	Accidental.	Cut bank. Associated with marsh (cienaga).	I	Orr 1962; Johnson et al. 2001.
Cardwell Bluffs Site (CA-SMI-678 and CA-SMI-679)	San Miguel Island, Channel Islands, California	12,240 – 12,000 cal BP	10,950 ± 45 (shell, marine res. 225 ± 35)	Predictive model?	Terrace. Upland site situated 1-2 km away from paleocoast at 125m asl.	I	Erlandson et al. 2011.
Daisy Cave (CA-SMI-261)	San Miguel Island, Channel Islands, California	~11,600 cal BP <sup>1</sup> 11,211 – 10,743 cal BP 9,095 – 8,440 cal BP	10,260 ± 90 (shell, marine res. 225 ± 35) 8,470 ± 120 (shell, marine res. 225 ± 35)	Previously recorded.	Cave. Steep but close to the paleocean.	I	Erlandson et al. 1996; Erlandson and Jew 2009; Erlandson 2007; Erlandson 1994.
Cross Creek Site (CA-SLO-1797)	South-central California	9,855 – 9,454 cal BP	9,230 ± 70 ( <sup>14</sup> C measured age) (shell, marine res. 290 ± 35)	Accidental.	Terrace. 9 km from present shoreline. 17 km away from Pleistocene shoreline, 9 km away from Pleistocene estuary.	C	Jones et al. 2002.
Diablo Canyon (CA-SLO-2)	South-central California	11,075 – 10,945 (0.064) 10,874 – 10,223 (0.936) cal BP human bone; 9,182 – 8,769 cal BP shell	9,320 ± 140 (human bone, no marine res. applied) 8,960 ± 190 (shell, marine res. 290 ± 35)	Mitigation.	Coastal terrace next to perennial stream. Large 3.5 metre deep multicomponent shell midden. 20 to 50 m asl.	C	Greenwood 1972.
Duncan's Point Cave (CA-SON-348/H)	Sonoma County California	9,477 – 8,972 (0.972), 8,915 – 8,896 (0.006), 8,884 – 8,864 (0.007), 8,830 – 8,788 (0.015) cal BP (no marine res.)	8,210 ± 110 (shell, unknown marine res.)	Archaeological survey.	Shell midden associated with caves.	C	Erlandson 1994.
Indian Sands Site (35CU67C)	Southern Oregon	12,691 – 11,802 cal BP	10,430 ± 150	Surface finds, stratigraphic work.	Deflated dune sediments. Inland site, ca. 1.5 – 2 km west of paleoshoreline.	C	Davis et al. 2004; Davis 2006, 2008.
Paisley Caves	Central Oregon	14,903 – 14,262 cal BP deposits; 14,530–14,525 (0.001), 14,520–13,979 (0.999) cal BP human coprolite; 13,425 – 13,274 cal BP stemmed point	12,450 ± 30, deposits; 12,260 ± 60, human coprolite; 11,500 ± 30, stemmed point	Previously recorded.	Cave. Overlooking paleolake.	C	Gilbert et al. 2008; Jenkins et al. 2012.
Bear Creek Site (45KI839)	Redmond, Washington	12,690 – 12,420 cal BP	10,590 ± 60	Mitigation, surface finds.	Outwash plain. Site located near paleolake.	C	Kopperl et al. 2015, 2016.
Chester Morse Lake	Washington	9,822 – 9,284 cal BP	8,540 ± 110	Mitigation.	Kame terrace. Beside lake near stream.	C	Samuels 1993.
Granite Falls (45SN28 and 45SN303)	Washington	~9,690 – 8,550 cal BP (OSL date) <sup>1</sup> ~8,750 – 7,810 cal BP (OSL date) <sup>1</sup>	9,120 ± 570 OSL 8,280 ± 470 OSL	Surface finds, mitigation.	Outwash plain, terraces.	C	Chatters et al. 2011.
Beech Creek Site (45LE415)	Washington	~9,700 – 8,700 cal BP (OSL date) <sup>1</sup>	9,200 ± 500 OSL	Excavated by national forest staff. Mitigation.	Inland mountain site.	C	Chatters et al. 2012; Mack et al. 2010.
Manis	Washington	13,860 – 13,763 cal BP	11,960 ± 17	Accidental.	Plain. Beside small kettle lake. Associated with bog.	C	Gustafson et al. 1979; Petersen et al. 1983; Waters et al. 2011a.

Name	Location	Calibrated Date (as published, or 2 sigma, Calib 7.1)	Radiocarbon Date (if published without error, <sup>14</sup> C)	How it was found	Landform and paleosetting	Cont. or Isl.?	References
Ebey's Prairie (Ferry House Site, 45IS221)	Whidbey Island, Puget Sound, Washington	9,490 – 9,265 cal BP	8,360 ± 50	Mitigation.	Edge of a bluff with prairie behind it. Beside stream.	C	Mierendorf and Weiser 2006; Weiser 2006.
Ayer Pond (45SJ454)	Orcas Island, Washington	13,968 – 13,745 cal BP	11,990 ± 25	Accidental.	Near or in small pond. Associated with bog.	I	Kenady et al. 2007, 2011; Wilson et al. 2009.
Stave Watershed, including Devil's Point (DhRn-16), DhRn-21, Cardinalis Creek (DhRn-29), DhRo-11, DhRo-53	Lower Mainland, British Columbia	12,404 – 12,051 cal BP	10,370 ± 40	Mitigation.	Inland associated with rivers and lakes.	C	McLaren 2003, 2016; McLaren et al. 2008.
Glenrose Cannery (DgRr-6)	Lower Mainland, British Columbia	9,547 – 8,434 cal BP	8,150 ± 250	Part of later Holocene archaeological site.	Associated with paleocoastline.	C	Matson 1976, 111; Matson 1996, 117.
Fort Langley	Lower Mainland, British Columbia	9,537 – 9,280 cal BP	8,420 ± 70	Part of later Holocene archaeological site, mitigation.	Mitigation for historical site. Located on delta of Fraser River.	C	Porter and Copp 1993, 7.
DIRt-10	Near Squamish, British Columbia	7,829 – 7,665 cal BP	6,900 ± 40	Archaeological survey.	Alpine, approx. 35 km from Squamish Harbour.	C	Reimer 2011; Reimer and MacDonald 2008.
Milliken (DjRi-3)	Lower Mainland, British Columbia	~10,300 – 10,100 cal BP <sup>2</sup> 10,509 – 9,657 (0.996) 9,644 – 9,632 (0.004) cal BP	9,080 <sup>14</sup> C 9,000 ± 150 CARD <sup>3</sup>	Part of later Holocene archaeological site.	Associated with salmon fishing. Adjacent to Fraser River.	C	Borden 1975; Mitchell and Pokotylo 1996.
Saltery Bay (DkSb-30)	Lower Mainland, British Columbia	7,670 – 7,570 cal BP	6,700 ± 40 (animal bone, unknown if needs marine res.)	Mitigation, archaeological survey.	Coastal site, shell midden. Beside stream.	C	Pegg et al. 2007.
Elsie Lake (DiSh-17)	Vancouver Island, British Columbia	7,260 – 7,020 cal BP	6,250 ± 40	Mitigation, archaeological survey.	Relic river terrace, associated with lake.	I	Forgeng et al. 2007.
Grace Harbour, Kahkaykay Village (EaSe-11)	Desolation Sound, British Columbia	7,520 – 7,270 cal BP 7,533 – 7,264 cal BP	7,400 ± 50 6990 ± 50 (marine res. 422 ± 50). CARD <sup>3</sup>	Part of later Holocene archaeological site.	Coastal site, shell midden. Beside stream.	I	Johnson 2010; Johnson and Lepofsky 2010.
Millard Creek (DkSf-2A)	Courtenay, Vancouver Island, British Columbia	9,661 – 9,641 (0.005) 9,635 – 8,644 (0.995) cal BP	8,300 ± 200 Known coal deposits in area.	Reported, surface finds.	Surface artifacts noticed after plowing on recently bulldozer cleared land ca. 2 miles up a branch of Millard's Creek. Further investigation took place downstream near Comox Harbour.	I	Capes 1964, 60. Capes 1977.
EdSn-35	Farquaharson Island, British Columbia	Likely ~6,500 cal BP due to marine res.	6,250 ± 110 (shell, marine res. 510 ± 50 or 310 ± 50)	Archaeological survey, part of later Holocene archaeological site.	Shell midden on current shoreline of Farquaharson Island, found by Don Mitchell survey in 1968.	I	Mitchell and Turnbull 1968. Mitchell 1972. Sawbridge 1970.
Bear Cove (EeSu-8)	Vancouver Island, British Columbia	~9,200 – 9,000 cal BP <sup>2</sup> 5,310 – 4,870 cal BP	8,200 <sup>14</sup> C, 4,470 ± 60	Part of later Holocene archaeological site.	Coastal site, shell midden, associated with marine adaptation. Earliest material on raised beach.	I	Carlson 2003.
Namu (EISx-1)	Central Coast, British Columbia	~11,200 – 11,000 cal BP <sup>2</sup> 11,601 – 11,546 (0.014) 11,495 – 11,429 (0.016) 11,411 – 10,656 (0.968) 10,616 – 10,607 (0.002) cal BP	9,700 <sup>14</sup> C 9,720 ± 140 CARD <sup>3</sup>	Part of later Holocene archaeological site.	Coastal shell midden site, associated with river.	C	Carlson 1996; Cannon 1996; Rahemtulla 2006.

Name	Location	Calibrated Date (as published, or 2 sigma, Calib 7.1)	Radiocarbon Date (if published without error, <sup>14</sup> C)	How it was found	Landform and paleosetting	Cont. or Isl.?	References
ElSx-1 (Upper Namu, ca. 20m elevation)	Central Coast, British Columbia	11,072 – 10,785 cal BP	9,570 ± 25	Paleocoastal archaeological survey, LiDAR, and sea level curve, surface finds.	Upland site. Surface and subsurface artifacts.	C	McLaren et al. 2015
ElTa-18, Hunter Island, Kildit Narrows	Central Coast, British Columbia	~11,400 – 11,200 cal BP <sup>2</sup>	9,940 <sup>14</sup> C	Auger and percussion coring, archaeological survey.	Shoreline midden with overlaying later Holocene archaeological site.	I	Cannon 2000.
Footprints (EjTa-4)	Central Coast, British Columbia	13,317 – 13,241 cal BP	11,435 ± 30	Paleocoastal archaeological survey and sea level curve.	Intertidal.	I	McLaren 2015.
Pruth Bay (EjTa-15)	Calvert Island, Central Coast, British Columbia	10,653 – 10,562 cal BP	9,370 ± 25	Paleocoastal archaeological survey and sea level curve.	Coastal site, intertidal, shell midden.	I	McLaren et al. 2015.
Triquet Island (EkTb-9)	Central Coast, British Columbia	14,086 – 13,613 cal BP	12,010 ± 180	Paleocoastal archaeological survey and sea level curve.	Coastal site, intertidal, shell midden, wet site.	I	Gauvreau and McLaren 2017.
Far West Point (GcTr-6)	Dundas Archipelago, Central Coast, British Columbia	11,203 – 11,084 cal BP 8,386 – 8,314 cal BP	9,690 ± 30, 7,510 ± 20	Paleocoastal archaeological survey and sea level curve.	Terrace associated with paleocoastal landforms, shell midden.	I	McLaren 2008; Martindale et al. 2009.
Gaadu Din 1 (1693T)	Haida Gwaii, British Columbia	12,684 – 12,547 cal BP	10,615 ± 30	Reported.	Cave, upland site.	I	Fedje 2008; Fedje et al. 2011a.
Gaadu Din 2 (1906T)	Haida Gwaii, British Columbia	12,169 – 11,949 cal BP	10,295 ± 25	Archaeological survey focussed on caves in karst terrain.	Cave, upland site.	I	Fedje and Smith 2009; Fedje et al. 2011a.
K1 Cave (FgUc-6)	Haida Gwaii, British Columbia	12,928 – 12,714 cal BP to 12,573 – 12,394 cal BP (bracketing dates)	10,960 ± 35 to 10,510 ± 35 (bracketing dates)	Reported.	Cave, upland site.	I	Fedje et al. 2004a, 2004b; Fedje et al. 2011a.
Kilgii Gwaay (1325T)	Haida Gwaii, British Columbia	~10,800 – 10,600 cal BP <sup>1</sup> 10,771 – 10,567 cal BP	9,440 ± 40	Paleocoastal archaeological survey.	Intertidal, associated with paleocoastline and pond	I	Fedje et al. 2001; Fedje et al. 2005b; Cohen 2014.
Richardson Island (1127T)	Richardson Island, east of Moresby Island, Haida Gwaii, British Columbia	~10,600 – 10,400 cal BP <sup>2</sup>	9,300 <sup>14</sup> C	Paleocoastal archaeological survey.	Raised beach associated with paleocoastline, intertidal component.	I	Fedje et al. 1996a. Magne 2004; Smith 2004; Steffen 2006; Storey 2008; Waber 2011.
Arrow Creek 1 (766T) and Arrow Creek 2 (925T)	Matheson Inlet, east of Moresby Island, Gwaai Haanas, Haida Gwaii, British Columbia	~10,500 – 10,200 cal BP <sup>2</sup>	9,200 <sup>14</sup> C 9,840 ± 100 CARD <sup>3</sup> 9,410 ± 60 CARD <sup>3</sup>	Paleocoastal archaeological survey, part of later Holocene archaeological site.	Raised beach, intertidal, subtidal.	I	Fedje et al. 1996b; Fedje and Christensen 1999.
Lyell Bay South (1354T) and Lyell Bay East (1355T)	Gwaai Haanas, Haida Gwaii, British Columbia	~10,000 – 9,600 cal BP <sup>2</sup> ~9,550 – 9,450 cal BP <sup>2</sup>	8,800 <sup>14</sup> C 8,450 <sup>14</sup> C	Paleocoastal archaeological survey, sea level history, auger testing.	Raised beach.	I	Fedje et al. 1996; Fedje and Christensen 1999.
Cohoe Creek (FjUb-10)	Haida Gwaii, British Columbia	~7,200 – 6,900 cal BP <sup>2</sup>	6,150 <sup>14</sup> C 6,980 ± 50 CARD <sup>3</sup>	Archaeological survey.	Raised beach.	I	Christensen and Stafford 2005; Ham 1990.
Lawn Point (FiTx-3)	Graham Island, Haida Gwaii, British Columbia	8,447 – 7,951 cal BP	7,400 ± 140	Archaeological survey.	Associated with paleocoastline.	I	Fladmark 1986, Fladmark et al. 1990.
Kasta (FgTw-4)	Haida Gwaii, British Columbia	~7,000 – 6,700 cal BP <sup>2</sup>	6,010 <sup>14</sup> C	Archaeological survey.	Shoreline site bluffs above the ocean.	I	Fladmark 1986.

Name	Location	Calibrated Date (as published, or 2 sigma, Calib 7.1)	Radiocarbon Date (if published without error, <sup>14</sup> C)	How it was found	Landform and paleosetting	Cont. or Isl.?	References
Forks (GaTw-9)	Graham Island, Haida Gwaii, British Columbia	8,003 – 7,938 cal BP	7,140 ± 20	Paleocoastal archaeological survey, LiDAR.	Raised beach.	I	Sanders 2009.
P011-1 (GbTo-185)	Digby Island, Prince Rupert Harbour, British Columbia	9,302 – 9,028 cal BP 8,347 – 8,186 cal BP	8,220 ± 40 7,445 ± 35	Paleocoastal archaeological survey.	Raised terrace about 11 m asl.	I	Letham et al. 2016.
Shuká Káa (49-PET-408; On Your Knees Cave)	Prince of Wales Island, Alaska	~12,100 – 11,900 cal BP <sup>2</sup> 11,591 –11,576 (0.006) 11,573 –11,565 (0.003) 11,404 –11,198 (0.990) cal BP (human remains, no marine res.)	10,300 <sup>14</sup> C 9,880 ± 50 (human bone, no marine res. applied)	Reported.	Cave.	I	Dixon et al. 1997; Heaton and Grady 2003; Kemp 2007.
Chuck Lake (CRG-237)	Heceta Island, SE Alaska	9,490 – 8,950 cal BP	8,220 ± 125	Mitigation, archaeological survey.	Shell midden, raised beach, associated with lake.	I	Ackerman et al. 1985; Moss 1998, 103.
Rice Creek (CRG-234, 235, 238)	Heceta Island, SE Alaska	~10,250 – 10,100 cal BP <sup>2</sup>	9,000 <sup>14</sup> C	Mitigation, archaeological survey.	Terrace associated with marine adaptation.	I	Ackerman et al. 1985.
Thorne River (CRG-177)	Prince of Wales Island, SE Alaska	8,411 – 8,199 cal BP	7,520 ± 59 (average of multiple dates)	Mitigation, archaeological survey.	High bank of Throne River 1 mile from mouth. Lithics similar to GHB 2, Hidden Falls, Chuck Lake.	I	Dale et al. 1989, 86; Ackerman 1996.
Hidden Falls	Baranoff Island, SE Alaska	12,443 – 11,823 cal BP	10,345 ± 95	Archaeological survey.	Terrace, associated with coastline.	I	Davis 1984, 1989; Chatters et al. 2012.
Groundhog Bay 2	SE Alaska	10,230 – 9,180 cal BP	8,880 ± 125	Archaeological survey.	Terrace, associated with coastline.	C	Ackerman 1968, 1979, 1992, 1996; Chatters et al. 2012.

1 Date or date range as published, preceded by a ~ symbol.

2 Where a radiocarbon date was published without error (shown with <sup>14</sup>C notation) the calibrated date used an error of ± 50 and generalized the results to the nearest 100 years, preceded by a ~ symbol.

3 CARD represents a date from the Canadian Radiocarbon Database, accessed at <http://www.canadianarchaeology.ca>.

4 Where a marine reservoir was used, noted in Radiocarbon Date column.

5 Bracketed percentage (e.g., 0.003) is the relative area under probability distribution for calibrated dates.

Table 3: Non-radiocarbon dated archaeological sites in the study area.

Name	Location	Dating Method	Date	How it was found	Landform and paleosetting	Cont. or Isl.?	References
Puget Sound Clovis	Washington	Technological	Paleoindian period, up to ~13,000 cal BP.	Accidental.	Some associated with bog.	C	Avey 1992; Croes et al. 2008; LeTourneau 2010.
DeStaffany Site (45-SJ-414)	San Juan Island, Washington	Technological	4,750 ± 60 BP; but probably older.	Reported.	Bedrock knob overlooking plains/ocean depending on age	I	Kenady et al.2002; 2008.
Cattle Point Site (45-SJ-1)	San Juan Island, Washington	Technological	9,000 – 4,500 years old; Cascade Phase	Part of later Holocene site.	Shell midden overlain by later Holocene site.	I	King, 1950; Stein 2000
Coquitlam Lake Reservoir Sites DiRq-1 through DiRq-35	Coquitlam Lake, British Columbia	Technological	11,000 years ago and younger	Mitigation, archaeological survey	Lake shoreline, lake outlet.	C	Brown and Oakes 2011; Reimer 2011, 160; Wright 1996.
Porteau T1 (DjRt-12)	Howe Sound, British Columbia	Technological	8,000 – 2,000 BP. Leaf shaped point.	Mitigation, archaeological survey	Two small rockshelters.	C	Reimer 2011.
Alberni Valley	Vancouver Island, British Columbia	Technological	No dates, technology suggests early.	Paleocoastal archaeological survey.	Upland areas along river, associated with sea level history.	I	McMillan 1996; McMillan and St. Claire 1982.
Tsini Tsini (FcSm-11)	Up the valley from Bella Coola, ~160 m asl	Technological, sea level	12,200 cal BP	Archaeological survey.	Relict glacio-marine delta about 30 m above the current Talchako River, 45 km east of Bella Coola.	C	Hall 1998, 2003.
Bish Cove (FITe-35)	Kitimat, Central Coast, British Columbia	Technological	No dates, technology suggests early.	Mitigation.	Terrace associated with paleocoastal landform.	C	Streeter 2006.
Gwaii Haanas Intertidal Sites	Haida Gwaii, British Columbia	Sea level, technological	10,700 cal BP	Paleocoastal archaeological survey.	Intertidal lithic sites, associated with paleocoastline. 130+ locations.	I	Mackie and Sumpter 2005; Fedje et al. 1996.
Collison Bay	Haida Gwaii, British Columbia	Sea level	~10,800 – 10,500 cal BP; 9,450 radiocarbon BP	Paleocoastal archaeological survey.	Intertidal, associated with paleocoastline and pond.	I	Fedje et al. 2011a.
Werner Bay	East of Moresby Island, Haida Gwaii, British Columbia	Sea level	~12,100 – 11,700 cal BP; 10,200 radiocarbon BP from sea level	Paleocoastal archaeological survey, bucket dredge 53 m below sea level.	Swath bathymetry-derived model of submerged terrestrial landscape.	I	Josenhans et al. 1997; Fedje and Josenhans 2000; Mackie et al. 2011.
Skoglund's Landing	Haida Gwaii, British Columbia	(4,165 ± 80 <sup>14</sup> C) 9,000 – 8,500 BP (based on sea level)	4,165 ± 80 sea level may suggest earlier	Archaeological survey.	Between 3-8 metres db in a gravel quarry embedded in coarse iron stained beach sands.	I	Fladmark 1979 for older date, Fladmark 1989 for <sup>14</sup> C. Breffitt 1993.
FIUd-12, Naden Harbour	Graham Island, Haida Gwaii	Technological	Ca. 9400 years ago, Kingii Complex and Moresby Tradition	Archaeological survey.	Tombolo, estuary.	I	Stafford and Christenson 2000, 75, 138; McKenzie 1891.

Table 4: Summary table for all archaeological sites reviewed in the study area.

Date (Table 2 only):	How it was found (Table 2 and Table 3):	Landform and paleosetting (Table 2 and Table 3):	Continental or Island? (Table 2 and 3):
Mean: 10,563 cal BP Median 10,504 cal BP 1 <sup>st</sup> Quartile: 9,487 cal BP 3 <sup>rd</sup> Quartile: 12,187 cal BP Maximum: 14,903 cal BP Skewness: -0.0001, slightly negative skewed.	Paleocoastal archaeological survey: 15 Mitigation: 14 Accidental/surface finds/reported: 12 Archaeological survey: 11 Previously recorded/part of later Holocene site: 9 Predictive model: 2 Auger and percussion coring: 1	Coastal or paleocoastal: 23 Terrace: 17 Near stream/river: 14 Shell midden: 13 Associated with lake/pond: 10 Cave: 8 Intertidal: 7 Associated with bog: 4 Outwash plain: 4 Bluff: 3 Alpine: 2 Dunes: 1	Both radiocarbon dated and non-radiocarbon dated sites:  n=65  Continental: 25 Island: 40

Selected information from Table 2 and Table 3 is summarized in Table 4. Table 4, Column 1 shows descriptive statistics for the radiocarbon dated sites listed in Table 2. These date statistics are calculated without the sites listed in Table 3, including the over 100 intertidal sites in Haida Gwaii that date to ca. 10,700 cal. BP, which would skew the sample. The total number of sites present, especially the many intertidal lithic sites in Gwaii Haanas (see Table 3) show the widespread use of marine resources by ca. 10,700 cal. BP. If we consider the peopling of the Americas using the coastal migration route theory, people would have first entered the Northwest Coast before about 14,500 cal. BP, which is one of the earliest accepted ages at Monte Verde, Chile. The actual route of migration into the Americas is still a subject of considerable debate. Most archaeologists accept that a coastal route is among the most plausible possibilities (Wheat 2012), however, direct evidence of people on the Northwest Coast is limited. Some of the first direct evidence of people on the coast are footprints found on the Central Coast, dated to a minimum age of 13,317 cal. BP (McLaren 2016), and basal dates at the Triquet Island site, dated to 14,086 – 13,613 cal. BP (1-sigma) (Gauvreau and McLaren 2017). Figure 11 is a histogram of the calibrated dates of the sites included in Table 2. As one would expect, there are fewer dates at the oldest side of the graph, ending with the earliest end of the earliest end of the 2-sigma calibrated date from Paisley Caves up to ca. 14,900 years ago. There are many factors involved with interpreting the dates from these sites, such as datable material availability, archaeological survey style, and others, however, it is interesting to look at overall trends in the data.

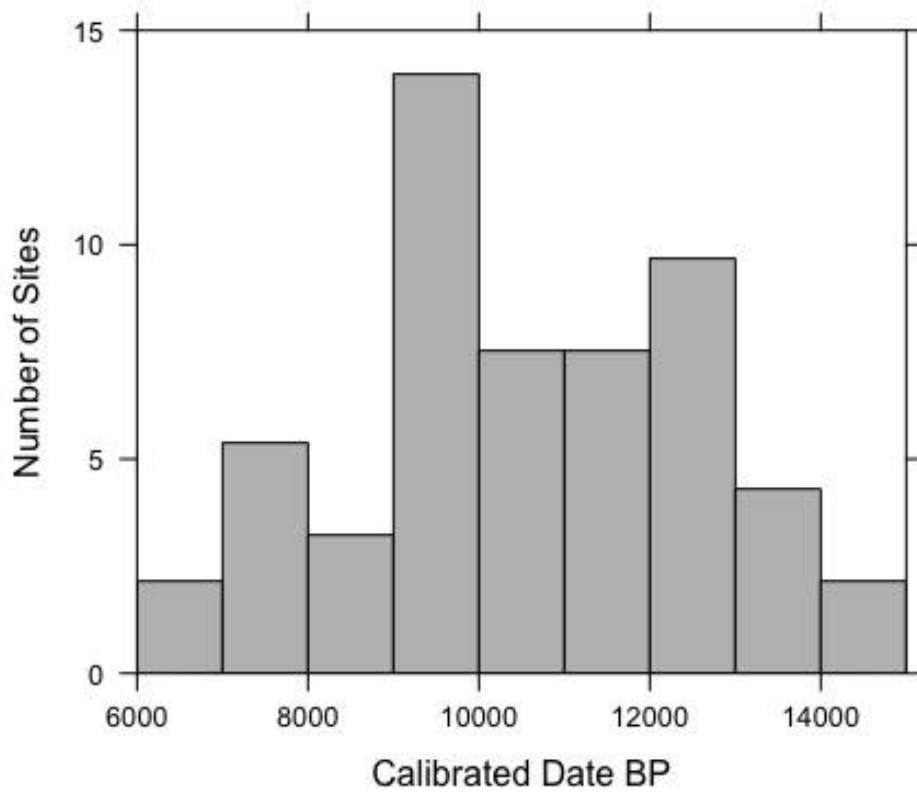


Figure 11: Histogram of radiocarbon dated sites (n=52) reviewed in Table 2.

In the context of the coastal route of entry to the Americas and late Pleistocene boat use by the first Americans, it is interesting to find that roughly two thirds of the early period sites reviewed in Table 2 and Table 3 are located on islands rather than on the continent (see Table 2, Table 3, Table 4). This finding certainly supports the use of boats in late Pleistocene – early Holocene America during this early time. Boat use in the early period has significant implications for site location and settlement patterns, which are explored throughout this thesis.

Reviewing all the proposed migration routes, Madsen (2015) provides a framework to characterize the initial occupation of the Americas given the available data. The coastal route is one of the most plausible, but other routes, such as the “Solutrean Hypothesis” are untested and may not be testable, leaving them neither ruled out nor proven. Madsen (2015, 234–236)

determines that people have been in the Americas by at least 14,500 years ago with evidence from Paisley Caves, Manis, Monte Verde, the Schaefer and Hebior mammoth sites, and several other early sites. Therefore, adding estimates for the time it would take human foragers to spread in the Americas, Madsen (2015, 236) concludes that it is very probable that the initial occupation of the Americas occurred between 17,000 to 14,000 years ago, if not earlier. Where are the sites that record this initial occupation if evidence exists in select locations south of the proposed coastal route? One way to look at this problem is to try to understand how early sites have been found thus far.

In 2002, Roberta Hall and colleagues created a database of 323 North American sites older than 7,500 years, focussing on discovery processes, dating methods, landforms, and materials found. I have used a similar method for qualitatively categorizing early sites on the Northwest Coast, which is summarized in Table 4. Importantly, early period sites on the Northwest Coast are found most often (though probably more-so in the last thirty years) through focussed archaeological surveys. Focussed archaeological surveys consider the paleoenvironment, such as reconstructing sea level histories to look at ancient shorelines, and may also obtain high resolution topographic data, such as LiDAR, to focus survey and ground-truthing time. The effects of focussed paleoenvironmental survey for early period sites can be seen on the overview map in Figure 10. Areas that have been subject to projects dedicated to finding early period sites have produced clusters of sites, seen for example on Haida Gwaii (Fedje et al. 2011; Mackie et al. 2011), on the Central Coast (McLaren 2008; McLaren 2016), and the Channel Islands (Erlandson et al. 2011).

Similar to Hall and colleague's (2002, 151) findings, mitigation or cultural resource management (CRM) is the second highest manner in which early sites have been discovered. A

close third discovery process is accidental finds, surface finds, and finds reported by non-archaeologists. If we count finds discovered through mitigation as being partially unintentional with regard to location, finds discovered through accidental processes make up a large proportion of early sites discovered on the Northwest Coast. Why is this? Several factors may play a role in the discovery of these sites, including archaeological survey strategies.

In the early 1990s, Lyman (1991) commented that archaeologists on the Northwest Coast have focussed most heavily on highly-visible shoreline shell midden sites for survey, investigation, and protection. A focus on later Holocene sites present on the current shoreline as shell middens may have contributed overall on the Northwest Coast to the lack of late Pleistocene – early Holocene sites discovered, but there are certain places where early period sites have been more fully explored, such as on Haida Gwaii. Importantly, early period sites often require a different approach for survey and investigation than later Holocene sites. Site visibility and recognition is also a factor in finding early period sites, and these processes are discussed in Chapter 3, Section 3.3.1.

Until we have more material evidence and knowledge about the people that initially colonized the Americas it will not get much easier to find more sites. Predictive modelling and simulation tools can help highlight target areas to search for late Pleistocene – early Holocene sites. However, given the complexity of early period site location, survival, visibility, and recognition, predictive modelling is largely about (1) finding good places to be (2) in the paleoenvironment (3) that people have used for a period of time such that remains will have built up, and (4) that have intact archaeological remains that survive until the present, at a minimum, all of which varies widely at a local-scale. Typically, the only material that survives on the

Northwest Coast from the early period are charcoal and lithic artifacts which contribute to our knowledge of early culture histories.

### 2.2.2 Regional culture history overview

Although there is little material evidence for the early period compared to the later Holocene, archaeologists have attempted to organize this evidence to try to gain insight. The people migrating into the Americas would have possessed their own unique cultures, however, archaeologists can only have limited knowledge of their practices through their material culture. To help organize patterns and styles through time by common traits, archaeologists create culture histories. Quadra Island lies at the edges of two broad culture histories: the Johnstone-Queen Charlotte Strait (Mitchell 1990) and Salish Sea (Carlson 1990; Matson 1996; Mitchell 1990). Because little archaeological material is available for the early period, it is helpful to include the culture historical sequence from Haida Gwaii for reference.

The most important culture historical periods to review for the early period include the Old Cordilleran: variously associated with the Pebble Tool Tradition, Olcott, and Cascade; the Western Stemmed Point Tradition, and the Kingii Complex of Haida Gwaii. Important technologies and trends associated with the early period include discoidal cores and the Paleoarchaic reduction sequence, stemmed, fluted, or leaf-shaped projectile points, microblades, expedient technology with larger flakes overall, and bipolar technology. Also important for coastal archaeology is the frequent use of locally available raw materials which are not typically of the highest quality on the coast.

Prepared cores in late Pleistocene – early Holocene coastal archaeology can typically be described as either unidirectional blade-like cores, or as discoidal (shaped like a disc) and

centripetal (flakes taken off radially towards the centre of the core). The discoidal and centripetal cores have also been described as Levallois-like, with some tools made from side-struck Levalloisoid flakes from the top of a discoidal core (Davis et al. 2012; Fedje et al. 2011b; Muto 1976).

Some of the most diagnostic lithic artifacts at early period sites are projectile points. In the Western Stemmed Tradition, projectile points are stemmed and ground, suggesting a socket type hafting style (Bryan 1980, 82) or side hafting style (Fedje et al. 2011b, 337). Other projectile point styles that are associated with the early period include fluted points and leaf-shaped points. Additional diagnostic features of late Pleistocene – early Holocene coastal lithics are associated with the reduction sequence. Davis and colleagues (2012, see also Fedje et al. 2011) use the term “Paleoarchaic” to refer to artifacts made using a reduction sequence that includes unidirectional blade cores and centripetal “Levallois-like” cores. These core technologies are present in the Western Stemmed Tradition and the Old Cordilleran, and make the Paleoarchaic distinct from the “Paleoindian” which includes Clovis. Beck and Jones (2010) suggest that the Western Stemmed Tradition may represent the earliest coastal migrants, and that it is as old or older than Clovis. Western Stemmed was originally suggested to be older than Clovis in the Northwest by Alan Bryan and Ruth Gruhn (Bryan 1980). These hypotheses may be supported by the view that Clovis technology spread to populations already in place (e.g., Waters et al. 2011b), rather than Clovis representing the first people in the Americas.

Microblades are first found in North America in central Alaska, at sites such as Swan point (Holmes et al. 1996). This technology seems to move south down the coast through time, with microblades found in SE Alaska at Groundhog Bay, Chuck Lake, and Shuká Káa (49-PET-408), then in Haida Gwaii at sites such as Richardson Island, Arrow Creek, Lawn Point, and

Kasta; and lastly, in the Strait of Georgia, at Saltery Bay and Elsie Lake (Magne and Fedje 2007). Microblades have also been found at several DILA project sites, including Crescent Channel (EbSh-81) (Fedje et al. 2016).

Expedient technology such as utilized flakes, along with pebble and cobble tools are common in early sites along the coast. Expedient tools such as cobble choppers, combined with Paleoarchaic reduction sequences, typically generate larger, thicker flake sizes than later Holocene archaeological sites. Bipolar technology is also present as an expedient technology, for example in sites on the Central Coast (McLaren 2014). Raw material choices can also play a role in the size and thickness of flakes, especially if the raw material chosen is coarse-grained, or only has weak conchoidal fracture properties.

These tool-making technologies are enabled by a wide variety of raw material use. Raw materials used for tool making on the coast are not typically of the highest quality. People on the coast in the late Pleistocene – early Holocene typically selected locally available raw materials such as fine-grained volcanic, metamorphic, or sedimentary rock (including meta-sedimentary) to use rather than use materials such as cherts and obsidian more common to other North American sites. For example, at the ca. 10,500 year old Richardson Island site, a high proportion of lithic raw material was metamorphic and igneous rock (Smith 2004, 11-13, 119-122), and at the ca. 10,700 year old Kilgii Gwaay site, 95 percent of raw material used was a locally-available siliceous argillite (Smith 2004; Fedje et al. 2001). Similarly, at the ca. 12,000–11,000 year old Bear Creek site, many artifacts were made from coarse-grained rock or were highly patinated. In order to designate artifacts as cultural, rules based on the presence of lithic attributes, such as bulbs of percussion, were determined with a panel of lithic experts (Kopperl et al. 2016, 162). In the late Pleistocene-aged Stratum Vc, the most common raw material was a fine-grained volcanic

(~35%), followed by a coarse-grained metasediment (~20%), a fine-grained metasediment (~15%), and chert (~12%) (Kopperl et al. 2016, 150). The fine-grained volcanic, coarse-grained metasediment, and fine-grained metasediment are available locally, while the chert was likely a rare find or brought in (Kopperl et al. 2016, 155). The raw material choices on the coast combined with the effects of sea level change and sometimes harsh weathering in acidic forest soils greatly effects archaeological visibility and artifacts may not always display clear lithic attributes.

The general characteristics described above are widely distributed throughout the coast. On Haida Gwaii, the 12,800–12,000 year old K1 and Gaadu Din caves contain evidence of early bear hunting, with stemmed and basally ground projectile points, tools created with blade-like flakes struck from centripetal cores, and a ground bone point (Fedje et al. 2011a). In the Stave watershed in the lower mainland of British Columbia, numerous artifacts of apparent early period age, including stemmed points, leaf-shaped points, and one fluted point, have been found in lag deposits in a reservoir (McLaren 2016). Other sites with these characteristics spread from SE Alaska to the Channel Islands, California, and are reviewed in Table 2 and Table 3. Lithic technology in the late Pleistocene – early Holocene differs in raw material, tool style, and manufacturing technique compared to the later Holocene. Middle and later Holocene culture historical periods in the Quadra Island area are set apart from earlier periods by the addition of ground stone (e.g., Charles Culture) (Pratt 1992; Matson and Coupland 1995) and obsidian (e.g., Obsidian Culture) (Mitchell 1988).

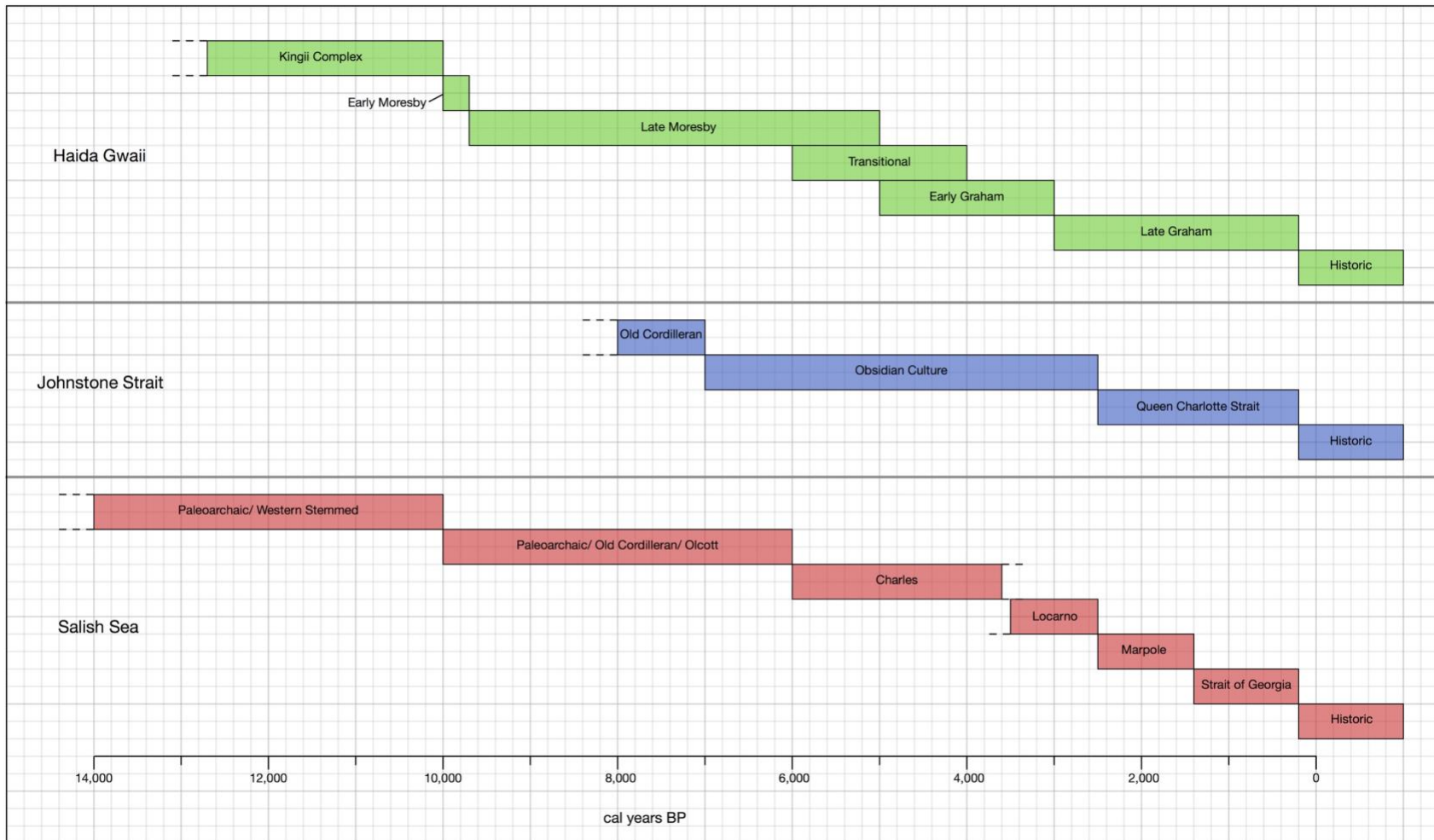


Figure 12: Timeline of culture history sequences for Haida Gwaii, Johnstone Strait, and Salish Sea (Ames and Maschner 1999; Butler 1961; Carlson 1970; Davis et al. 2012; Fedje 2008; Fedje et al. 2005a, 2008, 2011b; Kopperl et al. 2015; Matson 1996; Matson and Coupland 1995; Mitchell 1971, 1988, 1990; Mitchell and Donald 1988).

### 2.2.3 Regional-scale early period coastal archaeology

The oldest archaeological sites around the Quadra Island region are some of the youngest recorded in Table 2 which summarizes sites dated to over 7000 cal. BP in the study area. This emphasizes how poorly the local/regional archaeological record is known, probably due to lack of knowledge about the dramatic sea level change in the region. Figure 13 (Page 50) shows the locations of the oldest sites near Quadra Island. The oldest date is from Bear Cove, where the upper terrace associated with a raised beach and higher sea level dates to about 9200 – 9000 cal. BP (Carlson 1996). The next oldest is Saltery Bay on the mainland, site DkSb-30, with a basal date of 7620 cal. BP (Pegg et al. 2007). Near to Saltery Bay is Grace Harbour (EaSe-11), in Malaspina Inlet on the Gifford Peninsula, where a radiocarbon sample from a percussion core yielded a date of 7520 – 7270 cal. BP (Johnson and Lepofsky 2009, 21). To the south of Quadra Island site DiSh-17, found in survey of a reservoir at Elsie Lake on Vancouver Island, includes a microblade component that dates to 7260 – 7020 cal. BP (Forgeng et al. 2007). DiSh-17 is near Alberni Inlet, where surface finds of early period technological style stone tools have been found associated with raised terraces (McMillan 1996). This section will focus on the four sites that have been radiocarbon dated. The surface finds in Alberni Inlet suggest an early presence in that location, but need further investigation.

The oldest dates at three of the four sites nearest Quadra Island are within 600 years of each other, around 7300 cal. BP, and the archaeological record before and after this date is limited. This suggests an unknown limiting factor, whether it is the focus of archaeological survey in the region, survivability or preservation issues, other natural or cultural formation processes, or all of the above. These sites are also an average of 100 kilometres away from Quadra Island in all directions, leaving a gap in the known regional archaeological record around

the island. Reviewing the evidence from these nearest sites is helpful for determining what empirical evidence has survived in locations near Quadra Island, for gaining a partial understanding of how early people in the region were living, and for being familiar with the nearest archaeological evidence to inform our survey on Quadra Island.

Bear Cove (EeSu-8):

Bear Cove (EeSu-8) consists of a shell midden and a raised beach in a small cove in Hardy Bay on the northeastern coast of Vancouver Island. The site is divided into three areas, with Areas I and III nearest to the current shoreline, where there is shell midden with a maximum depth of 1.5 metres (C. Carlson 2003, 67). Area II represents the raised beach portion of the site, on an upper bench approximately 20 metres inland at an elevation of 9–11 metres above mean sea level (C. Carlson 1979, 180). The entire site runs parallel to the shore for about 85 metres, and extends approximately 30 metres inland (C. Carlson 1979, 180). An intermittent creek runs through the centre of the site, providing a division between Areas I and III. Poorly stratified silty loams and marine sands and gravels underlie the shell midden and continue upslope to the upper bench where they contain cultural and faunal remains.

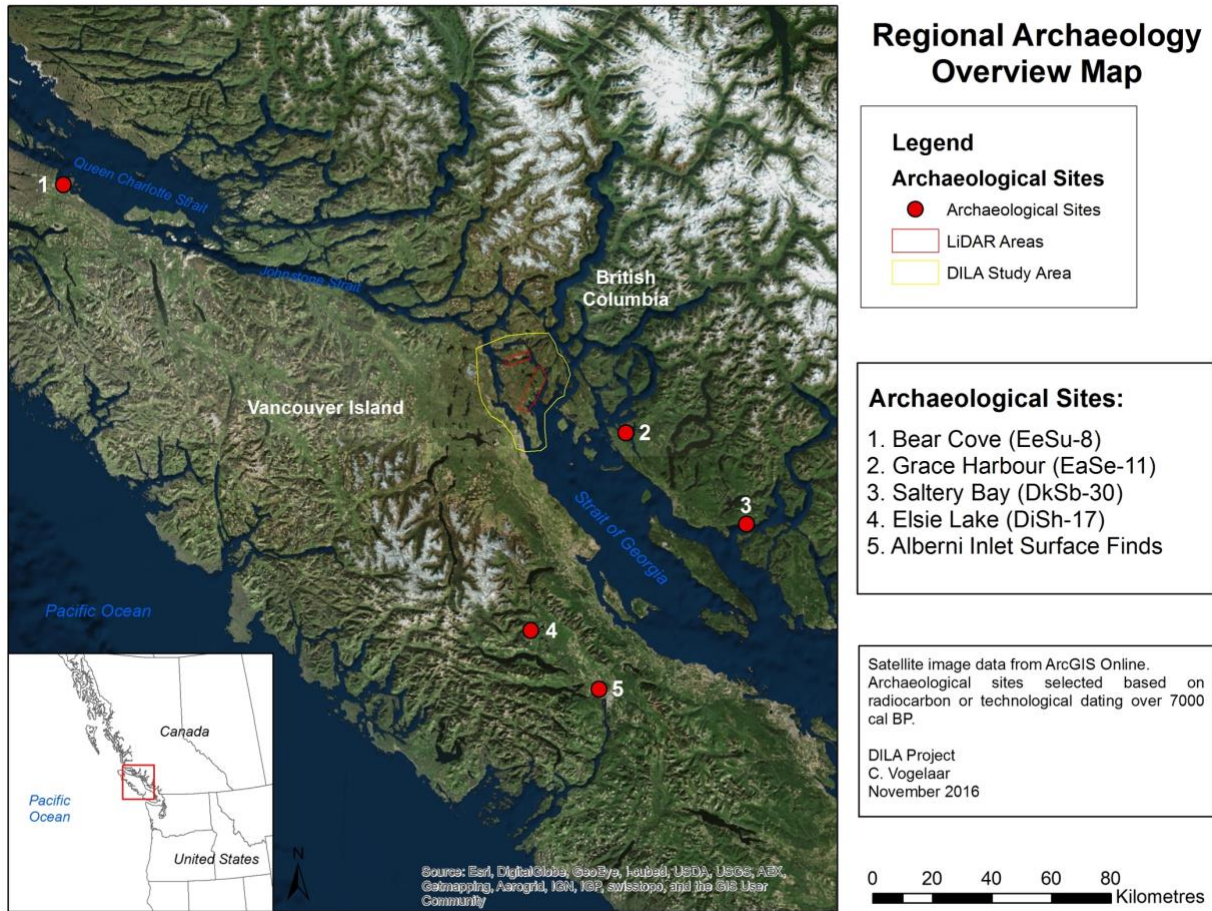


Figure 13: Overview of regional early period archaeology around Quadra Island.

The earliest occupation of the site is limited to Area II, the raised beach. The earliest cultural layer is Component I, which has a basal date of ca. 8880 cal. BP (8020 ± 110 RCYBP) on charcoal found 70 cm below the base of a sharp contact with overlaying shell midden layers (Component III). This contact was dated to 4877 – 4437 cal. BP (4180 ± 90 RCYBP) (C. Carlson 1979, 183). Two dates, run more recently, on sea lion bone and fur seal bone from Component I are younger. The sea lion bone was found 5 cm below the base of the shell midden layer and dates to 4446 – 3997 cal. BP (300 ± 50 marine reservoir, 4470 ± 60 RCYBP). The fur seal bone was found 45 cm below the base of the shell midden layer and dates to 4557 – 4216

cal. BP ( $300 \pm 50$  marine reservoir,  $4576 \pm 30$  RCYBP). These dates may suggest that part of Component I is not as old as previously thought.

Artifacts found in Component I are typical of the BC coast “Pebble Tool Tradition” defined by Roy Carlson (1990), which include tools made from rounded pebbles such as split cobble tools, cortex spall tools, pebble cores, retouched flakes, and multifacial cores (C. Carlson 1979, 184–187). These artifacts are typically made of locally available material and have an element of expediency or convenience to their manufacture.

With the previously early component fauna remains at Bear Cove re-dated to the middle Holocene, we do not know what role sea mammal hunting and fishing played at this site during the early Holocene. Salmon seem to be less important in the early components of the site, which may be a preservation issue, although other fishes are well represented, totalling 78% of the identified sample by MNI (C. Carlson 2003, 77). A lack of shellfish in the early component at Bear Cove may also be a preservation issue and might explain the origin of the black greasy sediment layers in the lowest strata, which could be interpreted as shell-less midden (e.g., Stein 1992, 12). However, it seems that salmon and shellfish play variable roles at other early period sites on the Northwest Coast, and may truly be less important during the earliest occupations at Bear Cove. For example, there is a heavy dependence on salmon in the early period at Namu (89% of fish) and no shellfish; some amount of salmon (3%) and shellfish at Glenrose Cannery; and small amounts of salmon (3.5%) and shell midden at Chuck Lake (C. Carlson 2003, 85). Overall, the fauna at Bear Cove suggests a maritime adaptation hunting and capturing sea mammals, birds, and sea fishes (Carlson 2003, 84).

Bear Cove is the oldest dated site near Quadra Island and is important because it and other sites on the Northwest Coast suggest that sea mammal hunting, fishing, and shellfish

collecting have played a large role in early period subsistence strategies. The site also contains a raised beach component reflective of past sea level history, a phenomenon that is also important for early period sites on Quadra Island. Some artifacts recovered from Bear Cove have an element of expediency using locally available coarse-grained raw materials rather than fine-grained, hard glassy materials more typically found archaeologically. These types of tools can be much harder to identify as cultural rather than natural, but are prevalent on the coast, meaning site visibility can impact archaeological survey.

#### Elsie Lake (DiSh-17):

To the south of Quadra Island on Vancouver Island is the Elsie Lake reservoir site (DiSh-17). Archaeological survey in the reservoir at low water draw-down located surface artifacts and intact subsurface deposits in 2001. The site is located on a terrace above the Upper Ash River at its inflow into Elsie Lake, which became a reservoir due to damming in the late 1950s (Forgeng et al. 2007, 13). In order to mitigate erosional processes due to reservoir action and vandalism by recreational vehicles, DiSh-17 has been investigated several times, with surface collection and subsurface excavation in 2001, 2002, and 2005 (Forgeng et al. 2007). Although the site can be covered with as much as 3 metres of water at high reservoir periods, intact deposits have survived. These subsurface cultural deposits were shallow, approximately 20 cm deep, but productive, with 1,600 lithic artifacts recovered (Forgeng et al. 2007).

Notable artifacts include microblades, obsidian from multiple sources (e.g., Anahim, Kingcome Inlet, Central Coast B), microblade cores, and a lack of bifacial technology. A single radiocarbon date from 2002 dates to a median probability age of 7192 cal. BP (6250 ± 40 RCYBP), and efforts to acquire more samples of that age unfortunately resulted in recent dates

(430, 300, and 290 BP). These dates are not representative of the microblade occupation, as microblades are not known regionally for at least a millennium. The artifact assemblage corroborates the earliest radiocarbon date, with microblade cores found that are similar to those on Haida Gwaii dating to the early Holocene (Forgeng et al. 2007, 47). The lack of bifacial technology and the use of microblades along with the date of 7192 cal. BP make the assemblage at Elsie Lake consistent with those of the Northwest Microblade Tradition, best known from SE Alaska and Haida Gwaii (Forgeng et al. 2007, 70). Although no fauna were recovered, Forgeng and colleagues suggest that microblades would have been hafted into bone or wooden handles as composite tools and used to process fish (2007, 52). The location and lithic assemblage point to Elsie Lake being a fishing camp. This site is important in relation to Quadra Island early period archaeology because it shows use of inland freshwater resources and the early use of microblade technology.

#### Saltery Bay (DkSb-30):

Saltery Bay is located on the mainland to the north of Texada Island in the Strait of Georgia. The site DkSb-30 was originally recorded as part of DkSb-14, a shell midden site to the north of DkSb-30 (Webster 1974). However, during foot survey it was determined to be a different site and given a new Borden number. DkSb-30 was excavated for mitigation of an underwater cable installation. This important stratified shell midden and burial (human remains left in situ) site was very productive for artifactual and faunal remains. The earliest component, Component I, is temporally associated with the Old Cordilleran, Pebble Tool Tradition, and Northwest Microblade Tradition. A basal date taken from animal bone (unknown if terrestrial or marine) in Layer 14, a black greasy sediment layer overlaying bedrock and underlying the

midden dates to 7670 – 7570 cal. BP ( $6,700 \pm 40$   $^{14}\text{C}$ ) (Pegg et al. 2007, 43). Layer 14 comprises Component I at the site, with two other dates of 6885 and 5960 cal. BP supporting a temporal range of early occupation.

Notable artifacts found at DkSb-30 include stemmed and leaf-shaped projectile points, microblades and microblade cores, slate tools, and bone tools. In total, 290 stone, bone, or antler artifacts were recovered along with over 4,000 pieces of lithic debitage (Pegg et al. 2007, 46). Notable artifacts in Component I include leaf-shaped and corner notched points, bifaces, microblades, flake tools, awls, and worked bone fragments (Pegg et al. 2007, 50-51). For the early period at the site, microblade cores dominate the Component I assemblage ( $n = 21$ ), and there is a notable absence of pebble tools (Pegg et al. 2007, 50-51). In comparison to Elsie Lake, the lithic assemblage at Saltery Bay is larger and more varied, with bifacial technology present. Microblades and microblade cores found at both Saltery Bay and Elsie Lake sites compare metrically to “late” microblade assemblages on Haida Gwaii, dating to about 7000 BP, which is consistent with radiocarbon dates at both sites (Magne 2007; Magne 1996). On Quadra Island, the later components of the Crescent Channel site (EbSh-81) may also fit into this category of sites with microblades and radiocarbon dates (Fedje et al. 2016).

An important early period feature at the site is a cooking pit with articulated harbour porpoise vertebrate found along with northern sea lion, deer, and harbour seal remains, and associated with a date of 7000 – 6770 cal. BP (Pegg et al. 2007, 37). Other fauna found in Component I include dogfish, salmon, rockfish, herring, domestic dog, ling cod, beaver, and wapiti (Pegg et al. 2007, 62). Invertebrate remains in Component I include clam and mussel, with cockle and barnacle also present at the site (Pegg et al. 2007, 66). Mussel and clam seem to be the earliest invertebrates collected, with cockle increasing through time (Pegg et al. 2007, 66).

However, most likely due to preservation issues, there is very little shell in the earliest component, with deer being the most common fauna present in Component I (Pegg et al. 2007, 71).

The information found for the earliest component of Saltery Bay is very informative for the Gulf of Georgia region. The lithic assemblage in Component I demonstrates the styles and material types that are important for the early period in the region, including bifacial technology, microblade technology, and bone technology. The faunal data for Component I show that both marine and terrestrial ecosystems were exploited with porpoise, harbour seal, fish, and deer remains present. Shell is not present in great quantities in Component I until the interface with Component II, which is most likely a preservation issue, especially since Layer 14 is described as black greasy sediment, typical of shell-less midden deposits elsewhere on the Northwest Coast. In relation to Quadra Island, this site is important for demonstrating the possible range of cultural materials that may be present at a site, and demonstrates subsistence strategies of the mid to early Holocene.

#### Grace Harbour (EeSe-11):

The nearest early site to Quadra Island is at Grace Harbour on the Gifford Peninsula in Desolation Sound, east of Quadra Island. Site EaSe-11 is recorded ethnohistorically as one of the Tla'amin People's winter village sites, where its location provides protection from both weather and currents while also providing easy access to resources (Johnson and Lepofsky 2009, 20). The bulk of the site consists of shell midden. Percussion coring was conducted throughout the site area to document the depth of midden, the site boundaries, and the site changes over time. Most of the radiocarbon samples from coring date to around 2500 cal. BP, however, one date from the

base of cultural deposits in a core of the midden (P024) returned a date of 7520 – 7270 cal. BP (Johnson and Lepofsky 2009, 21). This suggests the long-term occupation of the site by the Tla'amin people. The authors suggest that the site shifted from a smaller site located on bedrock (as recorded in Core P024) and expanded over time by creating usable terrain by the deposition of midden (Cores P002a, P005) (Johnson and Lepofsky 2009, 22). While no excavation was conducted, artifacts eroding out of the midden were collected and include two flakes, one slate point, one leaf-shaped point, and one microblade core. The artifacts are similar to those found at Saltery Bay (DkSb-30), and may therefore support the early date in the core (Johnson and Lepofsky 2009, 22).

These four sites represent the earliest archaeology recorded in the region around Quadra Island, and provide a glimpse into how people may have been subsisting and living during the early period. Though little evidence is present over this regional-scale, these sites show a range of behavioural patterns that may help us understand where to look and what to look for archaeologically on Quadra Island. Bear Cove, Saltery Bay, and Grace Harbour show a preference for marine resources such as sea mammals and shellfish during the early period. These resources are still used by many First Nations today, and these early sites suggest that their use extends into deep time. Lithic technologies at these early sites include microblades, which are typically part of composite tools and suggest established technologies using bone and other organic material types. Other technologies present include leaf-shaped points, pebble tools, and large expedient technologies created on locally available raw materials, such as at Bear Cove. Debitage pieces larger than 8 cm were only present in the earliest component at Saltery Bay (Pegg et al. 2007, 59). The archaeological culture history periods present at these sites include

the Pebble Tool Tradition, the Old Cordilleran, and the Northwest Microblade Tradition, each having their own associations with subsistence and technology.

An understanding of the earliest archaeological evidence in the region around Quadra Island can help us to focus our own survey of early archaeology and is essential to our understanding of how people were using the early period landscape. Knowledge from these sites helps us gain insight into how early period people lived, and building on the evidence from these sites is a starting point for uncovering more of the story during the early period in the Discovery Islands.

#### 2.2.4 Quadra Island archaeology

##### Archaeological Investigation Before 1970:

Compared to other areas of British Columbia, Quadra Island, the surrounding Discovery Islands, and the northern Strait of Georgia have been subject to relatively little archaeological investigation. On the Northwest Coast as a whole, some of the first archaeological inquiry was part of more general anthropological and ethnographic studies, such as those of Boas (1889, 1890, 1894, 1935), H. I. Smith (1903, 1907), Barnett (1938, 1939, 1955), Drucker (1940, 1943, 1951), Hill-Tout (1895, 1907, 1948), and Duff (1952, 1956, 1963).

Some of the first scientific archaeology in BC was conducted by archaeologists such as Charles Borden (e.g. 1950a, 1950b, 1951, 1954, 1957) Roy Carlson (e.g., 1960, 1970), and Donald Mitchell (e.g., 1963). The first investigations focussed on areas such as the Fraser delta and Gulf Islands, where more rapid development and expansion was influencing archaeological remains. It was through the efforts of these and other early BC archaeologists that the prehistory of the area and culture history sequences were established.

### Archaeological Investigations in the Discovery Islands before 1990:

Some of the first archaeological investigation in the Discovery Islands area included work by anthropologists H.C. Taylor Jr. and Wilson Duff (1956), who investigated broad population movements of the Kwakwaka'wakw. There were also large scale surveys of rock art starting with the Barrow's work in the 1930s (Hill 1985) and subsequently Hill's (1973, 1994) and Lundy's (1974) work. Probably the most important archaeological investigation on Quadra Island was conducted by Don Mitchell in 1967 and 1968, and summarized in his 1969 publication "Site Survey in the Johnstone Strait Region" where he recorded over 675 new archaeological sites. Most of these sites were shoreline shell midden sites which were visible by boat.

Before the DILA project, one of the only documented archaeological excavations on Quadra Island was in 1966 when Don Mitchell excavated at the Rebecca Spit (EaSh-6) trench embankment site. These investigations uncovered lithics, bone, antler, and shell artifacts, wooden artifacts, and faunal remains (Mitchell 1968). The site consists of a semi-circular embankment and ditch with three to four house platforms situated inside the area (Mitchell 1968). The site was abandoned prior to contact and occupation is estimated to date between the 16th and 18th centuries (Mitchell 1968, 44). Since this time, no other controlled excavation has occurred on Quadra Island, other than shovel testing, auger testing, and probing conducted by CRM archaeologists for various archaeological impact investigations.

In 1985, human remains were found at Cape Mudge (EaSh-3), during trenching for water pipes through a stratified midden deposit (Skinner 1986, 1). Subsequent analyses dated the human remains to  $2000 \pm 120$  (Skinner 1986, 6). Interestingly, a northern elephant seal bone was

also recovered from a different area of the village, a species that is no longer present on this area of the coast (Skinner 1986, 8).

#### Cultural Resource Management Projects (~1990 – present):

Most CRM archaeology on or near Quadra Island typically takes place in the form of Archaeological Impact Assessments (AIA's) or Archaeological Overview Assessments (AOA's) in advance of development, such as forestry (e.g., Engisch et al. 2012; Simonsen 1992).

In 1992, survey in advance of logging by Merrill and Ring Timber, of Port Angeles, Washington, occurred at Chonat Bay, Waiatt Bay, and Small Inlet (Simonsen 1992). Investigation and survey was conducted by a two-person crew, Bjorn Simonsen and Scott McNab for three days in August 1992. Through the course of their survey, 11 new sites and 6 previously recorded sites were investigated (Simonsen 1992, 6). Previously recorded archaeological sites included shell midden sites recorded by Don Mitchell and Ken Martin of the University of Victoria (Mitchell 1969), which they found to be underestimated in terms of size due to the nature of Mitchell's survey (Simonsen 1992, 4).

Archaeological assessments in advance of forestry have also occurred more recently (Arcas 2002; Eldridge et al. 2007; Engisch et al. 2012). In 2001, Arcas Archaeology investigated a forestry block near Little Main Lake on Quadra Island, but found no archaeological sites (Feddema 2002, 5). In 2002, Arcas Archaeology produced a predictive model for an Archaeological Overview Assessment (AOA) for the TFL Forest Limited Johnstone Strait Operation (Arcas 2002). This project included seven days of ground-truthing, including a helicopter flyover, work in Jackson Bay, and work around Sonora Island by boat. The only

ground-truthing conducted on Quadra Island was a landing of the helicopter at Kanish Bay (Arcas 2002, 65).

In an AOA conducted by Millennia Research in 2007, predictive models were created and tested through ground-truthing work (Eldridge et al. 2007). Seven predictive models were created according to different site types including CMT's, shell middens/habitations, fish traps, pictographs, petroglyphs, and trench embankments/refuges (Eldridge et al. 2007, v). Quadra Island falls within the study area of the Campbell River Forest District, but was not chosen as a ground-truthing location to test the model. The nearest ground-truthing location chosen was Barnes Bay just north of Quadra Island, on southern Sonora Island (Eldridge et al. 2007, 34, 110).

In 2010, Aaron Bible of Baseline Archaeology was issued a permit to conduct a number of Archaeological Impact Assessments (AIA) for forestry in the Campbell River Forest District (Engisch et al. 2012, 7). Quadra Island was included in the study area but was not impacted by any of the proposed forestry under this permit.

AIA's are completed in advance of development such as forestry or for property owners. There have been several CRM archaeological investigations conducted on private properties on Quadra Island (Simonsen 1990; Broly 1992; Simonsen 1993a, 1993b, 1995; Dewhirst 1995; Mathews 2005; Grant and Bible 2006; Engisch 2005). These mostly consist of investigation in private lots for archaeological remains or revisiting known archaeological sites. AIA investigations on Quadra Island include those at the Quathiaski Cove ferry terminal (Mathews 2005) and the Heriot Bay Inn (Grant and Bible 2006).

In 2011, Heather Pratt for Baseline Archaeology conducted an AIA at Bold Bay, Quadra Island in advance of a proposed subdivision of a 14 hectare property into five lots (Pratt 2011).

Pratt discovered a previously unrecorded midden site and associated subsurface archaeological deposits, comprising site EbSh-71 (Pratt 2011). This area is in Crescent Channel very near to the DILA Crescent Channel site, EbSh-81, which is located in the right of way between the subdivided lots (Fedje et al. 2016).

Monitoring of archaeological sites on Rebecca Spit occurred in 2011 when Stephanie Dawe (Baseline Archaeology) and Louis Wilson (Wei Wai Kai First Nation) revisited sites EaSh-6 and EaSh-7 for erosion mitigation and shoreline restoration (Dawe 2011). No new archaeological sites were observed.

Although there has been CRM work completed on Quadra Island over the years, these projects have produced no knowledge of the early period and little new information about archaeology in the region. Most projects typically found no sites or took place as mitigation for previously known sites. This left Quadra Island and the Discovery Islands as a gap in knowledge, especially for the early period until recent academic research projects were established.

#### DILA Project and other research:

The first academic archaeological project to take place recently on Quadra Island investigated middle and later Holocene archaeology, especially in the form of clam gardens. Dr. Dana Lepofsky and the Clam Garden Network have conducted fieldwork on Quadra Island to learn more about the relatively newly discovered Clam Gardens sites (Lepofsky et al. 2015; Puckett et al. 2014; Toniello et al. 2015). Clam Gardens are rock wall modifications in the lower intertidal area that increase habitat for clams, which are maintained and cultivated for human consumption. These investigations have discovered numerous clam gardens, especially around

Kanish and Waiatt Bays on Quadra Island, some of which date to ca. 2,000 years ago (Neudorf et al. 2017).

The Discovery Islands Landscape Archaeology (DILA) project has substantially extended the archaeological record in the area of Quadra Island. Using a focussed paleoecological survey approach including sediment basin coring and sea level history, the DILA project has identified over 35 new archaeological sites from 2014–2016, mainly on upland landforms. Multiple lines of evidence have informed the DILA project’s investigation of late Pleistocene – early Holocene archaeology in the area. Local knowledge from First Nations and a local collector have been used in conjunction with the little previous archaeological work in the region to understand site types and locations. Predictive modelling and LiDAR work by Alex Lausanne started in 2014 (Lausanne et al. 2017a, 2017b; in press), and further work in this thesis have been used to locate areas and landforms of high archaeological potential specifically for early period archaeology. Some of the most informative archaeological sites discovered by the DILA project, discovered outside of the scope of this thesis, are briefly reviewed below, and more information about these sites can be found in the 2014 Annual Report (Fedje et al. 2016) and the forthcoming 2015 Annual Report (Vogelaar et al. in prep), and the final DILA report (Fedje et al. in prep).

*Crescent Channel (Crow) Site (EbSh-81):*

Found with the knowledge of a local informant, the CROW site is located in a right of way off Bold Point Road, near Crescent Channel on Quadra Island. Several shovel tests and a 1 x 1 metre unit carried out in 2014 recovered more than 1700 chipped stone artifacts including microblades. Results of 2015 excavation (i.e., finishing the 2014 unit) and 2017 excavation are forthcoming. The basal sandy silt deposits include casts of marine shells, providing a convenient

marker of higher sea levels in combination with the temporal information from the sea level history. The stratigraphy at CROW is complex and includes a possible sloping pit feature. A radiocarbon date from 28 cm depth below the surface in a 1 metre unit dates to about 6500 years ago.

*Lactarius Road (EaSh-81):*

Lactarius Road site (EaSh-81) is located on a ca. 26 metre terrace above Village Bay adjacent to a creek. Analysis is still ongoing, but significant artifacts include a Cascade-type projectile point found in a shovel test and numerous flakes and other lithics found in a 1 x 1 metre unit. Radiocarbon dates suggest the site was occupied around 10,000 cal. BP or earlier.

*EbSh-95:*

EbSh-95 is located on a ca. 10 metre terrace adjacent to a small shallow bay in Small Inlet. Numerous artifacts were found on the surface, in tree throws, and in shovel testing. Artifacts are especially associated with a greasy black sediment layer, interpreted as a shell-less midden. Radiocarbon dates from this black greasy layer place occupation around 7,500 cal. BP. Further work may be carried out at EbSh-95 in the coming years.

*Hopespring Rockshelter (EaSh-82):*

Hopespring Rockshelter is located at the end of Hopespring Rd. on Quadra Island, about 100 metres above sea level. This site is significant because if it is associated with higher sea levels it would be close to 13,200 years old. Several shovel tests and two 1 x 1 metre units have been excavated, with artifacts recovered throughout the strata and down to about 1.25 metres below the surface in apparent marine deposits. Further work will be carried out at EaSh-82 in the coming years.

*Surge Road (EbSg-25 and EbSg-26):*

Surge Road is located on the northeastern side of Quadra Island near Surge Narrows Park. Archaeological remains recovered from Surge Road include lithics recovered from disturbed and undisturbed contexts associated with a road cut. The Surge Road area also includes a second site on a terrace investigated in 2015, where subsurface lithics were found during shovel testing. The oldest radiocarbon date associated with Surge is about 5200 cal. BP, however, this is much younger than anticipated and could relate to site disturbance or forest fire activity.

Overall, very little archaeological investigation has occurred on Quadra Island or in the Discovery Islands region until the DILA project. This makes the results and conclusions of the DILA project extremely important and relevant to the advancement of the archaeological record of the area. This archaeological information also contributes to larger picture stories about the Northwest Coast as a whole and the peopling of the Americas.

## 2.3 GIS Modelling

A model is a simplification of reality. This is exemplified by the modelling trope “all models are wrong, but some are useful” (Box 1978). This is one of the most important concepts to keep in mind when building, interpreting, and analyzing output from models in general and is especially important for archaeological predictive modelling. Predictive modelling emerged more widely out of the “new archaeology” or “processual archaeology” of the 1960s. Although predictive modelling became much more widespread with the introduction and use of computers and geographic information systems (GIS), the first predictive models predated this period, with Willey (1953) applying his knowledge of the Peruvian landscape to understand site location. This pairing of human settlement locations to environmental variables combined with the emphasis on quantitative methods in the 1960s, led to the creation of models expected to predict the locations of archaeological sites in areas where no sites had yet been found (Verhagen and Whitley 2012, 51). During the 1960s and 1970s, a variety of model types were called predictive models, including models of subsistence (Jochim 1976), of economy (Bronitsky 1983; Earle and Christenson 1980), and of site location. The site location models are the type of archaeological predictive models that are the focus here, which are defined by Kohler and Parker (1986, 400); where:

“Predictive modelling is a technique that, at a minimum, tries to predict the location of archaeological sites or materials in a region, based either on a sample of that region or on fundamental notions concerning human behaviour”.

This definition hints at two different recognized forms of predictive modelling, a dichotomy that emerged in the 1970s; between “inductive” and “deductive” predictive models

(Verhagen and Whitley 2012, 52). Inductive predictive modelling uses the scientific principle of induction, which involves making inferences from specific data to arrive at general rules or hypotheses. Inductive predictive models typically use known archaeological site locations as data for input into the model, and make correlations between the environment or other variables and the locations of sites. The model is then applied to areas where site locations are unknown in order to predict areas of possible site location. Most inductive predictive models use logistic regression, which involves statistically testing the known locations of sites against a variety of environmental or other variables to find variables correlated to site location (Kvamme 1988). Each individual environmental variable is tested using regression against the set of known archaeological sites. Variables that are found to be statistically valid are included in the model, and any variables found not to be statistically valid are removed. The theoretical and methodological issues surrounding the use of inductive models will be reviewed in Chapter 3 of this thesis.

Deductive predictive modelling uses the principle of deduction, which involves hypothesizing general rules and comparing them to known data in a “top-down” technique (Verhagen and Whitley 2012, 51). Deductive predictive models typically hypothesize general rules about site location, human behaviour, and the environment, such as proximity to water increasing site potential, in order to narrow down and predict site locations. Similar theoretical and methodological issues apply to deductive models as inductive models. Although associated biases with the archaeological record are lessened because deductive models do not typically use known archaeological sites as inputs to the model, there are many assumptions associated with the simplification of human behaviour for model rules.

Typically, the output of all types of archaeological predictive models are potential maps, which are maps of the entire landscape or study area with polygons ranked as low, medium, or high potential, or some other ranking scale. Theoretically, these polygons would then be tested or ground-truthed to confirm the validity of the model (Verhagen and Whitley 2012, 54). However, testing predictive models is rarely achieved in a statistically valid way, and will be further discussed in Chapter 3.

Predictive modelling became most widespread during the late 1980s, especially with the landmark publication of *Quantifying the Present and Predicting the Past: Theory, Method, and Application of Archaeological Predictive Modelling*, edited by Judge and Sebastian (1988). This volume, published by the U.S. Department of the Interior, Bureau of Land Management, spurred a development of predictive modelling throughout North America in the 1990s as a cutting-edge technique. During this time, predictive modelling was hotly debated, contested, and developed in academic and commercial archaeological circles (Verhagen and Whitley 2012, 53). Although it is a simplification to say that archaeological predictive modelling was mostly written off by the academic archaeological community, while being accepted by commercial or cultural resource management (CRM) archaeology, this is a general trend (Verhagen and Whitley 2012, 50). Predictive modelling subsequently went through a period of disuse in academic communities. However, in recent years, the development of more efficient, cheaper, and powerful computational technologies and the ability to gather high resolution data with techniques such as satellite imagery, LiDAR, multibeam sonar underwater, and others, predictive modelling has made a comeback in academic archaeological research. These models are typically framed as aiding site reconnaissance in hard to reach places (e.g., underwater, Monteleone et al. 2012), dense forest (Doneus et al. 2008), remote locations (Carson 2014), or to develop a better

understanding of processes in the past by analyzing spatial data (e.g., Breeze et al. 2015; Carlson and Baichtal 2015; Carrer 2013).

In CRM, predictive models have been applied very widely since the 1990s, and models hold a central place in the toolkit of the process of CRM and the conservation of the archaeological record (Verhagen and Whitley 2012, 50). Archaeological predictive models are typically implemented for one of two main reasons: (1) to inform archaeological survey (i.e., to find sites), or (2) to explain the spatial distribution of sites (i.e., to make inferences about human behaviour with regards to site location) (Wheatley 2004). One of the reasons for predictive modelling's persistence in CRM archaeology comes out of a realist assumption of economical and efficient archaeological reconnaissance—the perception that archaeologists “can't survey everywhere”. Predictive modelling has also been used to focus archaeological investigation on likely areas of archaeological material in order to maximize the amount of investigation possible under funding and time constraints (Verhagen and Whitley 2012, 51). Predictive modelling has also thrived under commercial archaeology because of its purported ability to find sites, and because predictive modelling output, in the form of potential maps, conforms to what is expected by state bureaucratic agencies. This brief history of predictive modelling puts the method in context for a theoretical evaluation, which is the topic of Chapter 3.

### 2.3.1 Predictive modelling in coastal settings

Coastal archaeology can be understood as a boundary area because of the traditional division between land and sea, with subaerial coastal archaeological investigations taking an interest in shell middens, and traditional underwater archaeology (i.e., maritime archaeology) taking an interest in ports and shipwrecks (Ford 2011). Although using terrestrial archaeological predictive models in coastal settings is common, using predictive models specifically developed

for coastal settings is less so. There are some notable exceptions, such as models developed specifically for assessing the potential of coastal archaeological features such as shell middens, or models developed specifically for finding culturally modified trees (CMTs); a leader in these aspects in BC has been Millennia Research Limited, led by Morley Eldridge (Eldridge et al. 2007, Eldridge and Parker 2007).

Modelling archaeology in coastal and underwater settings is a relatively recent phenomenon, with some of the first modelling for prehistoric remains happening in underwater archaeology in Denmark in the 1980s (Andersen 1985; Fischer 1987). These sites used a “presupposition model” (also called the Danish Model) for submerged prehistoric site discovery, which used site locations on land as analogues for underwater site locations (Benjamin 2010; Fischer 1993). Anders Fischer’s (1995) model is one of the most important analogues for qualitative modelling in this study. Fischer (1995, 374) used information from commercial fisherman in the Karrebæk Fjord to develop generalized rules for site location (see Figure 14 Left, below). Next, potential locations were circled on bathymetric maps and subsequently surveyed, with an 80% success rate for finding Mesolithic remains (Fischer 1995, 375) (see Figure 14 Right, below).

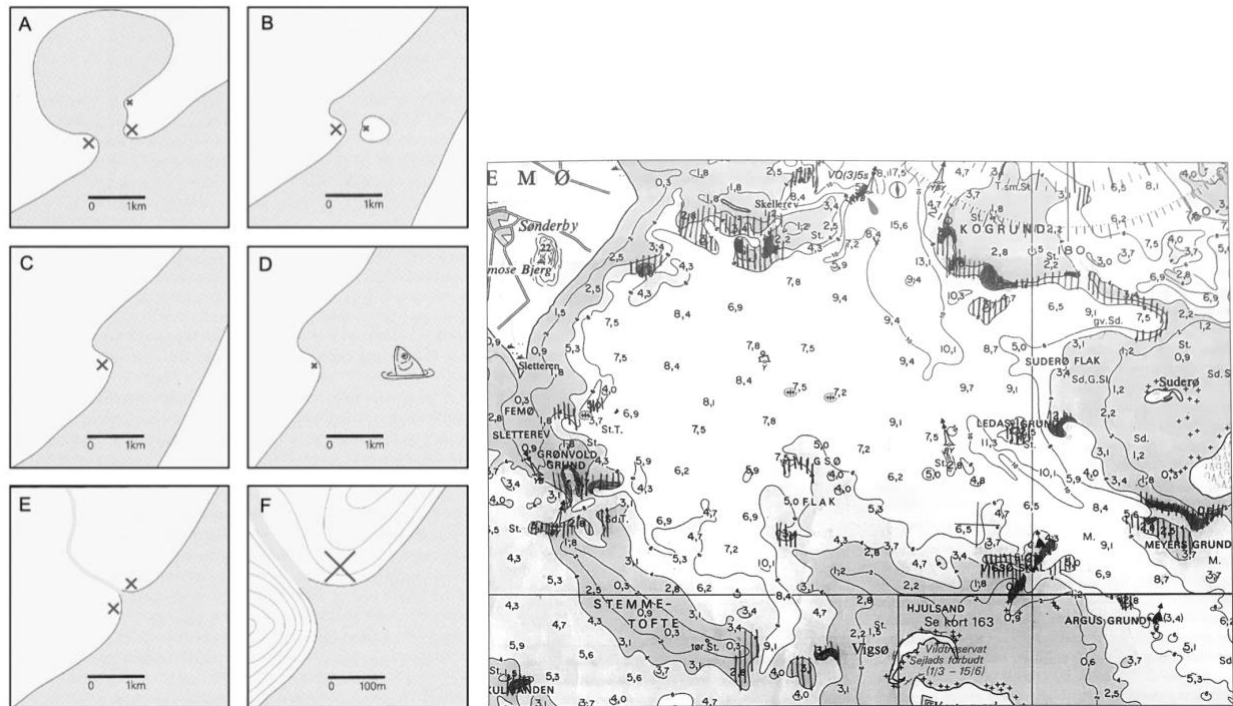


Figure 14: Left: Generalized model for underwater archaeological site location. A and B: Narrows and narrows between an island and the mainland, C and D: Tip of a headland, E and F: Mouth of a stream or river (Fischer 1995 in Benjamin 2010, 257). Right: Bathymetric map with model locations marked in black and hatch lines (Fischer 1995, 375).

Since then, modelling for underwater archaeology has occurred more often, primarily in an attempt to reduce expensive site reconnaissance time. Broad areas of underwater coastal modelling for prehistoric archaeology include Alaska (Dixon and Monteleone 2014; Monteleone et al. 2012), Oregon (Jenevein 2010; Punke 2001), the Baja Peninsula (Gusick and Davis 2010; Gusick and Faught 2011), the Gulf of Mexico (Faught 2002, 2004, 2014; Pearson et al. 2014), the North Sea (Firth 2011; van Heteren et al. 2014), the Arabian Peninsula (Bailey et al. 2015; Boivin et al. 2013; Erlandson and Braje 2015), the Baltic (Benjamin 2010; Jöns and Harff 2014), and Sahul and Australia (O’Connell and Allen 2015; Ward et al. 2015).

There have been several different specifically coastal models developed in recent years that have been reviewed for this thesis. Most recently is Robert Gustas’ (2015; Gustas and Supernant 2017) predictive model, using a least cost path method to understand early maritime

movement. Gustas (2015) conducted quantitative modelling to understand high-use coastal movement corridors and suggested the possibility for predictive capacity. Because most modeled site locations are drowned, there was no ground-truthing involved. Quantitative variables used to construct the cost surface for path modelling included beach slope, aspect, distance to freshwater, paddling distance, view to shore, protected waters, and coastline sinuosity.

Another recent model is Risa Carlson and James Baichtal's (2015) predictive model for finding raised shell-bearing strata in southeast Alaska. Carlson and Baichtal's (2015) predictive model is based primarily on the identification and dating of raised shell-bearing marine strata to model the early Holocene coastline and target the associated prime elevations for occupation at that time. Other variables considered included high resource availability areas, such as salmon streams, salmon pooling areas, tidal flats with intertidal bivalves, areas with access to upland hunting, and protected environments with southern exposure. Carlson and Baichtal (2015) conducted intermittent fieldwork ground-truthing their predictive model over the course of four years, resulting in a total of 70 new archaeological sites, 13 of which date to the early Holocene.

A third recent model is Kelly Monteleone's (2013; Monteleone et al. 2012) underwater archaeological predictive model, created during her PhD dissertation with E. James Dixon (Dixon and Monteleone 2014) at the University of New Mexico for finding underwater archaeological sites off the coast of southeast Alaska. Although Monteleone's model is created to find underwater archaeological sites, it takes a similar approach to models created for land-based archaeological survey. Incorporating paleoenvironmental data such as sea level history, Monteleone's model uses quantitative variables including slope, aspect, streams, lakes, shoreline complexity, tributary junctions, and nearby archaeological sites in a traditional weighted raster method (Monteleone 2013, Monteleone et al. 2012). In addition to creating this model,

Monteleone has done a limited amount of underwater ground-truthing due to the logistics and cost of underwater archaeological exploration (Dixon and Monteleone 2014; Monteleone 2013).

Jenevein's (2010; Davis et al. 2009) recent modelling of paleoshorelines off the coast of Oregon used a geoarchaeological approach in combination with GIS modelling of drowned paleocoastal environments. Jenevein's (2010) model is presented as a paleolandscape resource productivity model and is used to find areas of high potential. Variables for the resource productivity model include surface lithology, hydrology, slope, and solar insolation (Jenevein 2010, 57-58). An exploratory geoarchaeological excavation to supplement GIS modelling took place in Neptune State Park, Oregon, the results of which were used to evaluate the model, interpret processes of site formation, and interpret the surrounding landscape (Jenevein 2010). Stratigraphy at Neptune State Park was defined in high resolution and the study made conclusions about site formation, geomorphic history, and future directions (Jenevein 2010).

Punke (2001) created two different predictive models for locating late Pleistocene sites on the southern Oregon coast. One deductive model used distance to water, aspect, slope, geological units, soil units, and confluence locations as variables in an overlay model (Punke 2001, 73). The second model used a weighted overlay method of 13 different variables including proximity to different types of freshwater (lakes and streams); complex coastline features (e.g., estuaries); upwelling zones; strandflats; boat-beaching areas; nearshore rocks, reefs, or islands; ecotone boundaries; coastal bluffs; caves or rockshelters; lithic sources; slope; and stream terraces. Additionally, Punke (2001) modelled for more specific types of sites, such as coastal or inland resource residential camps, and coastal or inland resource field camps by modifying the weights of the variables.

Some interesting methods for predictive modelling and archaeological survey that are not necessarily coastal are Stewart and colleagues (2017) and Hitchings and colleagues (2013) use of predictive modelling and Bayesian approaches to archaeological foot survey in Cyprus and Jordan respectively. Most relevant for this thesis is that both Stewart and colleagues (2017) and Hitchings and colleagues (2013) qualitatively defined remnant Pleistocene landforms as targets for modelling. Polygons were then foot surveyed keeping in mind sweep widths (probabilities of finding artifacts within a certain width along a transect), which were used to update their Bayesian predictive model and assess how well each polygon had been surveyed (Banning et al. 2017).

Predictive modelling for coastal archaeology represents one of the ways that predictive modelling is being redesigned from a do-all black-box method to a transparent tool used for searching for specific types of archaeology. Future models and new techniques will likely lead to new discoveries.

## 2.4 False Start #1: Agent Based Modelling

Recently, Agent based modelling (ABM) has emerged as a cutting-edge technique to create more complex models that have the potential to not fall into the same theoretical and methodological pitfalls as traditional predictive modelling (e.g., Wurzer et al. 2015). ABM is a type of computational modelling that establishes unique and autonomous entities that interact with their local environment and other agents (Railsback and Grimm 2012, 10). Typically, ABMs are implemented through software packages and run as simulations. ABM has its roots in the origins of other topics that have become new fields of inquiry today, such as artificial intelligence, complexity theory, and chaos theory. An interrelated type of model are cellular

automata, consisting of two dimensional cells that run the same set of simple rules. ABM has more recently become more accepted in scientific disciplines due to the implementation of more strict publishing guidelines (e.g., Grimm et al. 2010) and more widespread awareness of the modelling process.

In archaeology, ABM has been gaining traction in recent years along with wider acceptance of archaeological simulation (Lake 2014). For example, one of the first archaeological ABMs explored Mesolithic subsistence economies in Western Scotland by simulating hazelnut gathering (model named MAGICAL) (Lake 2015). Recent reviews of ABM in archaeology are optimistic about the future of modelling, and tend to predict wide spread use and adoption in the coming years (Cegielski and Rogers 2016; Lake 2014; Wurzer et al. 2015).

Typically, ABM is used for theory building and testing, methodology and hypothesis testing, and as a heuristic device. Although more archaeologists are using ABM, practitioners of ABM have been reluctant to use it for predictive modelling purposes because simulations are highly reliant on initial conditions and small variations can build up through the simulation (Verhagen and Whitley 2012, 87). These factors have been used as advantages by some archaeologists to explore and better understand emergent and bottom-up processes that influence the archaeological record (Clark and Crabtree 2015, Crabtree 2016, Davies et al. 2016). Models such as these are typically framed within an “exploratory model” context, where simulations are run to explore the patterns that emerge from agent interaction and behaviour over multiple simulations. In the future, ABM may be an encouraging way to explore possible emergent processes that occur during the peopling of new territories. In this way, ABM may be suited to exploring concepts and possibilities regarding processes in archaeological site location.

Although ABM was not a central part of the research or theoretical process in this study, I created an expedient agent based model to calculate wind fetch. From reviewing the literature of ABM, it seems that it will have a promising future in archaeology and even archaeological site location modelling because future ABMs could incorporate current anthropological theory and simulate complex emergent processes that are complicated to do by other methods. A dedicated modelling community and more information about early period archaeology on the Northwest Coast will facilitate future study. In this study, ABM would require much more work to carry out and was therefore dropped due to issues with thesis scope and the utilization of other pre-existing tools.

## 2.5 Chapter Conclusion

In this large background chapter for this study, I have reviewed three major areas of research that are important inputs into predictive modelling for late Pleistocene – early Holocene archaeology on the Northwest Coast: the paleoecological and archaeological records, and GIS modelling. The scale of paleoenvironmental change has been drastic, with relative sea level playing an important role. In the late Pleistocene, sea level on Quadra Island was higher than modern, meaning possible late Pleistocene – early Holocene archaeology is stranded at higher elevations. Paleoenvironmental change on the coast means that few sites are known from the late Pleistocene- early Holocene time period. However, known sites provide important information about how people may have lived and what technologies they were using. Specifically, some lithic technologies may be diagnostic for the time period. It is also important to understand the history behind GIS modelling, which may help to find specific site types in a focussed survey. Agent based modelling could be further studied to understand emergent processes of the peopling of the Americas and processes of site location, but was not used for this study.

Understanding these broad areas, paleoecology, archaeology, and GIS modelling, and then applying this knowledge is essential for finding late Pleistocene – early Holocene sites in a landscape of dramatic paleoecological change. However, each of these fields is associated with theory that must be understood to best use knowledge critically. The next chapter reviews the theory associated with each of these fields and explains the theoretical approach of this study.

### **Chapter 3: Theory**

Theory is a very important aspect of research that bridges knowledge production and practice. To make sure that the ontological status and epistemological framework of research is not taken for granted, one must think critically, be reflexive, think about one's analytical object, and recognize the assumptions involved—following Wylie and Nelson (2007, 21) and the “third option” of scientific philosophy. This “third option” employs self-reflection and systematic inspection of the context of research in order to improve the value of research—producing an explicitly “value-rich” science, rather than a falsely “value-free” science (Wylie and Nelson 2007, 21). This concept was important to keep in mind while conducting this research—recognizing and explicitly stating my epistemology and the assumptions involved in GIS modelling research, which are outlined in my critique of predictive modelling (Section 3.2 and Section 3.2.1). This thesis embraces “value-rich” science by qualitative modelling and problematizes attempts to make quantitative modelling “value-free”.

At the core of the GIS modelling conducted for this study is a critique of predictive modelling. This critique reviews the shortcomings and lack of current theory employed in most predictive models, and contributed to the decision to not create a “traditional” predictive model. This method uses GIS modelling as a tool rather than an end in itself, addressing some of the recognized shortcomings and criticisms of archaeological predictive modelling and addressing the possibility that this research might be used in the future in different contexts (e.g., Martindale 2014).

Further important for this study is theory from anthropology and earth science. Significant to these sections are understandings of formation processes, especially with regard to site survivability, and ethnographic analogy, with regard to human behaviour. Humanistic

anthropological theory is also drawn on, including practice theory, dwelling, and phenomenology. Archaeology has successfully integrated theory and method from a wide variety of disciplines and it is important to recognize the range of underlying assumptions associated with each approach.

### 3.1 Critique of Predictive Modelling

As GIS was implemented as a new technology in archaeology in the 1990s, the use of GIS for predictive modelling was called a new method by some practitioners (Ebert 2000, 130). However, the implementation of GIS did not change the theory and method behind predictive modelling since it was first performed with overlain paper maps (Wheatley 2004). The theory behind predictive modelling is outdated and often overlooked or disregarded by creators and users of predictive models (Verhagen et al. 2013; Verhagen and Whitley 2012). Because of predictive modellings association with the explosion of new technologies such as GIS, the internet, and new data collection techniques, practitioners and users of predictive models typically forget about the assumptions that they are making when modelling or analyzing output (Ebert 2000). In this section, I will outline some of the major assumptions that typically accompany predictive modelling. Additionally, many of these assumptions have basic implications for Indigenous peoples and their rights, heritage, identity, and agency. There are also implications for the archaeological record and its interpretation.

One of the most basic critiques of predictive modelling is that the method does not work—predictive models cannot find sites or usefully inform archaeologists of site location or processes of settlement (Wheatley 2004, 3.2.1). However, because of the number of different predictive models and their variety of objectives and uses, this assertion is not always true. James Ebert (2000, 133) is critical of predictive modelling, and notes that predictive models are

typically evaluated by their creators as capturing sixty to seventy percent of the archaeological sites in a set area of a study area. He notes that this “is not really bad but it is not very good either,” —not good enough to justify spending money on predictive modelling instead of archaeological survey (Ebert 2000, 133).

A second basic criticism of predictive modelling is that models are environmentally deterministic, also known as the ecological fallacy (Verhagen and Whitley 2012, 57). Typically, theory behind predictive models of this type consists of simple cause and effect relationships between human settlement patterns and the environment. The explanation of the past by correlating human behaviour to environmental variables “is reductionist to the extent that it effectively de-humanises the past” (Wheatley 2004, 3.1). This has profound implications for Indigenous peoples, who, in these models, “are reduced to automata who behave according to a rule that connects their behaviour to their environment” (Wheatley 2004, 3.1). This form of predictive modelling replaces past people’s agency and behaviour with mathematical equations (Wheatley 2004, 3.1).

Creators and users of predictive models typically assume that it is the past that is predicted and modelled. However, almost all data incorporated into predictive models is from the present or derived from the present, such as elevation models, archaeological data, paleoenvironmental data, and landforms. This creates models that are anti-historical (Wheatley 2004, 3.1). Especially with dramatic environmental change, these types of models may miss ancient “high potential” areas that have changed to “low potential” in the present. Models using data from the present, especially inductive models, correlate archaeological site location—from an already biased archaeological record of sites (e.g., Hall et al. 2002)—to environmental data from the present, not the past.

Another common assumption is that predictive models predict archaeological ‘sites’. The aim of predictive models is to model and predict the locations of archaeological ‘sites’ in general, which are archaeological constructs from the present, consisting of concentrations of material evidence, landscape modification, or evidence of human activity (Ebert 2000, 130). Modelling for ‘site’ location assumes that these areas are circumscribed, discrete, and independent entities, which is not the case (Ebert 2000, 130; see also Dunnell 1992). This also can impact Indigenous peoples. For example, both predictive models and archaeology focus on ‘sites’ as one of the main units of analysis, where material concentrations and/or high intensities of landscape modification occur. Areas of low archaeological potential have similar connotations to archaeological areas with little or no material traces—termed sterile areas or zero potential areas—reminiscent of the *terra nullius* argument for the sovereignty of modern settler states (Wobst 2005, 20). This connotation has moral implications for the use and interpretation of predictive models, especially as primary tools in the process of CRM archaeology.

Models that correlate site location with environmental variables assume that environmental variables are important in the first place. However, humans modify their environment, and make complicated, sometimes illogical decisions. While ecological conditions may be one part of some peoples’ decision making, we cannot assume that environmental variables always played a determining role in decisions related to settlement location (Ebert 2000, 131). Such assumptions take away agency from people in the past, implying that they did not make decisions on their own or modify their circumstances to suit their needs (Wheatley 2004, 3.1). Inductive predictive models especially, correlate environmental variables to site locations without involving any consideration of cultural and other human components of settlement.

Often predictive modelling data are used uncritically. Archaeologists typically do not collect the data that are used in a predictive model (e.g., soil, elevation, etc.), and therefore, the data may have unknown biases and inconsistencies (Verhagen and Whitley 2012, 57). For example, the use of hydrological data collected for a different reason may be opportunely used for a correlative variable like distance to water. However, questions such as what defines a stream, what streams are included and not included, and what types of biases may be present in data collected are not asked by the predictive modeller, which can have ramifications for the model (Ebert 2000, 132). The data incorporated in a predictive model may then subsequently be criticized as being inaccurate or low resolution for archaeological purposes.

A major issue with predictive models are that they are very hard to test—indeed, some archaeologists have said that they cannot be tested (Ebert 2000). Testing a predictive model, whether inductive or deductive, is time consuming, difficult, and rarely properly done. Typically, in order to test predictive models, the Kvamme Gain statistic (Kvamme 1988, 329) is used, where:

$$\text{Gain} = 1 - \left( \frac{\text{percentage of total area covered by the model}}{\text{percentage of total sites within the model area}} \right)$$

The gain statistic is a measure of a predictive models “usefulness”, where a gain statistic approaching 1 means the model is more useful. According to the gain statistic, a model works well if the area predicted to contain sites is small, and the sites found in that area represent a large proportion of the sites in the total area (Kvamme 1988, 329). However, if the gain statistic is closer to 0, the model is less useful; the area predicted to contain sites is large, and the proportion of sites in the area is not significantly greater than the total area of the model on its own (Kvamme 1988, 329).

However, the gain statistic only evaluates the predictive model against sites that are already known (Wheatley 2004, 3.2.1). Of course, it would be very hard to test a model against unknown sites, but this would be needed to get a proper view of model usefulness. This creates a self-fulfilling feedback loop in which models are evaluated by themselves, continue to predict sites from a biased record, and further bias the record (see Figure 15) (Wheatley 2004, 3.2.1). Without perhaps excavating an entire regional area, a valid test of a predictive model is very hard to perform.

Different testing techniques are possible in theory, but would require extensive time and systematic fieldwork. These techniques involve conducting a statistically valid number of test excavations in a range of different potential polygons of a potential map in order to ground truth the model (i.e., to find out if there actually are more sites in the high potential areas than in the low potential areas). Consequently, the sample size of testing is also influenced by the number of ordinal classes of potential created for a model: common numbers of classes being three (high, medium, and low potential) and five (very high, high, medium, low, and very low potential). Therefore, as the resolution of the model increases, so too does the time one must spend to test it.

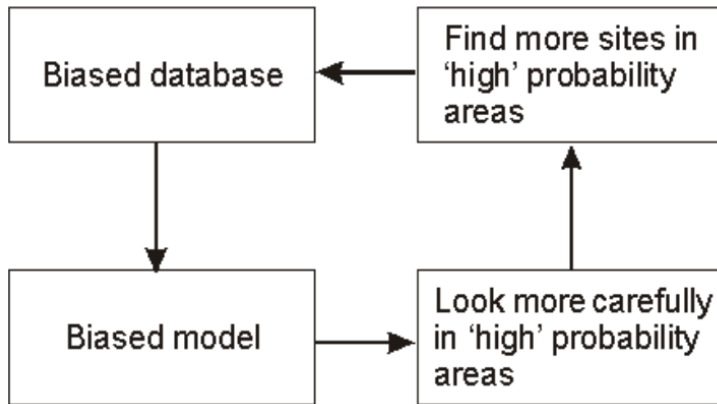


Figure 15: The self-fulfilling feedback loop of predictive model testing (Wheatley 2004, 3.2.1).

This critique represents some of the theoretical and methodological downfalls of predictive modelling and its typical use and misuse. There are further implications with how predictive modelling method and output may be misconstrued, misrepresented, and misused even after a study is finished, and these outcomes have further implications for Indigenous peoples (e.g., Martindale 2014).

### 3.2 Predictive Modelling and Heritage Protection in BC

The history of predictive modelling and CRM in BC is intertwined with the history of archaeology in the province (Nicholas 2006). It is interesting that predictive modelling has long been associated with CRM. One of the first volumes concerning predictive modelling in the Northwest Coast area was geared towards CRM in the United States (Darsie et al. 1985). Predictive modelling was also first explored in relation to CRM archaeology by the BC Archaeology Branch in the province (Eldridge and Mackie 1993; Moon 1993). This official exploration of the use of predictive modelling occurred after the publication of *Quantifying the Past* (Judge and Sebestain 1988), when Heather Moon of the BC Archaeology Branch assessed archaeological predictive modelling in a 1993 report for the Resources Inventory Committee of the BC Provincial and Canadian Federal governments. Her report reviewed the then new

technology of GIS archaeological predictive modelling, and assessed its viability for implementation in BC. Eldridge and Mackie (1993) also wrote a report assessing the possible implementation of predictive modelling with the existing site inventory of BC to better understand influences of site location, and enhance the provincial inventory of sites. Beattie (1995) was one of the first academic users of GIS to gain insight into land use and the relationship of the environment to site location in his study of archaeological landscapes in the Lower Mainland of British Columbia for his MA thesis at the University of British Columbia. One of the most influential predictive models on the Northwest Coast was Maschner and Stein's (1995) multivariate approach to site location—an inductive model that correlated environmental variables to site locations in the Alaskan Panhandle area. Predictive modelling has been used in CRM archaeology in the Province to adhere to the guidelines of the Archaeology Branch and heritage legislation in advance of development.

The mid 1990s were an important time for archaeology in BC, as decisions in several important Aboriginal land rights court cases, such as *Delgamuukw v. Regina*, influenced archaeological legislation. An important case for Aboriginal peoples in Canada was *R. v. Sparrow*, in which the Supreme Court established that Aboriginal fishing was an inherent right, never extinguished, and protected by the 1982 Constitution Act (Asch 1997, 267). The federal government further established that Aboriginal rights in Canada were never extinguished in a 1995 policy statement (Borrows 2005, 205). During this time, laws and codes such as the 1994 Protocol Agreement with the Ministry of Forests, the Forest Practices Code (1995) and a revision of the BC *Heritage Conservation Act* in 1996, formalized requirements of archaeologists to consult with Aboriginal peoples (Nicholas 2006, 357). Although Section 4 of the *HCA* details “agreements with First Nations”, there is no signed agreement between the Province and First

Nations, and no agreed upon and legislated meaningful role for First Nations in the heritage resource management process (McLay et al. 2004, 61).

The *HCA* is designed to protect the archaeological heritage of the Province, however, in practice, the Archaeology Branch, which takes care of the permitting system, has limited resources to enforce the protection of sites. Lack of funding and heavy workload means that the Archaeology Branch does not have the means to properly enforce heritage conservation laws, and unregulated land development, especially on private land, can occur (McLay et al. 2004, 42). Although sites are protected even on private lands, this is hard to police. This is complicated because only known sites can be protected, and these also do not necessarily include off-site archaeology or spiritual sites (Mohs 1994) which are important to Aboriginal peoples (McLay et al. 2004; Mohs 1994).

The *HCA* requires the completion of Archaeological Overview Assessments (AOAs) and Archaeological Impact Assessments (AIAs), which has further cemented predictive modelling as an aspect of CRM in BC. AOAs are large scale overviews of areas that can be used for mitigation and planning for the preservation of the archaeological record. This mandate means that predictive models are readily applied in AOAs, sometimes over extremely large areas (Eldridge et al. 2005). For example, the AOA in the Northeast of British Columbia, commissioned by the Oil and Gas Commission of British Columbia, covered an area over 78,000 square kilometres (see Figure 16) (Eldridge et al. 2005, 1).

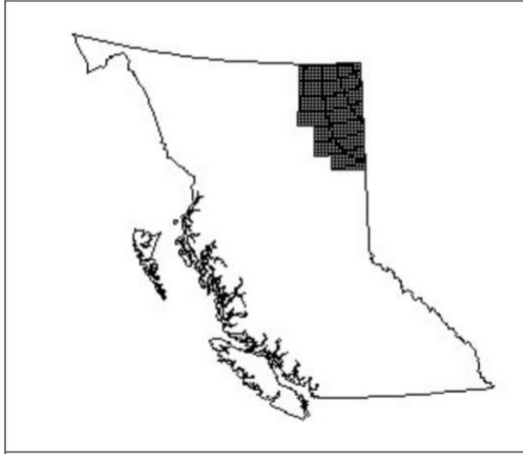


Figure 16: Study area of the Northeast AOA (Eldridge et al. 2005, 1).

Aboriginal peoples are rarely given the chance to voice their opinions about archaeology and the way that it is conducted in the Province (see Mclay et al. 2004; Nicholas 2005 for examples of some Indigenous views). In relation to predictive modelling, a 1995 AOA report for the Kalum Forest District, on the lower Skeena River, shows one opinion about predictive modelling (Eldridge et al. 1995). Mr. Marvin George, Lands and Resources Negotiator for the Wet'suwet'en Hereditary Chiefs Treaty Office, voiced major concerns about the entire report process to the archaeological consultants. He stated that it was offensive that contact about the project was initiated by the contractor (i.e., Millennia Research Ltd.) and not the client (i.e., the BC government) after the project had already been started (Eldridge et al. 1995, 5). He stated that contact should be made at the inception of the project, and that First Nations should be involved in primary research and reporting, rather than just as token suppliers of data (Eldridge et al. 1995, 5). He was also unhappy with the concept of archaeological potential, given the virtually complete ownership and use of land by the Wet'suwet'en people (Eldridge et al. 1995, 5). The authors of the report, and I, believe that these are common opinions of Aboriginal peoples in British Columbia about predictive modelling (Eldridge et al. 1995, 5). Today, there are certainly some examples of fuller and more culturally appropriate First Nations involvement

in archaeological projects (e.g., Angelbeck and Grier 2014; Grier and Shaver 2008), or even archaeological projects initiated and carried out by the First Nations themselves (e.g., HIRMD 2017; Hul'qumi'num Treaty Group 2005), however, there are still other examples similar to those from the mid-1990s.

One major issue with predictive models is their output. It is offensive for Indigenous peoples to have their traditional territory ranked into polygons of high, medium, and low potential, as they have always used the entirety of the land. Typically, the majority of land is ranked as low potential, for reasons related to model utility and the Kvamme gain statistic (Kvamme 1988, see page 81). These potential maps are then used by settler government bureaucracies for planning, such as resource extraction development. These potential maps also directly inform archaeological survey, with high potential polygons typically investigated, and most low potential areas neglected. When potential maps are looked at without disclaimers that they do not directly represent the archaeology of an area, the maps are reified, and treated as fixed maps of archaeological resources. This freezing of archaeological resources is detrimental to Aboriginal claims to the land, and detrimental to the archaeological record. The implementation of predictive modelling for archaeological sites and their output results is also in direct conflict with Indigenous ontological understandings and knowledge of the landscape. For example, in Hul'qumi'num territory, archaeological sites are understood as cemeteries, places where the past is part of the present, and places of ancestral agency (McLay et al. 2004).

Issues of archaeology and Indigenous peoples in BC have been focussed on discussions around burial sites, human remains, and who has the right to control the past. These issues have been at the forefront of discussion because of high-profile disagreements and cases such as The Ancient One (Kennewick Man) and the implementation of NAGPRA legislation in the United

States (Ferris 2003). However, the dominant form of archaeological investigation is through CRM mitigation projects from development, and the major part of CRM is non-burial archaeology (Ferris 2003). Therefore, predictive modelling is involved in wider debates of cultural property and laws surrounding the rights of Indigenous peoples and their ancestors. Whether or not non-burial archaeology should be treated any differently than burial archaeology is debated, however, it should be noted that this separation imposes a euro-centric division between religious and non-religious values (Ferris 2003, 167). Conveniently, this division also means that control of most of the archaeological record would remain with the government rather than with Aboriginal peoples (Ferris 2003, 167). There is a wide literature regarding the “ownership” of the past (e.g., Nicholas and Bannister 2004), which is really about control and authority over the archaeological record, and has implications for identity, land claims, development, and many other areas.

Most recently, a discussion in the *Canadian Journal of Archaeology* between La Salle and Hutchings (2016) and Martindale and colleagues (2016) has highlighted both still-outstanding issues and the improvement and partnerships that have formed in BC archaeology. La Salle and Hutchings (2016) contend that archaeologists are ignoring the state-sanctioned institutional racism and inequality that constitutes most archaeological practice. In La Salle and Hutchings’ (2016) view, archaeologists ignore and are complicit in the marginalization of Indigenous peoples and the destruction of Indigenous heritage along with archaeologies role in issues of elitism, racism, and at the most extreme, genocide. In response, Martindale and colleagues (2016) express that archaeology is beginning to change to be in service of Indigenous communities, where Indigenous communities determine archaeological value for themselves. Martindale and colleagues (2016) acknowledge that issues of colonialism and power are far from

solved in archaeology, but that lifelong partnerships in practice are a first step forward in challenging and changing the discipline of archaeology.

### 3.2.1 Quantitative modelling assumptions

The issues raised by a critique of predictive modelling and a brief look at the history of heritage protection in BC require recognizing and explicitly stating the assumptions and influences involved in modelling for this study. First, in order to model something, it must be reduced in some way, and for computational models, this is typically in the form of logical rules that can be interpreted by a computer. Such reductionism is important to consider when attempting to model aspects of complex human behaviour from multiple viewpoints. Reductionism is present in this study by using computers (e.g., GIS software), data (e.g., digital elevation data), and derived data (e.g., slope or wind fetch).

The most pervasive assumptions in this study revolve around our understandings of people in the past. Judgemental archaeological site survey typically involves assumption through educated guessing about locations that people in the past would have been depositing material culture. Although it is recognized that the past is infinitely complex and we will never know many aspects of it, assumptions are used in this study to attempt to find material culture and use it to better interpret the past. There are two main assumptions for quantitative modelling variables used in this study: For coastline complexity, we assume that more complex coastlines are a proxy for richer biodiversity and resource availability. Therefore, we assume that a more complex coastline is more attractive to people than a straight coastline. For wind fetch, we assume that wind fetch acts as a proxy for wind and wave exposure, and that less exposure would have been preferred by people during the study period. There are further assumptions made during qualitative modelling which are outlined in Section 4.4.

The output of quantitative modelling has also been considered in this study. Predictive modelling typically overlays a system of potential classification on the landscape. The reification and misuse of such predictive modelling output as showing *all* of the archaeology of a region is important to note. This has been especially damaging in the CRM industry, where predictive output areas of “low potential” can be left uninvestigated and impacted by development, and further, can have devastating consequences for Indigenous peoples’ land claims and archaeological heritage (Hutchings and La Salle 2015; as noted above in Sections 3.1 and 3.2). To avoid these pitfalls, GIS modelling in this study is explicitly used as a tool for focussing archaeological investigation specifically in time and space (i.e., the Pleistocene/Holocene transition, Quadra Island, LiDAR-flown areas of Quadra Island). This study does not try to find all archaeological sites, and does not try to find all archaeological site types (e.g., including fish traps, rock art, culturally modified trees, lithic scatters). However, assumptions are required in order to model phenomena for which we have little data from the material record.

It is important to understand the numerous assumptions, limitations, and consequences of using GIS modelling as a tool for site location, in order to use it critically. This section explicitly states some of those assumptions in an attempt to mitigate the possible effects.

### 3.3 Early Period Archaeological Theory

Archaeology of the late Pleistocene and early Holocene in North America has a long history, going back to the discovery of Clovis in New Mexico in the 1920s and 1930s. Clovis and other Paleoindian archaeological cultures such as Folsom were the focus of early archaeology in North America for decades. Researchers studied these assemblages from a culture

historical point of view, and tried to understand cultural processes by diffusionism (Trigger 2006, 279).

The ancestors of the first Americans have long been thought to have originated from Asia (e.g., Boas 1929), and the Bering land bridge was formally identified as a possible route in the 1930s (Johnston 1933; Howard 1935). When the chronology of Clovis started to emerge with radiocarbon dating (e.g., Haynes 1964), the hypothesized ice-free corridor between the Laurentide and Cordilleran ice sheets was thought as the most likely route of entry for the ancestors of Clovis and the first Americans, and formed a neat package with then current processualist theory and understandings of big game hunting in late Pleistocene America (Meltzer 2015).

From a more ecological perspective, Fladmark (1979) proposed a coastal route of entry for the peopling of the Americas, suggesting that the ice-free corridor would have been a marginal environment compared to the possibility of an ice-free coast. Since then, early period archaeological theory has further incorporated understandings of the landscape and paleoenvironment into research (e.g., Bailey and Parkington 1988). New research questions addressed more humanistic theory, from how humans interacted with the late Pleistocene – early Holocene environment (e.g., Erlandson 1994) to cultural transmission and how the earliest American cultures created stone tools (Davis et al. 2012). Understanding the paleoenvironment at a high resolution has become very important for the study of the earliest archaeology in North America (e.g., Fedje and Christensen 1999; McLaren 2008; Mackie et al. 2011), especially since this time has proven to be particularly dynamic. As a consequence of the little archaeological data available for the period, a reaction has been to use as much data from other sources as possible to try to find more sites. Including the focus on high resolution paleoecological

information, the idea that early period archaeological site location is controlled by the inherent probability of site survivorship and human behaviour is especially important theoretically for this study. Two concepts related to this idea are formation processes and ethnographic analogy.

### 3.3.1 Formation processes and survivorship

The substantive landscape changes that have occurred since the late Pleistocene – early Holocene make an understanding of formation processes of the archaeological record central to site survey. Theory about formation processes is derived from different scientific disciplines from which it takes its methods, such as chemistry, geology, and biology. The most influential academic on formation processes was Michael B. Schiffer, when he wrote about archaeological and systematic contexts in 1972, and subsequently published his book, *Formation Processes of the Archaeological Record* (1987). Schiffer (1987) split formation processes into natural and cultural categories, and further categorized natural formation processes by scale, into those that effect the artifact, the site, and the region. These categorizations can be useful to conceptualize the formation processes that may have effected late Pleistocene – early Holocene archaeology on Quadra Island.

At the artifact scale, non-cultural biological processes, chemical processes, and physical processes can affect artifact preservation at a site. On Quadra Island and elsewhere on the Northwest Coast, acidic forest soils typically degrade organic materials, leaving only inorganic and burned materials behind. Except under special preservation conditions, such as at wet sites, in shell middens, or in karst caves, the only cultural materials that survive are made of stone or those have been burned, including charcoal and calcined bone. For example, if people on the Northwest Coast had a toolkit made substantially of organic materials such as bone, that evidence is unlikely to survive to the present. Hints of the diversity of technology can be seen at

Kilgii Gwaay, Haida Gwaii, where an intertidal wet site component preserved organic environmental remains such as flora and fauna, and organic artifacts (Fedje et al. 2005; Mackie et al. 2011; Cohen 2014). Such organic technology may have also played a role in earlier times, as the bone point embedded in the mastodon rib found at Manis, Washington suggests (Waters et al. 2011a) or at Gaadu Din cave, where a bone point was found and dated to ca. 11,800 cal. BP (Fedje et al. 2011a).

Materials that survive for longer amounts of time can still be degraded, for example, lithic artifacts may be chemically weathered, affected by freeze-thaw cycles, or physically broken from disturbance, among a variety of other processes. Further, some of the lithic raw materials chosen in the late Pleistocene – early Holocene on the coast do not survive as well as others. Such low visibility archaeological sites require a survey strategy that utilizes shovel testing and evaluative units in order to identify lithics and materials such as charcoal and calcined bone. Sometimes natural site formation processes can strip the context from early sites. For example, in Gwaai Haanas, intertidal lithic scatters dated to 10,700 cal. BP have survived marine transgression and are surviving regression (Mackie et al. 2014). These sites represent a unique opportunity for site location and settlement patterns, however, for each individual site, little context is left in the lag surfaces.

At the site-scale, natural formation processes such as mass wasting events, sediment deposition, vegetation, bioturbation, and other disturbances influence site preservation, and at the local and regional-scales, landscape events and changes such as glaciers, earthquakes, volcanism, and sea level history influence site location and preservation (Schiffer 1987). Site visibility and recognition are important factors affecting our search for late Pleistocene – early Holocene sites on the Northwest Coast. Early period sites are likely to be deeply buried in sediment, sometimes

directly under later Holocene sites. Early period sites are typically obscured because of dynamic changes that have occurred on the landscape. This dramatic change of the landscape means that sites may not be located where archaeologists expect them to be based on present day landforms. Especially on the coast, complex paleoenvironmental change can obscure site location and erase evidence of sites through erosional processes.

Finding relict late Pleistocene – early Holocene landforms is a key aspect for finding archaeological sites. For this thesis, this was done through qualitative modelling of target areas using LiDAR data. A geoarchaeological approach is also useful for finding target areas. At the local and regional-scale, different interpretations of geological formation processes (e.g., how did a terrace form?) require fieldwork, testing, and quantitative measures such as grain size, suspension, and microscopic analysis. For the DILA project, Alex Lausanne, an MSc candidate in Geography at the University of Victoria is carrying out sedimentological analysis and OSL dating of sediments from select archaeological sites to aid geological interpretation and establish the age and origin of sediment and landforms (Lausanne et al. in prep).

Cultural formation processes can also operate at different scales to effect formation of the archaeological record. At the artifact-scale, reuse, cultural deposition, reclamation, and disturbance form main categories (Schiffer 1987). At the site-scale, cultural formation processes include any human site disturbance, such as digging. Cultural formation processes can also happen at the local and regional-scale, such as logging or other natural resource extraction, or at the continental-scale, such as building the modern road network. Historic logging is especially relevant for Quadra Island, as much of the Island was logged in the late-1800s and early 1900s, with the first logging occurring in Drew Harbour in 1882 and Gowlland Harbour in 1883. (Taylor 2009, 47).

An understanding of formation processes, survivorship, and landforms is essential to finding archaeological sites. In conjunction with interpreting formation processes, models of human behaviour are also important, and are developed from interpretations of the archaeological record and ethnographic analogy.

### 3.3.2 Ethnographic analogy and behavioural models

Issues with ethnographic analogy have been long known in archaeology (e.g., Ascher 1961; Wobst 1978), but still form an important aspect of inference about the past, especially for time periods with little material evidence, such as the early period. In some cases, using ethnographic analogy has been very productive, for example, the sub-discipline of ethnoarchaeology uses ethnographic fieldwork to better understand material culture (e.g., David and Kramer 2001). However, ethnographic analogy must be used critically. H. Martin Wobst (1978) states that archaeology based on ethnographic analogy may merely reproduce the form and structure of the ethnographic record in the archaeological record. Similarly, as ethnographic analogy is extended further back in the record, there is more time for cultural change. Ethnographic data has been used freely to order archaeological data, guide expectations, and explain patterns and variability in the archaeological record (Wobst 1978, 303).

Due to the broad classification and definition of hunter-gatherers, uniformitarianist notions implying cultural processes as constant and unchanging are sometimes evoked by archaeologists using ethnographic analogy (Hayter 1994). Many analogies of hunter-gatherers are based on subsistence, where generalized subsistence strategies between modern people and the archaeological record seem similar, so are treated as the same (Hayter 1994, 39). However, the ancestors of the first Americans and the first Americans themselves would have possessed unique and constantly changing cultures as they entered the Americas, and there are many

aspects of this we will not understand. Ann Stahl (1993, 236) reviews how archaeologists should not only be critical about how we select analogies, but also how we apply analogies to the past. She provides a poignant review of the implicit assumptions present in ethnographic analogy from a historical point of view.

Alison Wylie reviews critiques of analogy and its use in archaeology in her 1985 paper “The Reaction Against Analogy”. Wylie’s (1985) conclusion is that although archaeologists should always understand the limitations of using analogy, analogy plays an important role in archaeological inferences and can be legitimate and constructive. Further, Wylie (1985) argues that the critiques leveled against analogy and the improvements put forward by proponents of analogy can help to control and strengthen inferences based in analogy. One example of this is examining the similarities present in an analogy, but also the differences present, to further examine the relevance of the similarities (Wylie 1985).

In contrast to the uses of ethnographic analogy reviewed by critics, some studies utilize ethnographic analogy in a critical way to gain insight into patterns of thought and worldview that would not be accessible with material evidence alone. Aubrey Cannon’s (2011) edited volume *Structured Worlds* features papers that use archaeological evidence to try to understand hunter-gatherer worldviews. In the introduction, Cannon (2011, 2) states that attributing thoughts to people in the past can be problematic in two major ways: first, only attributing thoughts that may also be credited to other biological organisms, such as optimal behaviour, may miss ideas that are specifically human; and second, ascribing the people of the past with a simplified version of our own thoughts can miss thoughts both common to hunter-gatherers and those in specific cultural and historical circumstances.

Studies that utilize current anthropological and archaeological theory in conjunction with ethnographic analogy go beyond issues of ecology, social complexity, optimality, or external change such as environmental change or population growth, and are broadening the horizons of knowledge about the past (Cannon 2011, 1). However, these studies still use the concept of ethnographic analogy critically, engaging in dialogue about what it means to use analogical models for archaeological inference.

Archaeologists have also used oral histories and traditions to understand the early past, but there can be issues with this approach because histories are not passed on to specifically help find archaeological sites (e.g., Kii7iljuus 2005; Martindale 2006). Currently, there is little empirical evidence of lifeways during the late Pleistocene – early Holocene, but there are hints that it is different from the later Holocene (e.g., Mackie and Sumpter 2005). For example, one of the most significant findings of Mackie and Sumpter (2005) is that early period sites (e.g., ca. 10,700 BP) and later period sites (e.g., late Holocene) rarely occur at the same locations despite being located along the same shoreline. An especially significant variable for this thesis is the difference in shoreline intricacy between the locations of early and later period sites, where early period sites are more likely to be located on elaborate shorelines, and later period sites are more likely to be located on linear shorelines (Mackie and Sumpter 2005, 362). Mackie and Sumpter (2005) demonstrate that there is a significant difference between early and late period site location, and suspect that this is likely due to differences in lifeways.

Ethnographic analogy and environmental analogues did not directly inform behavioural models and qualitative modelling in this thesis, however, they did play an indirect role, influencing our understandings of the possible range of behaviour and activity during the late Pleistocene – early Holocene. Some such ethnographic analogues come from the wealth of

ethnographic information from BC First Nations, for this thesis, mainly from the Kwakwaka'wakw, Coast Salish, and Haida. Further ethnographic analogy comes from related environmental analogues such as the Aleuts in Alaska (Moss 2013; Turner 2008) and the Yamana in Tierra del Fuego (e.g., Bjerck and Zangrando 2013; Piana and Orquera 2009). For example, Aleutian hillside houses in Alaska could be analogous to the possibilities for housing during the early period on the Northwest Coast (e.g., Rogers 2011). Environmental analogues are especially relevant at higher latitudes where Pleistocene shorelines are more likely to be stranded, in areas such as Scandinavia (Breivik 2014; Breivik et al. 2017; Schmitt 2013, 2015) and Patagonia (Bjerck 2009).

#### Behavioural models:

Behavioural models informed qualitative modelling. One of the most important behaviours in a coastal environment relevant to site location is the use of boats. In Kenneth Ames' (2002) paper "Going by Boat: The Forager-Collector Continuum at Sea", he argues that the use of boats by people on the coast has major implications for the ways we conceptualize the archaeological record. Using ethnographic and historical evidence to review the types of boats used on the coast and their capabilities, Ames (2002) contextualizes how people used boats on an everyday basis—and how this is important theoretically. Boats dramatically change the way that humans interact with the landscape, from travel, to storage, and transport (Ames 2002). Ames (2002) reviews two main types of boat used on the coast: north Pacific skin boats and Northwest Coast dugouts. For each type, there is further review of capacities, distances and speed, universality, and disadvantages of boats. The use of boats on the Northwest Coast fundamentally changes the relationship between people and the environment compared to terrestrial models

(Ames 2002). This has implications for site location, settlement patterns, and the resources that people use. Hein Bjerck (2017) uses the theoretical idea of a machine to understand human-boat interaction in Mesolithic Scandinavia. A machine describes a set of interrelated processes, functions, parts, and characteristics that are all equally important for an outcome. For early boats as machines, parts of the machine include skins, wood, scrapers, lines, hunting strategies, human knowledge, physicality, and a hope for the future (Bjerck 2017, 280). Bjerck (2017) argues that the use of boats structured the early archaeological record and settlement pattern in the region because of the activities required by boats and people (e.g., boat maintenance). This structure can be understood through the analogy of the human-boat machine, representing a complex set of affordances and constraints based on dwelling in such a landscape (Bjerck 2017).

The use of boats is significant for site location in many ways, and is especially important to the transitional intertidal zone and the land-water interface. The most formally conceptualized behavioural models used in this thesis were about the use of terrace landforms at or near this land-water interface. For this there are two main models, described in Table 5.

Table 5: Behavioural models of terrace landform use.

Model:	Benefits and drawbacks:	Expected Dates:
1: Use of terraces at sea level	Very near water, flat spot, convenience for boat storage. Maybe more prone to flooding and large tidal cycles, possibly less-developed vegetation	Similar to sea level history date
2: Use of terraces at higher elevations	Sandy well-drained, flat spot, inside probable developed vegetation. Raised, but still near coastline, have to walk up to, but likely not hard, store boats further from shelter	Younger than sea level history date

This section has explored some of the most major theoretical influences for this thesis, including current early period archaeological theory, understandings of formation processes and survivorship of sites, and ethnographic analogy and behavioural models. Some of these theories

directly and formally informed this study, whereas others more indirectly influenced it, as is common in a long-term evolving and emergent research process. Enmeshed in these theoretical approaches is humanistic and anthropological theory.

### 3.4 Humanistic Theory

Humanistic theory, including concepts of dwelling, the theory of practice, and phenomenology have informed the theoretical approach of this study. One of the early goals of this study was to approach quantitative modelling from a more humanistic perspective, attempting to incorporate anthropological and post-processual theory into the methodology. One of the ways this was done was to explore different concepts related to living and being in the landscape. In conjunction with coursework and involvement in clubs such as the UVic Flintknapping Club, I explored, very superficially, some of the aspects that would have been part of life in the late Pleistocene – early Holocene around Quadra Island.

#### Dwelling and rapid sea level change:

One productive concept theoretically was Tim Ingold's (2000, 2008) notion of "dwelling" within the landscape and the weather world. Rather than separate exhabitants of the world, humans are inhabitants of it, dwelling within it, "immersed in the fluxes of the medium" (Ingold 2008, 1804). This approach counters naturalized western values and ontologies (Yanagisako and Delany 1995; Descola 2009). Looking at the early North American archaeological record through this theoretical approach may help better understand lifeways in the late Pleistocene–early Holocene.

The concept of dwelling put into perspective the dramatic changes of the landscape that have occurred since the late Pleistocene and early Holocene. Living in a landscape of rapid sea level change, regression from ca. 180 metres above modern sea level to ca. 5 metres above modern sea level would have been readily noticeable (e.g., regression of ca. 175 metres in ca. 1,400 years; 12.5 cm/year regression: greater than 5 metres in a typical lifetime and 20 metres in living memory). Mackie and colleagues (2014, 137-138) briefly discuss the human experience of such sea level change. Especially on a human time scale, small fluctuations that are missed on a simplified sea level curve could have major consequences for people living at the coastline. Sea level change can mean both good and bad landscape changes: for a regressing sea level, intertidal zones could be stretched out, or new areas of productivity such as estuaries and wetlands may form (Mackie et al. 2014, 138), but regression could also include massive dust storms as newly stranded and unvegetated intertidal zones dry out.

Relative sea level change also means the coastal environment, configuration, and landforms would have been vastly different and relatively ephemeral as sea level dropped. Figure 17 Left is a photo of the waters of Sutil Channel on Quadra Island looking east. Figure 17 Right is the same photo, with sea level flooded to ca. 25 metres above modern. Even with a difference of only ca. 25 metres elevation, a change in sea level can mean a completely different landscape.



Figure 17: Left: Photo of Sutil Channel taken from Quadra Island looking east. Right: The same photo 'flooded' to ca. 25 metres asl.

### Practice theory:

The theory of practice also informed the theoretical approach of this study. The theory of practice, or practice theory, takes from the work of Bourdieu (e.g., 1977) and Giddens (e.g., 1984) and views human action as structured by history, learning, experience, values, and perception. This approach gives people in the past agency and intentionality, while all actions contribute to defining and redefining larger social and cultural structures (Stahl 2002). Practice theory makes room for sensorially informed rather than linguistically informed cultural processes, shaped by practical and embodied forms of knowledge (Stahl 2002). Looking at dwelling in the landscape from a practice theory perspective meant trying to understand what people would need for site location in everyday practice. One way that practice theory was engaged in this study was through learning the basics of flintknapping. Learning how to flintknap aided the recognition and interpretation of lithic artifacts in the field. Further, there was a plan to engage with the use of boats and better understand the nuances of the water-and interface through a sea-kayaking trip around Quadra Island, but unfortunately, this did not take place. However, theoretical engagement with phenomenology did take place and is described below.

### 3.5 False Start #2: Phenomenology

Since its inception, phenomenology has acquired a damaging reputation in archaeology as a substandard method, more by word of mouth rather than academic critique (Hamilton and Whitehouse 2006). Informed by theorists such as Heidegger (1962), Merleau-Ponty (1996), and Bourdieu (1977), phenomenology was part of the call to include more social and anthropological theory in the post-processual response to processual archaeology. Early works came from British archaeology, typically focussed on experiences in Neolithic megalithic structures (e.g., Bender

1995; Bradley 2000; Gosden 1994; Tilley 1994). More recently, many different approaches have included phenomenological elements or theory in order to shift dominant perspectives, better understand human perception, and understand the relationships between time, dwelling, and dynamic human-environment interactions (Bailey 2007; Ingold 2008; Mathews 2014; Oliver 2007; Thom 2005). In this way, phenomenology and the literature surrounding practice theory may be able to offer much to archaeological site location modelling. For this study, phenomenology was initially reviewed to inform quantitative modelling. Although phenomenological theory may have informed this study indirectly, it did not do so as directly and formally as first thought. In a broader way, it helped understand the impact of environmental change and put into perspective the large scale dramatic landscape change of the late Pleistocene – early Holocene.

Originally, the method for incorporating phenomenology and practice theory in this study was to be camping and kayaking around Quadra Island and formally recording observations around the landscape, the land-water interface, and coastal landforms. However, with limited time and resources due to the scope of this study, only one night of camping was conducted.

#### Camping: February 8, 2016

Camping took place on Quadra Island, February 8, 2016 with myself and a colleague, John Murray. Compared to August 2015 during the 2015 DILA field season, the landscape was dramatically changed due to greater precipitation. Although it did not rain during camping, the forest was very wet from heavy rains the previous day. The hiking trails were flooded and draining water formed consistent creeks running across and down trails. While hiking into our campsite and imagining sea level change, it was quite easy to imagine paddling water craft rather than hiking. Kenneth Ames (2002) review of water craft on the Northwest Coast was a useful

reference when thinking about their importance. Not only would paddling be a quicker and more efficient way to travel, but we would be able to carry much more gear. We mused that travelling directly to a site in a canoe would be similar to driving directly to a site with all of our gear rather than hiking.

Imagining the scale of environmental change was put into perspective when we found our intended campsite flooded by fluctuating seasonal lake levels. In August 2015 during the 2015 DILA field season, a fantastic campsite on fine white sand was available on the western shore of Morte Lake, but when we arrived in February 2016, the lake level had risen so much that we initially walked right past the campsite area. We estimated the lake level had increased about 0.5 metres, and because the bulk of the campsite was a flat lakeside area, we estimated there to be a horizontal shoreline change greater than 15 metres. In hindsight, lake level fluctuation should have been obvious, as lakes worldwide change seasonally, especially when coastal winter precipitation increases, however this comparatively small environmental change took us by surprise. Imagining the types of changes that would have occurred on Quadra Island post-glacially, with significant relative sea level fall over a short period of time, was put into perspective by this experience. The insight into people's perceptions of the environment was one of the most productive results of camping (e.g., Leary 2009, 2011). Early people would have observed falling ocean shorelines, especially during times of rapid sea level change, and locations selected on the landscape would have changed as cultural and landscape processes changed.

This phenomenological approach provided a better understanding of the specific landscape of Quadra Island—an understanding greater than just a bird's eye view from a map, or a snapshot from a photograph. However, with better planning and theoretical intent, and more

formal observation and interpretation, phenomenological insights could form an interesting connection to quantitative modelling in the future, and allow for the integration of more humanistic and qualitative theory and methods into modelling.

### 3.6 Chapter Conclusion

Theory underlies the core of any research project, and is an important bridge between knowledge production and practice. This thesis has explicitly utilized a “value-rich” approach to science (Wylie and Nelson 2007). Central to the quantitative modelling approach taken was a critique of predictive modelling. Therefore, this studies’ methodology combining quantitative and qualitative modelling has been used to address some of the issues reviewed in this critique. Predictive modelling, the history of heritage protection and the relationship between archaeology and First Nations in BC has been briefly overviewed. Important to quantitative output and research results is how they may affect people in the future, and this research has attempted to search for early period sites without labelling the entire landscape with potential.

Important to understanding possible site locations are concepts of formation processes, survivorship, ethnographic analogy, and behavioural models. These ideas guided the approach to modelling in this thesis, recognizing that the presence of early period sites is a function of cultural behavioural processes/deposition and survivorship. Lastly, humanistic anthropological theories such as the concept of dwelling, practice theory, and phenomenology, have played a role in the overall approach and conceptualization of this study, informing the methodologies chosen and their implementation.

## Chapter 4: Methods

This study explores the novel application of quantitative modelling in combination with qualitative modelling to inform focussed archaeological survey. Methods are important in this thesis because one of the goals of this study is to partially evaluate the method itself. This is important because this study combines quantitative and qualitative modelling while being explicit about the aspects of modelling and archaeological survey that may typically be left out of reporting and publication. Many aspects of creating a quantitative modelling tool and of doing archaeological survey are inherently qualitative. For example, judgemental archaeological survey rather than systematic or randomized archaeological survey is common for inventorying surveys that do not test specific areas slated for development. From deciding on boundaries and numerical limits in modelling to interpreting the survey landscape by eye in the field, qualitative aspects can be very important to archaeological results. It is important to explicitly state assumptions and be self-reflexive when working with quantitative and qualitative methods.

The methods of this study are outlined in Figure 18, the workflow diagram of the methods used in this study. To start, quantitative modelling is carried out with paleoenvironmental data, LiDAR bare earth elevation data, and relative sea level history data as inputs. The quantitative modelling highlighted target areas that were then subjected to qualitative modelling. Qualitative modelling included aspects such as a behavioural model, a landform formation model, and human/expert judgement. Areas highlighted from quantitative modelling and selected as potential areas through qualitative modelling were then marked with a polygon for possible archaeological survey and testing. Rather than an entire landscape ranked with potential, output was used as a tool to mark potential areas, with all other areas not ranked. In

this way, the model was a means, a stage in a process, rather than a completed outcome in itself. Some of these marked polygon areas were then chosen for focussed archaeological survey.

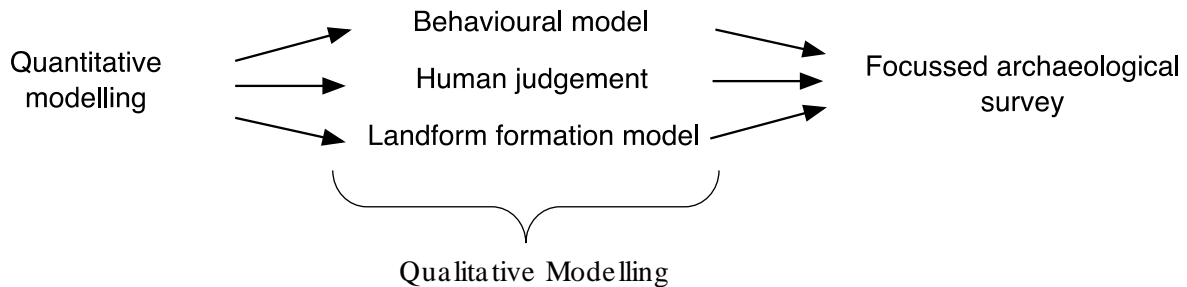


Figure 18: Overview workflow diagram of the methods used in this study.

The methods used in this study blend together the benefits of quantitative modelling and qualitative modelling and use them as a tool to carry out focussed archaeological survey. The benefits and drawbacks of such an approach will be discussed and evaluated in Chapter 6.

#### 4.1 Quantitative Modelling and GIS Methods

Quantitative modelling was the first step in the process of this study. Highlighted areas from quantitative modelling would then be subjected to qualitative modelling, and finally, if selected, then focussed archaeological survey. The most important quantitative data input is submetre resolution light detection and ranging (LiDAR) elevation data. This data is then processed to “strip” the vegetation to create a bare earth model of the landscape. Technical information about the LiDAR and the algorithms and programs used to process it are included in Appendix 1. The LiDAR data is at such a scale and resolution that archaeological features may be present and visible in the data itself. The other important input into quantitative modelling performed in this study was relative sea level history data collected by the DILA project (Fedje et al. 2016).

ESRI ArcGIS version 10.2 (ESRI 2013) and ArcGIS Pro version 1.4 (ESRI 2015) were used as the primary GIS software for this study, however, QGIS (QGIS 2017) and other programs such as LAStools (rapidlasso 2017) played a small role. Within ArcGIS, important resources were the toolbox and model builder.

The ArcGIS toolbox features geoprocessing tools that were invaluable to working with spatial data. ArcGIS model builder was used to semi-automate the tools found in the toolbox, and was used especially in the calculation of coastline complexity. The wind fetch tool uses Python, which is a programming language built-in to ArcGIS and QGIS. More information and technical details about quantitative modelling are available in Appendix 1.

Finding late Pleistocene – early Holocene coastal archaeology in the present is a function of two processes working simultaneously: survivorship (i.e., which sites have survived to the present) and human behaviour/deposition (i.e., where did people originally deposit material culture) (Mackie et al. 2014). These two processes, and their associated probability, control if a site exists in the present or not. The quantitative modelling performed for this study matches these two variables, with wind fetch being a proxy for exposure, initial use, and survivorship, and coastline complexity being a proxy for biological diversity and resource availability, potentially linking it to human use and deposition of material culture. These two variables may also be collinear, where a more complex coastline is also likely to have less wind fetch and be more protected.

#### 4.1.1 Coastline complexity

Coastline complexity refers to the shape of the coastline. Also referred to variously as involution (and derived involution index) (Mackie 2001; Mackie et al. 2014), geometric

complexity, irregularity, tortuosity, sinuosity (Bartley et al. 2001), shoreline intricacy (Mackie and Sumpter 2005), coastline sinuosity (Monteleone 2012), and fractal dimension (Tokeshi and Arakaki 2012), coastline complexity is a measure of the relative shape of a coastline, whether it is straight, sinuous, or extremely convoluted. The first archaeological mention of coastline shape is in Quentin Mackie's (2001 [1998]) PhD dissertation about settlement archaeology on the west coast of Vancouver Island. Mackie (2001, 15, 28) noted that highly involuted coastlines are a unique feature of coastal archipelagos, and can relate to carrying capacity, and in 2004, expanded on this idea in relation to First Peopling (Fedje et al. 2004a). In 2005, Alexander Mackie and Ian Sumpter (2005) used shoreline intricacy as a variable in their evaluation of shoreline settlement patterns in Gwaii Haanas National Park, Haida Gwaii. Dividing shoreline intricacy into four categories, linear, sinuous, elaborate, and intricate (linear being the least complex, and intricate the most) they found that early period sites were typically associated with elaborate shorelines and least associated with intricate shorelines. In 2007, Morley Eldridge and colleagues explored the use of coastline complexity in an archaeological overview assessment of the Campbell River Forest District. Kelly Monteleone used coastline sinuosity as a variable in her underwater predictive model created during her PhD (2010) to find submerged late Pleistocene sites near southeast Alaska. For the DILA project in 2015, Alex Lausanne calculated coastline complexity for her predictive modelling on Quadra Island (Lausanne et al. 2017a, 2017b, in press).

Although not directly related to archaeology, Bartley et al. (2001) relate coastline complexity to marine and terrestrial functions that play a role in energy regimes, water residence times, and other physical and chemical factors. Tokeshi and Arakaki (2012) outline how coastline complexity, referred to in their paper as the fractal dimension, part of habitat complexity, is correlated to increased species richness and number. For this study, we assume

that the relationship between increased species richness and diversity and coastline complexity can be extended back in time and that it was a potential attractant to people.

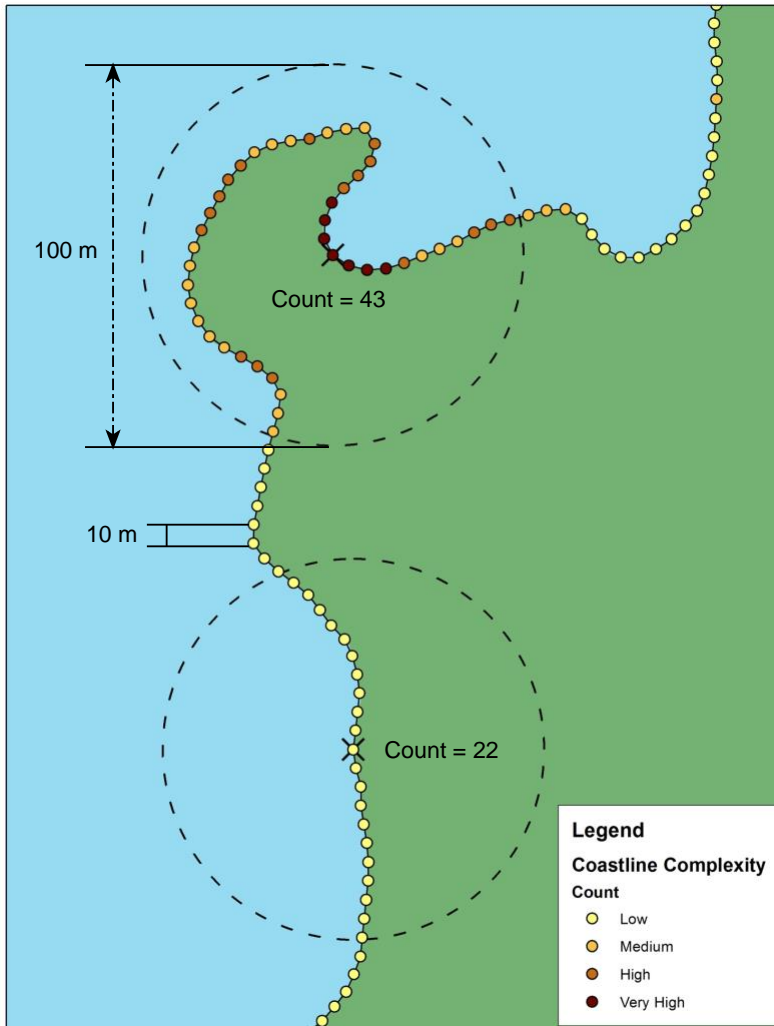


Figure 19: Diagram showing an example of coastline complexity counts and method.

Input for coastline complexity calculation was similar to Eldridge (2007), Monteleone (2010) and Lausanne (2017a, 2017b, in press), and consisted of 1 metre interval contours derived from LiDAR DEMs. In order to calculate a measure of one meter contour coastline complexity, points were generated along each contour at an arbitrary interval of 15 metres. Next, each point was buffered with an arbitrary diameter value of 400 metres. The judgemental values of 15 and 400 metres were influenced by the scale of the LiDAR contours (i.e., 1 metre resolution

contours) and the typical scale of archaeological relevant landforms (e.g., terraces) but were not chosen through any statistical method. This method of coastline complexity calculates the number of other points that fall into the buffer area and assigns this value to each point. After buffering, spatial joins (one to many) were performed from each buffer to the points that were within it. Lastly, a table join was performed from each buffer to each point to transfer the count value from the buffer to the point for visualization.

The output of this method therefore consists of each point having a count of the other points within a buffered distance (see Figure 19). In this study, each LiDAR contour at an interval of 5 metres was selected for coastline complexity calculation, starting from 2 metres above mean sea level. A 5 metre interval between contours chosen for coastline complexity calculation was chosen based on computation power and the average intertidal range of ca. 4 metres on Quadra Island (Government of Canada 2017). In total, potential paleoshorelines were quantitatively evaluated for coastline complexity at 5 metre intervals from 2 metres amsl to 202 metres amsl for each LiDAR swath. This almost continuous elevation, high resolution evaluation of potential paleoshorelines is novel for quantitative modelling.

#### 4.1.2 Wind fetch

Wind fetch refers to the distance that wind can travel in a straight line over water. Wind fetch has long been used as a proxy for coastal exposure because waves are primarily generated by the friction of wind on water. The US Shoreline Protection Manual (US Army Corps of Engineers 1984) details standards for calculating fetch. Fetch is part of the standard shoreline inventory data collection process in British Columbia, started by John Harper and colleagues in the early 1990s (Harper et al. 1993) and it is applied in a variety of disciplines including coastal

geology and geomorphology, fish resources, aquaculture capability, oceanography, and habitat studies (Harper et al. 1993, 27).

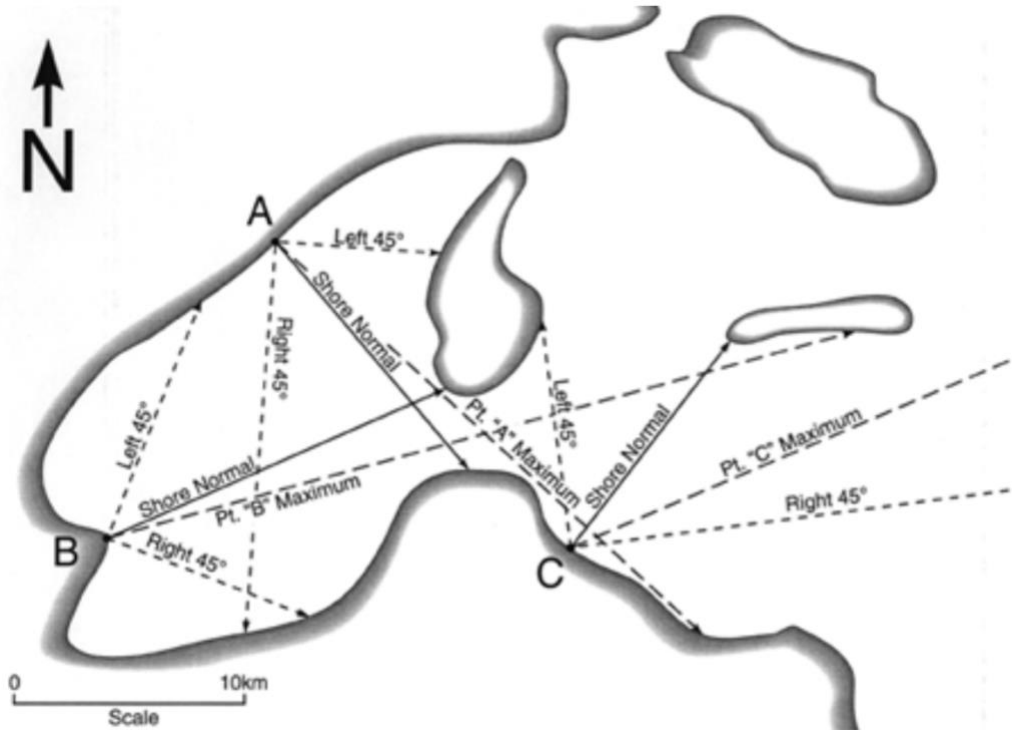


Figure 20: Diagram of different wind fetch calculations from Howes et al. 1993, 3.4, Figure C.1.

In the field, wind fetch is typically calculated on maps by measuring azimuth and distance. In the mid-2000s, David Finlayson at the University of Washington, wrote a python script for calculating fetch digitally for his PhD dissertation (2006) work on *The Geomorphology of Puget Sound Beaches*. Finlayson's (2006) python script automatically calculated fetch at user specified azimuths on a raster in ArcGIS 9.0. In 2008, Jason Rohweder and colleagues updated Finlayson's scripts for use in ArcGIS 9.2 as a toolbox. Their work was developed for assessing different development scenarios for fresh water habitat and rehabilitation projects in Capoli Slough, Wisconsin; Harper's Slough, Iowa; and Swan Lake, Illinois (Rohweder et al. 2008).

The toolbox developed by Rohweder and colleagues (2008) based on Finlayson's (2006) work is available free to download from the United States Geological Survey at [https://www.umesc.usgs.gov/management/dss/wind\\_fetch\\_wave\\_models\\_2012update.html](https://www.umesc.usgs.gov/management/dss/wind_fetch_wave_models_2012update.html). After downloading, one must download Pywin32, a Windows extension that allows Python to communicate with COM servers such as ArcGIS. Pywin32 is available to download from <http://sourceforge.net/projects/pywin32/files/pywin32/>. After installing Pywin32, the USGS toolbox must be installed in ArcGIS. Input into the wind fetch tool is a text file with user specified wind fetch azimuths in degrees, and a raster elevation dataset. Referring to present-day climate data for Quadra Island, the two prevailing wind directions were used for wind fetch calculation: southeast (135°) and northwest (315°). The tool calculates fetch on cells with a value of 0, less than 0, and NoData, which typically are water cells in a raster elevation grid file. However, to run the wind fetch tool at elevations higher than modern sea level, raster elevation data had to be manipulated to represent higher sea level. First, elevation raster data was made to represent higher sea level by subtracting the grid values using the raster calculator tool. Next, rasters were reclassified to binary layers representing land (a value of 1) and water (a value of 0). Wind fetch was calculated on TRIM raster elevation data with 10 metre grid cells at 10 metre elevation intervals, starting from 10 metres above mean sea level to 200 metres above mean sea level. Accordingly, rasters for these different sea levels were calculated, reclassified, and organized for input into the wind fetch tool.

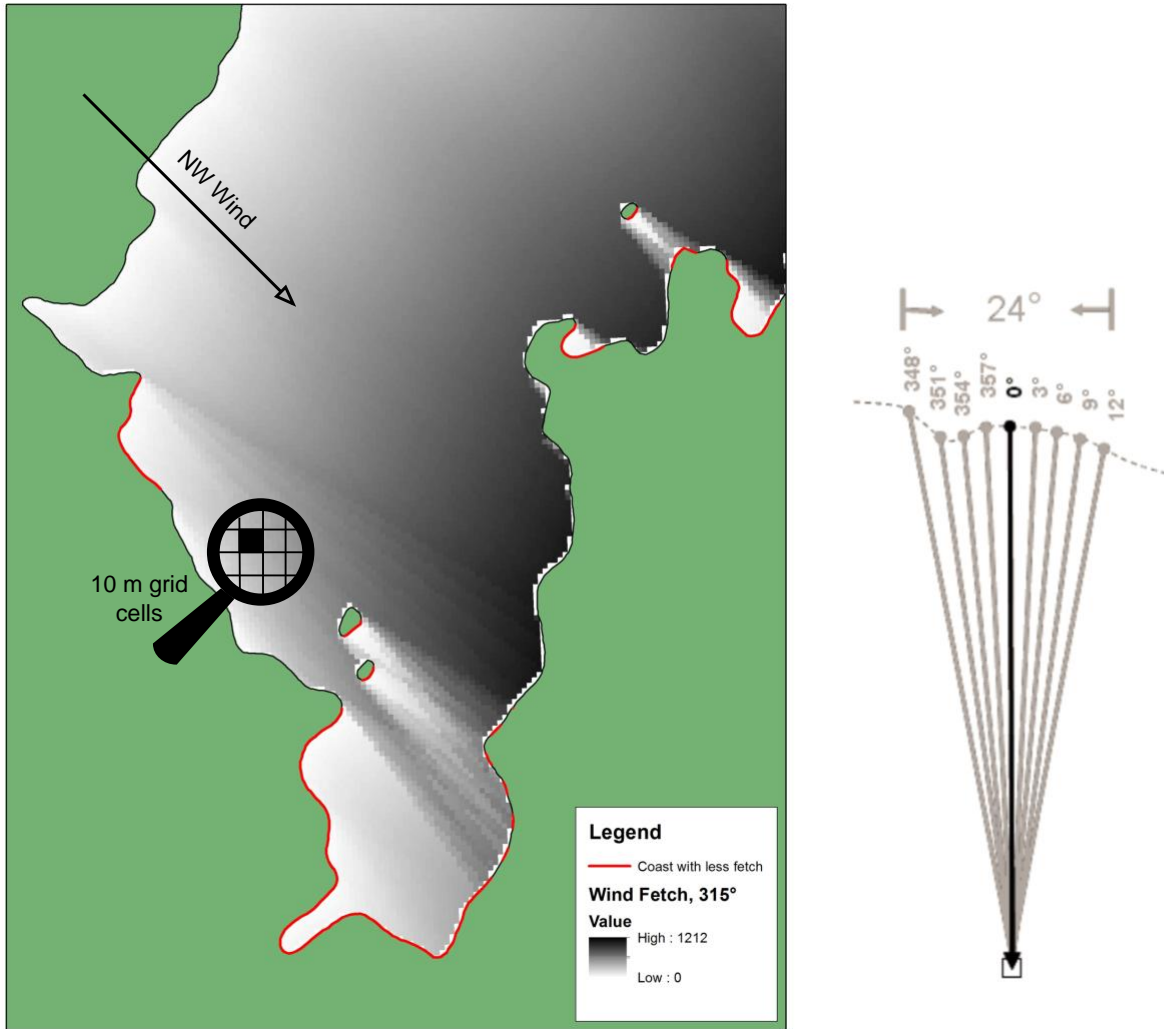


Figure 21: Left: Diagram of wind fetch calculation. Right: Diagram of the US Shoreline Protection Manual (US Army Corps of Engineers 1984) method for calculating wind fetch for a specific cell (Rohweder et al. 2008, 5).

During calculation, the wind fetch tool calculates fetch according to the standards of the US Shoreline Protection Manual (US Army Corps of Engineers 1984), which specifies calculating fetch at 3 degree intervals four times on each side of the specified azimuth, resulting in a total of nine calculations spanning 24 degrees (see Figure 21 Right). The output data from the wind fetch tool is a raster of wind fetch distance values in metres (see Figure 21 Left). Unbounded fetch (i.e., fetch that originates from an uncertain distance, such as from the edge of the raster data) was marked with a negative sign in the output raster data. Wind fetch raster

layers could be overlain to illustrate wind fetch variation as sea level regressed. It is novel to use quantitative modelling to calculate wind fetch for archaeology, especially at multiple different paleo-sea levels.

## 4.2 Quantitative Modelling and Heuristic Methodology

After calculating quantitative modelling output, a heuristic methodology was used for qualitative modelling (see Section 4.4) and archaeological survey (see Section 4.5). A heuristic approach uses practical methods for problem solving, learning, or discovery. Examples of heuristic techniques are for example, educated guesses or intuitive judgement, and can be derived from previous experience. In the most general sense, a model itself is a heuristic device which enables understanding of whatever is being modelled. Many different fields and problems can benefit from heuristic methodologies, including new product development, entrepreneurial decision making, and piloting an aircraft (Grandori 2015). Qualitative modelling allowed for the simultaneous evaluation of multiple variables in the specific context of each quantitatively highlighted target. This heuristic approach allowed for the integration of quantitative and qualitative modelling and used practical experience as a guide. This is a more humanistic approach to predictive modelling, where there is conversation between derived variables from the model and human judgement. Framed in this way, quantitative modelling is used as a tool to supplement archaeological survey, rather than controlling archaeological survey. McLaren (2008, 174) notes that the judgement-based paleoenvironmental method used by Fedje and Christensen (1999) and Fedje and colleagues (2005a) worked very well, where they qualitatively chose locations “based in part on protection from the open sea and the location of other early Holocene archaeological sites in Haida Gwaii” (Fedje et al. 2005a, 171). In a similar way, the

methods in this study take advantage of the benefits of human judgement heuristically combined with quantitative modelling as a tool.

### 4.3 False Start #3: Landform Classification

An important goal of this study was to successfully integrate quantitative and qualitative modelling. However, this was not achieved without some difficulty. An important learning example of this was an attempt to include computational landform classification as part of the quantitative modelling performed for this study. Landform classification, or geomorphometry, is an interdisciplinary field built from earth sciences, mathematics, and computer science, concerned with topographic quantification (Pike et al. 2009). Since the first digital elevation models on computers, geomorphometry has founded landform classification methods such as the creation of digital elevation models, hillshades, slope calculations, aspect calculations, and many of the tools common to digital terrain analysis (Pike et al. 2009). An important distinction in geomorphometry is that of specific and general geomorphometry. General geomorphometry analyzes terrain as a continuous surface, whereas specific geomorphometry analyzes discrete, bounded, landforms that may be discontinuous. Automated computational methods for the recognition of specific landforms is still being developed (Evans 2012, 97), whereas pre-existing tools for general geomorphometry are readily accessible.

Initially, the goal of quantitative landform classification in this study was that it would aid in the identification of archaeologically interesting landforms, such as terraces, and possibly identify relict coastal landforms from higher sea levels, stranded upslope, but perhaps visible in the LiDAR DEM. Landform classification for this study started with ready-to-use software and tools for general landform analysis called Landserf, developed by Jo Wood after his PhD in the subject (Wood 1996). Landserf is available free to download at [www.landserf.org](http://www.landserf.org) (Wood 2009).

The software can be used as a full GIS, but specifically, has a tool for feature extraction, which uses a moving window analysis of raster DEM data to classify each raster cell according to its neighbouring values. Cells are classified into one of six categories: pits, passes, peaks, channels, ridges, and planar (Wood 2009) (see Appendix 1 for definitions of each type). The features that are recognized by this type of landform classification are scalable with the size of the window. For example, on a DEM grid where cells are 1 metre by 1 metre, a moving window of 3 would classify a cell according to their neighbouring cells in a 3 metre by 3 metre window, with the cell being classified at the centre. This scale of analysis recognizes features near the scale of 3 metres. Similarly, a moving window of 55 would classify a cell according to the neighbouring cells in a 55 metre by 55 metre window with the cell being classified at the centre. Analysis at this scale recognizes larger features (see Figure 22). Major types of landforms identified in Figure 22 include ridges (yellow), channels (blue) and planar (grey).

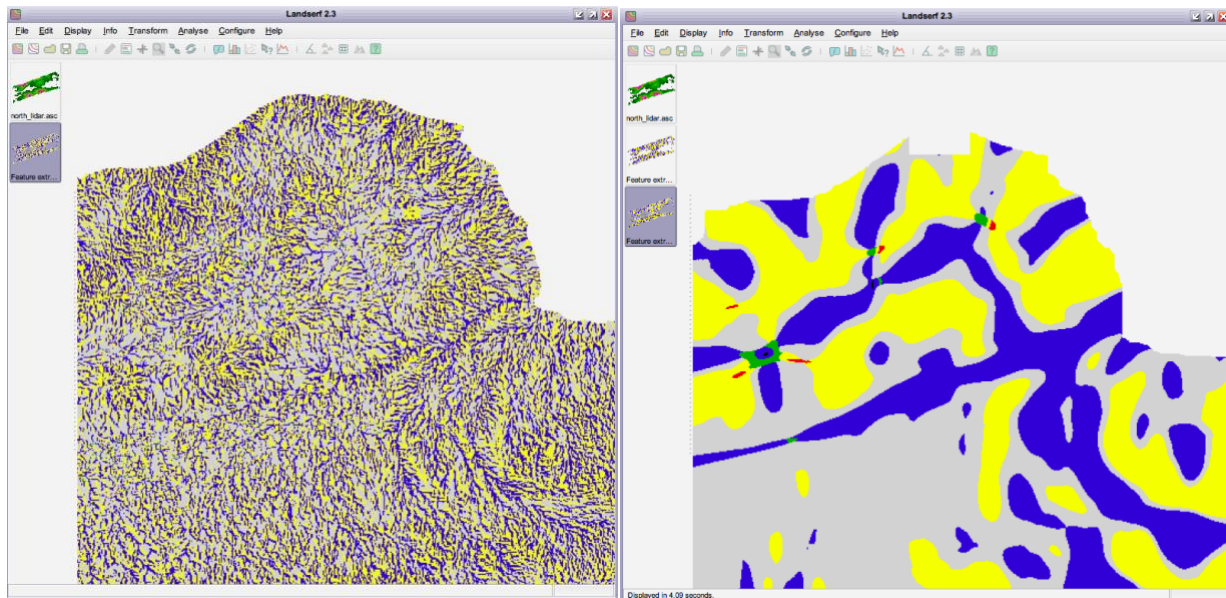


Figure 22: Left: Landform classification output from Landserf (Wood 2009) for an area of Small Inlet on Quadra Island, classified with a moving window of 3 metres. Right: Landform classification output for the same area of Small Inlet on Quadra Island, classified with a moving window of 55 metres. For both, blue is channels, yellow is ridges, and grey is planar.

From a general geomorphometry point of view, the continuous landform classification generated from Landsat was a success, but from an archaeological and practical point of view, it was not successful. Although there was some utility in displaying the results of landform classification at different scales and comparing the results, it became distracting to look at when faced with so many different classifications. Additionally, using 1 metre interval contours and hillshades from the LiDAR DEM, landforms were already apparent without automated classification. For example, when landform classification was performed on the LiDAR data, a large but coherent terrace visible qualitatively was broken up into many smaller terraces due to fairly insignificant undulations. This conclusion shows the conflict that can happen between quantitative and qualitative definitions of variables. The boundaries and limits set to denote landforms in the automated classification are quantitative. When these boundaries are compared to qualitative definitions of such landforms by humans, there can be major differences (Evans 2012). For example, many archaeologists would readily identify a “terrace” or “tombolo” on a contour map or DEM, but to create rules based on quantitative values capturing the range of scales, slopes, dimensions, and shapes associated with these landforms would be very labour intensive.

Field geomorphologists, geologists, and archaeologists qualitatively define landforms (e.g., Stewart et al. 2017), and create maps identifying landforms or geological units based on qualitative interpretation of empirical observations made in the field. Tools for specific geomorphometry are still being developed, some using supervised automation, even in archaeological contexts (e.g., Verhagen and Drăguț 2012). It is outside the scope of the thesis to develop an archaeological relevant tool even for one landform type. However, there is much potential for the future for these topics, especially with the development of machine learning to

integrate qualitative definitions of landforms such as “terraces”, and the proliferation of high resolution data such as LiDAR (e.g., Cerrillo-Cuenca 2016). This false start section has shown the qualitative nature of some seemingly quantitative things, such as landforms, and provided a case study of the difficulties of integrating quantitative and qualitative modelling.

Implementing theory in practice can be difficult. In this study, qualitative modelling was chosen in part to address calls for a better theoretical approach to modelling in archaeology. A review of humanistic theory showed that pursuing a value-rich science is productive, and that there can be many qualitative aspects of even a purely quantitative study. Accordingly, this study embraces the qualitative and tries to integrate the quantitative in a realistic and practical way.

#### 4.4 Qualitative Modelling

Before the qualitative modelling phase, quantitative modelling in this study highlighted areas that have complex coastlines, potentially indicating higher species diversity and biological resources, and areas that are more protected, potentially for shelter and better site survival. Qualitative modelling was performed with the results of quantitative modelling on the LiDAR and in the field. Areas highlighted by quantitative modelling are termed “target areas”.

Qualitative modelling performed in this study consists broadly of human and expert judgement, more specifically assessing landform and landscape modelling, and behavioural modelling. In addition to these elements, practical qualitative variables also influenced target selection (see Section 4.4.4).

For the landform formation model, behavioural model, and practical qualitative variables, tables review qualitative variables that were considered while looking at the quantitative modelling output and LiDAR in this study. I have used tables to present the variables, however,

this is not done as an attempt to quantify the qualitative. Rather, tables are used for simple and concise presentation of what was desirable and not as desirable for each variable. The benefit of a qualitative analysis for considering these variables was that many different variables could be evaluated simultaneously with respect to the specific context and circumstances of the target.

#### 4.4.1 Human and expert judgement

Human and expert judgement was the basis of qualitative modelling, and included understandings of both landform formation and behaviour. Much of human and expert judgement is based on previous archaeological experience. One of the advantages of human and expert judgement was the ability to synthesize and evaluate many variables at once in a heuristic fashion. Each target area highlighted by quantitative modelling was evaluated individually according to each areas specific context on the LiDAR data in a GIS, and in the field while conducting archaeological survey. The landform formation model and behavioural model review some of the major elements of human and expert judgement that were discussed during qualitative modelling.

#### 4.4.2 Landform formation model

The qualitative variables related to landforms, landform formation, and the landscape are reviewed in Table 6. An important empirical dataset that informs the landform formation model is relative sea level history data collected by the DILA project. This data is assessed alongside other geomorphological, geological, and other paleoecological experience and knowledge.

The beginning of the DILA project was widely concerned with these elements. In conjunction with sediment basin coring to establish the sea level history, the LiDAR data was qualitatively reviewed by geomorphologist Ian Walker, geographer Olav Lian, Master's student

Alex Lausanne, and archaeologist Daryl Fedje. Field interpretations of the landscape also took place in addition to reviewing the LiDAR data. These interpretations are a fluid and qualitative process in itself—hypotheses and interpretations are constantly revised and reworked according to new data.

Interpretations about landforms, landform formation, and the landscape are used in conjunction with interpretations about the behavioural model and applied with human/expert judgement in an iterative process. The heuristic methodology of qualitative modelling is well suited to this iterative and fluid process of knowledge production. Table 6 reviews the type of qualitative assessment and variables involved in the landform formation model.

Table 6: Table of landform and landscape qualitative variables.

Landform and landscape qualitative variables:	Assumption
Coastal landform	Is there evidence of a coastal landform still present on the landscape? (e.g., spit, tombolo, terrace etc.).
Current landform	What is our current interpretation of the landform history since sea level regressed past this elevation?
Scale of landform	Large area (e.g., 5000 m <sup>2</sup> ), that may be hard to test? Smaller area (e.g., 625 m <sup>2</sup> ) conducive to testing?
Areas of bedrock	Where is bedrock located near the target? Bedrock itself not good for archaeological deposits, but may suggest stability of adjacent landform area.
Microtopography	Rough indicating lots of blowdown/logging/other disturbance?
Erosional/Depositional	Is the area currently in an erosional or depositional regime?
Nearby sediment information	What do we expect the sediment to be like? Have there been tests/exposures nearby that may give us a clue?
Slope	Lower slope more desirable, higher slope less desirable.
Aspect	South facing? North facing? Not as important as other variables.
Stream nearby	Is there a stream nearby? Is it a long-lived stream? (i.e., deeply incised, bedrock cut)

#### 4.4.3 Human behavioural model

The behavioural model of qualitative modelling is influenced by the landform formation model and conclusions from human and expert judgement, and in turn, provides feedback into these forms of qualitative modelling. Qualitative modelling in this section is based mainly on two forms of evidence: current interpretations of the archaeological record, and ethnographic analogy (see Section 3.3.2).

The first major element of the behavioural model is current interpretations of the archaeological record. Considering the archaeological evidence found at the local, regional, and continental-scales of analysis, current interpretations of the archaeological record incorporated ideas reviewed in the background in Chapter 2, Section 2.2. This included ideas around material culture and the use of tools, subsistence, settlement patterns, the timing and tempo of the peopling of the Americas, among other current interpretations. This element of behavioural modelling also considered evidence found at a wider coastal world-scale, such as that from northeast Asia and globally, for example, evidence for the use of boats in the Pleistocene (Ames 2002; Leppard and Runnels 2017). Importantly, the qualitative assessment in this element of the behavioural model is based in material evidence.

The second major element of the behavioural model is ethnographic analogy. Ethnography analogy did not directly inform the behavioural model, but influenced it indirectly (see Section 3.3.2). A full review of ethnography and using it formally for qualitative modelling is outside the scope of this thesis. However, ethnography from the Northwest Coast, especially from the area around Quadra Island, along with Indigenous oral histories, and historical accounts can influence our understanding of the range of potential behaviour in the late Pleistocene and early Holocene. It is common for literature making inferences about the early period to draw on

ethnographic analogy from these sources. Table 7 reviews the type of assessment and variables involved in the human behavioural model.

Table 7: Table of human behaviour qualitative variables.

Human behaviour qualitative variables:	Assumption
Boat use and the land water interface	Accessible deep water or a short distance, low slope sand beach may be easier for boat departure and return. Less desirable are long mud flats that heavily depend on tides for boat use.
Flat area for settling	Living areas built on flat. (Although, could be built into hillside, e.g. Alaskan hillside houses—depends on behavioural model).
Break in slope from potential terrace/intertidal area division surviving	Area above a plausible paleointertidal zone that people could have been living?
Viewshed	Is view a factor at the site? Guarding, beauty, watching (lookouts), other sites, etc.?
Potential vegetation	Interaction of potential vegetation types with landforms and sediment (e.g., terrace and open pine forest? Grasses and coastal dunes?).
Nearby ecological niches	Flat muddy estuarine area nearby? Potential salmon stream? Rocky intertidal shellfish area?
Other ethnographic analogy	What are people on the landscape doing? Is there a difference between site functions?
Settlement patterns	Many average campsites? Few larger base camps and many low artifact density campsite deposits? Differences between forager versus collector subsistence strategies.

All elements of qualitative modelling, including landform formation and human behaviour, interacted and were evaluated at the same time by human and expert judgement. Some variables have implications from both a landform and behavioural perspective. Theoretically, there are many different possible permutations that may have characterized the past. One way this can be graphically represented is as a matrix (see Table 8). The matrix shows the theoretical interaction between variables and the difference in results depending on the

interpretation of the variables. Each cell represents a theoretically possible scenario that depends on the interpretation of unknown variables (e.g., scenario A1a versus scenario B2a). In this case, only three interacting variables creates eight possible scenarios, and each scenario could have implications for varying site locations.

Table 8: Theoretical matrix diagram of potential interactions between landform formation and behavioural modelling variables.

	1) Rapid sea level change		2) Still stand sea level	
	a) Vegetation colonization rapid	b) Vegetation colonization slow	a) Vegetation colonization rapid	b) Vegetation colonization slow
A) Terraces used at sea level	A1a	A1b	A2a	A2b
B) Terraces used above sea level	B1a	B1b	B2a	B2b

Variable 1: A), B). Unknown whether terraces were used at, above, or both at and above sea level.

Variable 2: 1), 2). Sea level change was likely non-uniform.

Variable 3: a), b). Unknown whether vegetation rapidly colonizes, slowly colonizes, or non-uniformly colonizes newly exposed marine sediment.

The matrix also shows how the results could change, for example with the reworking of a variable or introduction of a new variable. Knowledge is produced and constantly re-evaluated, incorporating the newest available data. The heuristic methodology used in this study suits this form of knowledge production well.

#### 4.4.4 Practical qualitative variables

Practical qualitative variables relate to the realities of archaeological practice, and likely underlie or play a role in many archaeological projects. In this study they are being reviewed because it is important to be especially explicit about all assumptions and methods. Many times, these variables can greatly impact methods, practice, and results, and yet, are not explicitly acknowledged as potential skewing factors. Many of the variables are external factors of a project, but nonetheless can impact the approach and results.

Table 9: Table of practical qualitative variables that played a role in qualitative modelling.

Practical qualitative variables:	Assumption
Access	Is the target easily accessible by road, boat, hiking?
Data	Is the target in the LiDAR data swaths?
Permission	Is the target on permissible land?
Time required	How much testing will be needed? How much time invested?
Efficiency	E.g., a group of three target areas close to each other could be investigated before a single target area in a hard to reach area.
Personnel/Equipment	Who will be able to go? What is required for the trip?
Previous archaeological experience	What previous archaeological experience is required and what will be available (e.g., for survey or testing)?
Local knowledge	Is there local knowledge of archaeological materials at particular locations (e.g., First Nations, long-time residents)?

Practical qualitative variables and the method of qualitative modelling overall also act in a reflexive manner that ensures quantitative modelling output and quantitative modelling assumptions are explicitly evaluated. This iterative process of modelling and evaluation constitutes a more humanistic form of modelling and proved to be a useful methodology for searching for late Pleistocene – early Holocene archaeology.

#### 4.5 Archaeological Methods

Focused archaeological survey was the last step in the methods process of this study. In this phase of the study particularly, I was very lucky to be part of the larger DILA project, with many archaeological experts involved who have many years of experience. Archaeological survey included surface evaluation of tree throws and sediment exposures and archaeological testing by shovel testing and occasionally augering or probing.

#### 4.5.1 Survey and archaeological testing

Survey methodology included field walking, with the examination of tree throws and other sediment exposures within and around target areas. Occasionally, exposed sediments would be screened, or shovel testing would take place in a tree throw. Archaeological testing consisted of shovel testing in 40 by 40 centimetre square tests. Although these tests are called shovel tests, the majority became controlled evaluative unit style trowel tests. Typically the test would start with a shovel to remove the root mat and humic layer, and then excavation with a trowel in 5 to 10 centimetre arbitrary levels would occur. Use of the shovel would resume if hard-packed or concreted sediments were encountered, or if it was determined that further excavation was required past arms reach with the trowel. An average shovel test was 40 by 40 centimetres and 80-90 centimetres deep. Occasionally, augering or probing would take place in addition to shovel testing, or for example, augering deeper from the base of a shovel test. All shovel test excavated matrix was dry screened through 6 mm mesh. Occasionally 3 mm mesh was used at the judgement of the supervising archaeologist. At Beadless Creek site, a 1 metre by 1 metre controlled evaluative unit was conducted, with all sediment screened through nested 6 mm and 3 mm mesh. Whether a controlled evaluative unit would be conducted was decided by the larger DILA project, with shovel testing and field walking being the main forms of testing for this study.

#### 4.5.2 Archaeological survey qualitative variables

In the field during archaeological survey, qualitative modelling continues with judgemental archaeological survey methods. Not only was this project judgemental in finding target areas to test through quantitative and qualitative modelling, but further judgement took place during archaeological survey. For example, about locations of shovel tests on the target

landform. This further qualitative judgement can be important, especially if an archaeological site was present, but with a low density of cultural material.

Further qualitative judgement and interpretation takes place at the trowels edge, in the screen, and at the lab. The excavating archaeologist must make judgements and interpretations about the sediment and any possible features or artifacts present throughout the excavation. Similarly, all excavated sediments were dry screened through 6 mm mesh, however, the archaeologist at the screen must then make a judgement and qualitative assessment about whether a particular piece is cultural or not. A liberal approach was taken throughout fieldwork for possible cultural material, where anything possibly cultural was collected and further interpreted in the lab. Finally, the last qualitative judgement and interpretation takes place during lab analysis.

Table 10: Table of qualitative variables involved in archaeological survey.

Archaeological survey qualitative variables:	Assumption
Preliminary field interpretations	What sediment is visible on the surface (e.g., large rocks)? What does the vegetation tell us about the sediment, the landform, and its history (e.g., second growth fir? Maples? Springboard notched stump?)
Good location on target landform	According to GPS, maps, and LiDAR contours, and our current interpretation of the landscape/paleoecological history?
Test area/Disturbance	Flattish area? Does it look disturbed at all (e.g., by logging?)
Vegetation clear or cleared	Not over a rotting log? Generally a comfortable place to dig?
Results of first tests	Believe positive? Negative? Need more? Shallow sediment?
Equipment/Personnel	What equipment is used (e.g., ¼ inch mesh)? Water to wash potentials? Electric lights if dark? Who is testing?
Weather	Pouring rain and dark? Warm, sunny, and bright?

#### 4.5.3 Model testing

Section 3.1, the critique of predictive modelling, reviews how adequately testing predictive models is very difficult, if not impossible. Although a formal test of this modelling exercise arguably cannot be performed, the archaeological survey results may give an impression of how well the model and importantly the method performs. The limited fieldwork and testing conducted constitutes a partial ground-truth of the target areas that were qualitatively selected for focussed archaeological survey.

## Chapter 5: Results

This chapter is split into two major results sections: the first, representing the results of quantitative modelling, and the second, representing archaeological results. These results are then interpreted and discussed in Chapter 6.

### 5.1 Model Results

Results of quantitative modelling included data output for both coastline complexity and wind fetch variables. Potential paleoshorelines from ca. 5 metres ahht to ca. 200 metres ahht for both the north and south LiDAR swaths were evaluated, with results at both the site-scale (i.e., individual targets) and the local-scale (i.e., whole LiDAR swath results). Quantitative modelling was very effective at highlighting target areas and thereby reducing the total amount of shoreline and possible paleoshorelines to search.

A total length of ca. 4,000 kilometres of combined potential paleo-coastline length was evaluated, from 200 metres above modern sea level to the current shoreline. For example, in the north LiDAR swath, the total distance of potential paleoshorelines was ca. 1,000 kilometres compared to a total modern distance of 49 kilometres. In the south LiDAR swath, the total distance of potential paleoshorelines was ca. 3,000 kilometres compared with 73 km of total modern coastline within the south LiDAR today.

#### 5.1.1 Coastline complexity

One method to review coastline complexity results at the scale of an entire LiDAR swath is by taking the average value of coastline complexity at a particular elevation and comparing it to other elevations. In this way, the changes in coastline complexity by elevation can also be seen as changes in coastline complexity through time.

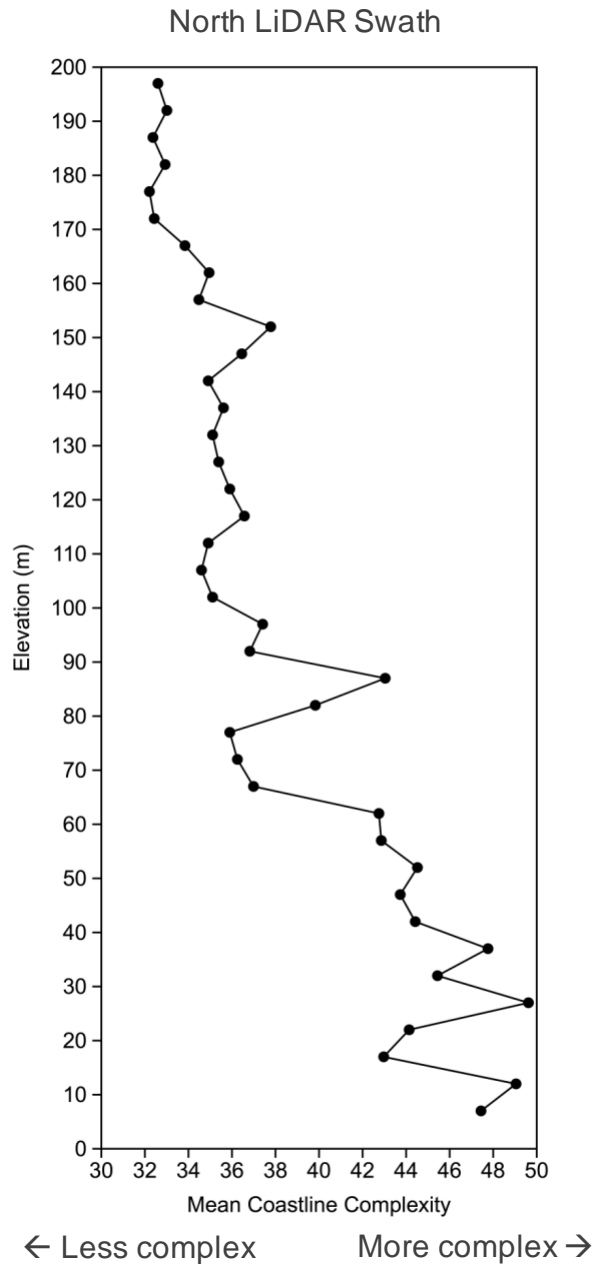


Figure 23: Mean coastline complexity for each calculated elevation in the north LiDAR swath. Red bars indicate hypothesized still stand levels.

steep bedrock cliffs at upper elevations, which could mean coastlines that are straighter.

In the south LiDAR swath, graphed average coastline complexity does not seem to have any significant patterns (see Figure 24). Coastline complexity is highest in three different

In the north LiDAR swath, average coastline complexity in a graph highlights possible sea level change still stand levels that are more complex overall than other elevations (see Figure 23). Coastline complexity can be related to sea level change as changing relative sea level exposes glacial and early post glacial landforms to coastal geomorphological processes. Further, a consequence of sea level still stands are better developed marine landforms which influence coastline complexity, such as the development of tombolos or spits. Another interesting trend in the north swath average coastline complexity data is that generally, coastline complexity increases through time. This is also likely due to many different constraining factors of the landscape, such as underlying bedrock geology, long term geomorphic history, and slope. A possible explanation could be higher slope, including

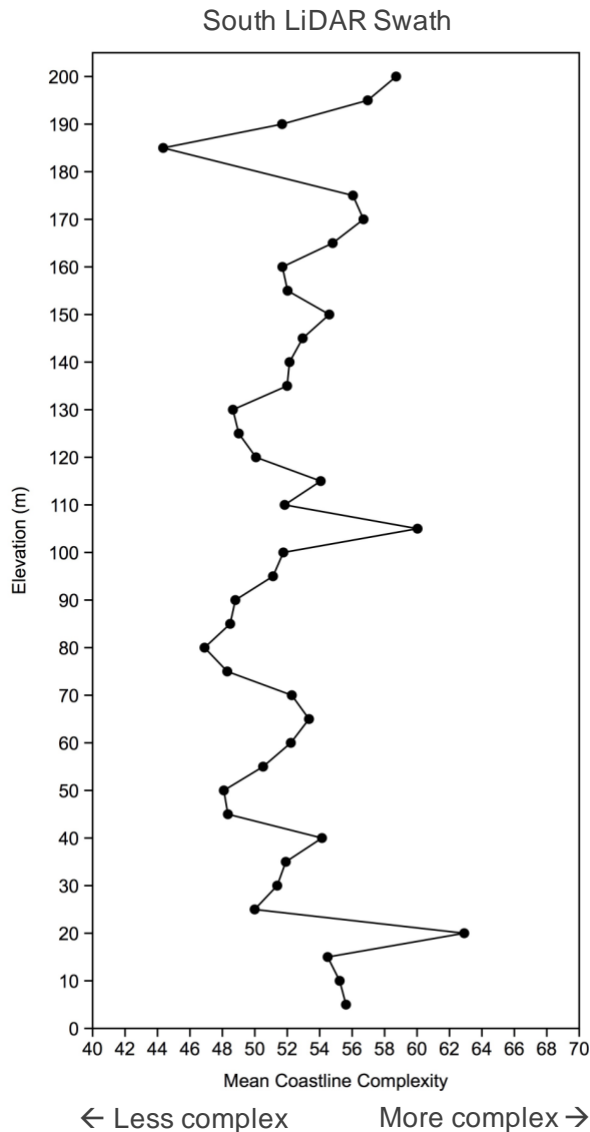


Figure 24: Mean coastline complexity for each calculated elevation in the south LiDAR swath.

elevation zones, ca. 200 metres, 100 metres, and 20 metres. Overall, there is greater variation and range in coastline complexity values for the south LiDAR swath. This is perhaps related to the south swath being a higher energy environment with greater exposure, especially open to the primary southeastern wind direction. High exposure can have a relationship to shoreline crenulation, such as the west coast of Haida Gwaii in Gwaii Haanas National Park, where rocky shorelines with high exposure are in the process of being broken up and are very crenulated (A. Mackie et al. 2017).

The coastline complexity method used in this study was effective for quantitative modelling of coastline shape, and for visualization of areas with higher overall

complexity. One caveat of the method is that it is based on contour lines as a representation of shorelines and potential paleo-shorelines. A problem with this is that contours generated from a DEM do not always sufficiently represent a shoreline. For example, one consistent problem area in this study was flat areas, such as deltas, or other planar low slope areas. The contours generated in these areas are very sinuous because during generation they track slight changes in

elevation over a generally flat area. This caused the coastline complexity calculation to rank these areas with much higher complexity than other areas of truly high complexity, skewing the average coastline complexity values. This problem was solved statistically by excluding the values from flat areas, which almost always represented the top 1% of all values, and were classified as outliers. The problem was also solved heuristically for qualitative modelling by modifying the symbology classes to exclude these skewed areas.

At a site-specific scale, results were useful for highlighting target areas which were then qualitatively evaluated. Symbology for coastline complexity results was visualized through both classified and stretched symbol types which allowed for rapid identification of areas with higher than average coastline complexity. It is not possible to review every highlighted area from quantitative modelling, however, I will review some interesting areas that were selected for fieldwork investigation.

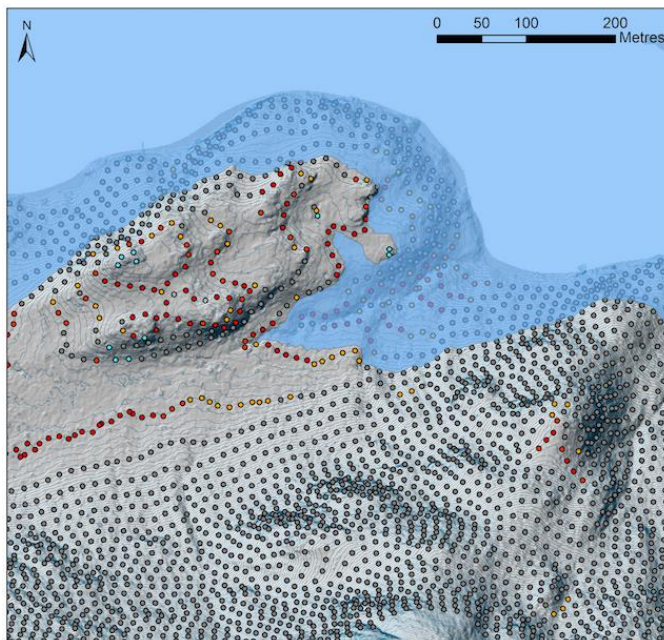


Figure 25: Coastline complexity results for an area in Small Inlet flooded to 30 metres ahht. Higher complexity is shown in red, while lower complexity is shown in blue.

Figure 25 shows coastline complexity for an area in Small Inlet. The results of coastline complexity modelling highlighted this area which was then qualitatively evaluated and several target areas were chosen for further investigation through fieldwork. Several landform scale targets were chosen in this area, all of which produced cultural material (see Figure 26). Further, several other locations near these targets were chosen for testing after field walking and in-field qualitative modelling using LiDAR maps. Coastline complexity results show that this variable may have a relation to late Pleistocene – early Holocene archaeological site location on Quadra Island.

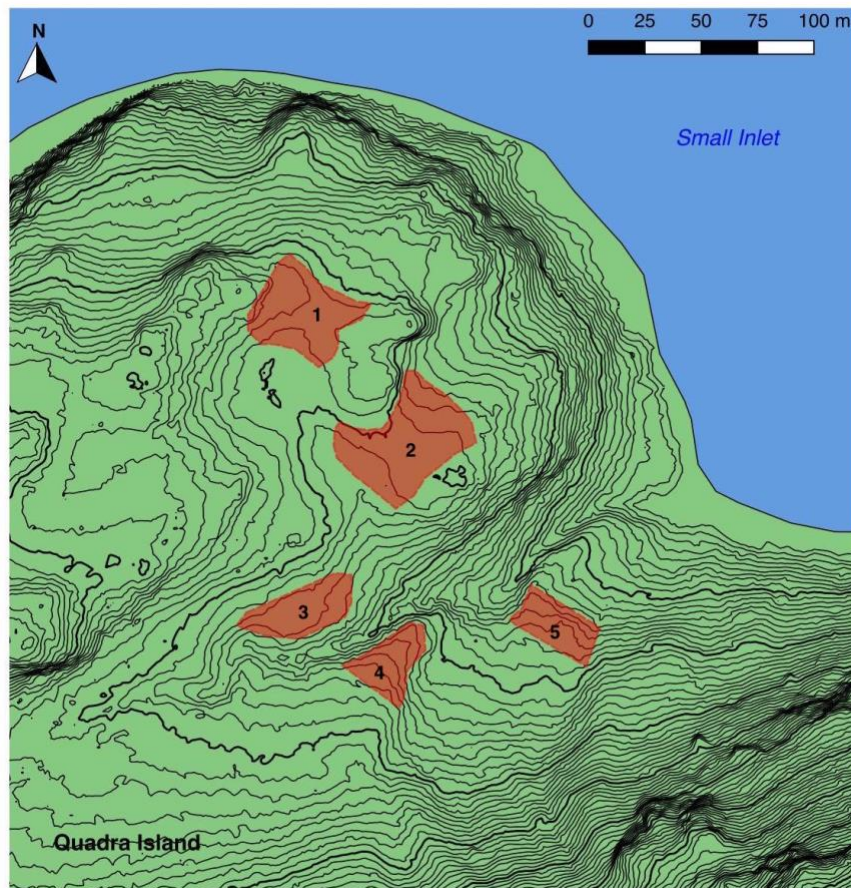


Figure 26: Landforms, highlighted in red, targeted through modelling or identified in-field in Small Inlet. 1 and 2: Small ‘saddle’ areas between bedrock outcrops. 3: flat terrace beside small stream. 4: Possible remnant raised beach. 5: Small raised terrace edge above break in slope. Major contour interval is 10m and minor interval is 1m.

### 5.1.2 Wind fetch

Although it is novel to calculate fetch for quantitative archaeological purposes, wind fetch has long been manually collected for a variety of other fields, including coastal geomorphology and shoreline monitoring. One such resource available in British Columbia, and in other parts of the Northwest Coast is ShoreZone Inventory mapping data that is publically available (Howes et al. 1993). Wind fetch is a standard component of the data that is collected for ShoreZone mapping purposes, and is available for Quadra Island (see Figure 27).

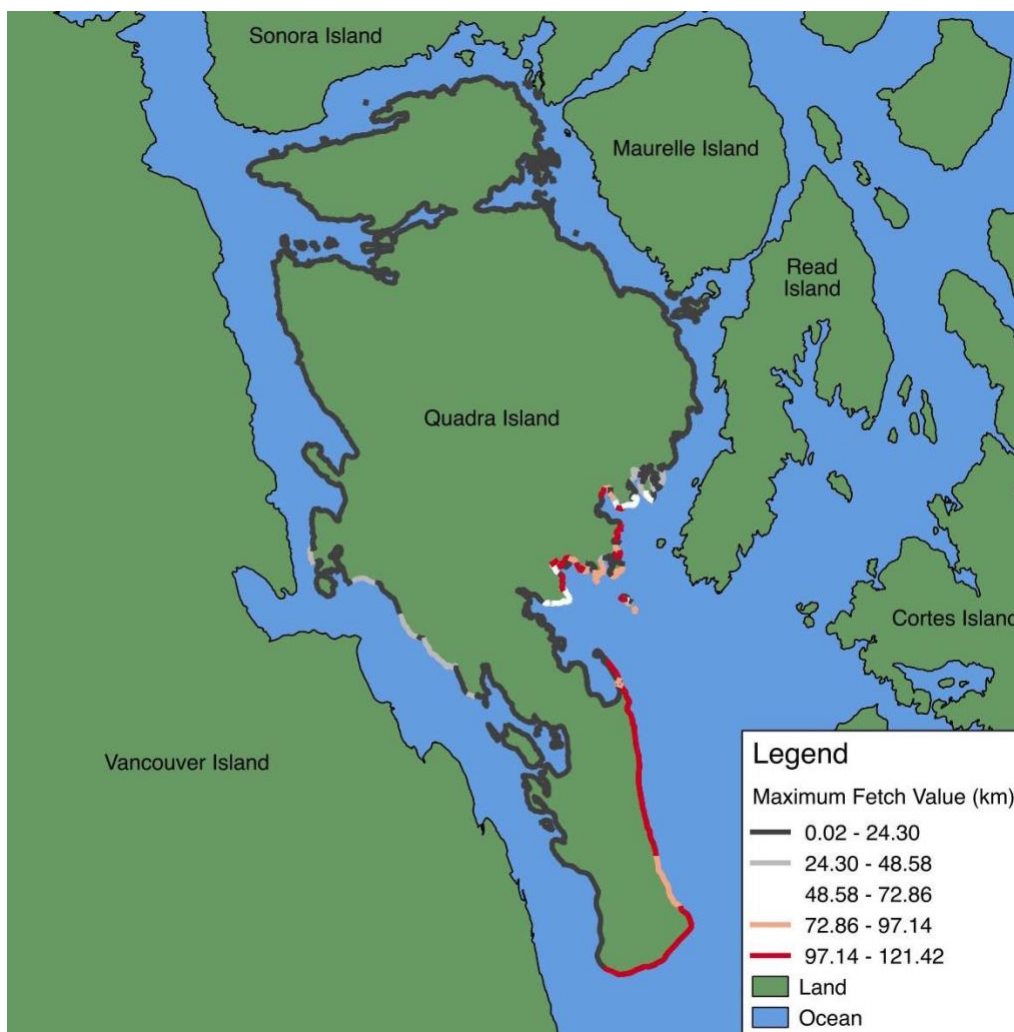


Figure 27: Maximum fetch values from ShoreZone dataset, Quadra Island (Howes et al. 1993).

Qualitatively and practically, the ShoreZone results confirm that the most exposed areas of Quadra Island today are those that face the southeast and are open to weather from the Strait of Georgia. However, in the past, with different sea levels, the impact of exposure to particular shorelines from this direction and from the northwest, changes. In this study, wind fetch was calculated for multiple hypothesized paleo-shorelines. Figure 28 shows wind fetch from the northwest direction for the north LiDAR area. This figure shows that wind fetch, and by proxy exposure, changes considerably through time for different paleo-shorelines. This can have an impact on the location of archaeological sites from a humanistic location perspective and from a site survivability perspective. Although present-day prevailing wind directions were used to calculate wind fetch in this study, it is possible that prevailing wind directions in the past could have been different, however, due to continental-scale weather processes, were likely similar. This study assumes that prevailing wind data can be extrapolated to the past, due to the complexities in trying to reconstruct such paleoenvironmental data. Especially with such dramatic paleoecological change occurring in early post-glacial times, there could have been many unknown factors related to exposure that could be different than the present-day. Depending on the time period, one possibility during very early times are katabatic winds flowing from the northeast from ice sheets, or outflow winds from valley glaciers. These winds and other paleoenvironmental factors such as glacier calving could have played a role in exposure in late Pleistocene times.

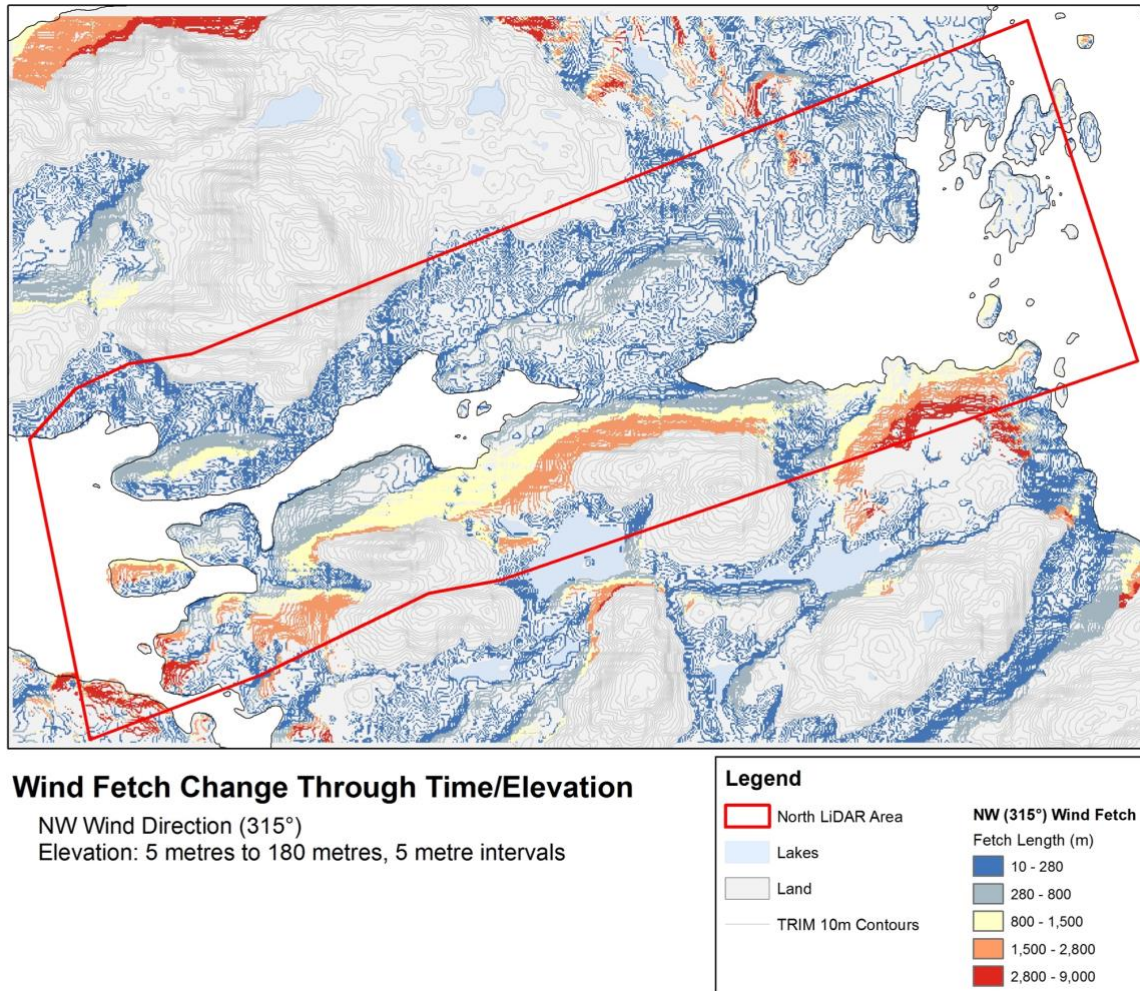


Figure 28: Wind fetch length change through time and elevation for the north LiDAR swath. Wind direction from the NW.

Wind fetch results were output as raster data showing the wind fetch for each water cell. Wind fetch was calculated at 5 metre intervals for all of Quadra Island. Some of these results are shown in Figure 29, which shows northwest wind fetch results at four different elevations for Small Inlet in the north LiDAR area. The changes in fetch values at the paleo-shorelines are considerable, especially in areas that are less protected due to higher sea levels. As Figure 29a shows, at higher relative sea level, wind fetch is considerably higher, and at some points makes its way through channels affecting areas sheltered at lower sea levels. As relative sea level drops, Small Inlet becomes more protected.

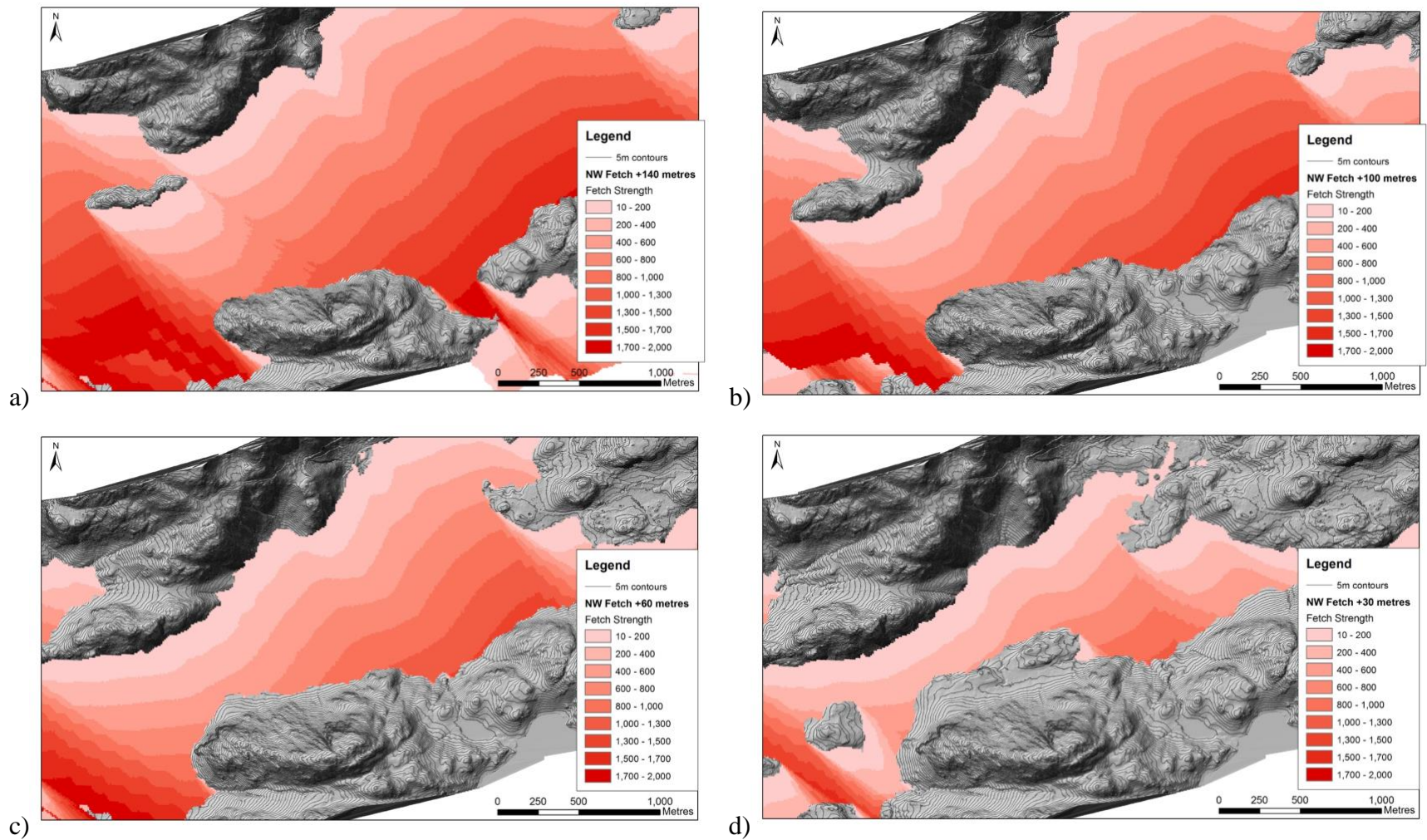


Figure 29: Area of Small Inlet, north LiDAR swatch, with different elevations of wind fetch results overlain: a) NW fetch at 140 metres above modern, b) NW fetch at 100 metres above modern, c) NW fetch at 60 metres above modern, and d) NW fetch at 30 metres above modern.

One problem with wind fetch results at the landscape-scale is dealing with edge effects, making comparison of quantitative values from one area to another difficult. If a fetch calculation area is completely surrounded by land, it bounds the total fetch values, and edge effects are not an issue, however, if fetch calculation starts on cells coded as water, the total fetch length is unknown, or unbounded. Unbounded fetch is an edge effect issue because there could be land just outside of the data edge, in which case the wind fetch distance might be small, or there may be hundreds of kilometres of water outside the data edge, in which case the wind fetch distance would be large.

One way to solve unbounded fetch issues might be to take the absolute fetch value and compare it to the bounded fetch values, however, this incorporates the arbitrary distance of the data edge. Another way to address unbounded fetch is to remove it and not use the values, however, this may leave an arbitrary gap in the data that could be misinterpreted. For this study, both strategies for dealing with unbounded fetch were employed in a critical, qualitatively informed manner. Unbounded fetch values were used as a comparison when a data gap was found, or removed if they hindered interpretation. In using unbounded fetch for comparison, knowledge of the surrounding landscape outside of the data edge was a factor: for example, for a southeast fetch for the south LiDAR swath, all unbounded fetches were assumed to represent high or very high exposure due to the open Strait of Georgia laying outside the data edge. In the north LiDAR swath however, unbounded fetches are likely to represent less exposure from any direction, because there is more surrounding land, even at higher sea levels. Another factor to keep in mind is that this wind fetch model is a relatively simple model of wind fetch and exposure, which does not include, for example, the potential effects of wave refraction around and into bays, or the effects of constructive or destructive wave interference.

Other sources of error in quantitative modelling and data are difficult to account: for example, the downcutting of a stream can look like a narrows or create a false embayment when flooded with a hypothetical higher sea level. Many of these issues were qualitatively identified and accounted for.

These sources of error also affect derived wind fetch values and descriptive statistics. For example, the average fetch value for a particular elevation could be affected by an unbounded fetch or a false embayment. Average fetch values are affected by the exclusion of unbounded fetches. For example, using only bounded fetch results, average wind fetch at 160 metres above modern is lower than average fetch at 5 metres above modern. This is not the case, but because there is more unbounded fetch data excluded at the 160 level the average is lower. These factors make quantitative comparison of wind fetch results difficult.

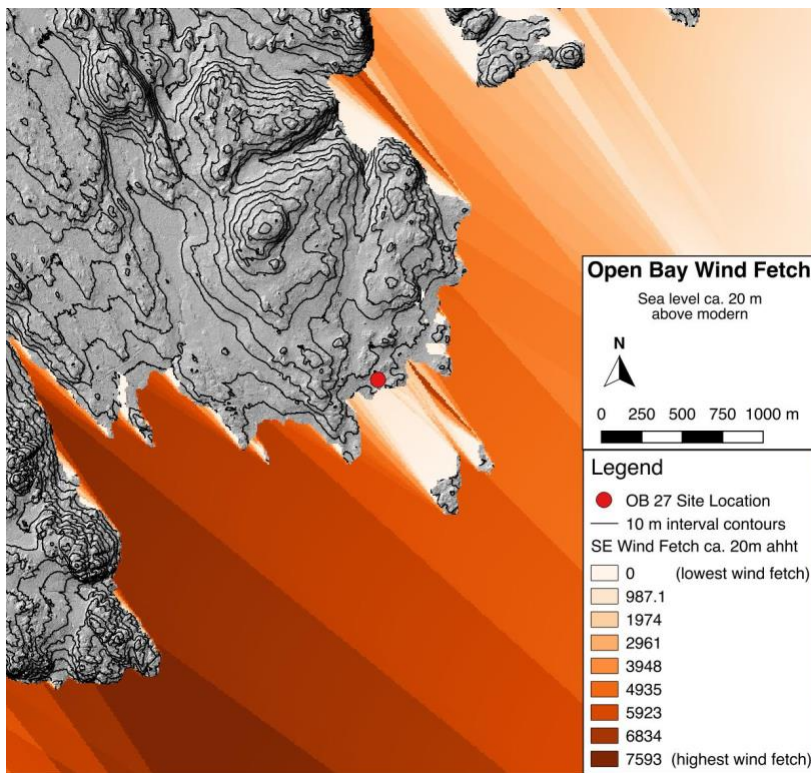


Figure 30: SE Wind fetch results for an area of Open Bay, south LiDAR area.

At the site-scale, wind fetch results may play a role in archaeological site location and survivability. In Open Bay, a site found at 27 metres above modern sea level is better protected from a southeast wind fetch than the surrounding area by several small islets that are present on the paleo-shoreline at that sea level elevation (see Figure 30). In Small Inlet at ca. 30 metres above modern sea level, a small protected bay provides shelter from a northwest wind fetch exposure (see Figure 31). The wind fetch results highlight that these site areas are more protected from wind fetch, and by proxy, exposure, which may have played a role in archaeological site location and/or survivorship.

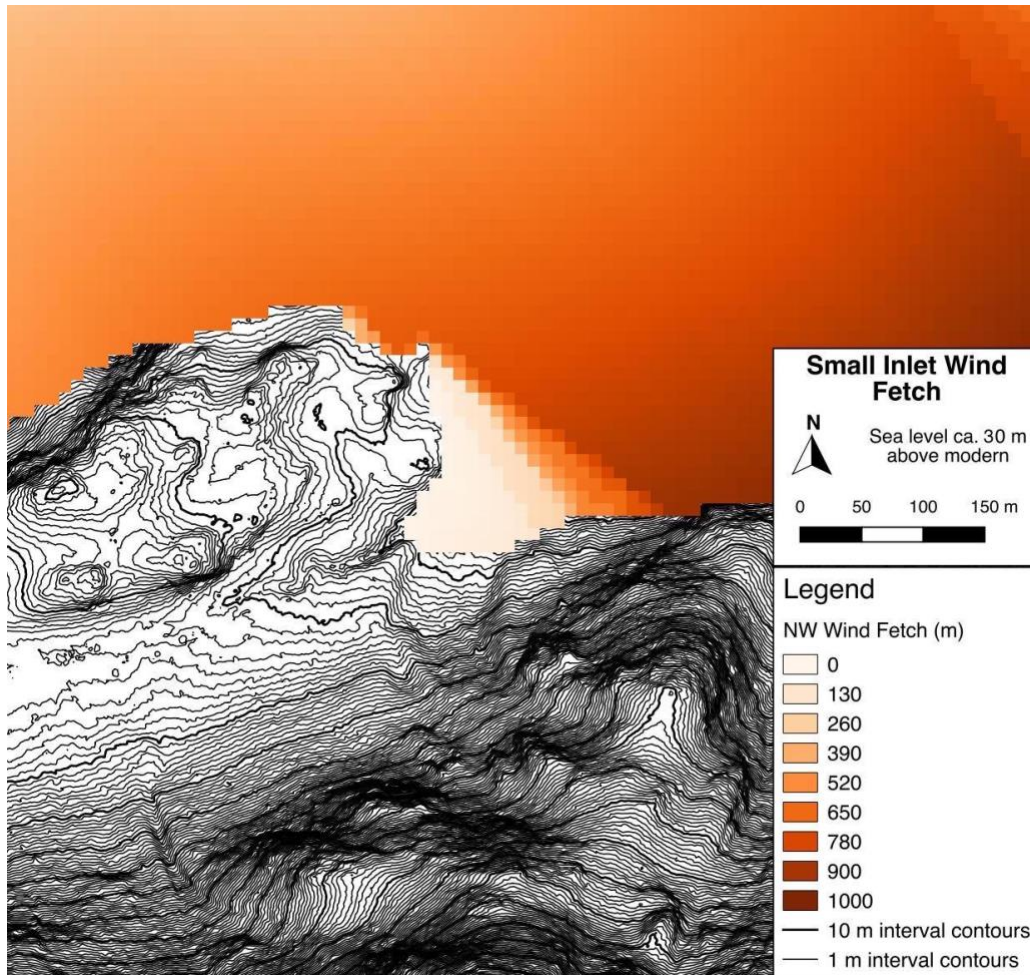


Figure 31: Wind fetch results for Small Inlet, ca. 30 metres above modern sea level.

## 5.2 Fieldwork Results

Results of fieldwork during this study were encouraging. In total, 22 target areas were tested, and 14 new sites were found during July and September 2016 fieldwork. Figure 32 shows the archaeological sites found during this study. Many are concentrated in Small Inlet, in the North of Quadra Island, where the bulk of the fieldwork took place during September 2016. Field testing took place specifically within the boundaries of the two LiDAR swaths.

### 5.2.1 July 2016 fieldwork

The model created for this study was preliminarily tested in July 2016 on Quadra Island for field testing maps and methods, and ground-truthing target landforms. This was important to better understand the results of the quantitative modelling, and was the only fieldwork undertaken in the southern LiDAR swath (see Figure 33). Additional benefits of this pilot ground-truthing fieldwork included a better understanding of the logistics of using the quantitative model results in the field and familiarity of using the model in both planned and “on the fly” capacities. One of the main goals of testing was to understand what kinds of landforms were targeted by the model and why. Modelling was focussed on paleocoastal landforms such as spits, tombolos, narrows, terraces, and other coastal landform types. The landforms and sites chosen (model targeted areas) were subsequently ground-truthed in order to understand their geomorphological formation and history, get feedback for additions and revisions to the model, and evaluate the accuracy of the data.

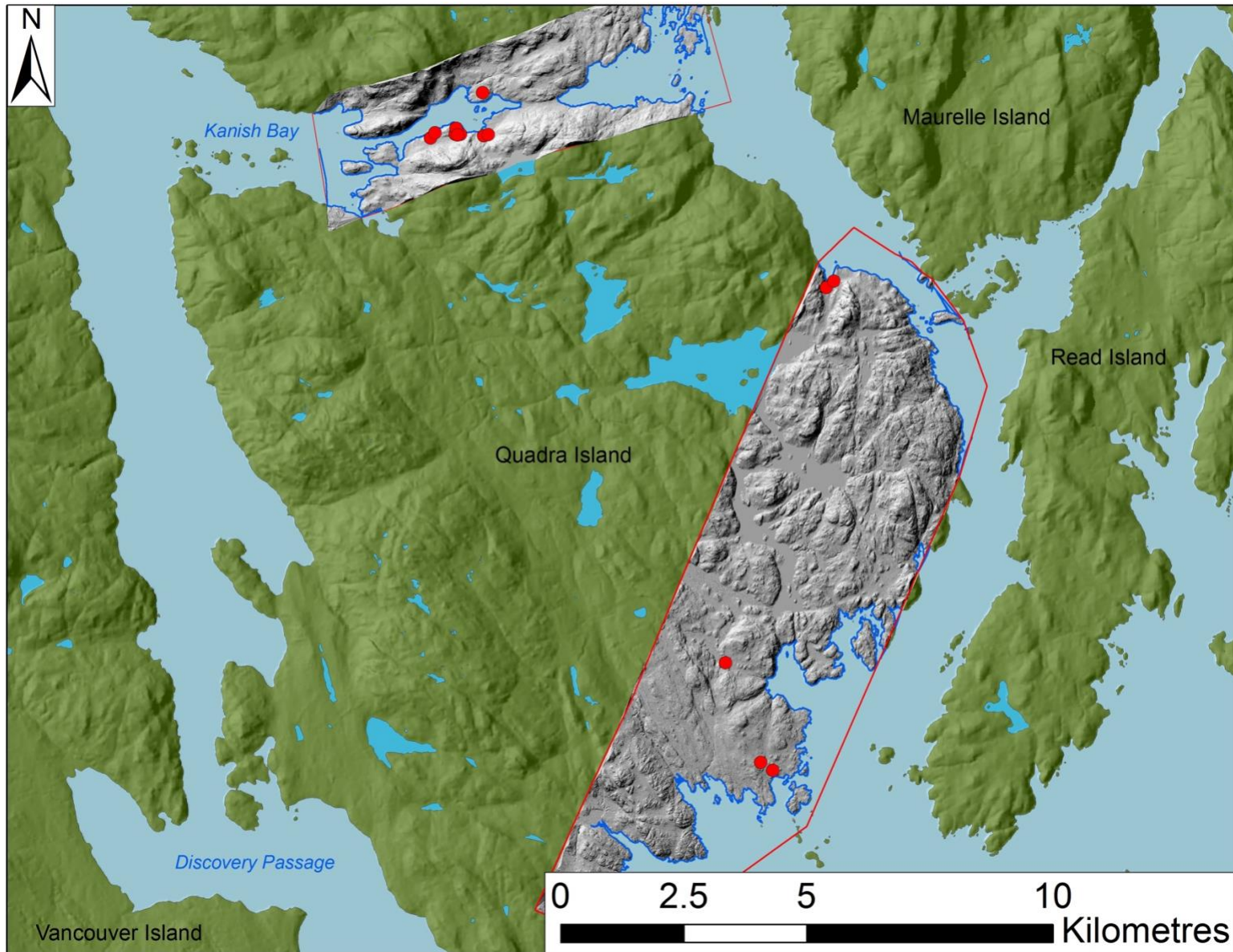


Figure 32: Overview map of new sites (red dots) found during this study.



Figure 33: Map of broad areas investigated in July 2016. 1. An area south of Hyacinthe Bay, 2. An area in Open Bay, 3. An area west of Village Bay in the Kellerhals' Family woodlot, and 4. A high elevation area northwest of Hyacinthe Bay near Mt. Sweat.

Within the south LiDAR boundary, four broad areas highlighted by the model were investigated: (1) an area south of Hyacinthe Bay; (2) an area in Open Bay; (3) an area west of Village Bay in the Kellerhals' Family woodlot; and (4) a high elevation area northwest of Hyacinthe Bay near Mt. Sweat (see Figure 33). Within these four broad areas, eleven paleocoastal targets were investigated. A paleocoastal target was classified as a specific landform that was highlighted by quantitative modelling and then qualitatively judged to be feasible for ground-truthing.

Table 11: Summary of preliminary July 2016 fieldwork results.

Temp. Target Name	Area	Description	Elev.	Total tests	
				Pos.	Neg.
Above Hyacinthe Bay	1	Terrace with break-in-slope that potentially represents paleo-shoreline edge.	40 m	0	5
Open Bay Paleotombolo 1	2	Large paleo-tombolo area.	47 m	0	2 + 1BD
Open Bay 45	2	Small embayment.	45 m	1	0
ST6	2	Shoreline edge of paleo-bay.	25 m	0	1
ST-CV2	2	Flat area near paleo-spit area that was grounded-truthed as rockfall.	33 m	0	1
Open Bay 27	2	Paleotombolo protected from SE by islets during higher sea level.	27 m	2	1
Boletus Road	3	Well-defined terrace beside stream that would have been a paleo-inlet.	29 m	1	5
Three Knobs	3	Flat area behind three bedrock outcrops overlooking stream and potential paleo-tidal channel.	36 m	0	3
Mt. Sweat Gravel Pit	4	Gravel pit area off of Koker Main Rd. area showing complex high elevation stratigraphy. Just surface inspection.	134 m	0	0SO
140 Lagoon and tree throw	4	Shoreline surrounding paleo-lagoon area.	142 m	0	1+ 1BD
150 Tombolo	4	Paleo-tombolo between two large bedrock outcrops.	149 m	0	2

1. SO stands for surface object.

2. BD stands for blow down.

In total, 11 target areas were tested and 3 new archaeological sites were found in July 2016 fieldwork (see Figure 34). July 2016 testing took place in the south LiDAR swath only due to boat access restraints. Table 11 reviews the areas tested and the number of tests conducted at each area. An important result of the preliminary July 2016 fieldwork was that the “on-the-ground” experience and conclusions about specific landforms sometimes differed from what was originally interpreted through the bare earth model.

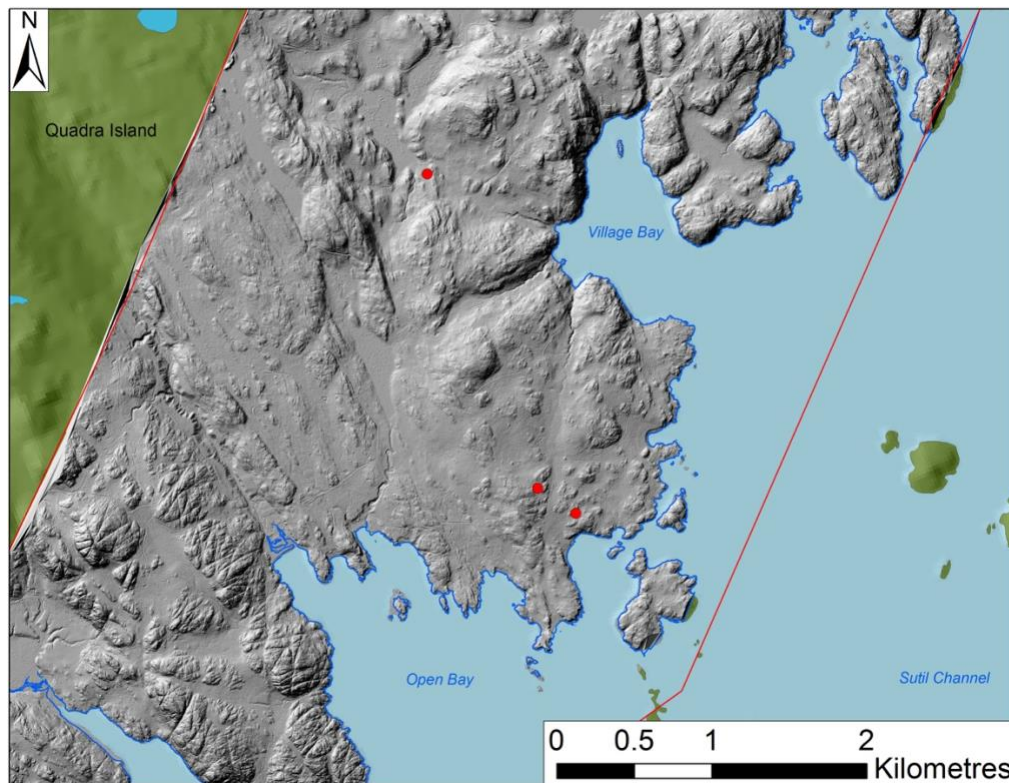


Figure 34: Map of sites found in the south LiDAR swath, July 2016.

One example is a target area that looked to be a small, flat, well defined terrace and possible paleo-coastal feature but was actually rock fall (see Figure 35). This feature looked good from a quantitative sense because its coastline had a higher complexity value than the surrounding coastline, and it was protected from the southeast fetch direction. It also looked good qualitatively because it projected out into a paleo-lagoon type area, it was flat, near other target areas, and met many of the other qualitative factors that are outlined in Chapter 4.

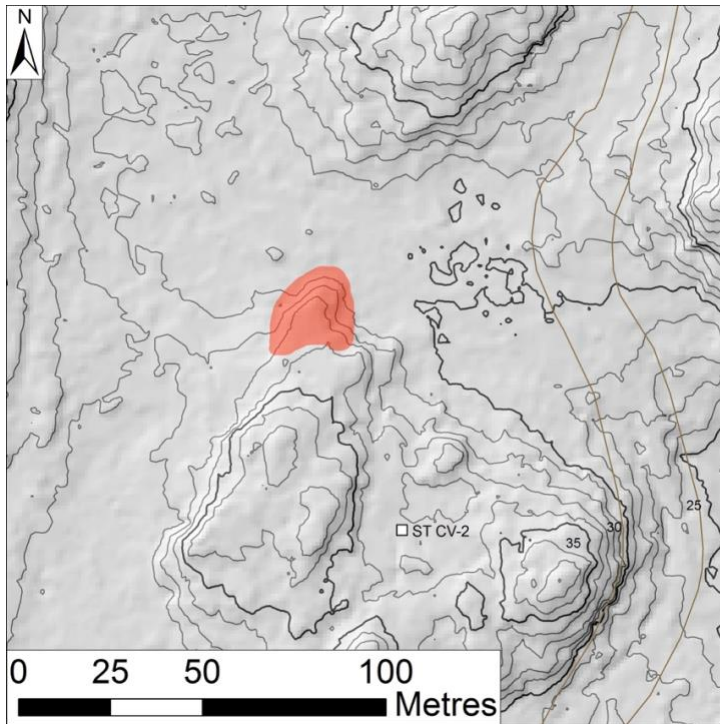


Figure 35: Target area (highlighted in red) at Open Bay discovered to be rockfall. Also visible is negative shovel test ST CV-2.

A second area that was ground-truthed in July 2016 was a potential paleotombolo feature in Open Bay, in the south LiDAR swath. Although this area was highlighted by quantitative modelling, when ground-truthed, the area was much larger than anticipated (see Figure 36). This model targeted area shows one of the disadvantages of working qualitatively with contours, where the landform was exaggerated by coincidence with a major contour line (i.e., Paleotombolo 1 was located on the 50 metre amsl contour, highlighting the landform). Another disadvantage of a large target area landform is that a low density of archaeological material requires more testing time and a higher number of test locations to cover the larger area. On smaller target area landforms, archaeological material is more concentrated in a smaller area and therefore may require less testing to find.

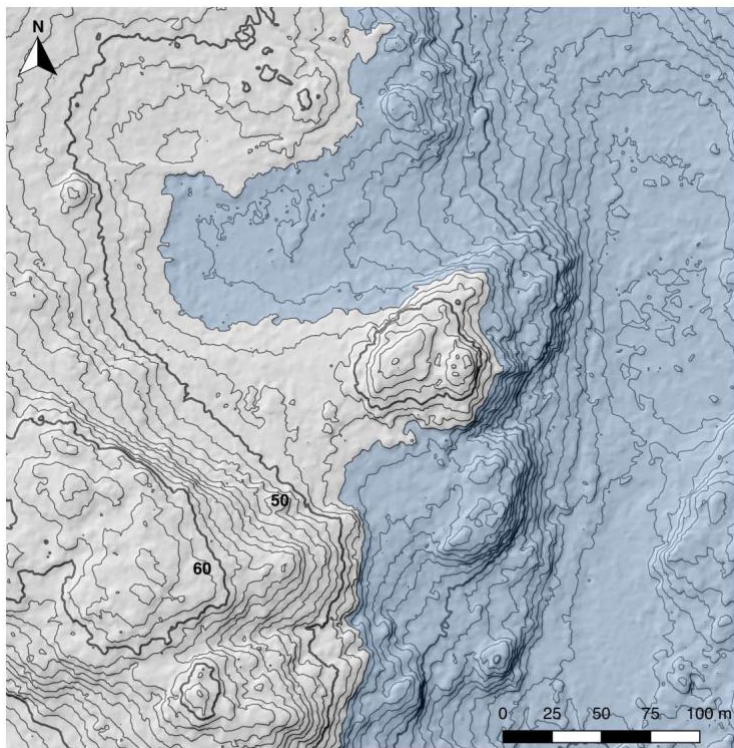


Figure 36: Map of Open Bay Paleotombolo 1, flooded to 48 metres ahht, or 50 metres amsl. Major contour interval 10m and minor interval 1m.

Similarly, some negative areas investigated in July 2016 (e.g. ST-6, ST-CV2, Mt. Sweat Gravel Pit) are represented by only one shovel test, and may not accurately represent the presence or absence of archaeological material. Typically, in order to adequately test a landform (and indeed a potential model), systematic testing on a defined grid or with a statistically valid number of tests would be conducted, however, due to limits of time and resources, some areas were only quickly or opportunistically assessed. The experiences in July 2016 informed further modelling and archaeological survey in September 2016.

### 5.2.2 September 2016 fieldwork

The main period of fieldwork for this study took place in September 2016 from September 7, 2016 to September 25, 2016. All fieldwork in September 2016 took place in the North LiDAR swath in Small Inlet due to boat availability. The boat was driven from Granite Bay north into Kanish Bay and then east into Small Inlet. All target areas were hiked to from the

current shoreline after securing the boat. During the September 2016 field season, 12 areas were investigated and all had archaeological remains (see Table 12, Figure 37). Table 12 reviews the areas tested and the number of tests that were conducted.

Table 12: Summary of September 2016 fieldwork results.

Temp. Site Name	Description	Elev.	Total tests	
			Pos.	Neg.
Beadless Creek (CLN02-OTBeadless-03)	Flat terrace with two associated raised beaches and a steep bedrock cliff. Long-lived creek flows through bedrock notch.	22 m	7+ 2BD + 1SO	3+ 1BD
Bluff Top (CLN02-LW-03)	High bluff top above Beadless Creek site. Could be paleocoastal, but would have been a very small islet.	44 m	1	0
Horseshoe (CLN02-LW-01)	Terrace associated with possible paleo-lagoonal area.	31 m	5+ 1BD	1
Otherside Horseshoe (CLN02-AM-03)	Raised beach and flat terrace held in place by surrounding bedrock.	28 m	2+ 1SO	5
25 m Terrace (CLN02-DF-01)	Flat terrace beside small creek.	27 m	2	1
Finger (CLN02-NS-02)	Small remnant terrace or raised beach landform beside small creek. Could be part of a debris flow.	24 m	1	0
Quartz Crystal (CLN02-JC-02)	Raised terrace with defined break in slope. Likely a paleobeach, but could be associated with later Holocene upland use.	17 m	1	0
Newton Creek (CLN02-AM-01)	Terrace beside long term creek outflow from Newton Lake.	36 m	1+ 1SO	1
Squirrel Terrace (CLN02-AM-02)	Terrace beside long term creek outflow from Newton Lake.	41 m	3	2BD
Northside Small Inlet DF (CLN02-DF-02)	Northside of Small Inlet on a small raised terrace overlooking a paleo-bay.	29 m	1BD	0
Yeatman Bay Road Cut (CLS04-DF-01)	Southern edge of Yeatman Bay on well-defined raised beach cut by a historic road.	14 m	1+ 1SO	0
Yeatman Bay Ridge (CLS04-JC-01)	Eastern side of Yeatman Bay on paleo-spit-like ridge associated with a raised beach.	19 m	1+ 3BD	1

1. SO stands for surface object.
2. BD stands for blow down.

Site locations in September 2016 were typically raised terrace features found at a variety of elevations in Small Inlet. Cultural material was typically comprised of a low density of lithic artifacts found on the surface and/or in the subsurface. Site location testing took place in the same way as that in July 2016, by shovel testing target areas, field walking, and utilizing sediment exposures and tree throws opportunistically.

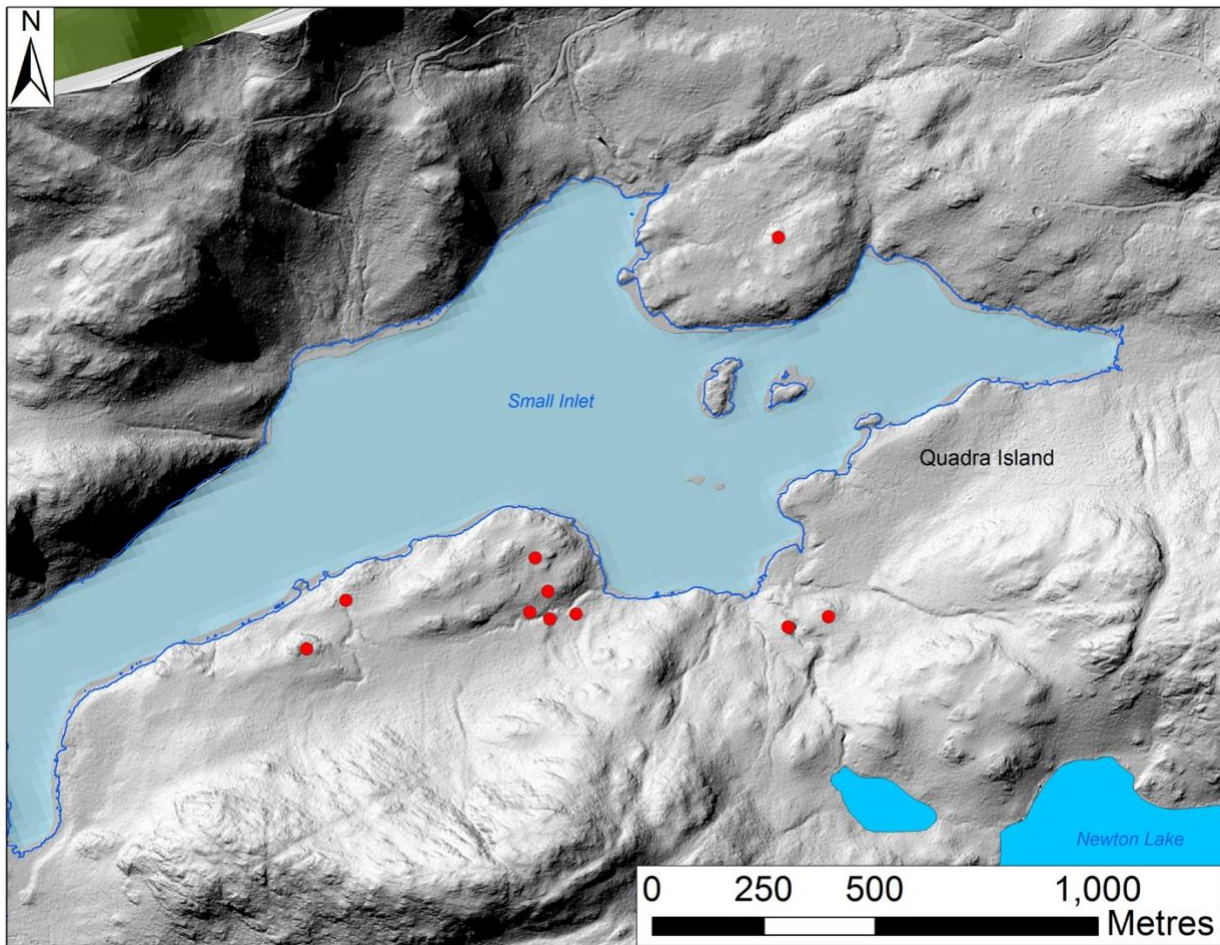


Figure 37: Map of sites found in Small Inlet in September 2016. Each red dot represents an archaeological site.

Target areas for September 2016 fieldwork were chosen through qualitative modelling of quantitative results, and several other areas around these were tested opportunistically after in-field identification. Four major areas in Small Inlet were tested in this way, as seen in the clusters of 10 sites on the map in Figure 37.

### 5.2.3 Lab analysis

Radiocarbon dating and lithic analysis are a primary means of dating archaeological sites. The fortuitous involvement of this study with the Hakai Institute meant that radiocarbon dating and lithic analysis took place as part of the wider DILA project. A total of four radiocarbon dates were taken from three sites related to this study, and are reviewed in Table 13 below. Although a complete lithic analysis is ongoing as part of the DILA project, for the scope of this study, a preliminary lithic analysis was performed.

#### Radiocarbon dating:

Some radiocarbon dating samples were taken and submitted from select sites for 2016, and were dependant on the larger DILA project goals, priorities, and budget. Three sites reported in this study were radiocarbon dated: Beadless Creek (CLN02-OTBeadless-03), Yeatman Bay Road Cut (CLS04-DF-01), and Yeatman Bay Ridge (CLS04-JC-01). Results of the radiocarbon dating are reported in Table 13.

Table 13: Table of radiocarbon dating performed at the sites in this study.

UCIAMS #	Sample Name	Site Name	<sup>14</sup> C Age	Calibrated Age (2 σ, Calib 7.1)	Median Probability
179748	Yeatman Bay STJA1 35cm	Yeatman Bay Ridge	8,680 ± 20	9679 – 9552 cal. BP	9,609 cal. BP
179749	Yeatman Bay STDF1 65cm	Yeatman Bay Road Cut	8,405 ± 20	9485 – 9412 cal. BP	9,453 cal. BP
179750	Beadless EU1 85cm	Beadless Creek	2,795 ± 20	2953 – 2850 cal. BP	2,898 cal. BP
179751	Beadless EU1 90cm	Beadless Creek	2,530 ± 15	2741 - 2697 (0.546), <sup>1</sup> 2633 - 2616 (0.136), 2589 - 2536 (0.263), 2529 - 2506 (0.056) cal. BP	2,704 cal. BP

<sup>1</sup> Bracketed percentage is the relative area under probability distribution for calibrated dates.

All radiocarbon samples were submitted to the Keck Carbon Cycle AMS Facility at the University of California Irvine for analysis as part of the DILA project. All samples were

charcoal. Radiocarbon dates for two of the three sites are encouraging. At Yeatman Bay Ridge (CLS04-JC-01) two shovel tests were conducted in addition to evaluating three tree throw exposures. One shovel test and all exposures were positive for cultural material. A radiocarbon sample from 35 cm dbs was selected for analysis and returned a date of ca. 9,600 cal. BP (see Table 13). About 200 metres away from Yeatman Bay Ridge site (CLS04-DF-01) is the Yeatman Bay Road Cut site. One shovel test was conducted at Yeatman Bay Road Cut in addition to observed lithics in the exposed sediment of the road cutbank. One radiocarbon sample from 65 cm dbs was selected for analysis and returned a date of ca. 9,450 cal. BP. This date is similar in age to the date acquired from Yeatman Bay Ridge, however, they do not overlap at 2-sigma calibrated range.

Radiocarbon date results for the Beadless Creek Site (CLN02-OTBeadless-03) were unexpected. Two radiocarbon samples from evaluative unit 1 (EU1) were selected for analysis. One sample was from 85 cm dbs in the NE quad and returned a date of ca. 2,900 cal. BP. The other sample was from 90 cm dbs in the NE quad and returned a date of ca. 2,700 cal. BP. In the field, these samples were interpreted as from a possible hearth feature at the base of the unit, overlaying a clay hardpan layer. However, the results of the dating suggest that this feature was not a hearth, and is more likely disturbance from a burned root. The dates are out of stratigraphic order and do not overlap at the two-sigma range. No further radiocarbon samples from sites found in this study were submitted. Further evidence for site dates comes from preliminary lithic analysis, reviewed in the discussion in Section 6.2.1.

#### Preliminary lithic analysis:

A preliminary lithic analysis was performed to assess whether shovel testing units and exposures were positive or negative for cultural material. These results are summarized in Table

14, which includes the site number, shovel test number, test elevation, artifact description, and depth found. Lithic analysis was conducted at the University of Victoria Archaeology Lab with Quentin Mackie. Initial culling was performed by myself and ambiguous finds were interpreted with Dr. Mackie's input. I would also like to thank my colleagues in the archaeology lab who were always willing to interpret specimens, especially, Callum Abbott, Angela Dyck, Seonaid Duffield, and John Murray. Although some artifacts collected may help with site dating, no diagnostic artifacts (e.g., projectile points) were found at sites discovered during this thesis.

A further, complete, lithic analysis is ongoing at the University of Victoria as part of the larger DILA project. For the scope of this thesis, only the preliminary results are reviewed. A wide variety of lithic material was recovered from the sites found during this study, including scrapers, bipolar flakes and cores, choppers, primary and secondary reduction flakes, cores, and biface reduction flakes. A selection of artifacts have been photographed or illustrated to demonstrate the breadth of material found and highlight some significant finds. Information about the provenience and typological description of each artifact is supplied in the caption.



Figure 38: Small biface reduction flake found at Yeatman Bay Road Cut (CLS04-DF-01) in ST-DF-Yeat1 from 65-70 cm dbs. Other artifacts found in same level. Arrow points to platform.

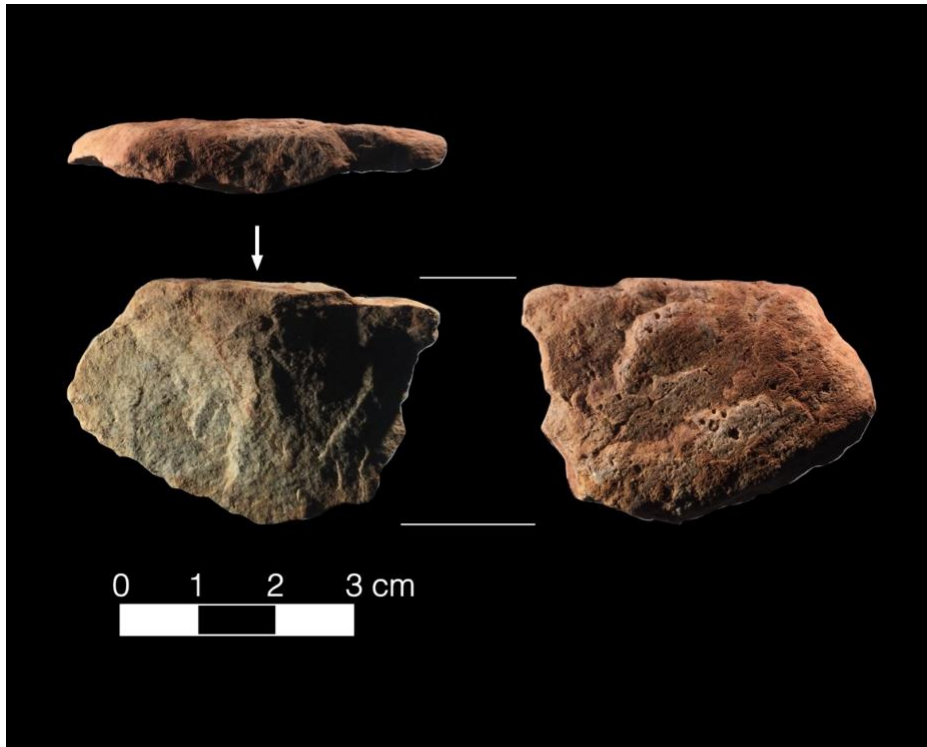


Figure 39: Primary reduction flake found at Horseshoe Site (CLN02-LW-01) in ST-DF-01 from 20-25 cm dbs. Arrow points to platform.

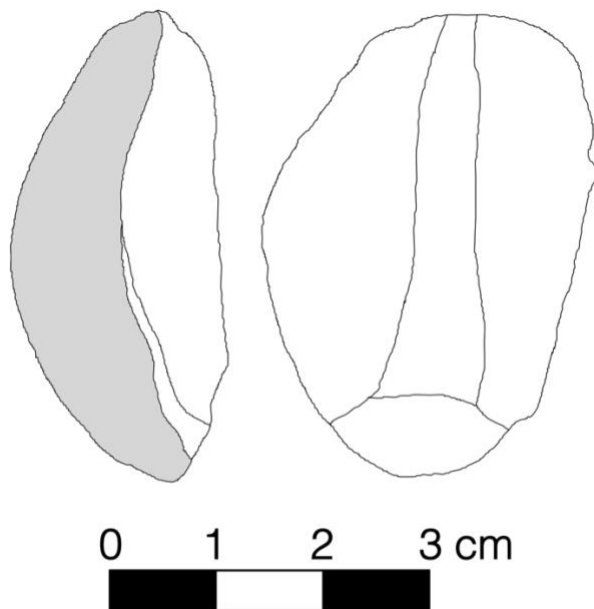


Figure 40: Bipolar core found at Horseshoe Site (CLN02-LW-01) in ST-DF-01 from 30-36 cm dbs. Grey coloured area is cortex. Cemented sediment sticks to a variety of surfaces on this artifact.



Figure 41: Scraper found at Boletus Road site (Area 3) in ST2 from 25 cm dbs. Arrows point to platform and flake scars.

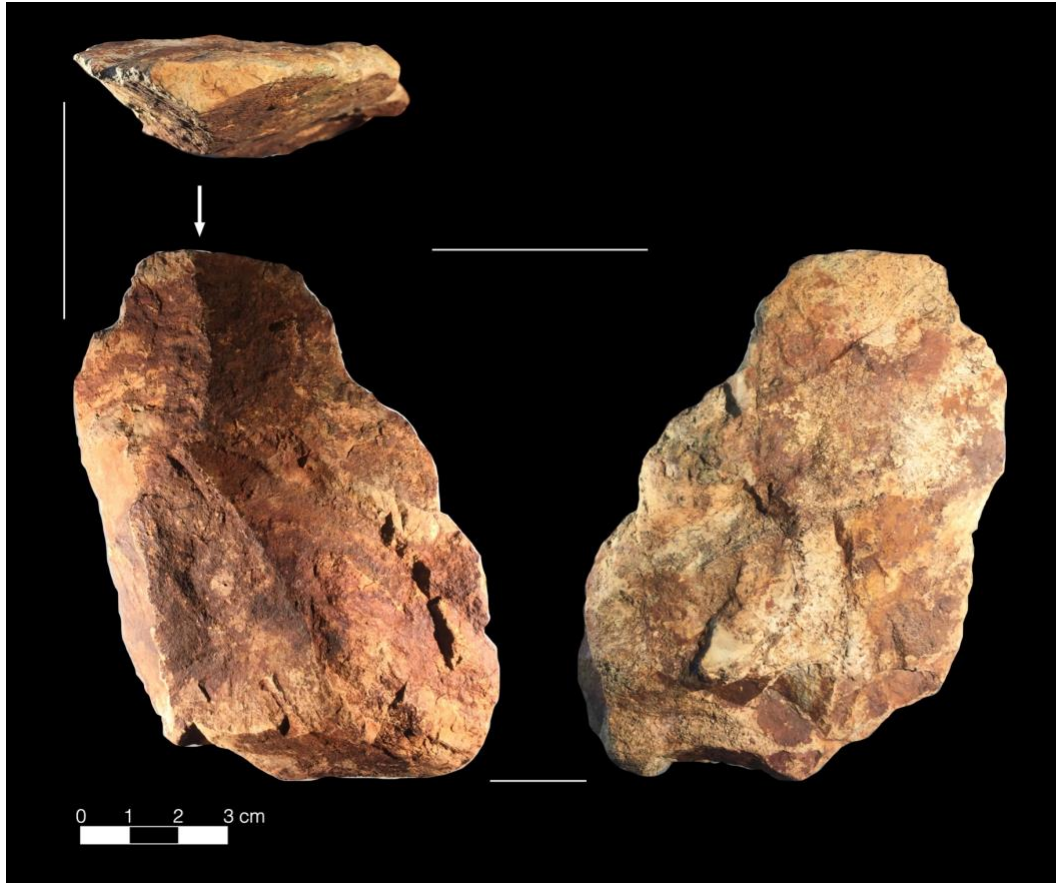


Figure 42: Large flake (secondary reduction) found at Newton Creek site (CLN02-AM-01) on the surface at SO-1. Arrow points to platform. Note the complex dorsal face on left.

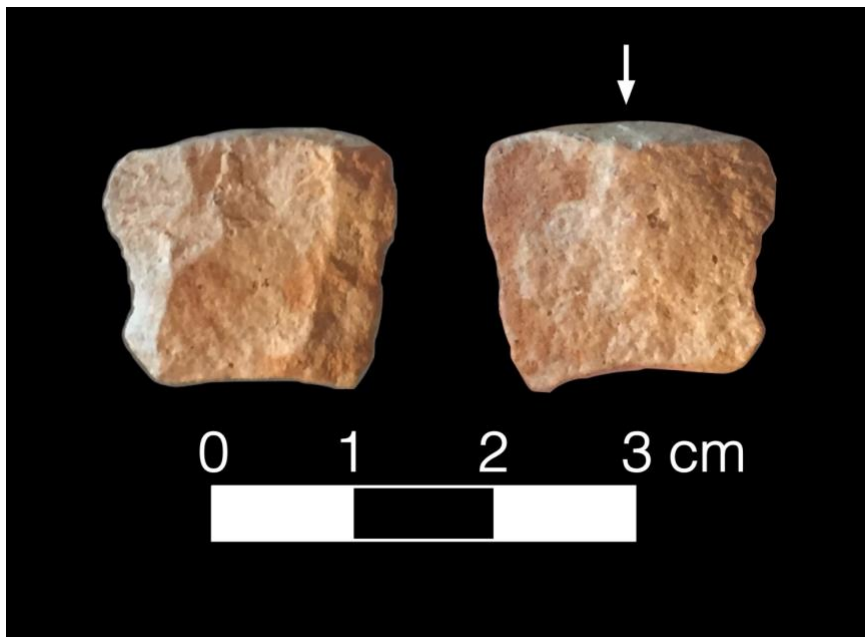


Figure 43: Flake from OB27, ST-9 at 70 cm dbs. Arrow points to platform on ventral face.

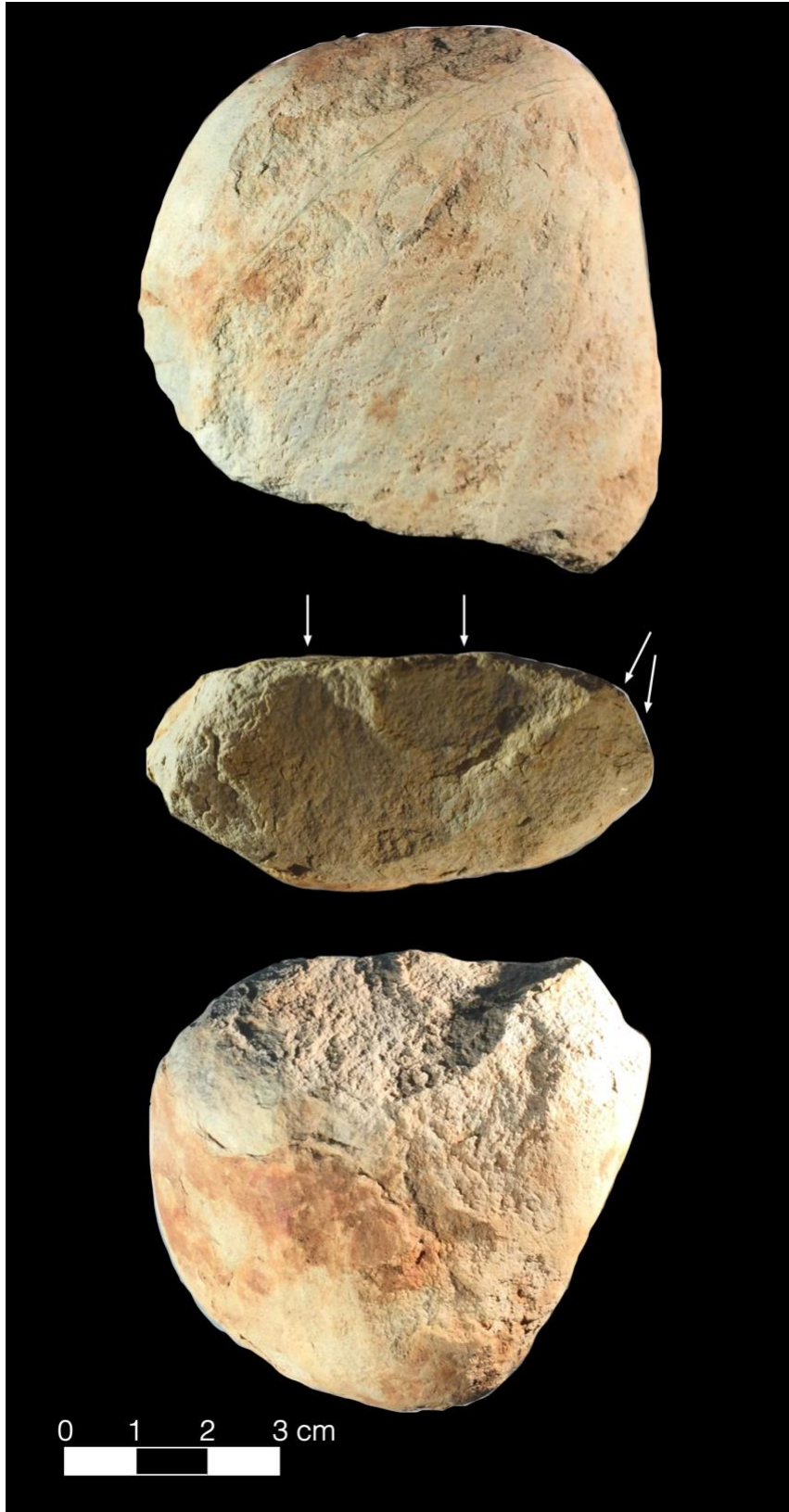


Figure 44: Cobble chopper found at Newton Creek site (CLN02-AM-01) in ST-AM-01 from 80-90 cm db. Arrows point to flake scars.



Figure 45: Discoloidal core found at Yeatman Ridge site (CLS04-JC-01) in a tree throw exposure, BD3. Arrow points to flake scar from Levallois-like flake removal or core rejuvenation flake removal.

These artifact figures show a variety of artifact and raw material types which will be further discussed in Chapter 6, Section 6.2.1. Callum Abbott, a Master’s Candidate at the University of Victoria is studying the different raw material types found at sites on Quadra Island (Abbott, in prep). The results in Table 14, below, help to put each site and artifact in context.

The results of this study are encouraging, but only constitute a preliminary analysis of materials collected during the 2016 DILA field season. Complete analysis of these results will be available in the DILA project reports in preparation.

Table 14: Summary of preliminary lithic analysis results.

Temp. Site No.	Site Name	Test Elev. (m ahht)	Test No.	Definite artifact description:	Depth (cm dbs)
OB27	OB27	27	ST-7	Bipolar flake	30-40
			ST-8	Proximal flake (see Figure 43)	70-80
				Spokeshave	70-80
Boletus	Boletus Road	29	ST-2	Scraper (see Figure 41)	25
CLN02-OTBeadless Creek-03	Beadless Creek	25	ST-AL-01	Core	0-10
				Flake	10-20
		23	ST-AL-03	Bipolar flake	0-20
		22	ST-AL-04	Core	30-40
		23	ST-DF-01	Proximal flake	50-60
		26	ST-DF-02	Medial flake fragment	30-40
				Large flake	40-50
		23	ST-CN-04	Core fragment	10-20
				Core	32
		24	ST-CN-20/ EU1	Analysis ongoing	n/a
		27	BD-Chris Flake	Cortex spall tool	0
		38	BD-01	Scraper	0
		21	SO-Creek Cut	Core	0
				Core fragment	0
Flake	0				
Flake	0				
Large flake	0				
CLN02-LW-03	Beadless Bluff Top	44	ST-LW-02	Flake	65-70
				Possible core	70-80
CLN02-LW-01	Horseshoe Site	32	ST-CJ-01	Scraper	15-35
				Large flake	35
				Flake	80-90
		30	ST-LN-01	Flake	0-10
				Flake	10-20
				Hammerstone	40
		31	ST-QLN-01	Scraper	50

Temp. Site No.	Site Name	Test Elev. (m ahht)	Test No.	Definite artifact description:	Depth (cm dbs)
CLN02-LW-01	Horseshoe Site	31	ST-QLN-01	Flake	60-65
		31	ST-JJ-01	Flake	55-60
				Large flake	75-80
				Possible medial flake fragment	90-105
		31	ST-DF-01	Primary flake (see Figure 39)	20-25
Bipolar core (see Figure 40)	30-36				
30	BD-NS-01	Ground stone wedge/adze	0		
CLN02-AM-03	Otherside horseshoe	23	ST-LC-03	Flake	85-95
		25	ST-LC-04	Flake	35-45
		26.5	SO-JC-01	Scraper	0
CLN02-DF-01	25 m terrace	25	ST-DC-01	Discoidal core rejuvenation flake	35-45
		24	ST-LJC-01	Possible graver	30
CLN02-NS-02	Finger	24	ST-LN-02	Flake	55-60
				Flake	70
CLN02-JC-02	Quartz Crystal	18	ST-JC-02	Quartz crystal flake	0
				Core fragment	75-80
				Core	85-89
CLN02-AM-01	Newton Creek	33.5	SO-1	Large flake (see Figure 42)	0
		34	ST-AM-01	Proximal flake	50-55
				Cobble chopper (see Figure 44)	80-90
CLN02-AM-02	Squirrel Terrace	40	ST-AN-01	Core	10-20
				Flake	55-65
		41	ST-AN-02	Flake	25-30
		42	ST-LC-01	Flake	25-35
CLN02-DF-02	Northside Small Inlet DF	27	BD-DF-10	Flake	<50
CLS04-DF-01	Yeatman Bay Road Cut	13	ST-DF-Yeat1	Flake	25-30
				Flake	35-45
				Proximal flake	45-50
				Flake	60-65
				BRF (see Figure 38)	65-70
				Flake	65-70
				Distal flake	70-75
				Flake	75-80
		12	SO-01	Discoidal core, not collected.	0
				BRF, not collected.	0
Scraper, not collected.	0				
CLS04-JC-01	Yeatman Bay Ridge	18	ST-JA-1	Flake	10-20
				Flake fragment	45-50
				Retouch flake	45-50
		18	BD-01	Chert flake	0
		16	BD-02	Large BRF	0
		18	BD-03	Discoidal core (see Figure 45)	0
				Large flake	0
OB45	Open Bay 45	45	ST-3	Biface reduction flake	50

## Chapter 6: Discussion

### 6.1 Recent Models and Results

There have been several uses of GIS modelling for coastal archaeological site location in recent years including Gustas (2015; Gustas and Supernant 2017); Carlson and Baichtal (2015); Monteleone (2013); Jenevein (2010); and Punke (2001; Punke and Davis 2006) (as reviewed in Section 2.3.1). This study takes a different approach than each of these recent models.

In contrast to Gustas (2015), this thesis embraces qualitative modelling for including complex multivariate data involved in landform formation and human behaviour processes. Gustas (2015; Gustas and Supernant 2017) included variables related to landforms and human behaviour, such as beach slope, but quantitatively defined them for inclusion in their cost surface model. Similarly, other variables that are typically qualitative were quantified for inclusion in the cost surface, such as the maximum distance that can be travelled by a fully loaded canoe in 12 hours. Gustas (2015; Gustas and Supernant 2017) used a distance of 57.6 kilometres of paddling distance per day, derived from experimental archaeological literature (cited in Ames 2002). However, this distance was too large to be useful for Gustas' (2015) model, and 10 percent of the distance was used, creating a 5760 metre buffer of lower movement cost around landmasses. This thesis takes a contrasting approach to Gustas (2015, Gustas and Supernant 2017) and uses qualitative modelling to incorporate variables that are difficult to include in a quantitative method.

One of the main variables for Carlson and Baichtal's (2015) predictive model is the presence of raised shell-bearing layers. The absence of shell bearing layers on Quadra Island due to formation processes and the homogenous nature of the strata and sediments means that a model similar to Carlson and Baichtal's (2015) cannot be used. Similarly, a slightly drier climate

on Quadra Island makes the area more prone to forest fires, which reduce the ability to find archaeological sites through the presence of charcoal, and makes site dating through radiocarbon more difficult. Overall, this study's modelling approach is likely most similar to Carlson and Baichtal's (2015) model, with quantitative modelling used as a tool to inform further qualitative modelling and archaeological survey.

Similar to Gustas' (2015; Gustas and Supernant 2017) model, Monteleone's (2013) model uses quantitative modelling in a weighted raster method to find areas of archaeological potential. Monteleone (2013) uses many traditional predictive modelling variables of both deductive (e.g., slope, aspect, distance to streams) and inductive (e.g., nearby archaeological sites) types. Monteleone's (2013) model also differs from this study in terms of scale, where limited bathymetric data resolution limited model resolution to 5 metres (25 metres interpolated to 5 metres).

The primary role that geoarchaeological methods plays in Jenevein's (2010) model for submerged archaeology off the coast of Oregon, including site formation processes and survivorship, is noteworthy. However, this model is different from this thesis with its focused geoarchaeological methodology and the environmental differences of the Oregon coast compared to Quadra Island, especially with regard to the typically linear shorelines of the Oregon coast, where erosional unconformities can eliminate millennia's worth of stratigraphy (Jenevein 2010, 128).

Punke's (2001) two models constitute one of the first fully quantitative models for coastal and early period archaeology. As deductive and weighted overlay methods, they fall into a similar class as Monteleone's (2013) model. Subsequent geoarchaeological research (Punke 2005; Punke and Davis 2006) expanded on the notion of the importance of site formation

processes and landscape history to narrow down the possible locations of sites, also expressed in Punke's (2001) models which included geological and soil unit variables.

This thesis used coastline complexity and wind fetch variables to highlight target areas, and subsequently used qualitative modelling and expert judgement to identify target landforms to investigate, identifying landforms through judgement of LiDAR data in a similar way to predictive models used by E.B. Banning and colleagues (e.g., Hitchings et al. 2013; Stewart et al. 2017). Overall, this study can be situated within the existing literature on coastal archaeological predictive modelling, however, the methodology used in this study is quite different than most recent models. Quantitative modelling is especially useful for variables which are not readily modelled qualitatively, such as coastal complexity or wind fetch, especially with the dramatic changes in coastline configuration through time with relative sea level change. Qualitative modelling successfully incorporated complex variables rapidly, including aspects of human behaviour, formation processes, and logistics, focussing archaeological survey. The approach taken in this study worked well to address the specific circumstances for archaeology on Quadra Island and address some of the issues involved in the methodology of predictive modelling.

## 6.2 Archaeological Site Location

What are the characteristics of the archaeological sites found on Quadra Island during the course of this study, and how do they relate to the larger regional and continental coastal picture? In terms of quantitative modelling conducted for this study, it seems that coastline complexity and wind fetch do have a relation to site location. The sites found through this study are in areas highlighted by quantitative modelling that have higher than average coastline complexity and low wind fetch. Negative site locations add to the discussion of site location and the

paleoecological approach for the future. Further, archaeological sites found are located on paleocoastal landform features such as terraces, tombolos, and embayments. Most of the sites are low density deposits, likely from brief depositional episodes. These factors largely agree with the wider regional and coastal archaeological record for the early period. Further work is required to satisfactorily date the deposits in this study, requiring a multivariate approach that incorporates radiocarbon and other forms of absolute dating, technological dating, and sea level history dating.

#### Coastline Complexity and Wind Fetch:

The sites found during the course of this study suggest that coastline complexity and wind fetch can play a role in site location. Overall, sites were found on the basis of fieldwork conducted specifically in target areas highlighted by quantitative modelling of coastline complexity and wind fetch. Therefore, as expected, coastline complexity values at sites are higher than the average coastline complexity. Since coastline complexity is a proxy for higher biological diversity and higher biological resources in an area, these factors could have been an important component of site location.

Similarly, wind fetch can play a role in site location. As a proxy for exposure to weather, wind, and waves, wind fetch can be related to site location on two fronts: one, in a humanistic way that assumes areas sheltered from large storms are better places to be than areas that are not sheltered, and two, in a site survival way, where sites and the landforms they are on must survive erosional and depositional processes so that they are found in the present. Sites such as Open Bay 27 and the Horseshoe site suggest wind fetch is a useful tool for quantitative modelling and show that exposure and/or survivability of sites can play a role in site location.

### Differences between North and South LiDAR Swaths:

An interesting result of site locations in this study is the greater number of sites located in Small Inlet in the North LiDAR swath versus the number of sites located in the South LiDAR swath. One possibility for the density of sites found in Small Inlet is the general dispersal and deposition of lithic artifacts across the landscape through long term landscape use. There are many previously recorded middle to late Holocene sites within a relatively enclosed landscape area, including a large number (n=15) of clam garden sites (e.g., Lepofsky et al. 2016). We would expect long term use of this landscape would deposit cultural material in a low density over a large area (including inland), and in a high density at certain points. This could also represent the importance of inland and upslope resources throughout the Holocene, and especially during the middle and late Holocene. Dwelling in the landscape for thousands of years means archaeological materials are spread throughout the area, defying the notion of the site in this regard (c.f. Dunnell 1992). However, no artifacts seem typical of a mid-late Holocene assemblage, and for many of the reasons outlined in Section 6.2.1, it is argued that most of the sites found in this study likely date to the late Pleistocene – early Holocene.

Alternatively, the differences seen between the density of sites found in Small Inlet versus other areas of the study may be explained through environmental exposure regimes and study time spent in the area. For example, assuming the prevailing wind directions have stayed the same or similar through the late Pleistocene and Holocene, the South LiDAR swath would have been heavily exposed to weather (and therefore more destructive formation processes and lower inherent behavioural attraction) from the early period to the present. The North LiDAR swath could have been exposed in very early post-glacial times, but then would have been

protected for a longer period of time. This could enable greater survivorship of sites and greater cultural deposition, leading to more sites overall.

Study time likely also played a role in these differences. This study spent three weeks in Small Inlet versus one week in the South LiDAR swath. There was also a larger crew ( $n = 10$ ) during the September 2016 fieldwork, which covered more area, conducted more testing than the crew ( $n = 4$ ) could in July 2016 in the South LiDAR swath, and had improved judgement from the experiences of fieldwork in July 2016.

Most probably, the North LiDAR has more sites locations than the South LiDAR due to a little bit of all three factors. Some of the lithic material (for example, lithic material collected on the surface) could represent a general lithification of the landscape and middle to late Holocene inland and upslope land use. However, these differences are also likely due to a better survival and exposure situation in comparison to the South LiDAR and three times the amount of study time with a larger crew spent in Small Inlet versus the South LiDAR.

#### Negative locations:

Data collected in this study and previous literature such as Mackie and Sumpter (2005) suggest that coastline complexity and exposure (i.e. wind fetch) can be important factors for archaeological site location. However, these factors are constituents of a larger complex process, which means that there can always be outliers to these patterns. This is reflected in some of the negative target areas surveyed in the South LiDAR swath. These areas also constitute important data for late Pleistocene – early Holocene archaeological site location.

Negative locations may reflect several different factors. Firstly, the South LiDAR swath may represent a different environment than the North LiDAR swath. This is most readily seen in

the exposure of the South LiDAR swath to southeasterly weather. This assumes that the current patterns of weather can be extrapolated into the past (see Section 5.1.2 about other possibilities). This difference in the South LiDAR compared to the North LiDAR may necessitate differences in testing strategy. For example, cultural material could be in lower density compared to the North LiDAR swath. There may be different overall survivability of sites in the South LiDAR, differences due to formation processes, or different early period land use in a highly exposed environment. Further, many of the negative areas are represented by only one shovel test. This constraint was due to time, however, there is potential that with more testing some cultural material could be found. Lastly, there is the possibility that there is no cultural material left in these target areas, either due to no initial cultural deposition, or site destruction due to formation processes.

#### Paleocoastal landforms:

All of the sites found during this study and many of the early coastal sites reviewed in Table 2 are located on paleocoastal features. These features include marine terraces, tombolos, spits, embayments, beaches, and other coastal landforms that have survived or have been buried since the late Pleistocene.

This may be evidence that the coast was just as important in early period land use and settlement patterns as it was in the later Holocene and today. A growing area of Northwest Coast archaeology today is the investigation of inland and upslope area land use, from the subtidal to the mountain top, by First Nations. However, the importance of the coastal margin has long been known and investigated (e.g., shell middens), perhaps too much in that it has skewed the coastal archaeological record (e.g., Lyman 1991). The fact that archaeologists are finding early period sites on paleocoastal features means that the coast was important in the early period as well.

Focussed paleoecological projects incorporating sea level history and landform survey approach have a high chance of success to find early period sites in a landscape of dramatic environmental change. Most early period sites, perhaps some with important evidence for the peopling of the Americas, should be located on paleocoastal landforms at paleo-shorelines along the entire coast of BC.

Low density deposits:

Most sites found in this study are low density deposits or have not been sufficiently tested to determine the density. This has several implications: (1) it may tell us about settlement patterns in the early period on Quadra Island, (2) it may be an effect related to rapid sea level change, and (3) other processes maybe involved for higher artifact density site locations.

Land use and settlement patterns can be related through the subsistence concepts of foraging and collecting as first conceptualized by Binford (1980). In a foraging mode, movement mostly occurs as a group moving to resources. In theory, this leads to the archaeological site formation of many small camps throughout a landscape. In a collecting mode, movement occurs mostly as small excursions from a main camp to collect resources. In theory, this leads to the archaeological site formation of a few main base camps with lots of cultural material, and many small camps, with little or no cultural material.

In the most basic theoretical sense, the presence of many low density deposit sites and few high density sites may suggest a specific type of settlement pattern in the region during the early period related to collecting. However, this basic theoretical implication may be complicated in the context of aquatic environments or with transport technology such as boats (Ames 2002). Further, the concept of collectors and foragers does not originally address issues of human

agency, social relationships, exchange, mobility, and storage (Habu and Fitzhugh 2002). This subsistence/settlement model is also based on short-term ethnographic observations and does not necessarily take into account long-term variation (Habu and Fitzhugh 2002).

The presence of many low density sites may also support a smearing effect due to rapid sea level change in an area. In a landscape of rapid sea level change, people moving with the changing coastline will result in cultural deposition that is spread out, or smeared, along a slope rather than concentrated along one shoreline. This hypothesized smearing of archaeological material would mean that material is hard to find because it is spread thinly throughout a paleo-shoreline area as sea level regresses. The two behavioural models outlined in Section 3.3.2, (starting on page 95) are relevant with regard to this hypothesized smearing effect. If behaviour is typically of Model 1, where people closely track the falling sea level, the smearing effect is likely to occur, however, if behaviour is typically of Model 2, where people use raised terraces at or during sea level fall, these areas are more likely to build up cultural deposits.

An interesting and useful analogue for site locations and settlement patterns in relation to artifact density are intertidal lithic sites in Gwaii Haanas, Haida Gwaii, dating to ca. 10,700 years ago. Being in the intertidal zone, these sites inherently possess two important factors for site location: cultural deposition/behaviour and survivorship (Mackie et al. 2014, 142). The number of lithics (i.e., density) found at intertidal sites in Gwaii Haanas shows a similar pattern to that observed on Quadra Island, with many low density deposits, and few high and highest density deposits (see Figure 46). In fact, using data first compiled by Mackie and Sumpter (2005) and updated with new information up to 2015 (A. Mackie et al. 2017), 102 sites of 134 have less than 10 lithics, 18 sites have between 10 and 50 lithics, 9 sites have between 50 and 300 lithics, and only two sites have greater than 300 lithics (A. Mackie et al. 2017; see Figure 46).

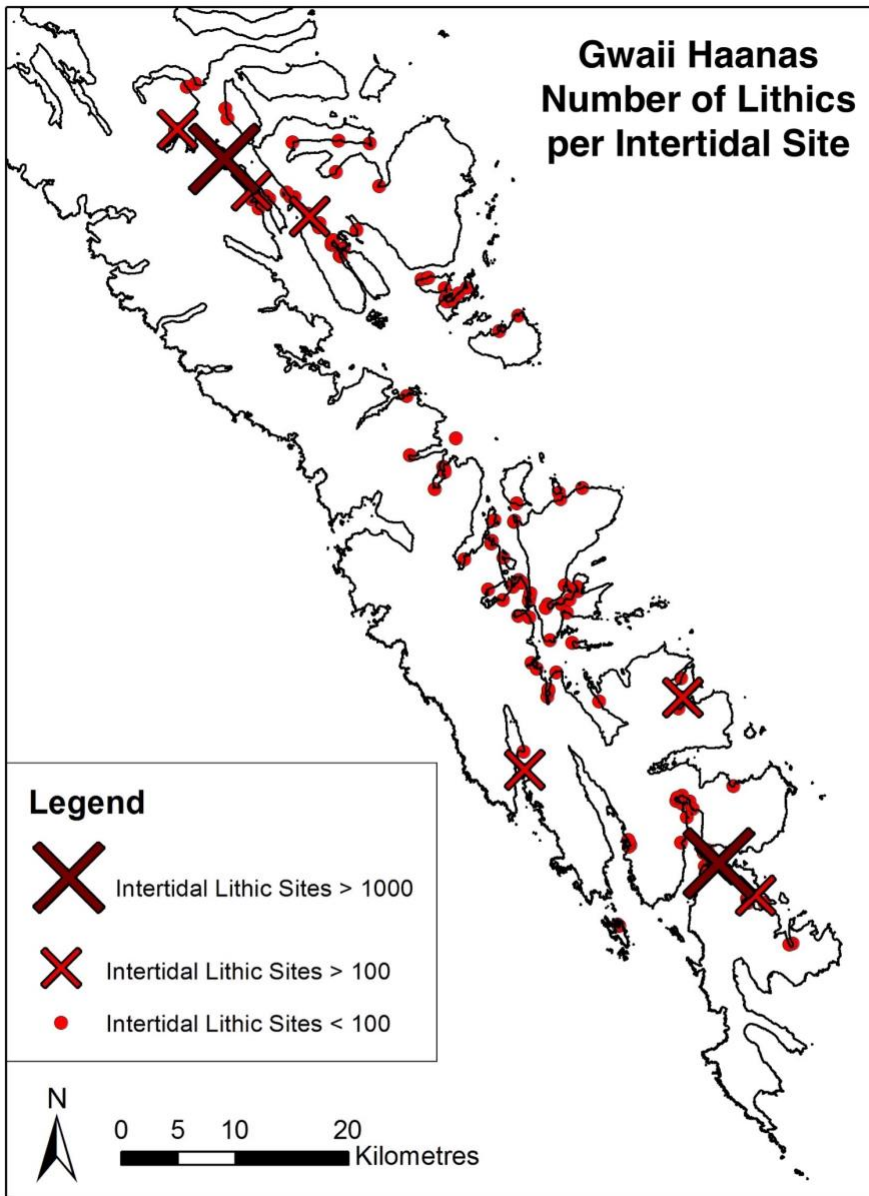


Figure 46: Quantities of lithics found at intertidal lithic sites (n=134) dating to ca. 10,700 years ago in Gwaii Haanas, Haida Gwaii (A. Mackie et al. 2017).

This larger sample size of sites are situated along an extremely well surveyed shoreline, and under the assumption that these data can be compared with the data for the early period on Quadra Island, lend further evidence for this type of settlement pattern for early period coastal peoples.

To find higher artifact density sites, a key aspect of site location will be to further our understandings of early period land use and settlement patterns. In this thesis and the DILA project as a whole, there are many smaller low density sites, and only few higher density sites. For example, the highest artifact density site found during 2016 fieldwork was Yeatman Bay, however, this area is not necessarily better than other places in terms of the model, so a range of other factors must influence site location in the early period, especially of “base camps” or higher density sites. These other factors likely relate to cultural processes, local-scale environmental factors that we cannot consider, and human agency.

The evidence found during this study along with other sites and archaeological evidence found on Quadra Island during the DILA project, suggest that people were dwelling in the landscape at what is now Quadra Island near the late Pleistocene – early Holocene transition. This lends support to a late Pleistocene – early Holocene date for the low density deposits found in this study.

#### Regional archaeology:

The sites found in this study and the rest of the DILA sites fit well into the emerging record of early period archaeology on the coast. The importance of paleocoastal landforms and a paleoecological approach, complex deposition and survivability of sites, sometimes relatively deeply buried (i.e., greater than 50 cm db), ephemeral and higher density deposits, are all important aspects of the current early period coastal archaeological record, and will be important for the future.

The DILA project has pushed back the record in the Quadra Island regional area significantly, with the oldest sites in the regional area reviewed in Chapter 3, Figure 13. The

radiocarbon dates at Yeatman Bay are at least 250 years older than the oldest date at Bear Cove. Further, the dates at Lactarius Road (EaSh-81), another DILA site, are at least 1,250 years older than Bear Cove. Overall, site locations support an early Holocene occupation in the Quadra Island area. There are hints at other Quadra Island sites such as water rolled basal artifacts, artifacts encased in apparent paleo-estuarine or marine sediments, and optical dates, that this occupation could be into the late Pleistocene, however, more work is needed to investigate and securely date this potential.

### 6.2.1 Archaeological site dating

Archaeological sites on the Northwest Coast are readily dated through radiocarbon dating, technological dating, and sea level history dating (see Table 2 and Table 3). For this study, all three of these techniques were utilized.

Although these sites can be dated through a combination of radiocarbon results, technological dating, and sea level history dating, archaeologists typically rely on tight chronological control with radiocarbon dating to properly establish a late Pleistocene – early Holocene occupation. Ephemeral deposits and low density sites normally cannot be subjected to the chronological rigor that is required to date the deposits, especially when much of the charcoal present is apparently from non-cultural forest fire events. This means that a multivariate approach to site dating must be taken, which may include other forms of absolute dating such as optically stimulated luminescence (OSL).

#### Radiocarbon dating:

Radiocarbon dating is reported in Table 13 above (p.150), where a total of three different sites from this thesis study had radiocarbon samples dated. Of the sites with radiocarbon dating,

the two sites at Yeatman Bay are the most interesting. Although the calibrated dates do not break into the late Pleistocene, they are ca. 500 years from one conventional boundary (10,000 cal. BP), and further work is still required at the site. There is high potential for older and deeper deposits at both Yeatman Bay sites. There is also high potential for archaeological material throughout the entirety of Yeatman Bay that is of similar age, with two radiocarbon dates from test units that are ca. 200 metres apart within ca. 200 years of each other.

The Beadless Creek site produced unexpectedly young dates. With the elevation of the site on a paleoshoreline, we would expect dates of ca. 12,800 years BP rather than ca. 2,800 years BP. There are several possible explanations for these young dates:

First, using charcoal to date cultural occupations in an area subject to frequent forest fires is prone to problems, especially in small tests where features cannot be confirmed. Typically, contamination can occur through processes such as root burn and bioturbation (such as tree throws) and represents later Holocene forest fire activity. Well-aeriated sandy sediments on Quadra Island enable especially deep root burns. In this explanation, the date of the cultural occupation of the site is older than the radiocarbon results, and is supported by technological cross-dating methods, sea level history dating methods, and stratigraphy. This explanation is also supported by the fact that the radiocarbon dates are out of stratigraphic order and do not overlap at 2 sigma range. This could suggest bioturbation and even different forest fires, different roots, or other disturbance. For example, roots can grow through old roots (including burnt roots) for nutrients, leading to “root highways” (J. Cohen pers. comm. 2017). This explanation also includes support from the stratigraphy at the site, where the radiocarbon dates and artifacts are directly overlaying what is interpreted as late Pleistocene beach deposits (coarse yellow-grey sand) within 4 centimetres of bedrock. This means that in order for this layer to date to the late

Holocene, there would have to be very little sediment deposition or an erosional disconformity event before deposition, evidence for which was not noted.



Figure 47: Detailed profile view of the NW corner of EU1, Beadless Creek site. Radiocarbon samples from charcoal feature indicated by arrow.

A second possible explanation for these young dates is that the site does indeed date to the later Holocene, but it is an uncharacteristic spot. This explanation would be interesting in that it would add to the evidence of First Nations inland and upslope land use, and would have similar broad implications for First Nations and CRM (as explained in Chapter 7). However, this requires unexpected site formation processes to take place that were not noted in the field.

#### Technological dating:

Especially before the advent of radiocarbon and other absolute dating, archaeological sites were dated through stylistic and technological means through relative dating (cross-dating)

and seriation. Some of the characteristics of early coastal sites are reviewed in the culture history section of Chapter 2. These characteristics contribute to a multivariate approach to evidence for site dating.

One primary technological characteristic of early period deposits is the lithic reduction method. Davis and colleagues (2012) argue that in Northwestern North America, a lithic co-tradition occurred in the early period where there were two main forms of lithic reduction, termed the Paleoarchaic and the Paleoindian. The Paleoindian reduction sequence uses unidirectional blade-cores for prismatic blades and extensive biface reduction from large spalls as a main source of stone for tools, while the Paleoarchaic reduction sequence utilizes discoidal and centripetal cores for stone tools, working from Levallois-like flakes. A discoidal core was found at Yeatman Bay (see Figure 45), potentially evidence for Paleoarchaic reduction.

The Paleoarchaic is also associated with Western Stemmed Tradition points and leaf-shaped points, whereas the Paleoindian is associated with fluted points. There were no points found during investigations in 2016, however, there are hints from previous DILA excavations (e.g., Lactarius Road, radiocarbon date of ca. 10,000 cal. BP and a leaf-shaped Cascade style or possible Western Stemmed style point) that some sites are associated with these early diagnostic technologies (DILA in prep; Fedje et al. 2016).

Microblades are used on the Northwest Coast during the early period in the Northwest Microblade Tradition from Southeast Alaska, through Haida Gwaii, and further south, however, the time period associated with this technology is broad. Microblades have been found on Quadra Island at EbSh-80 (VBL Island) and EbSh-81 (CROW) (see Abbott, in prep), but not at any sites found on raised marine features in 2016.

Many expedient tools such as choppers, flake tools, scrapers, and bipolar flakes were found at sites in 2016. For example, the chopper found at Newton Creek (see Figure 44) and large flakes at many sites (see Figure 39, Figure 42) are potential indicators of an early period date. Further expedient bipolar technology is seen at several sites including Beadless Creek, Horseshoe site (see Figure 40), and Open Bay 27.

These expedient artifacts are typically made with locally available raw materials. These materials are sometimes very low quality compared to the cherts, obsidians, and chalcedony utilized at many Interior and some coastal sites. On Quadra Island there is a very diverse assemblage of materials (e.g., see variety of materials in artifact photos, Figure 38–Figure 45). Callum Abbott is looking at material types and technology on the island, and has identified a material type collection with over 50 different qualitatively and quantitatively identified rock types, including different patinas and chemical weathering patterns, using thin section and XRF methods combined with qualitative petrography (Abbott, in prep). This material includes sites from throughout the Holocene, however, is still an interesting result relating to the early period.

Some sites have later Holocene components which represent long-term use of the landscape. For example, the Quartz Crystal site is ca. 18 metres higher and ca. 80 metres inland from a later Holocene shell midden site (EbSh-8), and therefore the surface artifacts and shallow subsurface artifacts could represent later Holocene use of upslope areas. Quartz crystal as a material has been used throughout the Holocene on the Northwest Coast (McLaren and Gray 2017), but is also associated with some very early deposits—for example, a quartz crystal Clovis point at El Fin du Mondo site in Sonora, Mexico (Sanchez et al. 2014); and a potential (not yet analyzed) quartz crystal stemmed point base from a rockshelter in Gowlland Harbour on Quadra Island (DILA in prep).

Technological dating can be more difficult with local low quality raw material and formation processes playing a role in artifact survival, and some expedient tools being less diagnostic. Lithic material can be chemically weathered (see Figure 44) and physically weathered, or even heavily cemented in concreted sediment (see Figure 40), reducing artifact visibility. Some (e.g., Bryan 1969; Krieger 1962) have suggested that the earliest people in North America had a toolkit that relied heavily on organic materials such as bone and antler, which would not as readily survive. Organic components in a toolkit were clearly important, especially, for example, in sites where microblades are found (e.g., see Page 57 in Waber 2011). Further, organic toolkit components are likely underestimated due to differential preservation processes, as exemplified at sites such as Kilgii Gwaay (Fedje et al. 2001; Cohen 2014). However, it is unlikely that a toolkit would be one hundred percent organic, and that at least some lithic material would have been used, for example, to form and work bone and antler into tools.

Although technological dating is not typically a means in itself for dating an archaeological site without diagnostic artifacts, it can contribute to a multi-faceted process. This approach is readily used for this study because of the nature of the low artifact density deposits and the formation processes involved in coastal environments since the late Pleistocene.

#### Sea level history dating:

Another form of dating for archaeological sites is by their association with sea level history, used especially in underwater contexts. For example, off the coast of Haida Gwaii, the Werner Bay flake site, found by Fedje and Josenhans (2000) at minus 53 metres below modern sea level, has been dated to a minimum of ca. 11,900 years old (10,200 RCYBP). Dating archaeological sites by sea level history is harder in stranded contexts because of the palimpsestic nature of human landscape use—upland areas have always been used. Although we

cannot exclusively rely on sea level history dating except in the most ideal circumstances, it can contribute to site dating in a multivariate context. For example, in Gwaii Haanas National Park on Haida Gwaii, over one hundred intertidal lithic scatters have been dated to approximately 10,700 years ago. This is due to the special circumstances provided by the sea level history and the technological history of the area: sea level was at the modern shoreline 10,700 years ago and was undergoing transgression, and has not been back to the modern shoreline until present. Technologically, there is also no known bifacial lithic reduction after 8,000 years ago, so any bifacial technology found in the intertidal zone is likely to date to 10,700 years ago. Similarly, in Scandinavia, archaeological sites found at certain elevations are assumed to be ca. 11,500 years old after proving a clear pattern of Mesolithic shoreline use (Bjerck 2009; Schmitt 2013). Further, especially at sites stranded above modern sea level, artifacts that show evidence of water-rounding or water-rolling from an association with an intertidal zone can provide evidence that a site may be dated through sea level history.

For this study, we cannot assume that a site is old because of elevation alone, however, some sites make a better case than others. We must use multiple lines of evidence to support an early sea level date, and many times more work is needed to secure such a date. It is not in the scope of this study to definitively date the sites found, but it is possible to make inferences and discuss the time period possibilities of some of the sites that were found during this study.

According to sea level curve dating at the Beadless Creek site, this location would have been an optimal shoreline for settlement ca. 12,600 years ago. This is supported by the sites location. For the past 12,000 years, the Beadless Creek site has lain at the top of a steep bedrock slope 20–25 metres above the modern shoreline. If one wishes to utilize boats and transport material up and down a steep slope, this is not a typical site location. This is especially so with

other middle and late Holocene sites known in the same area, and in better spots, including a clam garden site (EbSh-58) below and to the west of Beadless Creek site at the modern shoreline.

However, when sea level was 22-23 metres higher than modern levels, the Beadless Creek site would have been a prime flat area with both shallowly sloped beaches and deep water areas alongside a small creek (see Figure 48). This location makes sense from a more typical site location point of view and is supported by the technology found at the site.

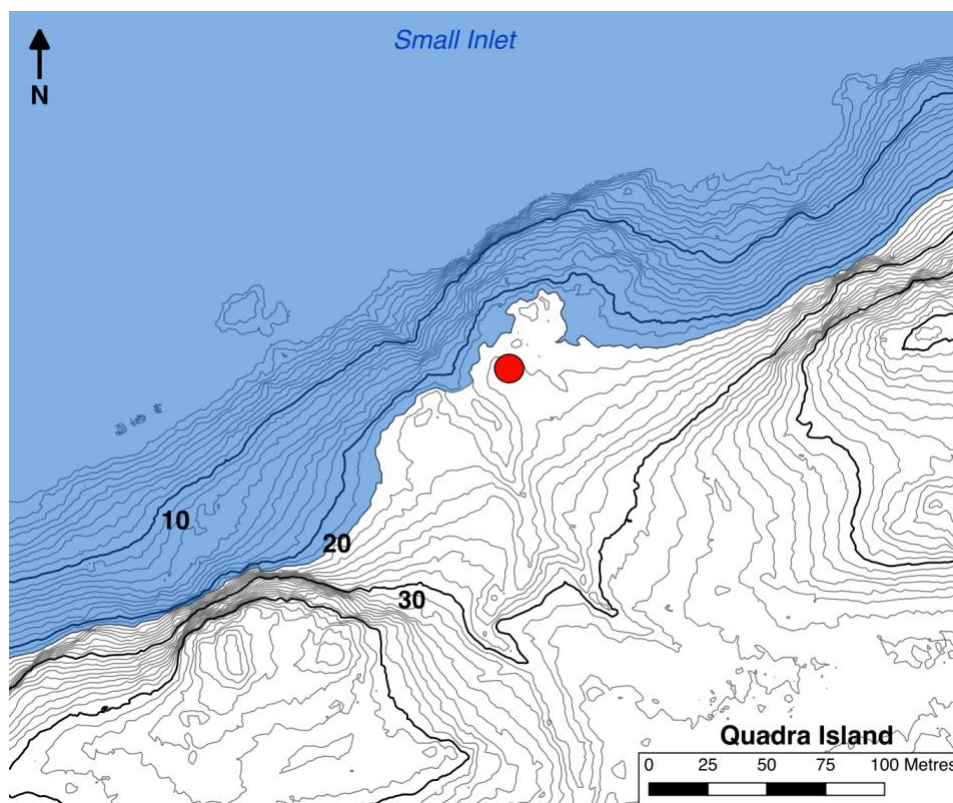


Figure 48: Map of the Beadless Creek Site, flooded to ca. 22 metres ahht, showing shallow beaches to either side of the site, and deep water in front.

Similarly, the Open Bay 27 site is currently 140 metres as the crow flies from the shoreline and 27 metres above modern sea level. The location of this site could be evidence for upslope use in the Holocene, however, when combined with the stratigraphic evidence and site

formation processes, this site is more likely to represent an early period occupation. The same arguments can be made for sites such as Boletus Creek, Squirrel Terrace, Newton Creek, and Horseshoe site. These arguments can never be definitive in themselves, but add to a multi-faceted approach to site dating.

Taken together, the results of radiocarbon, technological, and sea level dating show that many of the sites found during this study have a probability of a late Pleistocene or early Holocene date, however, more work would be needed for a more secure date. Although testing conducted had good control, units were small and not ideal for date sampling. In some cases, especially for very low artifact density sites, it may not be possible to disprove equifinal circumstances. Two radiocarbon dates make the case for at least an early Holocene occupation, and overall, the results of this study start to demonstrate that late Pleistocene and early Holocene archaeology is present on Quadra Island.

### 6.3 Heuristic Method

An important aspect of this study was using quantitative modelling as a tool to find late Pleistocene – early Holocene sites. This was accomplished by the integration of both quantitative and qualitative modelling and the use of a heuristic method. A heuristic method and approach was important for overcoming some of the methodological and theoretical issues involved with quantitative modelling, incorporating complex and practical variables, humanising the modelling approach, and ensuring that the landscape was not labelled with values of potential.

With the large advances in computational power and new forms of modelling, all modelling completed for this study, including the qualitative modelling, could likely be completed quantitatively. However, this type of model would likely become large and extremely

complex very fast (e.g., in establishing many sets of fuzzy boundaries). This type of model would quickly become impeded by long processing times, numerous definitions and boundaries, and complex algorithms and probabilistic statements. Likely, a model of this sort would become so complex that it may require human supervision and input despite attempts to exclude it. Further, quantitative modelling requires that qualitative judgements be made throughout the creation of the model. Another problem may be that a model produces thousands of possible targets and results, and the consequence of this would be to qualitatively sort through and evaluate these results after output. In this study, a heuristic method addressed these issues and proved to be the best of both quantitative and qualitative worlds.

Using qualitative judgement means that one can quickly evaluate an area based on complex multivariate relationships. Modelling these variables quantitatively is possible, but it is more practical and readily applied in other contexts when qualitative judgement is used. Practical qualitative variables were important in this study. Methodologically, biases, errors, or inaccuracies can be usefully accounted for with qualitative input. Issues that can affect the results and biases that influence the final output or interpretation of modelling can be accounted for, talked about, and mitigated. For example, flat areas having an extremely high coastline complexity value could be identified and corrected quickly and practically. Theoretically, qualitative modelling in addition to quantitative modelling allows for the incorporation of complex variables that would be difficult to include otherwise. These factors are beneficial in modelling, combining the advantages of quantitative modelling with the advantages of qualitative modelling, while excluding negative aspects of both.

A heuristic methodology allowed for adaptation to a realistic fieldwork setting, where permits, equipment, crew, and permissions are required. Targets could only be investigated for

areas in which the project had the permission to work. For example, in the south LiDAR swath, the total area of data is 61.01 km<sup>2</sup>. However, not all of that swath area is usable or accessible to the DILA project. Of the total swath area, 13.31 km<sup>2</sup> is ocean and 47.7 km<sup>2</sup> is land. Of the land, 30.76 km<sup>2</sup> is accessible to the DILA project, 11.5 km<sup>2</sup> is not accessible, 2.44 km<sup>2</sup> is lakes, 2.38 km<sup>2</sup> is private land that the DILA project has acquired permission from the owner, 0.53 km<sup>2</sup> is right of ways, and 0.08 km<sup>2</sup> are First Nations reserve lands. This makes a total of 33.67 km<sup>2</sup> that the DILA project is able to investigate (Crown and parks land, private land with permission, and right of ways). 70% of the South LiDAR swath was land, and only 55% of the land was available to investigate. Limitations such as land permission are common in many field projects, however, are rarely reported as a limitation or process that may affect results.

Modelling becomes more humanistic with the blending of quantitative and qualitative modelling. Incorporating a variable that is based in human perception such as wind fetch further humanises the quantitative modelling process. It is also humanistic to address some of the impacts that a model may have outside of a study, or its implications for the real world. Completing a critique of predictive modelling showed that it was important that output of computer modelling did not label the landscape with values of potential. These values have the potential to be misconstrued or misinterpreted in the future, impacting areas well outside the scope of this study. Although this study and the broader DILA project is focussed on investigating the earliest sites on the Northwest Coast, it is clear that Aboriginal peoples have been dwelling in the landscape since time immemorial.

## 6.4 Paleoecological Approach

Archaeological survey projects that take into account aspects of the paleoenvironment including relative sea level history, landform formation processes, and changes in flora and fauna through time are most successful at finding late Pleistocene and early Holocene archaeological sites in North America.

In a review of early sites across the Northwest Coast as a whole (see Table 2, Table 3), most sites were found accidentally, whether through mitigation projects or truly by accident. The second most common way that early sites were found was through dedicated paleoecological survey projects. In fact, looking at a map of the earliest coastal sites, one can see clusters of sites that are the result of a paleoecological survey project in the area (see Figure 10). Regional or local relative sea level histories are very important to these projects, as is the acquisition of high resolution elevation data such as LiDAR. These data tell us whether we have to look at, above, or below the modern sea level for early period sites. This also informs what method may be necessary, such as underwater AUV/ROV technology, that will likely lead the way in finding new drowned sites (e.g., Mackie 2015; Mackie et al. 2017).

Several other methodological and theoretical approaches are involved in paleoecological survey projects. A humanistic approach is important to understand dynamic landscape change. Similarly, an awareness of assumptions and biases regarding site location will be important for the future of early period site discovery. Understanding landform development and site formation processes is important and goes hand in hand with local-scale understandings of paleoecology. The paleoecological approach will be important for future studies. Humanistic archaeological theory and heuristic methods can inform paleoecological studies to provide context to paleoecology and human dwelling in the landscapes of the late Pleistocene.

## Chapter 7: Conclusions and Future Directions

I've learned a great deal through the course of this thesis, from false starts to working with LiDAR data to digging shovel tests in the coastal rainforest, it has been a journey into the world of the late Pleistocene. The results of this study have shown that using GIS modelling as a tool to apply paleoenvironmental knowledge is useful and can aid in late Pleistocene – early Holocene archaeological site survey.

It is important to use GIS modelling as a tool and not a means. In practice, sometimes creating a predictive model and attempting to work out modelling processes become goals themselves, where the model starts to control the method and therefore the results. Predictive modelling and its outputs must be used critically to avoid the major methodological and theoretical critiques that have been outlined in this thesis. One way that this can be achieved is by combining both quantitative and qualitative modelling methods in a critical and self-reflective way. Being practical in solving problems and being transparent in one's approach are important.

The heuristic methodology used in this study led to the discovery of new late Pleistocene – early Holocene archaeological sites, adding to the archaeological record and our knowledge of this early time period. The findings further stress the importance of paleoecological data, high resolution elevation data, and the utility of GIS modelling for archaeological surveys.

The discovery of these early period sites on Quadra Island has added another dot to the map of late Pleistocene – early Holocene settlement on the Northwest Coast. Further work is needed to gain greater insight into the story of the First Peoples dwelling on the coast around Quadra Island, however, with this preliminary data, we can start to think about issues of settlement patterns, land use, technology, and livelihood. Archaeologists need more time and

funding to better understand this period and contribute to contemporary problems such as climate change adaptation and ecological sustainability.

Important factors involved in finding late Pleistocene – early Holocene coastal archaeological sites include site-scale and local-scale understandings of formation processes and survivorship. Also important is an understanding of where cultural deposition may occur, informed by qualitative modelling and behavioural models. All of these factors played a role in both coastline complexity and wind fetch quantitative variables. Further, essential data for this thesis included high resolution LiDAR data and paleoecological data (especially sea level history).

This study may prove useful for other researchers in the future interested in the possibility of integrating quantitative and qualitative modelling for archaeology. The methods and theoretical approach used in this study could be applicable in many other coastal contexts. Perhaps most importantly, the results of this study have significant implications for First Nations and CRM in British Columbia.

## 7.1 Applications in Other Contexts

Aspects of this study may be applied in other contexts in the future. One simple way this could happen is by applying the same methods in a different area, such as a different part of the BC coast, or on other coastlines that have similar properties around the world. For example, the methods of this study were applied to paleoshorelines that are now drowned off the coast of Haida Gwaii in Gwaii Haanas National Park (Mackie et al. 2017). Although a preliminary study, the results of applying these methods were a unique way to explore the underwater archaeological potential of late Pleistocene shorelines in a different context on the same coast.

Similarly, the heuristic method of this study could be used or built on in future studies for finding coastal archaeological sites or exploring the integration of quantitative and qualitative modelling.

## 7.2 Implications for First Nations

All research has implications for the present and for the future, which is part of the reason to conduct it in the first place. However, a researcher must be aware of some of the possible inadvertent consequences of research. For example, although my research question does not explicitly analyze issues surrounding Indigeneity or land and repatriation claims, my results and conclusions can have an impact on these and many other issues

Research involving First Nations archaeology and issues can have important consequences. Watkins (2003) and Kakaliouras (2012) review the state of North American archaeologists' involvement with First Nations, and the consequences it can have for legal disputes, understandings of culture, and inequality. Fabian (1983) and Liebmann (2012), review some of the conscious and unconscious effects that western scientific knowledge can have on Indigenous people, such as the denial of coevalness (Fabian 1983) or the dismissal of Indigenous agency (Liebmann 2012). There can also be serious ethical effects, requiring ethics as a process to be considered throughout the duration of the research, and afterward with the dissemination and changing meanings of research (Bruchac 2010). With respect to these issues, this study did not create a predictive model that blanketed the landscape with values of archaeological potential.

The results of this study support First Nations claims for land, rights, and title for use and ownership in BC since time immemorial. Complex paleoenvironmental change can mean that evidence for First Nations occupation may be in archaeologically-unexpected areas, but nonetheless there is strong potential for a record back to ca. 14,000 years or older.

### 7.3 Implications for CRM

The results of this study also have implications for cultural resource management in BC. Typically, CRM companies are responsible for making sure that possible development in an area does not impact archaeological resources, and if it may, to make sure that a plan for mitigation is in place. With the possibility of late Pleistocene and early Holocene archaeology on the coast, the paleoecology of an area should be known before survey or development decisions take place. Known paleoecological information should then be used to make better decisions about archaeological resources in an area.

Similarly, archaeologists should be aware that dramatic environmental change can mean that archaeological sites are not necessarily in standard “expected” locations. More attention should be paid to possible paleoshoreline areas that are stranded where Pleistocene relative sea level was higher than modern, and areas that are drowned where Pleistocene relative sea level was lower.

All of these results are also relevant for predictive modelling in BC archaeology. Predictive modelling in the province has a long and interesting history (see Chapter 3), and it constitutes a key part of CRM assessment and testing procedure. If predictive models are based on outdated theory and use data that could be unsuitable for modelling needs, archaeology will be missed and affected by development practices. There are examples of models with very specific purposes in CRM that are a step in the right direction, such as predictive models developed specifically for redcedar CMT’s. However, these models should be continuously updated with the latest understandings of site location, and should not solely control where archaeological survey is carried out.

CRM archaeologists should try to be aware of the latest theory and discoveries that can impact the way archaeological method and practice is carried out. In the future, standard archaeological practices in CRM should evolve to include knowledge and data regarding paleoecology, paleoshorelines, and atypical lithic technology.

#### 7.4 Dissemination of Results

Dissemination of results is important for academic research to reach audiences outside the academic sphere. Importantly, copies will be sent to the First Nations on whose traditional territory myself and the DILA project worked: the We Wai Kai, We Wai Kum, Xwemalhkwa, K'omoks, Kwaikah, and Klahoose Nations. A copy will also be available to the BC Archaeology Branch.

Further, there is the possibility for a journal article publication for more widespread academic dissemination. Following this, a copy of this thesis will be available to download on the University of Victoria d-space online. This is available to all that wish to access it. Following the release of this thesis on the University of Victoria dSpace, I plan to make it available on other publically accessible websites and hosting services such as academia.edu, researchgate, and socarxiv. My name and current email address are accessible online for those that wish to directly contact me for clarification or discussion of these results.

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## Appendix 1: Metadata and Quantitative Method

### LiDAR metadata:

LiDAR data was acquired on August 7, 2014 by the UNBC Lidar Research Group by Brian Menounos and Rob Vogt. Data was tied into the GNSS station on Quadra Island that is part of the Western Canada Deformation Array. Data was processed in ellipsoid heights, but converted to CGVD28 vertical datum.

### Scanner specifications:

<b>Scanner Type:</b>	Riegl VQ-580
<b>Max. scan angle:</b>	$\pm 30^\circ$
<b>Flying speed:</b>	225 km/h
<b>Flying height:</b>	475 m
<b>Pulse Rep. Rate:</b>	380 kHz
<b>Flight line overlap:</b>	60%

### Point Density Coverage:

	<b>North LiDAR Swath</b>	<b>South LiDAR Swath</b>
<b>Area of Coverage</b>	14.35 km <sup>2</sup>	47.71 km <sup>2</sup>
<b>Density per flight line</b>	9.8 pts/m <sup>2</sup>	11.9 pts/m <sup>2</sup>
<b>Average density</b>	18.2 pts/m <sup>2</sup>	20.1 pts/m <sup>2</sup>
<b>Ground point %</b>	10%	13%

Ground point % indicates the percentage of points classified as ground to total points. Therefore, for the North LiDAR swath, the bare earth DEM is based off of an average of 1.82 points/m<sup>2</sup>, while the South LiDAR swath bare earth DEM is based off of an average of 2.613 points/m<sup>2</sup>.

GIS modelling method:

*Coastline complexity:*

Preparation: Separate contours into single contour files. Organize files for input.

Input data: Contours in single form with elevations in file names.

Calculation: Points are added to contours at desired distance with ArcGIS Pro tool “Generate points on lines”. Next points that were generated are buffered using the buffer tool to desired buffer distance. Next, perform a spatial join, one to many to count number of points within each buffer. Lastly, perform a table join to join the count field in the buffer file to the point file for ease of use and display. Throughout the whole process, ensure consistency in file names and organization.

Output data: Point shapefiles with count attribute field showing coastline complexity.

*Wind fetch:*

Preparation: Recalculate data according to desired paleo-sea level. Reclassify raster data as binary for ease of use and organize files for input.

Input data: Ensure data inputs are in right format, including azimuth text file of desired directions to be calculated, raster elevation data. Make sure workspaces in GIS are set.

Calculation: Calculates fetch by rotating the raster grid so that the inputted azimuth is north and counting the number of cells classified as water. Calculates fetch according to the US Shoreline Protection Manual (US Army Corps of Engineers 1984) using multiple degrees to the left and right of the desired fetch azimuth, so rotates grid and counts multiple times. Adds the count value to each cell, marking the unbounded fetches as negative numbers and the bounded fetches as positive.

Output data: Raster of wind fetch distance values in metres.

*Landform classification:*

All information for landform classification is available on the Landserf website (Wood 2009), which includes a user guide and download. Landforms were classified into six categories representing differences in quantitative measures such as profile curvature, and slope (see Table 15).

Table 15: Landform classification categories from Landserf (Wood 1996; 2009).

<b>Landform Class:</b>	<b>Colour in maps:</b>	<b>Description:</b>
Pits	Black	Cell on a local concavity (all neighbours higher)
Passes	Green	Cell on a local convexity orthogonal to a local concavity.
Peaks	Red	Cell on a local convexity (all neighbours lower)
Ridges	Yellow	Cell on a local convexity next to a line with no convexity/concavity
Channels	Blue	Cell on a local concavity next to a line with no convexity/concavity
Planar	Grey	Cell with no convexity/concavity

## Appendix 2: Shovel Test Log

Temp. Site No.	Site Name	Test No.	Test Elev. (m ahht)	Stratigraphy:	Def. artifact s (n=)	Definite artifact description:	Depth (cm)
OB27	OB27	ST-7	27	0-10 cm dbs: some angular granite cobbles on surface (disturbed from logging?) Dark brown organic humic layer with subangular to rounded gravel and pea gravel. 10-25 cm dbs: Lighter brown sandy soil with large cobbles and subangular rounded gravels. 25-35 cm dbs: Continued light brown sandy soil with less cobbles. 35-65 cm dbs: Continued light brown sand with subangular to rounded gravels. 65-70 cm dbs: start of second cobble-rich layer. 70-80 cm dbs: some larger cobbles and coarse sand.	1	Bipolar flake	30-40
OB27	OB27	ST-8	27	0-30 cm dbs: medium brown silty sand with rounded pebbles and occasional larger cobbles. 30-40 cm dbs: lots of smaller pea gravel showing up. Colour grading to lighter brown. 40-70 cm dbs: same as above. 70 cm dbs: found flake so going deeper. 70-75 cm dbs: large rock in unit 75-80 cm dbs: lots of small pebbles in lighter yellow sediment.	2	Proximal flake (see Figure), spokeshave	70-80
CLS04-DF-01	Boletus Road	ST-2	29	0-5 cm dbs: root mat and quick Ah horizon. 5-75 cm dbs: medium brown sandy silt with some angular to subangular gravels. 75 cm dbs: sandy silt grading to yellow colour 80 cm dbs: hard packed olive-grey clay layer. Can break apart with the shovel but very hard and homogenous.	1	Scraper (see Figure)	25
CLN02-OTBeadless Creek-03	Beadless Creek	ST-AL-01	22	0-10 cm dbs: Organics and humic layer including burnt log. 10-20 cm dbs: silty fine sand with occasional clay balls, some rounded gravels. Definite flake. 20-35 cm dbs: Same as above, slightly siltier. Lots of clay nodules, almost no rock. Occasional decomposing granite or schist. 35-45 cm dbs: Unconsolidated layer of same as above, former root? 45-50 cm dbs: still unconsolidated silty sand with clay nodules/concretions and charcoal flecks from root burn. 60-70 cm dbs: same as above. 70-90 cm dbs: blue silty clay with clay nodules. Likely marine surface ripped up by wave action/beach?	2	Core, flake.	0-10, 10-20

Temp. Site No.	Site Name	Test No.	Test Elev. (m ahht)	Stratigraphy:	Def. artifacts (n=)	Definite artifact description:	Depth (cm)
CLN02-OTBeadless Creek-03	Beadless Creek	ST-AL-03	23	0-10 cm dbs: Ah humic 10-25 cm dbs: red brown silt, some subrounded pebbles and gravel (0.5 to 2cm diameter) a couple larger clasts. 25-50 cm dbs: yellow silt, still some rocks same as above. 50-65 cm dbs: same as above but lighter colour. Clay nodules, mostly pea gravel sized. Very few to no rocks.	1	Bipolar flake	0-20
CLN02-OTBeadless Creek-03	Beadless Creek	ST-AL-04	22	0-10 cm dbs: Ah humic, disturbed by logging. 10-40 cm dbs: brown silt with gravels and pebbles, unconsolidated. 40-70 cm dbs: grey decomposing clay.	1	Core	30-40
CLN02-OTBeadless Creek-03	Beadless Creek	ST-DF-01	23	0-10 cm dbs: humic layer with cobbles. 10-70 cm dbs: brown silts with cobbles. Cobbles taking up 3/4 of unit.	1	Proximal flake	50-60
CLN02-OTBeadless Creek-03	Beadless Creek	ST-DF-02	26	0-5 cm dbs: humic layer. 5-15 cm dbs: brown sandy silt. 15-75 cm dbs: brown silt.	2	Medial flake fragment, large flake	30-40, 40-50
CLN02-OTBeadless Creek-03	Beadless Creek	ST-CN-04	23	0-9 cm dbs: humic layer. 9-20 cm dbs: orange brown silt with sub- angular gravels. Pea gravel showing up. At 12 cm dbs we found possible core. 20 cm dbs: clay content increasing, much charcoal and some red burnt clay. More gravels appearing. 20-33 cm dbs: fire altered sediments and charcoal. Soil sample taken at 33 cm. Core right next to burn. 40 cm dbs: we have come into clay layer with gravels and cobble. lots of burn stain still showing. On Northside still going down in continuous burn feature. South side is clay. 60 cm dbs: some orange silty clay appearing in clay layer. Large angular spall on top of clay were burn feature was happening. There is brown mottling within the clay and more charcoal. Seems to be isolated fleck of charcoal at 68 cm. 80 cm dbs: started auger. Auger to 1 metre, same grey clay throughout.	2	Core fragment, core	10-20, 32
CLN02-OTBeadless Creek-03	Beadless Creek	ST-CN-20/ EU1	24	1 metre by 1 metre unit analysis ongoing.	n/a	Analysis ongoing	n/a
CLN02-OTBeadless Creek-03	Beadless Creek	BD-Chris Flake	27	Artifact found on the surface in a tree throw.	1	Cortex spall tool	0

Temp. Site No.	Site Name	Test No.	Test Elev. (m ahht)	Stratigraphy:	Def. artifact s (n=)	Definite artifact description:	Depth (cm)
CLN02-OTBeadless Creek-03	Beadless Creek	BD-01	38	Surface find in a tree throw.	1	Scraper	0
CLN02-OTBeadless Creek-03	Beadless Creek	SO-Creek Cut	21	Surface finds in creek cut.	4	Core, core fragment, flakes, large flake	0
CLN02-LW-03	Beadless Bluff Top	ST-LW-02	44	0-5 cm dbs: humic with a burn layer on the bottom. 10-60 cm dbs: Sandy gravel, no cultural material. 60-65 cm dbs: clean up leaves and needles from leaving the hole open. 65-70 cm dbs: sandy gravel and level bag. 70-80 cm dbs: getting more silty downwards still gravel and pea gravel, level bag collected. 80-90 cm dbs: large rock in corner of test digging deeper past it. 90-98 cm dbs: silty sand with some gravel and pea gravel continues, decomposing granite in corner.	2	Flake, possible core	65-70, 70-80
CLN02-LW-01	Horseshoe Site	ST-CJ-01	32	0- 5 cm dbs: humic layer. 5-7 cm dbs: loose, dry, ashy burn layer. 7-45 cm dbs: orange brown silty loam with subrounded to subangular pea gravels. Occasional pebbles and small cobbles. 45-65 cm dbs: More subangular pebbles with occasional rounded pebbles. More larger pebble size rocks. Colour change to lighter orange/yellow. 65-75 cm dbs: lighter silty sediment. 75 cm dbs: big boulder blocking most of the unit. Continue to dig in SE corner. 106 cm dbs: In SE corner past cobble blocking unit, haven't hit clay. Starting auger test in bottom. Used auger in corner and hit clay before being rocked out (bedrock?).	3	Scraper, large flake, flake,	15-35, 35, 80-90

Temp. Site No.	Site Name	Test No.	Test Elev. (m ahht)	Stratigraphy:	Def. artifact s (n=)	Definite artifact description:	Depth (cm)
CLN02-LW-01	Horseshoe Site	ST-LN-01	30	<p>0-10 cm dbs: humic layer in top 5 cm then almost ashy below. Orangey silt underlying, flakes.</p> <p>10-20 cm dbs: continuation of orangey silt, flakes.</p> <p>20-30 cm dbs: at 25 cm there is charcoal scatter (root burn possible but scattered) possible graver or drill and possible core graver.</p> <p>30-40 cm dbs: as above with orange brown silt, real and possible flakes and possible calcine bone, lots of charcoal chunks.</p> <p>40 cm dbs: large flake lying flat on change in strat from all silt to orange brown silt with pea gravel and sub angular gravel.</p> <p>40-50 cm dbs: as above with rounded cobbles, flake and possible bone.</p> <p>50-60 cm dbs: change to gravelly sediment in a grey silt much drier than sediment above.</p> <p>60 cm dbs: large cobbles and hard packed, cemented clayey conglomerate like chunks mixed with gravel, cobbles, and pebbles.</p> <p>65 cm dbs: well into light grey silty clay with sections concreted among loose.</p> <p>68 cm dbs: more rounded gravels bit of pea gravel still in grey silty clay.</p> <p>70-80 cm dbs: less chunky bits more gravels and grey silty clay.</p> <p>80 cm dbs: rock or hard pan across unit, tried to auger past but couldn't.</p>	4	Flakes, hammerstone	0-10, 10-20, 40
CLN02-LW-01	Horseshoe Site	ST-QLN-01	31	<p>0-19 cm dbs: humic layer.</p> <p>19 cm dbs: transition to red orange brown silt with gravels and cobbles.</p> <p>20-50 cm dbs: root burn throughout, possible flake collected, possible slate flake collected.</p> <p>50 cm dbs: transition to drier orange silt with some sand, slightly darker red than above, continuation of sub angular gravels and pebbles, found scraper at 50 cm dbs, collected.</p> <p>50-70 cm dbs: as above.</p> <p>70 -84 cm dbs: dry orange silt with sparse sand subangular pebbles, large rock at 78 cm dbs and transitioning to light grey silt with sand.</p> <p>84-89 cm dbs: start augering. As above and bottom on rock.</p>	2	Scraper, flake.	50, 60-65
CLN02-LW-01	Horseshoe Site	ST-JJ-01	31	<p>0-10 cm dbs: humic layer</p> <p>10-60 cm dbs: gravelly silty sand</p> <p>60-70 cm dbs: sandy silt light tan brown</p> <p>70-90 cm dbs: sandy pea gravel with larger clasts, gravel to cobble size.</p> <p>90-105 cm dbs: silt with some cobbles (very large ones) some angular bits of gravel may be artifacts.</p> <p>105-115 cm dbs: sandy silt with pea gravel and rounded pebbles.</p>	3	Flake, large flake, possible medial flake fragment	55-60, 75-80, 90- 105

Temp. Site No.	Site Name	Test No.	Test Elev. (m ahht)	Stratigraphy:	Def. artifact s (n=)	Definite artifact description:	Depth (cm)
CLN02-LW-01	Horseshoe Site	ST-DF-01	31	0-10 cm dbs: Ah humic horizon. 10-30 cm dbs: Orange brown gravelly sand with large pebbles and cobbles, and as go down less sandy and more silty with smaller clasts overall, possible flakes between 15-25 cm dbs. 30-40 cm dbs: shifting into silty sand and charcoal appearing, finer silty sand with gravel and pea gravel, bipolar core tool found at 30-36 cm dbs. 40-50 cm dbs: Pea gravel, sub angular increasing. 50-60 cm dbs: shifting to clayey silt layer, rounded gravels. 60-70 cm dbs: as above. 70 cm dbs: blocky pieces of silt/clay nodules, one large rounded cobble at 75 cm, large pebbles and cobbles emerging.	2	Primary flake (see Figure), bipolar core (see Figure)	20-25, 30-36
CLN02-LW-01	Horseshoe Site	BD-NS-01		Surface artifact found in tree throw.	1	Ground stone wedge/adze?	0
CLN02-AM-03	Otherside horseshoe	ST-LC-03	23	0-15 cm dbs: humic and small ash burn layer. 15-60 cm dbs: Medium brown sand with gravel and pea gravel, sub angular to rounded. Occasional larger pebbles and concretions of orange iron stained coarse sand. 60-70 cm dbs: transition to less gravelly medium sand. Very nice well sorted sand! 70-95 cm dbs: very sandy, medium sand with small amount of gravel, with occasional large cobble. Ended shovel test at 95cm, and did auger sample 95-124 cm dbs.	1	Flake	85-95
CLN02-AM-03	Otherside horseshoe	ST-LC-04	25	0-10 cm dbs: humic layer. 10-15 cm dbs: Ae with rock fall from up slope. 15-70 cm dbs: orange brown coarse sand and gravel. Not much silt and no clay. Definite flake found, 35-45 cm dbs.	1	Flake	35-45
CLN02-AM-03	Otherside horseshoe	SO-JC-01	26.5	Surface artifact in small intermittent creek bed.	1	Scraper	0
CLN02-DF-01	25 m terrace	ST-DC-01	25	0-15 cm dbs: Humic layer, sandy. 15-25 cm dbs: transition from silty loam to grey brown sandy silt. 25-35 cm dbs: dark red brown to a light yellow brown dominantly sand. 35-45 cm dbs: pea gravel showing up, same as above 45-50 cm dbs: Hardpan layer at 50 cm dbs, otherwise same as above. 50-60 cm dbs: same as above. 80-90 cm dbs: change to more clay.	1	Topknot	35-45

Temp. Site No.	Site Name	Test No.	Test Elev. (m ahht)	Stratigraphy:	Def. artifact s (n=)	Definite artifact description:	Depth (cm)
CLN02-DF-01	25 m terrace	ST-LJC-01	24	0-10 cm dbs: humic layer. 10-65 cm dbs: Sandy silt, medium brown with pea gravels and rounded gravels. 65-70 cm dbs: silty clay sediment with concreted nodules.	1	Possible graver	30
CLN02-NF-02	Finger	ST-LN-02	24	0-20 cm dbs: humic with lots of roots and charcoal. 20-50 cm dbs: orange silt with pea gravels and sparse cobbles. 50-60 cm dbs: lighter grey orange silt with clay between 55-60, a possible flake collected. 60-70 cm dbs: light grey silt with some pea gravels. Large rock across quarter of unit at 56 to 68 cm dbs. 70-80 cm dbs: as above but more hard packed, clay content increasing, flake at 70 cm dbs and some maybe flakes at this depth, more cobbles and large pebbles. 80-86 cm dbs: more clay nodules appearing. Auger test in bottom: 86-92 cm dbs: hard packed and clay nodules. Some sparse pea gravel lighter grey colour. 92-98 cm dbs: as above. 98-107 cm dbs: clay and clay nodules with sparse subangular gravels. 107-112 cm dbs: clay and clay nodules with no gravels.	3	Flakes	55-60, 70
CLN02-JC-02	Quartz Crystal	ST-JC-02	18	0-30 cm dbs: start test on rotten log. 30-60 cm dbs: Sticky mottled silt with lots of charcoal. Mottled with orange sediment. 60 cm dbs: some angular gravel collected. Rounded and subangular gravels until now. After one screen full of angular, back to rounded at about 65 cm dbs. 75-85 cm dbs: Rounded gravels and occasional angular piece. Broken granite. Colour shifting from medium brown to lighter medium brown. 100 cm dbs: start auger. At 100 transitions to grey clay. Auger end at 130 cm dbs where we hit grey clay and rock.	3	Quartz crystal flake, core fragment, core	0, 75-80, 85-89
CLN02-AM-01	Newton Creek	SO-1	33.5	Surface find where growing tree lifting sediment up a bit. Artifact in humus but with yellow brown silt adhering and underneath.	1	Large flake (see Figure)	0

Temp. Site No.	Site Name	Test No.	Test Elev. (m ahht)	Stratigraphy:	Def. artifact s (n=)	Definite artifact description:	Depth (cm)
CLN02-AM-01	Newton Creek	ST-AM-01	34	<p>0-20 cm dbs: humus.</p> <p>20 cm dbs: burned zone as if burning log fell here under humus</p> <p>20-40 cm dbs: orange brown silty with rare rounded gravel of different sizes some sub angular. small nodules of blue-grey clay. clay probably a significant fraction as wet sediment is slick on fingers. Also some small clumps of layered sand.</p> <p>40 cm dbs: NW corner light yellow silt and clay showing up but did not show up on east side until. 70-75 cm dbs.</p> <p>50-55 cm dbs: 1 decent looking flake not clear if from orange or yellow matrix but seemed to have some orange adhering so could be from basal orange layer.</p> <p>60-70 cm dbs: another possible flake in yellowish layer.</p> <p>82 cm dbs: charcoal in sand concretion but could be on surface of sand glob. some root action at this level.</p> <p>90-95 cm dbs: large pebbles, small cobbles in yellowish sandy silt with clay.</p> <p>95 cm dbs: start auger in bottom.</p> <p>95-115 cm dbs: In auger test. Light yellow sediment lower half from ca. 105 cm dbs.</p> <p>115-122 cm dbs: pure very fine well sorted yellow sand. could be aeolian?</p> <p>122-134 cm dbs: sand greyer or more olive with laminated structure maybe alluvial? Soil sample taken from 130-132 cm dbs.</p>	2	Proximal flake, cobble chopper (see Figure)	50-55, 80-90
CLN02-AM-02	Squirrel Terrace	ST-AN-01	40	<p>0-10 cm dbs: humic layer.</p> <p>10-25 cm dbs: darker brown sandy silt with pebbles and larger roots. One possible core 15-20 cm dbs.</p> <p>26-60 cm dbs: burned layer on top of brown clay, rich silts, and some sands. Very few pebbles--angular and subangular, lots of decomposing granite. Increasingly rounded and more frequent with depth. Sediments are quite loose and soft as if previously disturbed. Logging or burrow or tree throw?</p> <p>60-75 cm dbs: yellow brown silts with round small pebbles and some medium pebbles. Some possible flakes and other angular and subangular pebbles.</p> <p>75-80 cm dbs: change in texture seems a bit harder and more pebbles. No longer quite so soft and loose. Pebbles still few.</p> <p>80-90 cm dbs: much harder compacted sediment, probably due to increase in clay content. Pebbles similar frequency. No cultural material.</p> <p>90-95 cm dbs: auger test in bottom of unit. Same stuff as above but bottomed out on rocks or bedrock. Seemed wetter too.</p>	2	Core, flake	10-20, 55-65

Temp. Site No.	Site Name	Test No.	Test Elev. (m ahht)	Stratigraphy:	Def. artifacts (n=)	Definite artifact description:	Depth (cm)
CLN02-AM-02	Squirrel Terrace	ST-AN-02	41	<p>0-5 cm dbs: dark brown humic with granite? Flat rounded boulder standing on end in middle unit just below moss; therefore disturbed to at least 15 cm dbs.</p> <p>5-30 cm dbs: yellow brown silty medium to coarse sand with pebbles in varying sizes--fairly abundant, mostly rounded with some angular and subangular. One large flake at bottom layer?</p> <p>30-40 cm dbs: yellow sandy silt, finer and softer apparently same amt pebbles incl larger ones. By and large are rounded and appear water worn.</p> <p>40-60 cm dbs: olive grey coarse sand with pebbles and pea gravel. Gravelly but not very compact just hard to excavate. A couple of cobbles--rounded. Looks alluvial?</p> <p>60-70 cm dbs: coarser and sandier with more cobbles and holding more moisture. Possibly some clay but matrix largely coarse sand.</p> <p>70 cm dbs: extremely compact almost rock like sediment with cemented fines and boulders. Visible in creek bed. Eroding there very slowly. Basal sediments impossible to excavate.</p>	1	Flake	25-30
CLN02-AM-02	Squirrel Terrace	ST-LC-01	42	<p>0-10 cm dbs: humic and root mat.</p> <p>10-12 cm dbs: burn layer and ashy.</p> <p>12-32 cm dbs: orangey brown gravelly sand with quite a bit of pea gravel. In bottom half of 12-32 cm dbs turning more brown then orange.</p> <p>32 cm dbs: transitioning to a more olive colour gravelly sand with pea gravel.</p> <p>45 cm dbs: Lots of pea gravel in medium brown silty fine sand matrix. Occasional iron concretions of coarse sand and gravel. Pea gravel and gravel are round to sub round pieces.</p> <p>55 cm dbs: very gravelly with occasional large cobble. Matrix getting coarser sand with depth.</p> <p>60 cm dbs: gravelly coarse sand more compact. Matrix still coarse but getting stickier with more clay content? Still pea gravel but slightly less when matrix gets more clay, about 75 cm dbs.</p> <p>80 cm dbs: End test and try auger. Couldn't auger more than about 4 cm due to extreme compact clay layer (same as in bottom of creek--clay with casts where rocks used to be).</p>	1	Flake	25-35
CLN02-DF-02	Northside Small Inlet DF	BD-DF-10	27	<p>Informal test in tree throw. 1/4' screen used. Tree throw pulled up probably 10-15 cm compared to true surface. Ah horizon present in tree throw.</p> <p>Mostly medium brown silt with some rounded gravels. More silt as getting deeper. Test informally down to 50 cm dbs.</p>	1	Flake	n/a

Temp. Site No.	Site Name	Test No.	Test Elev. (m ahht)	Stratigraphy:	Def. artifact s (n=)	Definite artifact description:	Depth (cm)
CLS04-DF-01	Yeatman Bay Road Cut	ST-DF-Yeat1	13	0-10 cm dbs: Humic layer 10-20 cm dbs: Disturbed orange sand with gravel. 25 cm dbs: red horizon, probably old A horizon or burn zone that has been buried. Very thin layer. 25-30 cm dbs: burn zone in old soil with definite artifacts. 35 cm dbs: coarse sand with concreted clumps, iron cemented. Occasional gravel. 45 cm dbs: No change from above, still concreted clumps. Rust coloured sediment. 50 cm dbs: More gravel, same coarse to medium sand, gravel and pea gravel. Rust coloured. 65-70 cm dbs: More rock, pebbles, occasional cobble. More definite lithics. 70-80 cm dbs: Granitic looking pea gravel, subangular to angular in sand. 80-95 cm dbs: Colour change to a grey-green silty layer, Olive fine sand. Concretions of very fine sand to silt. 100 cm dbs: start augering, get two sediment samples, 105-110 cm dbs and 110-125 cm dbs.	8	Flakes, proximal flake, BRF (see Figure), distal flake.	25-30, 35-45, 45-50, 60-65, 65-70, 70-75, 75-80
CLS04-DF-01	Yeatman Bay Road Cut	SO-01	12	Surface finds in the sediment exposure of the road cut, not collected.	3	Discooidal core, BRF, scraper, not collected.	0
CLS04-JC-01	Yeatman Bay Ridge	ST-JA-1	18	0-10 cm dbs: humic layer. 10-40 cm dbs: mixed ash with orange sandy silt, mottled, upper portion very loose, likely logging disturbed. 40-50 cm dbs: more brown and lighter in colour, sandy silt with some rounded pea gravel, silt sticking to rocks so visibility low. 50-65 cm dbs: lighter colour silty sand, more compact, sand concretions with iron oxide. 65-70 cm dbs: gets more compact, still silty sand with pebbles and cobbles. 70-80 cm dbs: silty sand, mostly pea gravel, clumps of sand concretions.	3	Flake, flake fragment, retouch flake	10-20, 45-50
CLS04-JC-01	Yeatman Bay Ridge	BD-01	18	Surface find in tree throw.	1	Chert flake	0
CLS04-JC-01	Yeatman Bay Ridge	BD-02	16	Surface find in tree throw.	1	Large BRF	0
CLS04-JC-01	Yeatman Bay Ridge	BD-03	18	Surface finds in tree throw.	2	Discooidal core (see Figure), large flake	0
OB45	Open Bay 45	ST-3	45	0-55 cm dbs: orange sandy matrix, a few larger cobbles. 55-70 cm dbs: Transition to lighter gray clay rich-matrix at 55 cm dbs, gravel and rock still present in clay. Test ended at 70 cm dbs.	1	Biface reduction flake waterworn.	50