"When the Tide Is Out, the Table Is Set": Shellfish Harvesting Throughout the Holocene at Labouchere Bay, Southeast Alaska

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“When the Tide Is Out, the Table Is Set”
Shellfish Harvesting Throughout the Holocene at Labouchere Bay, Southeast Alaska

BY

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DISSERTATION

Submitted in Partial Fulfillment of the Requirements for the Degree of Doctor of Philosophy

Anthropology

The University of New Mexico
Albuquerque, New Mexico

May, 2022
DEDICATION

This dissertation is dedicated to the people of Prince of Wales Island, especially Mary Triplett and all the members of the Craig Tribal Association who extended amazing hospitality to a wet and bedraggled young graduate student in 2012.

Gunalchéesh. Thank you.
ACKNOWLEDGEMENTS

Founded in 1889, the University of New Mexico sits on the traditional homelands of the Pueblo of Sandia. The original peoples of New Mexico – Pueblo, Navajo, and Apache – since time immemorial, have deep connections to the land and have made significant contributions to the broader community statewide. I honor the land itself and those who remain stewards of this land throughout the generations and also acknowledge our committed relationship to Indigenous peoples. I gratefully recognize our history.

This research was conducted within the traditional territory of the Takjik´aan Kwáan, also known as northern Prince of Wales Island, Alaska. I acknowledge that Tlingit Peoples have been stewards of the land on which we work and reside since time immemorial, and I am grateful for that stewardship and incredible care. I also recognize the neighboring ancestral homes of the Haida and Tsimshian, and I commit to serving their peoples with equity and care. I recognize the series of unjust actions that attempted to remove them from their land, which includes forced relocations and the burning of villages. I honor the relationships that exist between Tlingit, Haida, and Tsimshian peoples, and their sovereign relationships to their lands, their languages, their ancestors, and future generations. I aspire to work toward healing and liberation, recognizing our paths are intertwined in the complex histories of colonization in Alaska. I acknowledge
that we arrived here by listening to the peoples/elders/lessons from the past and these stories carry us as we weave a healthier world for future generations.

I heartily acknowledge Dr. Emily Jones and Dr. James Dixon, my advisors and dissertation co-chairs, for continuing to encourage me through the years of classroom teachings and the long number of months writing and rewriting these chapters. Their guidance and professional style will remain with me as I continue my career. I also thank my committee members, Dr. David Dinwoodie, and Dr. William Taylor, for their valuable recommendations pertaining to this study and assistance in my professional development. Gratitude is extended to the NSF Office of Polar Programs, Nara National Research Institute for Cultural Properties, and Jean & Ray Auel for the funding to pursue this research. To Timothy Marshall and Risa Carlson at the Tongass National Forest, thank you for your guidance in planning and executing three seasons of fieldwork. To the volunteers who helped with excavations at Lab Bay and artifact analysis at the Maxwell Museum, thank you all for putting up with me! To Dr. Dale Croes, Kathleen Hawes, and everyone at Mud Bay who encouraged me to make the life-changing decision to become an archaeologist, I thank you from the bottom of my heart. To my parents, Robert and Helena and my brother Adam, who gave me immeasurable support over the years, your encouragement is greatly appreciated. And finally to my girlfriend, Desiree Deschenie, your love is the greatest gift of all.
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HOLOCENE AT LABOUCHERE BAY, SOUTHEAST ALASKA

by

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ABSTRACT

“When the tide is out, the table is set” is a familiar saying among Native communities on the Northwest Coast of North America. This phrase encapsulates traditional ecological knowledge passed down for generations concerning intertidal marine resources. Recent archaeological excavations of shellfish gathering camps at Labouchere Bay confirm that ancient people may have followed similar principles
throughout the Holocene (c.9,500 -2,500 years ago). For millennia, shellfish have been a highly reliable food source that helped support sedentary fisher-hunter-gatherer settlements. Although shellfish habitats represent highly predictable foraging opportunities, optimal foraging strategies must be carefully managed to avoid overharvesting. Collecting just enough to meet a family’s immediate needs ensured that humans and shellfish could sustainably coexist, and awareness of nature’s cyclical timeframe minimized the potential risk of consuming deadly algal toxins. The knowledge passed down from shellfish gathering camps such as Labouchere Bay has ensured that subsequent generations survived and flourished.
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Chapter 1. Introduction

The middle Holocene (c. 7,000 - 3,500 calendar years ago) marked a transition in the development of the sedentary fisher-hunter-gatherer societies that characterize the Northwest Coast of North America. During this period, the occasional opportunistic shellfish consumption that characterized the early Holocene developed into a deliberate practice of sustainable resource management and cultivation spanning multiple generations. The Labouchere Bay sites, located on the northern tip of Prince of Wales Island in Southeast Alaska’s Alexander archipelago, present an opportunity to examine this period of important change. The sites on the shores of Labouchere Bay include several well-preserved shell middens, which encapsulate a record of human activity spanning most of the Holocene. The following chapters examine the archaeofaunal record of Labouchere Bay, framed within increasingly broad analytical lenses.

Chapter 2 is a case study examining the first of the shell middens to be excavated, site 49-PET-746. Analysis of this middle Holocene site employs zooarchaeology and community paleoecology to interpret the invertebrate assemblage. Analysis of this site is primarily descriptive, quantifying the differences observed in the shellfish assemblage. The excavation techniques and data analysis methods established at this site set the standard for subsequent excavations at Labouchere Bay, which are described in Chapters 3 and 4.
Chapter 3 applies the methods I developed in Chapter 2 to examine the four best-preserved shell middens at Labouchere Bay. Analysis of these assemblages extends the statistical analysis developed in Chapter 2 to also include ethnographic analogy drawing from accounts of shellfish use among descendant communities in the recent past. In addition to describing the quantitative patterns observed in the faunal record, this chapter also evaluates possible cultural factors that may be related to changes in shellfish foraging strategies.

Chapter 4 uses GIS modeling and paleoshoreline reconstructions to examine the changing environmental and cultural settings that affected the occupation of all the sites on Labouchere Bay, including sites that did not contain shell middens. Intertidal coastal areas are highly reliable and productive environments, but they are affected disproportionately by changing sea levels, especially in recently-deglaciated high-latitude regions. In Southeast Alaska, ancient humans relied on intertidal ecosystems throughout the Holocene, but they had to contend with rapidly fluctuating sea levels, as well as changing cultural practices. This chapter examines humans’ evolving relationship with the intertidal landscape of Labouchere Bay starting at the end of the last glacial period.
Chapter 2. Changes in Middle Holocene Shellfish Harvesting Practices: Evidence from Labouchere Bay Site 49-PET-476, Southeast Alaska

For as long as humans have lived in coastal regions, shellfish have been an important source of food (Colonese et al., 2009; Dupont et al., 2009; Erlandson, 1988; Gutiérrez-Zugasti et al., 2013; Habu et al., 2011; Mannino et al., 2007; Mayer, 2002; Nadel, 2002; Price, 1989; M. Stiner et al., 2003; van der Schriek et al., 2007). As early as 164,000 years ago, the inhabitants of South Africa collected and ate oysters (Jerardino & Marean, 2010). On the Northwest Coast, evidence for opportunistic shellfish consumption dates back to 12,000 calendar years ago (Moss, 2011). Widespread evidence for intensive shellfish harvesting first appeared during the middle Holocene, around 7,000-4,000 calendar years ago (Ames, 1994; Ames & Maschner, 2000; Erlandson, 1988; Porcasi, 2011). This period was marked by a shift in both settlement and subsistence patterns on the Northwest Coast of North America, as highly mobile hunter-gatherer groups transitioned to a more sedentary lifestyle (Ames, 2006). The coincident appearance of both shell middens and permanent settlements throughout the

\[\text{except where otherwise noted, all dates in this chapter are presented as calendar years before present. All radiocarbon dates were calibrated using the IntCAL13 terrestrial atmospheric curve (Reimer et al., 2013) and have been left as originally reported in this paper’s publication in 2017. Updated radiocarbon dates using the more recent IntCAL20 calibration curve are presented in Chapter 2. The differences in radiocarbon calibration are minor and do not alter the conclusions reached in this chapter.}\]
Northwest Coast suggests that shellfish harvesting may have played a role in the development of sedentism (Yesner, 1980).

Among ethnographically-documented foragers living on the Northwest Coast, shellfish are generally considered low-ranked, low-status foods (De Laguna, 1990; Moss, 1993; W. P. Suttles, 1990). Individual shellfish can accumulate deadly levels of undetectable toxins, which means that although shellfish are easily acquired and processed, their consumption entails an element of personal risk (Acres & Gray, 1978; Moore et al., 2010; Trainer et al., 2003). For this reason, elite members of society tended to avoid consuming shellfish (Moss, 1993). Although ancient ancestral communities likely had similar dietary rules discouraging the frequent consumption of shellfish, shellfish remains represent a large portion of the archaeological assemblage at Northwest Coast sites. However, the specific shellfish harvesting practices employed during the middle Holocene are not well-understood (Daniels, 2014; Moss, 1993).

Fladmark’s (1985) initial model for the development of sedentism and cultural complexity on the Northwest Coast proposed that sedentary lifeways and social stratification were the direct consequence of the re-establishment of salmon migration routes that had been disrupted by Pleistocene glaciation. Under this model, once sea level stabilized and salmon began migrating up the rivers of the Pacific coast, the inhabitants of the region were provided with an unprecedented bounty of food, and that salmon alone supported the growing human population (Fladmark, 1985).
However, further analyses of early Northwest Coast sites have demonstrated not only that seasonal spawning migration and human harvesting of salmon predate sea-level stabilization (Campbell & Butler, 2010; Finney, 1998), but also that salmon were not the most prevalent food source at every site (Moss & Cannon, 2011). The superabundance of resources reported by early European settlers is best explained as the response of prey populations to the removal of the top-tier predator: humans. When the native human population was reduced by introduced diseases, the predatory pressure they exerted on the environment lessened, and prey populations rebounded (Butler, 2000; McKechnie et al., 2014; Moss & Cannon, 2011).

The inhabitants of the Northwest coast were not passive recipients of an endless bounty of nature. The long-term success of a village depended on carefully managing the environment to ensure that harvests remained within sustainable levels. Although the timing and location of annual salmon runs are highly predictable, traditional ecological knowledge must also take into account the expected yield since the size of salmon runs can vary greatly from year to year. Abrupt, multi-decade reversals in the oceanic and atmospheric conditions of the North Pacific have profound impacts on coastal salmon fisheries (Hare et al., 1996; Mantua et al., 1997; C. F. West, 2009). These climactically driven cycles of high and low productivity among salmon stocks predate European contact. Long-term fisheries management must take into account patterns of change that play out over multiple generations (Rogers et al., 2013).
Harvesting and storing migratory salmon were undeniably important activities for the ancient inhabitants of the Northwest Coast, but the annual and decadal variation in salmon productivity would have necessitated a dynamic subsistence system that also included terrestrial, intertidal, and marine resources. The systematic incorporation of shellfish into a logistical foraging system (cf. Binford 1980) may have helped the inhabitants of early sedentary settlements overcome periodic resource shortfalls in the absence of agriculture (Yesner, 1980).

Shellfish are available year-round, can be found in dense concentrations in predictable locations, are sessile, and require minimal technological investment to harvest. They can easily be collected by all demographics within a segmented society, including children and elders (Bird & Bliege Bird, 2000; F. Thomas, 2007; Yesner, 1980). Shellfish have high reproductive rates, so carefully-managed harvests can produce high yields of mature individuals without causing significant population decline (Daniels, 2014). Habitat modification through the construction of walled clam gardens can further improve the long-term yield of shellfish beds (Groesbeck et al., 2014; Lepofsky et al., 2015).

Examining how these natural and cultural processes may have affected the relationship between humans and shellfish can be accomplished by documenting patterns of change in the material remains at shellfish-harvesting sites. The Labouchere Bay sites present excellent examples of seasonally occupied coastal foraging camps from the
middle Holocene. The exceptional preservation conditions at these undisturbed middens have yielded a high-quality invertebrate fauna assemblage suitable for this type of analysis (Williams and Dixon, 2014, 2016).

Archaeological Setting

The Labouchere Bay sites (49-PET-746) are located on the northern tip of Prince of Wales Island, Alaska (Figure 1). The sites lie within the traditional territory of the Takjik’aan Tlingit Kwáan, and are currently administered by the US Forest Service Craig Ranger District. In 2012, a pedestrian survey first identified cultural material at these sites (Williams et al., 2013). Additional testing and excavation in 2013 and 2014 expanded the boundaries of the study area to encompass eight separate sites, five of which contained undisturbed shell midden deposits (Williams and Dixon, 2014, 2016).
The Labouchere Bay sites (49-PET-746) are located on Prince of Wales Island, AK (indicated by the star on the inset map). They comprise eight discrete cultural deposits encompassing rockshelters, shell middens, and a raised marine beach deposit containing lithic artifacts (indicated the star on the primary map). This paper specifically examines the shell midden at Labouchere Bay midden 13.3. Other early to middle Holocene sites in the region are included for context.

The shell midden sites are located along a wave-cut terrace roughly 9-12m above modern sea level overlooking a sheltered inlet of Labouchere Bay. Midden 13.3, which is
the focus of this paper, is a shallow rockshelter located at the base of a bedrock bluff where the wave-cut limestone forms a slight overhang (Figure 2).

Figure 2. Labouchere Bay shell midden 13.3 is located under a shallow overhang in the karstic limestone bedrock, as indicated in this profile drawing. The midden extends down to bedrock and is overlain by a layer of fallen limestone cobbles. Bounding dates of 6,568 ± 73 and 2,604 ± 115 cal BP were obtained from the lowermost and uppermost levels of the midden.
Based on the volume of fallen boulders and cobbles overlying the midden, the overhang would have been even larger during the site’s occupation. From the bottom of the fallen cobbles and boulders, the midden extends down another meter to meet bedrock. Two radiocarbon dates from wood twig charcoal provide lower and upper bounding dates for the midden of 6,568 ±73 and 2,604 ± 115 cal BP (Table 1).

**Table 1: Two-sigma bounding radiocarbon date ranges for Labouchere Bay midden 13.3, calibrated using IntCal 13.**

<table>
<thead>
<tr>
<th>Sample</th>
<th>Depth (cm)</th>
<th>2σ Calibrated Age (BP)</th>
<th>Uncalibrated Age (BP)</th>
<th>Material</th>
<th>Lab Reference #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Midden Upper Extent</td>
<td>110</td>
<td>2,604 ± 115</td>
<td>2,492 ± 24</td>
<td>Wood Twig Charcoal</td>
<td>D-AMS 010116</td>
</tr>
<tr>
<td>Midden Lower Extent</td>
<td>175</td>
<td>6,568 ± 73</td>
<td>5,770 ± 25</td>
<td>Wood Twig Charcoal</td>
<td>NOSAMS 118293</td>
</tr>
</tbody>
</table>

**Sea Level History**

Prince of Wales Island was subject to significant loading from glacial ice during the last ice age, and isostatic rebound from this glaciation greatly affected Holocene sea level changes along the Pacific coast. The relative sea level at Prince of Wales Island reached a maximum extent of 14m above modern sea level around 9,800 to 9,100 years ago, and then slowly receded to modern level around 5,300 to 4,900 years ago (R. J. Carlson & Baichtal, 2015; Carrara et al., 2007; Shugar et al., 2014).

Moss (2011) has proposed that the location of coastal foraging camps tracked with changing sea levels, with foragers relocating their seasonal base camps to keep pace
with both rising and falling shorelines. Recent work by Baichtal and Carlson (2015) verified this pattern for early Holocene (c. 10,500 – 7,500 cal BP) sites on Prince of Wales Island using a predictive model for site location based on elevation.

Based on the topography and elevation of the surrounding area, Labouchere Bay would have remained a highly productive environment throughout the entire Holocene, despite the changing sea level. Labouchere Bay itself was overridden by glacial ice only briefly during the peak of the last glacial maximum and the surrounding mountains served as a refugium (a locally ice-free biome that could support large-bodied land mammals) during much of the last ice age (Dixon, 1999; Heaton et al., 1996; Heaton & Grady, 2003). During the middle Holocene, the combined factors of global sea level rise, local isostatic rebound, and tectonism resulted in the stabilization of the coastline at modern sea level (Baichtal et al., 1997; Carrara et al., 2007). The sheltered inlet would have provided relatively easy access to multiple ecological communities and afforded strategic control of important surrounding waterways throughout these changes, making it an appealing location for a seasonal foraging camp.

**Regional Archaeological Context**

The middle Holocene marked the widespread appearance of an economic and settlement pattern in which foraging activity at seasonal gathering camps supported the permanent reoccupation of strategically-located winter villages (Ames & Maschner, 2015).
2000; Moss, 2011). Only a small number of sites on the northern Northwest Coast with middle Holocene components have been systematically tested. These include Kit’n’Kaboodle (49-DIX-46), Shuka Kaa Cave, formerly On Your Knees Cave (49-PET-408), an unnamed lithic scatter on a raised marine beach (49-PET-207), Rosie’s Rockshelter (49-CRG-236), Rice Creek (49-CRG-234 and 49-CRG-235), Chuck Lake (49-CRG-237), and Cape Addington Rockshelter (49-CRG-188), as described below.

The closest analog to the Labouchere Bay sites is the North Rockshelter at Kit’n’Kaboodle Cave (49-DIX-46), located 157 km to the southwest on Dall Island. The Kit’n’Kaboodle site comprises three distinct site locales spaced roughly 20m apart, along and within the base of a karst bluff 10m above sea level. The site was occupied over a period from c.5,590 to c.1,700 calendar years ago (Moss and Erlandson 2010:3365). The species occurrence in the Kit’n’Kaboodle middens is similar to that of Labouchere Bay, although Kit’n’Kaboodle contains a larger amount of barnacles (*Semibalanus cariosus*) and mussels (*Mytilus spp*). While barnacles are generally considered an incidental inclusion in Northwest Coast middens, there is clear evidence for their consumption at Kit’n’Kaboodle (Moss & Erlandson, 2010). Midden accumulation at the Kit’n’Kaboodle North Rockshelter was low (1.87cm/100 years), with indications of recurring animal activity, reflecting a long-term pattern of seasonal abandonment and reoccupation (Moss, 2015).
Shuká Kaa Cave, formerly On Your Knees Cave, (49-PET-408) is an early Holocene cave site located in steep karst 1.6km north of Labouchere Bay. Analysis of the artifacts and human remains from nearby Shuká Kaa (PET 408) demonstrate that people inhabited the vicinity of Labouchere Bay as early as 12,097 ±136 cal BP (Dixon et al., 2014). Isotopic analysis of human remains from the individual known as Shuká Kaa, $^{14}$C dated to 10,342 ±144 calendar years BP indicate heavy consumption of high tropic level marine resources during the early Holocene (Dixon et al., 2014). The site was revisited during the middle Holocene, as indicated by a bone implement dated to 6,577 ±95 calendar years BP (Dixon, 1999).

49-PET-207 is an early Holocene (9,831 ± 278 to 9,435 ± 244 cal BP) raised marine beach deposit in a stream estuary 1.2 km west of Labouchere Bay (Greiser et al., 1993). Although originally identified as a shell midden, subsequent reanalysis of the site’s shell component indicated that it is non-cultural in origin (T. Marshall and R. Carlson, personal communication, 2013). The stratigraphic sequence of raised marine gravel, fossil shell bed, and glacial till is comparable to that at 49-PET-746-12.1 and the depositional sequence suggests a similar geological history of uplift and subsidence. The few lithic artifacts recovered from 49-PET-207 resemble those from the lithic scatter at Labouchere Bay site 12.1.

Rosie’s Rockshelter (49-CRG-236) is a middle Holocene (4,682 ± 169 to 3,518 ± 639 cal BP) site on Heceta Island located 27.92 m above sea level at the base of a
limestone cliff. It contains two thin (5-10cm) lenses of culturally deposited shell separated by 5-10cm of sterile rockfall (Ackerman et al., 1985, p. 97). *Saxidomus gigantea, Protothaca staminea,* and *Mytilus edulis* comprise the majority of the midden (Ackerman et al., 1985).

The Rice Creek sites (49-CRG-234 and 49-CRG-235) are lithic workshops on Heceta Island that tentatively date to the early Holocene (10,234 ± 347 cal BP) (Ackerman et al., 1985, p. 89). The sites comprise lithic artifacts in raised marine beach sediments overlying glacial till exposed by a small creek at 7m and 13-17m above sea level. On a nearby terrace overlooking the creek, *Saxidomus gigantea* and firecracked rocks visible in the upturned roots of a fallen tree indicate the presence of a shell midden. The presence of this site was noted in the report but it was not sampled. A stone tidal fish weir (49-GCR-238) is present at the mouth of the creek (Ackerman et al., 1985).

The Chuck Lake (49-CRG-237) is an early Holocene site located 13-15m above sea level on Heceta Island. The site comprises six distinct localities across 1 km², three of which contain thin (c. 20 cm) lenses of shell midden. Within the middens, *Saxidomus gigantea* were most abundant shellfish species, followed by *Protothaca staminea* and *Mytilus edulis.* Fish dominated the vertebrate fauna assemblage, although there were few salmon remains (1-3% of the total). A small number of marine and terrestrial animal bones were also present (Ackerman et al., 1985). The patchy deposition of artifacts and
shell lenses suggest low-intensity periodic occupation from 9,220 ± 270 to 5,484 ± 191 cal BP (Okada et al., 1989, 1992).

Cape Addington Rockshelter (49-CRG-188) is a late Holocene (1,900 ± 90 to 430 ± 120 cal BP) site on Noyes Island located 2-4m above sea level at the base of a wave-cut karst outcrop. The site contains a shell midden characterized by the rapid accumulation of mussels (*Mytilus sp*). The small quantity of periwinkles and limpets did not represent a substantial contribution to the midden assemblage (Moss, 2004a, p. 229). Cod and halibut are the most abundant vertebrate species, and a small number of salmon bones are also present. (Moss, 2004a, pp. 159–171) The midden directly overlies beach deposits, suggesting that the rockshelter was inhabited as soon as they were above the reach of storm surf (Moss, 2004a, pp. 40–41).

These sites indicate that around the same time that permanent winter villages were becoming widespread on the Northwest Coast (6,000-5,000 calendar years ago), archaeological shell deposits shifted from thin, discontinuous lenses to thick, well-defined middens. This may indicate that during the middle Holocene, human foraging behavior became less opportunistic, and increasing emphasis was placed on organized harvesting and habitat management. The Labouchere Bay shellfish assemblage provides the test to examine this hypothesis.

**Methods**
Sampling

The recovery of faunal materials at Labouchere Bay followed the methods developed at the Qw’u?g’wes and Sunken Village sites (D. R. Croes et al., 2004, 2009). Excavation of 1m x 1m test units was conducted using 5cm arbitrary levels and 3.2mm (1/8 inch) mesh. All vertebrate fauna elements within the unit were collected, and shellfish were collected from a designated quadrant within each unit. Bivalve shells were collected only if the umbo (the joint where the two halves of the shell meet) was greater than 50% intact. Univalve shells and chiton plates were collected if they were greater than 50% intact. Barnacle fragments were collected if they were at least ¼ inch long on one side.

This sampling strategy provided the best balance between efficient field sorting and manageable transportation of samples. Cumulative species richness (NTAXA) was assessed across the excavated assemblage (after Lyman and Ames, 2004) to confirm that midden was sampled to redundancy. This collection method ensured that the number of identified specimens (NISP) in the sample assemblage was representative of the actual midden contents without being prohibitively heavy to transport from the remote field camp.
Identification

Each element in the invertebrate fauna assemblage was identified to the most specific possible taxonomic level. Fragments that lacked diagnostic features could not be conclusively assigned a taxonomic group. Identification was conducted using printed field guides (N. R. Foster, 1991; Morris, 1966; Rehder et al., 1981) and the author’s personal comparative collection. With the exception of whelks and limpets, all elements were identified to species. Quantification of the assemblage was conducted using NISP instead of mass in order to compensate for the heavily fragmented state of the shells.

Statistical Model

Data from individual species were aggregated according to ecological community for analysis. Ecological communities are two or more species that simultaneously occupy the same habitat (Krebs, 1972). Communities are not static taxonomic categories, but rather reflect dynamic interactions between multiple coexisting species. Paleoenvironmental reconstructions according to community type can help identify consistent trends in these species-level interactions, and can reveal whether such changes are induced by environmental vs. biological factors and whether the trend reflects gradual change vs. punctuated equilibrium (Hoffman, 1979).

Shellfish can be broadly categorized into two communities depending on their preferred habitat type: soft substrate (characterized by mudflats and sandy beaches) vs.
hard substrate (characterized by rocky shores and tide pools) (N. R. Foster, 1991; Morris, 1966; Rehder et al., 1981). These two habitats (Figure 3) represent opposite ends on the coastal erosion-lithification cycle, in which bedrock is broken down and redeposited in sedimentary layers (Taylor & Wilson, 2003, p. 7). Soft substrate habitat is comprised of sediments that are moved by regular tidal action. Particles in these sediments include clay, silt, and sand ranging in size from 0.001 to 2 mm in diameter. (Cosentino-Manning et al., 2010). Species in the soft substrate community included *Saxidomus gigantea*, *Protothaca staminea*, *Clinocardium nuttallii*, *Macoma nasuta*, *Tresus capax*, and *Cryptomya californica*.

Hard substrate habitat is comprised of rocks greater than 256mm in diameter that are not moved by regular tidal action (Cosentino-Manning et al., 2010). Species in the hard substrate community included *Littorina sitkana*, *Katharina tunicata*, *Balanus glandula*, *Mytilus californianus*, *Cryptochiton stelleri*, *Tonicella lineata*, and *Balanus nubilus*. 
Figure 3. The shellfish in the midden were categorized according to habitat preference: soft substrate mudflats (A, above) vs. hard substrate tide pools (B, below). Photos by Mark Williams and Melyssa Huston.

Although these habitat types are occupied by different shellfish communities, they can be accessed interchangeably by human foragers. On a given stretch of coastline, both habitats can be found adjacent to each other and may also contain microhabitats supporting small pockets of the other community. Gravel and cobble substrates represent intermediate stages of the coastal erosion-lithification cycle and contain particles ranging
from 2 to 256 mm in diameter (Cosentino-Manning et al., 2010; Taylor & Wilson, 2003).

These intermediate substrates may be populated by either hard or soft substrate species, depending on the specific local conditions.

Additional abiotic habitat constraints for each species obtained from the Encyclopedia of Life geodatabase (EOL, 2015e, 2015g, 2015k, 2015l, 2015a, 2015b, 2015c, 2015d, 2015f, 2015h, 2015i, 2015j). These variables included the minimum and maximum: latitudinal range (°), longitudinal range (°), water depth (m), water temperature (°C), water nitrate concentration (µmol/l), water silicate concentration (µmol/l), water phosphate concentration (µmol/l), water dissolved O$_2$ concentration (ml/l), water O$_2$ saturation (%), and water salinity (psu). An analysis of variance (ANOVA) test was conducted to determine if any of these factors varied significantly between the hard and soft substrate communities.

To quantify changes in the overall representation of different ecological communities within the midden assemblages, the individual taxonomic abundances were used to calculate a community relative abundance index (RAI$_c$) that reflects the overall representation of each community (rocky tide pools vs. soft mudflats) within the midden assemblage sample. RAI$_c$ is determined by dividing the total number of identified specimens (NISP) of species from soft substrate habitats (Saxidomus gigantea, Protothaca staminea, Mya arenaria, Tresus capax, Macoma nasuta, and Clinocardium nuttallii) by the total NISP of all species:
\[ RAI_c = \frac{NISP_{soft-substrate \ taxa}}{NISP_{soft-substrate \ taxa} + NISP_{hard-substrate \ taxa}} \]

The higher the community index, the higher the proportion of soft substrate species in the assemblage: a community index of 1 reflects an assemblage comprised entirely of clams and cockles, while a community index of 0 reflects their complete absence.

**Results**

The assemblage of 11,773 individual shells recovered from Labouchere Bay midden 13.3 comprised fifteen different taxonomic groupings (Table 2). The complete breakdown of shellfish counts by taxon and excavation level is available for download through the University of New Mexico’s digital data repository (Williams, 2017). Of all the abiotic habitat constraints examined, only minimum water depth differed significantly between hard and soft substrate communities (p=.032), with hard substrate species tolerating longer exposure to air and thus surviving closer to the maximum high-tide mark.

Table 2. Shellfish count by taxon. Species that prefer hard substrate habitat (rocky tide pools) are listed in the upper portion. Species that prefer soft substrate habitat (mudflats) are listed in the lower portion

<table>
<thead>
<tr>
<th><strong>Hard Substrate Community</strong></th>
<th><strong>Scientific Name</strong></th>
<th><strong>Common Name</strong></th>
<th><strong>NISP</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Littorina sitkana</em></td>
<td>Sitka Periwinkle</td>
<td>5,966</td>
<td></td>
</tr>
<tr>
<td><em>Katharina tunicata</em></td>
<td>Black Katy Chiton</td>
<td>3,287</td>
<td></td>
</tr>
<tr>
<td>Lottia sp.</td>
<td>Limpets</td>
<td>224</td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td>------------------</td>
<td>-----</td>
<td></td>
</tr>
<tr>
<td><em>Balanus glandula</em></td>
<td>Acorn Barnacle</td>
<td>157</td>
<td></td>
</tr>
<tr>
<td>Gastropoda sp.</td>
<td>Whelks</td>
<td>76</td>
<td></td>
</tr>
<tr>
<td><em>Mytilus californianus</em></td>
<td>California Mussel</td>
<td>54</td>
<td></td>
</tr>
<tr>
<td><em>Cryptochiton stelleri</em></td>
<td>Gumboot Chiton</td>
<td>25</td>
<td></td>
</tr>
<tr>
<td><em>Tonicella lineata</em></td>
<td>Lined Chiton</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td><em>Balanus nubilus</em></td>
<td>Giant Acorn Barnacle</td>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

### Soft Substrate Community

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
<th>NISP</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Saxidomus gigantea</em></td>
<td>Butter Clam</td>
<td>1,250</td>
</tr>
<tr>
<td><em>Protothaca staminea</em></td>
<td>Littleneck Clam</td>
<td>547</td>
</tr>
<tr>
<td><em>Clinocardium nuttallii</em></td>
<td>Cockle</td>
<td>48</td>
</tr>
<tr>
<td><em>Macoma nasuta</em></td>
<td>Bent-nosed Clam</td>
<td>14</td>
</tr>
<tr>
<td><em>Tresus capax</em></td>
<td>Horse Clam</td>
<td>13</td>
</tr>
<tr>
<td><em>Cryptomya californica</em></td>
<td>California Softshell Clam</td>
<td>1</td>
</tr>
</tbody>
</table>

In the oldest portion of the midden, just above bedrock (c. 6,568 ± 73 cal BP), shellfish from the soft substrate community composed only 6% of the total assemblage.

In the youngest portion of the midden (c. 2,604 ± 115 cal BP), shellfish from the soft substrate community composed 73% of the total assemblage (Figure 4).
Figure 4. The relative abundance of species from soft substrate communities increased over time in the midden assemblage.

This gradual change in the community abundance index was driven primarily by a decline in the total number of individuals from the hard substrate community. The total number of individuals from the soft substrate community did not vary significantly (Figure 5).
Figure 5. The total amount (NISP) of hard substrate shellfish in the sample assemblage decreased over time, while the total amount of soft substrate shellfish remained relatively constant.

The assemblage was dominated by the two most abundant species within each community. *Littorina sitkana* (Sitka periwinkle) and *Katharina tunicate* (black Katy chiton) together comprised 94% of the hard substrate assemblage and both similarly declined in abundance over time. *Saxidomus gigantea* (butter clam) and *Protothaca staminea* (littleneck clam) together comprised 96% of the hard substrate assemblage, and their abundance did not vary significantly over time (Figure 6). The extremely low occurrence of all other species suggests that they were either incidental inclusions, or in
the cases of Cryptochiton stelleri (gumboot chiton) and Tresus Capax (horse clam), preferred deeper water habitats that were difficult to access regularly.
Figure 6. Patterns of change were consistent among the two most abundant species in each community (hard substrate: *Littorina sitkana* and *Katharina tunicata*; soft substrate: *Saxidomus gigantea* and *Protothaca staminea*), which together composed the majority of the midden assemblage.
Discussion

These preliminary data suggest there may be consistent trends in how humans at Labouchere Bay interacted with shellfish communities in the past. Over the period spanning 6,568 ±73 through 2,604 ± 115 calendar year ago, people harvested and consumed increasingly fewer shellfish from hard substrate communities. At the same time, the yield from soft substrate communities did not change significantly. In other words, this sample suggests that as the centuries passed people were collecting fewer and fewer periwinkles and chitons from the tide pools, but they were still digging up the same number of clams from the mudflats. This pattern of gradual change is evident not just in a single species but across entire ecological communities.

These changes are unlikely to have been induced by abiotic environmental factors alone. Since all the species in this study exist in close proximity and have similar tolerances for water temperature, ocean acidification, salinity, and dissolved trace elements, it is unlikely that changing water conditions could completely explain the differential patterns of abundance in the midden assemblage. Changes in sea level, temperature, silting, or salinity likely did affect the baseline abundance of various shellfish populations at different points in time, but it would have done so across all species. Although relative sea level had stabilized by the time the midden was first deposited, erosion and/or sedimentation may have affected the distribution and
accessibility of shellfish communities in the local area. Mollusk populations in the
intertidal zone are particularly susceptible to local sea level changes, but repopulate
rapidly by recruiting from reserve populations in deeper waters (Daniels, 2014).
However, erosional processes that would decrease the amount of hard substrate habitat
through silting would simultaneously increase the amount of soft substrate habitat. Thus,
if erosional processes were driving the changes in the Labouchere Bay midden
assemblage, one would expect to see an inverse relationship between the total count of
hard and soft substrate shellfish: as periwinkles and chitons from tide pools became more
scarce, clams from mudflats would become more common. This is not supported by the
data, in which the total yields of the two communities change through time independently
of each other.

A more likely explanation is that the decline in the abundance of hard substrate
shellfish is the result of interaction with human predators. This predator/prey relationship
would have been strongly mediated by tidal cycles, since shellfish in cold high latitude
waters can only be practically harvested when they are exposed at low tide. Hard
substrate shellfish congregate in tide pools and on seaweed fronds during low tide, so
they can be gathered by the thousands using mass-harvest techniques such as scraping
(Figure 7). Hard substrate shellfish have a higher minimum water requirement and can be
accessed even when the tide is not fully out.
Although soft-substrate shellfish tend to be larger in size, they must be dug up individually. This activity requires greater effort, more specialized tools, and must be coordinated to coincide with extremely low tides. As the inhabitants of Labouchere Bay built up their traditional ecological knowledge, they would have learned how to take advantage of the tides to exploit these resources more efficiently.

Figure 7. Field volunteer Carlos Michelen inspects Labouchere Bay’s rocky shoreline at high tide (above, A). As the tide recedes, periwinkles, chitons, and other hard substrate shellfish cluster together in the pools of water that remain, facilitating mass harvest (below, B). Photos by Mark Williams.
As a result, the more easily accessible hard substrate communities may have undergone more pronounced resource depression, with humans consuming individuals faster than they could reproduce. Furthermore, the yield of soft substrate communities could have been improved through the construction of clam gardens or by using canoes to transport clams from other nearby bays. As long as harvests did not heavily exploit immature individuals, shellfish populations could have remained stable despite human predation. Hard substrate habitats, which tend to experience much stronger wave action, would have been more difficult to modify and would have been harder to access via canoe.

Alternatively, changing cultural preferences and/or social organization may have influenced the priorities of individual foragers. The Labouchere Bay sites most likely served as seasonal satellite camps associated with a central winter village. During the summer, a few individuals (possibly organized into family groups) harvested and processed shellfish here, perhaps setting aside a surplus for winter storage.

The widespread emergence of formal hierarchical social structures throughout the northern Northwest Coast around 7,000-4,000 calendar years ago may also have played an important role in shaping shellfish gathering practices. These changes may have enabled households to exert control over access to strategic shellfish-gathering locations (Ames, 2006). In the potlatch-driven economies typical of the Northwest Coast during the late Holocene, there was an obligation to give away resources according to collectively-
understood quotas determined by one’s social rank (Kan, 1989; Mauss, 1954). This gift economy governed not just the collection and distribution of high-prestige items such as banquets, but also more mundane resources such as winter food stores. Although elites strived to give away as much as possible, exceeding the expected quotas for food resources carried diminishing returns, since such surplus must be shared equally after harvesting but consequential gains in social capital would not be realized immediately (Tropper, 2009). A shift toward site specialization due to increasing emphasis on quota-driven clam harvesting (as opposed to other, more general foraging activities) could also explain the decline in the amount of hard substrate shellfish in the midden assemblage coupled with an unchanging amount of the soft substrate shellfish.

**Conclusion**

Over time, the use of this site on the shore of Labouchere Bay became increasingly focused on harvesting shellfish from soft substrate habitats. This change was characterized by a decline in the amount of hard substrate shellfish in the midden assemblage. Over the four thousand years between the first and last cultural deposition at Labouchere Bay midden 13.3, the contribution of soft substrate communities did not change significantly, while the contribution of hard substrate communities experienced a decline. Although abiotic factors may have played a role in determining the baseline productivity of the local environment, this analysis suggests that the primary driving
factor behind the changing representation of shellfish in the midden were most likely due to human behavior. These changes may have been the result of tidally influenced foraging strategies, or they may reflect an increasing social hierarchy of household economic units. Ethnographic analogies suggest that shellfish harvesting, while affording little prestige, may have served as a reliable, low-investment subsistence activity that complemented more seasonally restricted events such as salmon migrations. This research suggests that a dynamic system in which people of different social ranks performed increasingly specialized tasks at different times of the year may have been developing in and around northern Prince of Wales Island between 6,500 – 2,500 years ago. The data from Labouchere Bay midden 13.3 help document the emergence and long-term sustainability of sedentary subsistence systems on the northern Northwest Coast.
Chapter 3. Development of Sustainable Middle Holocene Shellfish Harvesting Strategies at Labouchère Bay, SE Alaska

The Northwest Coast of North America is famous for the development of the sedentary fisher-hunter-gatherer societies that established high-density sedentary settlements supported by foraging-fishing economies, rather than agricultural economies more characteristic of sedentary societies elsewhere in the world (Ames & Maschner, 2000; Davis, 1990; Finlayson & Warren, 2017; Lepofsky et al., 2015; Lightfoot, 1993; Renouf, 1984). During the middle Holocene (7,000 to 4,000 calendar years ago\(^2\)) social systems and subsistence patterns emerged that became pillars of NWC fisher-hunter-gatherer lifeways. Moss (2011) characterizes the middle Holocene as a period in which highly localized environmental changes were the major forces driving cultural change. In particular, post-glacial tectonic restabilization resulted in a constantly-shifting nearshore littoral zone, which presented varying opportunities and obstacles for coastal foragers (Baichtal et al., 1997). Under this model, changes in the archaeological record primarily reflect adaptations to the physical conditions in a specific locale. The systematic exploitation of shellfish was one element of an increasingly diverse suite of subsistence

\(^2\) Except where otherwise noted, all dates in this chapter are presented as calendar years before present. All radiocarbon dates were calibrated using the IntCAL20 terrestrial atmospheric curve (Reimer et al., 2020).
strategies tailored to maximize a location’s ability to support a growing human population (Moss, 2011).

The widespread adoption of systematic shellfish harvesting may also relate to development of social systems regarding traditional ecological knowledge (TEK) and economic obligations of reciprocity that were recorded in the recent ethnographic past (Lepofsky et al., 2015; Trosper, 2009; Turner et al., 2000). Shellfish served as a reliable resource that could offset nutritional shortfalls in other types of food (Burchell, Hallmann, et al., 2013; Erlandson, 1988; Mannino et al., 2007; Price, 1989; Williams & Croes, 2012). However, the risk of deadly paralytic shellfish poisoning (PSP) meant that although shellfish were a necessary resource during difficult times, they were not generally a desired resource (Acres & Gray, 1978; De Laguna, 1972). Specific ecological knowledge and habitat management techniques were required to safely cultivate shellfish (A. Cannon, 1998; Groesbeck et al., 2014; Lepofsky et al., 2015), yet the product of this cultivation had limited utility other than immediate consumption. Shellfish served as a critical nutritional safety net: they were a readily available source of protein and calories that could be relied upon to carry a family through the lean winter if they ran out of stored food (De Laguna, 1972). However, shellfish’s social stigma as a “starvation food”, combined with the risk of PSP in warmer months suggests that outside of this specific use, shellfish had little value in a reciprocity-driven prestige economy. Nonetheless, the widespread appearance of shell middens in the archaeological record, and the density of
shellfish remains within those middens indicate that shellfish formed a critical component of the typical Northwest Coast diet throughout the middle and late Holocene (Ames & Maschner, 2000; A. Cannon, 1998; Daniels, 2014).

Although anthropologists have a robust general understanding of shellfish harvesting thanks to ethnographic observations and ecological models (Boas & Codere, 1966; Butler & Campbell, 2004; Davis, 1990; De Laguna, 1990; Hunn et al., 2003; Lepofsky et al., 2015; W. P. Suttles, 1990), the specific shellfish harvesting practices employed on the Northwest Coast during the middle Holocene are not well documented (Daniels, 2014; Moss, 1993). Understanding the optimal foraging strategies employed by ancient fisher-hunter-gatherer communities can help inform modern efforts to revitalize sustainable resource management practices (Finney et al., 2000; Groesbeck et al., 2014; Stram & Evans, 2009; Whitepigeon, 2020). This paper examines four shell middens located near the shore of Labouchere Bay on northern Prince of Wales Island, Alaska with an occupation period spanning the end of the early Holocene through the beginning of the late Holocene. These sites are not associated with permanent habitation structures, but rather represent seasonally reoccupied foraging camps focused almost exclusively on shellfish harvesting (Williams and Dixon, 2014, 2016). This singular focus and broad timespan make Labouchere Bay an effective case study for examining changing patterns in how ancient people managed shellfish resources, as well as the environmental and cultural factors that may have driven those changes.
Archaeological Setting

The Labouchere Bay sites (49-49-PET-746, 49-49-PET-786, 49-49-PET-787, 49-49-PET-788, 49-49-PET-789, 49-49-PET-790, 49-49-PET-791, and 49-49-PET-792) are located on the northern tip of Prince of Wales Island, Alaska (Figure 8). The sites lie within the traditional territory of the Takjik’aan Tlingit Kwáan and are currently administered by the US Forest Service Thorne Bay Ranger District (Sealaska Heritage Foundation, 2000; US Forest Service, 2021). Four of these sites (49-49-PET-746, 49-49-PET-789, 49-49-PET-791, and 49-49-PET-792) contain undisturbed shell middens (Williams and Dixon, 2014, 2016) and are the primary focus of analysis. The midden sites are located on a wave-cut marine terrace at approximately at 10-15m elevation. The sites are distributed along the base of an undulating bedrock bluff at 50-100m intervals, with karst limestone mountains rising to the north (Prussian & Baichtal, 2007), the exposed outer coast of Sumner Strait to the west (Figure 8-A), and a sheltered inlet of Labouchere Bay to the east (Figure 8-B). Numerous small freshwater streams emerge from the karst aquifers to form small estuaries along the shoreline.
Figure 8: Map of Labouchere Bay sites and surrounding vicinity. Inset A shows the rocky outer shore adjacent to Sumner Strait and inset B shows the mudflats of Labouchere Bay.
The sites’ occupations span the middle Holocene, with bounding dates of $9,455 \pm 85$ through $2,525 \pm 55$ cal BP (Table 3). All radiocarbon dates were obtained from wood charcoal and calibrated in OxCal using the terrestrial IntCal20 atmospheric calibration curve (Reimer et al., 2020). Charcoal samples were selected from sapwood fragments in order to minimize radiocarbon offset (Schiffer, 1986).

<table>
<thead>
<tr>
<th>AHRS #</th>
<th>Depth Below Surface (cm)</th>
<th>Uncalibrated Age (BP)</th>
<th>2σ Calibrated Age (cal BP)</th>
<th>Material</th>
<th>Lab #</th>
</tr>
</thead>
<tbody>
<tr>
<td>49-PET-746</td>
<td>110</td>
<td>2492 ± 24</td>
<td>2590 ± 135</td>
<td>Wood Charcoal</td>
<td>D-AMS 010116</td>
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<td>49-PET-746</td>
<td>175</td>
<td>5770 ± 25</td>
<td>6575 ± 25</td>
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<td>NOSAMS 118293</td>
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<tr>
<td>49-PET-792</td>
<td>60</td>
<td>3511 ± 25</td>
<td>3780 ± 90</td>
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<td>D-AMS 041221</td>
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<tr>
<td>49-PET-792</td>
<td>120</td>
<td>4014 ± 32</td>
<td>4480 ± 90</td>
<td>Wood Charcoal</td>
<td>D-AMS 025808</td>
</tr>
<tr>
<td>49-PET-791</td>
<td>10</td>
<td>4071 ± 32</td>
<td>4575 ± 225</td>
<td>Wood Charcoal</td>
<td>D-AMS 025807</td>
</tr>
<tr>
<td>49-PET-791</td>
<td>175</td>
<td>4916 ± 31</td>
<td>5640 ± 80</td>
<td>Wood Charcoal</td>
<td>D-AMS 025806</td>
</tr>
<tr>
<td>49-PET-789</td>
<td>50</td>
<td>7823 ± 30</td>
<td>8620 ± 100</td>
<td>Wood Charcoal</td>
<td>D-AMS 041220</td>
</tr>
<tr>
<td>49-PET-789</td>
<td>150</td>
<td>8436 ± 51</td>
<td>9455 ± 85</td>
<td>Wood Charcoal</td>
<td>D-AMS 025809</td>
</tr>
</tbody>
</table>

The sites included in this case study form a representative sample of activity at Labouchere Bay spanning the middle Holocene. The younger sites (49-PET-746, 49-PET-792, and 49-PET-791) share overlapping radiocarbon dates, and the gap between the abandonment of the oldest site (49-PET-789, c. 8600 BP) and the establishment of the next oldest (49-PET-746, c. 6600 BP) is best explained by low site visibility. The similarity in character and spatial distribution of these sites suggest that additional shell middens from this period likely exist nearby but remain undetected. Ground surface visibility in the project area is poor, except in areas where alluvial erosion or tree-throws...
have exposed the underlying sediment. The ground surface is obscured by temperate rainforest vegetation, rapid accumulation of forest humus, heavy rockfalls, and disturbance from logging activity in the 1990s. Two of the excavated midden sites (49-PET-788 and 49-PET-790) were excluded from radiocarbon dating because they displayed evidence of postdepositional taphonomic disturbance. Six additional shell deposits of undetermined origin were identified during survey but were not subject to systematic subsurface testing due to time constraints (Williams and Dixon, 2016).

*Optimal Foraging and Resource Management*

Mobile and sedentary foraging represent two ends on a continuum, and societies vary in the degree to which they express characteristics of mobile or sedentary foraging (Binford, 1980; Kelly, 1995). During the middle Holocene, levels of sedentism and mobility in Northwest Coast societies seem to relate to socio-environmental pressures, with increased sedentism during winter months and increased mobility during summer months (Binford, 1980; Bliege Bird et al., 2002; Burchell, Cannon, et al., 2013; A. Cannon, 1998, 2002; A. Cannon et al., 2008; De Laguna, 1972; Moss, 1993). Nonetheless, over the span of multiple generations, these societies shared a trajectory toward increasing sedentism across the entire Northwest Coast. This trend culminated in hereditary chiefdoms with specialized resource procurement and management strategies (Ames & Maschner, 2000; Hunn et al., 2003; Lepofsky et al., 2015; Lepofsky & Caldwell, 2013; Stein, 1998).
The middle Holocene marked the widespread appearance of a shared economic and settlement pattern in which foraging activity at seasonal gathering camps supported the permanent reoccupation of strategically located winter villages (Ames & Maschner, 2000; Moss & Cannon, 2011). Although the social dynamics of middle Holocene foraging camps cannot be directly observed, they can be considered through the lens of ethnographic analogy. In recent ethnohistoric times, these types of villages were unified by the social construct of reciprocity: the obligation to share resources: either at formal potlatch gatherings or informally at the household level (Bliege Bird & Bird, 1997; Cronk, 1991; Davis, 1990; De Laguna, 1972; Hunn et al., 2003; Lepofsky & Caldwell, 2013; Smith Jr., 2003; W. P. Suttles, 1990; Trosper, 2009). At the individual level, reciprocity provides insurance against misfortune, because individuals can call upon distributed social networks for support during periods of local resource shortfall (Bliege Bird et al., 2002). At the community level, reciprocity reduces incentive to overharvest, because individuals are expected to share their good fortune (Moss & Cannon, 2011; Trosper, 2009).

In a potlatch setting, public generosity could be leveraged to increase the giver’s social standing by indebting the recipients (Kan, 1989; Mauss, 1954; Rubel, 1978; Sahlins, 1965, 1972). However, what if you had a gift that no one wanted to accept? Although shellfish have long been a part of the Northwest Coast diet, consuming shellfish carries the risk of deadly paralytic shellfish poisoning (PSP). Filter feeders such as clams
and oysters accumulate toxins from algal blooms which can be fatal to humans. Before the invention of modern molecular testing techniques, toxin levels in shellfish flesh were impossible to determine (Acres & Gray, 1978). For this reason, shellfish in ethnohistoric accounts had a reputation for being a poor person’s food, which no one would openly admit to consuming – despite the physical presence of shell middens behind every house (De Laguna, 1972, 1990). Excess shellfish might be shared among lower-status families during hard times, but such reciprocity offered limited opportunity for social advancement; offering a gift of shellfish would imply that the recipient was truly desperate, while simultaneously implying that giver had nothing better to offer.

As an explanatory framework based on ethnographic analog, reciprocity optimizes the collective fitness of the community, rather than the individual (Trosper, 2009). The reciprocity model stands in contrast to classical optimal foraging theory, which emphasizes the fitness of an individual actor (Bettinger, 2009; Charnov, 1976; Kelly, 1995; Smith et al., 1983; Stephens & Krebs, 1986). In an optimality model, foraging agents in both models act on foreknowledge of local conditions (Bettinger, 2009; M. D. Cannon & Broughton, 2010; Dincauze, 2000; Winterhalder & Smith, 2000). Humans, having lived alongside the Alexander Archipelago’s intertidal ecosystem thousands of years, would have developed and established traditional ecological knowledge about which types of shellfish were preferential to collect, and when and where they were safest to collect (Berkes, 1993; Lepofsky & Caldwell, 2013).
Environmental Setting

The effort required to obtain shellfish depends primarily on their habitat, which can be broadly characterized as soft substrate (mudflats and sandy beaches) vs. hard substrate (rocky shores and tide pools) (N. R. Foster, 1997; Morris, 1966; Rehder et al., 1981). These two habitats represent opposite ends on the coastal erosion-lithification cycle, in which bedrock is broken down and redeposited in sedimentary layers (Taylor & Wilson, 2003). Although the geomorphic spectrum is a continuum, shellfish communities are dichotomous: they fall into either the soft substrate or hard substrate category. Soft substrate habitat is comprised of sediments that are moved by regular tidal action. Particles in these sediments include clay, silt, and sand ranging in size from 0.001 to 2 mm in diameter. Hard substrate habitat is comprised of rocks greater than 256 mm in diameter that are not moved by regular tidal action (Schaeffer et al., 2007). Gravel and cobble substrates represent intermediate stages of the coastal erosion-lithification cycle and contain particles ranging from 2 to 256 mm in diameter (Cosentino-Manning et al., 2010; Taylor & Wilson, 2003). These intermediate substrates may be populated by either hard or soft substrate species, depending on the specific local conditions. Both hard substrate and soft substrate habitats are easily accessible just a few hundred meters from the Labouchere Bay sites (Figure 9). Since the two ecological communities have dichotomous habitat constraints, changes in the erosion-lithification cycle that would
benefit one community (e.g. silting) would have an equal and opposite effect on the other community (Figure 9).

The nature of these habitats shapes the physiology and behavior of the species that inhabit them. Hard substrate taxa tend to be small but gregarious. When the tide is out, they congregate densely within tidepools and on bull kelp strands to conserve moisture (EOL, 2015g). Consequently, harvesting hard substrate shellfish is a relatively straightforward task. Tidepools are easy to locate and require no particular expertise or specialized tools to harvest (M. C. Stiner et al., 2000; F. Thomas, 2007). When the tide is
out, periwinkles can be scooped up by the thousands and placed in a container (Cummins et al., 2002). Thus, they can easily be harvested in bulk with minimal effort. In optimal foraging terms, the hard substrate community has low search and handling costs.

Harvesting soft substrate shellfish requires more dedicated effort. Soft substrate taxa are large but solitary. When the tide is out, they burrow deeper into the mud to retain moisture (EOL, 2015j). Thus, their handling time (i.e. effort required to dig them up) is relatively high. Certain soft-substrate taxa, such as horse clams, exclusively inhabit depths that are only accessible during the lowest seasonal tides, making them extremely difficult to procure (EOL, 2015l). Timing the tides is critical to a successful harvest, since these organisms prefer deeper areas that are only exposed at low tide. Clams in this region typically burrow a foot or more into the mud, so a digging stick or other similar tool is required (Olsen, 2019). In optimal foraging terms, the soft substrate community has high search and handling costs compared to the hard substrate community.

Perhaps most importantly for how humans interacted with these communities was their capacity to harbor paralytic shellfish poisoning. Soft substrate taxa are predominantly filter-feeding bivalves, which are much more likely to accumulate deadly levels toxins from free-floating dinoflagellate plankton. Hard-substrate taxa are predominantly grazing gastropods, which feed on sessile algae that grow on rocks and are less susceptible to toxic blooms (Mons et al., 1998; Trainer et al., 2003). The difference in the underlying food web of these two communities meant that foraging in the hard
substrate community entailed lower risk than the soft substrate community. This risk could be mitigated through traditional ecological knowledge (e.g. harvesting only when local environmental conditions were unfavorable for algal blooms) (Burchell, Cannon, et al., 2013; A. Cannon, 1998), but due to the undetectable nature of PSP, the risk could never be entirely eliminated (Trainer et al., 2003).

Foraging Predictions

The explanatory model for resource management at Labouchere Bay examines the competing goals of optimal foraging (to maximize returns), vs those of management (to minimize effort), framed within the archaeological context of increasing sedentism, environmental context of shellfish reproductive strategies, and social context of ethnohistorical documented reciprocity networks. Optimal foraging theory predicts that initially, the most abundant taxa in the middens would be the those that had the highest returns relative to the effort of acquisition (i.e. the lowest search and handling time) (M. C. Stiner et al., 2000). Over time, these top-ranked resources would become depleted due to human predation, eventually being supplemented or replaced with other, formerly lower-ranked resources (Charnov, 1976; Kelly, 1995; Smith et al., 1983; Webster & Webster, 1984). In contrast, management models predict that there is an upper limit to even the most optimal foraging strategy: an individual aims to be productive, but not so productive that they personally pass the point of diminishing returns. Within the context ethnographic analogy, the underlying principle of Northwest Coast resource management
was that of reciprocity: the obligation to give away any returns that exceeded what one
could personally use (Trosper, 2009). Since gifts of shellfish would not necessarily elicit
an increase in social prestige, this obligation to share would place an artificial limit on the
desired returns.

The outcome of these foraging models is reflected in the faunal remains recovered
from archaeological assemblages (Kelly, 1995). In an optimal foraging model, the
abundance of a preferred resource in an archaeological assemblage follows a polynomial
curve: rising until foraging reaches diminishing returns, and then declining as the
resource is overexploited (Figure 10). This pattern is predominantly driven by the
abundance of prey in the surrounding environment. In a management model,
sociocultural factors (e.g. reciprocity) impose an artificial limit on foraging behavior, so
that the abundance of a preferred resource does not exceed the point of diminishing
returns (Figure 10). The pattern is predominantly driven by the cultural factors
determining how resources are managed.
Figure 10. Anthropogenic effects on resource abundance in an archaeological assemblage. Optimal foraging predicts that abundance of a preferred resource will rise and fall. Management predicts that abundance of a preferred resource will stabilize within a predetermined range below the point of diminishing returns.

All of the shellfish present in the Labouchere Bay shell midden assemblages benefit from source-sink dispersal, a reproductive pattern in which mature individuals in established deep water habitat (20 to 350 meters below sea level) produce offspring that can rapidly colonize unoccupied intertidal areas (Holt, 1985; Park et al., 2003). This reproductive strategy makes shellfish particularly resilient to changing geological conditions, so shellfish communities would have been consistently accessible to humans throughout even the extreme sea level fluctuations of the Pleistocene and early Holocene (R. J. Carlson & Baichtal, 2015). Source-sink dispersal also provides a buffer against terrestrial predation. Unlike the modern commercial shellfishing industry, which has the
demonstrated potential to extirpate species entirely, regardless of depth (Cosentino-Manning et al., 2010; Stram & Evans, 2009), the impact of ancient shellfish harvesting would have been limited to affecting species’ availability in reasonably accessible nearshore areas across timeframes measured in human lifespans.

**Methods**

The recovery of faunal materials at Labouchere Bay followed the methods developed at the Qw’u?g’ws shell midden site (45TN240) at Mud Bay, Washington (R. Foster & Croes, 2004; Williams, 2011). Over the course of three field seasons at Labouchere Bay, I excavated a total of nine test units at shell-bearing sites (Williams and Dixon, 2016). Except where otherwise noted, excavation of 1 x 1 m test units was conducted using 5 cm levels and water-screened through 3.2 mm (1/8 inch) mesh. Due to logistic constraints at 49-PET-789, I was only able to obtain samples from the uppermost and lowermost levels of an exposed portion of the hillslope.

I collected diagnostic shellfish elements from a designated 50 x 50 cm quadrant within each unit. Between field seasons, I assessed species richness (NTAXA) across the excavated assemblage to confirm each midden had been sampled to redundancy (Lyman & Ames, 2004). This sampling strategy provided the most effective balance between efficient field sorting and manageable transportation of samples while ensuring a representative sample was obtained. We identified each element in the invertebrate faunal assemblage to the most specific taxonomic level possible using printed field guides (N.
R. Foster, 1991; Morris, 1966; Rehder et al., 1981) and the authors’ personal comparative collection. I aggregated data from individual taxa according to ecological community for analysis.

Since the stratigraphic profiles of every site indicated that there were no depositional unconformities, I interpolated the mean 2-sigma $^{14}$C determinations from the uppermost and lowermost excavation levels (Table 3) to estimate the age of each intermediary sublevel for analysis. This time model takes into account the time-averaging that occurs in midden formation, since middens are the product of recurring discrete events in which individual loads of shell are dumped onto the pile.

I analyzed the archaeofaunal assemblage at two levels of data aggregation: individual taxa and ecological community. I used Number of Identified Specimens (NISP) to determine each taxon’s representation in the assemblage and Relative Abundance Indices (RAI) to examine how humans interacted with entire shellfish communities. I calculated goodness of fit regression equations to quantify patterns of change in NISP and RAI over time. I evaluated both linear and polynomial regression models and determined that polynomial equations provided the strongest framework for correlation analysis.

I selected NISP (after Lyman 2008) for this analysis rather than mass to compensate for both the fragmented state of the shells as well as the impracticality of
transporting sufficiently representative bulk samples from the remote field location\(^3\). To account for varying dimensions of excavation subunits, each subassemblage’s NISP was divided by the amount of excavated material (in m\(^3\)).

I calculated Relative Abundance Indices (after Cannon 2001) to quantify the proportion of different shellfish in the Labouchere Bay midden assemblages according to ecological community: soft-substrate (mudflats) vs. hard-substrate (tide pools). RAI is calculated by dividing the total NISP of species from hard-substrate communities by the total NISP of all species. The higher the RAI, the higher the proportion of hard-substrate shellfish in the assemblage. An RAI of 1 reflects an assemblage that is 100% hard-substrate taxa. An RAI of 0 reflects an assemblage that is 100% soft-substrate taxa. In this way, RAI serves as a proxy for the overall yield of the different communities, and changes in RAI reflect changing ways in which humans interacted with these communities.

**Results**

*Number of Identified Specimens*

\(^3\) See also (Allen, 2011). Correlation analysis of the sublevel assemblages from 49-PET-746 indicates that both mass and count yield comparable measures of taxonomic abundance: butter clam \((n=1254, df=13, r=.67, p=.01)\), littleneck clam \((n=545, df=13, r=.80, p=.001)\), Sitka periwinkle \((n=5966, df=13, r=.93, p<.001)\), Black Katy chiton \((n=3283, df=13, r=.75, p=.002)\). Contrast with (Moss, 2008) for an example in which mass is a more practical measure.
Two taxa from each ecological community overwhelmingly dominated each recovered assemblage (Table 4). Within the hard-substrate community, Black Katy Chiton (*Katharina tunicata*) composed 51% of the excavated assemblage, Sitka Periwinkle (*Littorina sitkana*) composed 42%, and all other taxa combined composed 7%. Within the soft-substrate community, Littleneck Clam (*Protothaca staminea*) composed 49% of the excavated assemblage, Butter Clam (*Saxidomus gigantea*) composed 46%, and all other taxa combined composed 5%.
### Table 4: NISP by taxa and ecological community

#### Hard-Substrate Taxa

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
<th>NISP</th>
<th>% of Hard Substrate Taxa</th>
<th>% of All Taxa</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Katharina tunicata</em></td>
<td>Black Katy Chiton</td>
<td>17,719</td>
<td>51%</td>
<td>41%</td>
</tr>
<tr>
<td><em>Littorina sitkana</em></td>
<td>Sitka Periwinkle</td>
<td>14,645</td>
<td>42%</td>
<td>34%</td>
</tr>
<tr>
<td><em>Lottia sp.</em></td>
<td>Various Limpets</td>
<td>679</td>
<td>2%</td>
<td>2%</td>
</tr>
<tr>
<td><em>Buccinidae sp.</em></td>
<td>Various Whelks</td>
<td>483</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td><em>Balanus sp.</em></td>
<td>Acorn Barnacle</td>
<td>338</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td><em>Balanus nubilus</em></td>
<td>Giant Acorn Barnacle</td>
<td>241</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td><em>Mytilus Californianus</em></td>
<td>California Mussel</td>
<td>224</td>
<td>1%</td>
<td>1%</td>
</tr>
<tr>
<td><em>Cryptochiton stelleri</em></td>
<td>Gumboot Chiton</td>
<td>146</td>
<td>0.4%</td>
<td>0.3%</td>
</tr>
<tr>
<td><em>Semibalanus cariosus</em></td>
<td>Thatched Acorn Barnacle</td>
<td>6</td>
<td>0.02%</td>
<td>0.01%</td>
</tr>
<tr>
<td><em>Tonicella lineata</em></td>
<td>Lined Chiton</td>
<td>4</td>
<td>0.01%</td>
<td>0.01%</td>
</tr>
<tr>
<td><em>Hiatella arctica</em></td>
<td>Arctic Hiatella</td>
<td>1</td>
<td>0.003%</td>
<td>0.002%</td>
</tr>
<tr>
<td><em>Crassedoma giganteum</em></td>
<td>Giant Rock Scallop</td>
<td>1</td>
<td>0.003%</td>
<td>0.002%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>34,487</td>
<td></td>
<td>81%</td>
</tr>
</tbody>
</table>

#### Soft-Substrate Taxa

<table>
<thead>
<tr>
<th>Scientific Name</th>
<th>Common Name</th>
<th>NISP</th>
<th>% of Soft Substrate Taxa</th>
<th>% of All Taxa</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Protothaca staminea</em></td>
<td>Littleneck Clam</td>
<td>4,050</td>
<td>49%</td>
<td>9%</td>
</tr>
<tr>
<td><em>Saxidomus gigantea</em></td>
<td>Butter Clam</td>
<td>3,760</td>
<td>46%</td>
<td>9%</td>
</tr>
<tr>
<td><em>Macoma nasuta</em></td>
<td>Bent-nosed Clam</td>
<td>195</td>
<td>2%</td>
<td>0.5%</td>
</tr>
<tr>
<td><em>Clinocardium nuttallii</em></td>
<td>Cockle</td>
<td>176</td>
<td>2%</td>
<td>0.4%</td>
</tr>
<tr>
<td><em>Tresus capax</em></td>
<td>Horse Clam</td>
<td>45</td>
<td>1%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Veneridae sp.</td>
<td>Unidentifiable Clam</td>
<td>10</td>
<td>0.1%</td>
<td>0.02%</td>
</tr>
<tr>
<td><em>Mya arenaria</em></td>
<td>Softshell Clam</td>
<td>8</td>
<td>0.1%</td>
<td>0.02%</td>
</tr>
<tr>
<td><em>Callithaca tenerrima</em></td>
<td>Lined Clam</td>
<td>3</td>
<td>0.04%</td>
<td>0.01%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td>8,247</td>
<td></td>
<td>19%</td>
</tr>
</tbody>
</table>

**Grand Total** | 42,734

Relative Abundance Index
The data from all four sites reflect a general trend in which the RAI starts high (i.e., a midden assemblage composed predominantly of hard-substrate taxa) and declines over time (Figure 11). Regression analysis indicates that for all sites, variation over time is best expressed as second order polynomial equations which describe parabolic increase and decrease consistent with classic models of resource depression in which a highly-ranked resource is initially preferentially targeted but becomes less abundant over time due to predation pressure and diminishing returns (Butler & Campbell, 2004; Charnov et al., 1976; Mitchell et al., 2012). Under this nonlinear model, time before present (cal BP) significantly predicts RAI scores at three out of four sites and explains a significant proportion of variance in RAI at two out of four sites (Figure 11). Logistical limitations at 49-PET-789 yielded insufficient sample size to obtain statistically significant results.
Figure 11: The relative abundance of soft substrate vs. hard substrate shellfish in the middens (indicated with points) followed statistically significant trends predicted by optimal foraging theory (indicated with lines). Nonlinear regression indicates significant correlation with a polynomial model (indicated in bold) for sites PET-746, PET-791, and PET-792.

**Normalized NISP**

While RAI provides an overview of general trends in shellfish use, analysis of NISP reveals differences in how humans interacted with hard vs. soft substrate ecological
communities, and how these interactions influence changes in RAI. Regression analysis of the normalized NISP of the archaeological assemblage from the hard substrate community indicates that variation over time is best expressed as second order polynomial equations which describe either declining diminishing returns (49-PET-746) or a boom-and-bust cycle (49-PET-791, 49-PET-792) (Figure 12). Under these nonlinear models, time before present (cal BP) significantly predicted RAI scores at three out of four sites and explained a significant proportion of variance in RAI at two out of four sites (Figure 12). Again, logistical limitations at site 49-PET-789 yielded insufficient sample size to obtain statistically significant results, but at sites 49-PET-746, 49-PET-791, and 49-PET-792, the archaeological assemblage matches the predictions of optimal foraging theory.
Figure 12: The amount of hard substrate shellfish in the middens (indicated with points) followed statistically significant trends predicted by optimal foraging theory (indicated with lines). Nonlinear regression indicates significant correlation with a polynomial model (indicated in bold) for sites PET-746, PET-791, and PET-792.

Regression analysis of the normalized NISP of the archaeological assemblage from the soft substrate community indicates that variation over time did not follow any statistically significant trend (Figure 13). Linear regression models were also evaluated, but likewise failed to yield statistically significant results. At all four sites, the archaeological assemblage does not match the predictions of optimal foraging theory, but
rather expresses shorter-term variation that stays within bounded limits, which is consistent with the predictions of the management model.

Figure 13: The amount of soft substrate shellfish in the middens (indicated with points) followed the upper and lower bounding limits predicted by management model (indicated with boxes). Nonlinear regression indicates no significant correlation with a polynomial model for any sites.

Discussion
Changes in the abundance of shellfish resources in the Labouchere Bay middens could have been due to a number of factors: anthropogenic optimal foraging, anthropogenic resource management, nonanthropogenic habitat change, or other coincidental factors such as changing dietary preferences or outside environmental effects. The results of these analyses indicate that anthropogenic factors were the primary source of change in midden composition. Changes in the relative abundance indices follow statistically significant polynomial curves, which are not consistent with the inverse linear relationship predicted by erosional habitat alteration. Instead, they are most consistent with the dynamic interactions of anthropogenic factors. The primary anthropogenic factors were different for the two ecological communities. Hard substrate shellfish followed patterns consistent with the predictions of the optimal foraging model: abundance increased up to the point of diminishing returns, at which it declined due to overexploitation. Soft substrate shellfish followed patterns consistent with the predictions of the management model. Abundance remained within a set of upper and lower bounds and did not exceed the point of diminishing returns. Although it is possible that these patterns of change were coincidental due to unmeasurable external factors, statistical analyses demonstrates that they closely follow the predictions of optimal foraging and resource management models.

These data suggest that the inhabitants of Labouchere Bay treated different ecological communities of shellfish in fundamentally different ways. Hard-substrate
tidepools seem to have been valued as a \textit{convenient} source of food, while soft-substrate mudflats were a \textit{critical} source of food – one that could not afford to be overexploited and thus was actively managed to ensure it was not overharvested. This opposing yet complementary aspect of these two ecological communities was an important element of the traditional ecological knowledge (De Laguna, 1972; Lepofsky et al., 2015; Lepofsky & Caldwell, 2013) that facilitated the establishment of sedentary fisher-hunter-gatherer communities on the Northwest Coast.

Traditional ecological knowledge was organized holistically according to ecological communities, rather than at the level of specific individual species. The presence or absence of taxa and their proportional representation within each ecological community’s assemblage are consistent with the habitat requirements of the respective taxa in the near-shore intertidal zone. Within each ecological community, human foragers minimized search time by collecting whichever type of shellfish were most readily available; they did not overtly pass over particular taxa within that area in search of higher-yield targets. This behavior suggests that the inhabitants of Labouchere Bay applied broad categories of taxonomic organization. While modern biology narrowly categorizes organisms into a strict Linnaean taxonomy, these data suggest that these ancient foragers based their foraging decision-making at the level of ecological communities (e.g. tide pools vs. mudflats) rather than individual species (e.g. \textit{Katharina tunicate} vs. \textit{Protothaca staminea}). Such a strategy would be consistent with the decisions
modern fisher-hunter-gatherers make when hunting small game (Groesbeck et al., 2014; E. L. Jones, 2004; McKechnie et al., 2014; Sosis, 2001; M. C. Stiner et al., 2000; F. R. Thomas, 2007)

Zoarchaeological analysis and ethnographic accounts agree that shellfish-harvesting camps did not operate in isolation; they were part of a coordinated seasonal round in which many individual family units contributed to the overall economic stability of the clan (Blierge Bird et al., 2002; A. Cannon, 1998; A. Cannon et al., 2008; De Laguna, 1972; Moss, 1993). This semi-sedentary seasonal round is similar to the transhumance practiced by nomadic pastoralists (Evans-Pritchard, 1940; S. Jones, 2005). Such an explanation is consistent with the results of the RAI analysis. In general, RAI at all sites started high, reflecting a midden assemblage composed predominantly of hard-substrate taxa, and declined over time, reflecting increased exploitation of soft-substrate taxa. Site 49-PET-746 presents the most comprehensive faunal record and has chronology which encompasses both the early and middle Holocene. During the early occupation of 49-PET-746 (as well as contemporaneous 49-PET-746), RAI declined only gradually, indicating that the preferred prey of chitons and periwinkles were not subject to heavy human predation. However, at approximately 3,500 cal BP, the RAI declined rapidly, indicating unsustainable levels of human predation. This point of inflection coincides with a region-wide increase in human population density (Ames & Maschner, 2000; Campbell & Butler, 2010; Fedje et al., 2004), which would have sharply amplified
the effects of resource depression in unmanaged prey populations. The need to supply a rapidly increasing human population may explain the sudden drop in RAI at 49-PET-746 and reflect a time when preferred prey were being harvested faster than they could reproduce. The occupation of 49-PET-791 began around this same time (c. 3680 ± 35 cal BP), and the assemblage from this site documents a rapid increase in RAI, followed immediately by an equally rapid decline. The pattern at 49-PET-792 is characteristic of the middle Holocene, during which RAI values tended to precipitously decline. The normalized NISP results indicate that the changes in RAI were driven primarily by changing numbers of hard-substrate taxa. Since hard substrate taxa are highly resistant to fragmentation, none of these trends can easily be explained by postdepositional taphonomic factors. In other words: the number of clams harvested from Labouchere Bay remained within relatively consistent upper and lower limits over the course of 5,000 years, while the number of marine snails and chitons systematically declined.

**Conclusion**

Over approximately 5,000 years, human foragers at the Labouchere Bay sites made optimal use of the shellfish resources harvested from the surrounding soft substrate mudflats and hard substrate tidepools, but they had different conceptions of what was considered “optimal” for each of these ecological communities. The invertebrate faunal record recovered from the Labouchere Bay shell middens reveals that while the yield from the hard substrate shellfish community experienced diminishing returns consistent
with the predictions of optimal foraging theory, the yield from the soft substrate shellfish community remained within an artificially constrained range throughout all of the sites’ occupations. This divergence from the predictions of optimal foraging theory cannot easily be explained by environmental changes, since these shellfish communities occupy opposite ends of a habitat continuum, any ecological forces affecting the soft-substrate habitat would have an equal and opposite effect on the hard substrate habitat⁴.

Rather, these differences suggest that ancient foraging decisions were driven by social pressures analogous to those observed among Northwest Coast societies during the recent ethnographic past. Historically, shellfish were an important source of food that ensured that every family would survive the late winter and early spring when stored food ran low and other sources of fresh food were scarce. However, within the broader reciprocal prestige economy practiced by these societies, shellfish had limited (or even negative) value outside the immediate family. Shellfish’s social stigma as a starvation food was further reinforced by the risk of paralytic shellfish poisoning. While the social obligation to share one’s excess nonetheless extended to shellfish, such a gift would not only imply a state of poverty on the part of both the giver and the receiver, it might also inadvertently kill the recipient. Thus, there may have been strong incentive to harvest just

⁴ Chapter 4 examines the specific relationship between geological/environmental changes and human activity at Labouchere Bay in greater detail.
enough to get one’s immediate family through lean times when no other food was available, without accumulating an excess that one would be obligated to share with the wider community.

If a precursor to this ethnohistorical management system was emerging during the middle Holocene, it would be consistent with the patterns seen in the archaeofaunal record at Labouchere Bay. The obligation to share without the potential for upward mobility would have altered the optimal foraging calculus, prompting individual foragers to place greater priority on minimizing effort as opposed to maximizing returns. Assuming family sizes remained roughly the same from generation to generation, once an individual family’s needs were met, there was no incentive to expend further effort foraging for soft substrate shellfish. This in turn would have capped soft substrate shellfish harvests within a sustainable range, with the added benefit of ensuring that intertidal clam beds were never overexploited beyond their capacity to repopulate. This strategy for limited harvesting of soft substrate shellfish stands in contrast to the unconstrained harvesting of hard substrate shellfish, which had a much lower risk of PSP and might therefore have served as suitable gifts that could be distributed in exchange for prestige.
Intertidal coastal regions (the areas of the shore that are cyclically submerged and exposed between high tide and low tide) serve as the interface between marine and terrestrial ecosystems and are important both commercially for their production of food and other natural resources and ecologically as biodiversity hotspots (Wilmers et al., 2012). A particularly productive and diverse variety of nearshore ecosystem exists along the coast of the north Pacific, which support a high degree of biodiversity and primary productivity as well as a deep history of both vertebrate (e.g., salmon, herring) and invertebrate (e.g., littleneck clam, butter clam, Olympia oyster) fisheries (Moss & Cannon, 2011; Orensanz & Jamieson, 1998; Williams & Croes, 2012). Over the last few decades, the viability and stability of these coastal ecosystems has become of great concern due to overexploitation and anthropogenic climate change (Caldeira & Wickett, 2003; Campbell & Butler, 2010; Jackson et al., 2001). In order to fully understand the implications of recent environmental changes, researchers, stakeholders, and policy makers must be able to place these ecosystems within their long-term historical context. In particular, a thorough understanding of how humans have responded to changing sea levels would greatly benefit efforts to conserve natural resources and revitalize traditional fisheries practices (McCauley et al., 2015; Whitepigeon, 2020).
This paper examines the human occupation history at Labouchere Bay, Alaska to
determine how external environmental changes and internal cultural adaptations affected
peoples’ relationship with the intertidal ecosystem. Using a LiDAR DEM and subsurface
sonar bathymetry, I reconstruct sites’ location in relation to a modeled paleoshoreline that
takes into account tidal range. Examining how sites are situated in relation to the
contemporaneous intertidal zone reveals how humans responded to changing
environmental and cultural conditions.

**Background**

The highly productive ecosystems of the Northwest Coast of North America
would have facilitated the migration of humans out of Asia along a “kelp highway”
(Erlandson, Graham, et al., 2007; Erlandson, Moss, et al., 2007). Subsequent generations
of humans living along the coast made heavy use of marine resources, as evidenced by
the frequent occurrence of shellfish remains in archaeological sites (Ames, 1994; A.
Cannon et al., 2008). Shellfish provided a predictable, resilient resource base which may
have facilitated the establishment of sedentary hunter-gatherer communities by mitigating
unpredictable shortfalls in other food resources (D. R. Croes & Hackenberger, 1988;
Yesner, 1980). Although the prevalence of shell middens along the Northwest Coast
reveals that ancient people made use of intertidal resources, the changing conditions
within these intertidal ecosystems remains understudied (Moss, 2004b). Reconstructing
the dynamics between human foraging camps and ancient shell beds is crucial to understanding the entire food web during this period of rapid environmental change.

During the early Holocene (c. 11,700 - 7,000 calendar years ago\(^5\)), the Northwest Coast of North America experienced profound geological and climactic changes. Prince of Wales Island, located in Southeast Alaska near the western edge of the North American plate’s continental shelf (Figure 14), was subject to dramatic sea level changes as a consequence of the combined forces of global sea level rise, isostatic rebound, and forebulge collapse that occurred during the early Holocene (Baichtal et al., 1997; Carrara et al., 2007). Relative sea levels reached a maximum extent of 14m above the modern level around 9,000 years ago, and then slowly receded to modern level around 5,000 years ago (Baichtal & Carlson, 2010; Shugar et al., 2014). These changes would have been most pronounced in the intertidal areas, which serve as an ecotone between terrestrial and marine habitats.

\(^5\) Except where otherwise noted, all dates in this chapter are presented as calendar years before present. All radiocarbon dates were calibrated using the IntCAL20 terrestrial atmospheric curve (Reimer et al., 2020).
Two general models have been proposed to frame the relationship between ancient humans and the changing intertidal landscape they depend upon for survival on the Northwest Coast: one focused on human societies’ localized responses to external environmental change (Moss, 2011), and one focused on these societies’ specific expressions of region-wide patterns of internal socioeconomic change (Ames, 1991). These models are complementary, not contradictory: they address different aspects of human societies’ interactions with their environment and inform the interpretation of different aspects of the archaeological record.

Figure 14. The Labouchere Bay sites in Alaska’s Alexander Archipelago

*Societal Change*

Two general models have been proposed to frame the relationship between ancient humans and the changing intertidal landscape they depend upon for survival on the Northwest Coast: one focused on human societies’ localized responses to external environmental change (Moss, 2011), and one focused on these societies’ specific expressions of region-wide patterns of internal socioeconomic change (Ames, 1991). These models are complementary, not contradictory: they address different aspects of human societies’ interactions with their environment and inform the interpretation of different aspects of the archaeological record.
Moss (2011) characterizes the middle Holocene as a period in which highly localized environmental change was the primary driver of cultural evolution. In particular, post-glacial tectonic restabilization resulted in a constantly-shifting nearshore littoral zone, which presented varying opportunities and obstacles for coastal foragers. Under this model, changes in the archaeological record primarily reflect adaptations to the physical conditions in a specific locale. The systematic exploitation of shellfish was one element of an increasingly diverse suite of subsistence strategies tailored to maximize a location’s ability to support a growing human population. Moss’ framework predicts that the location of coastal foraging camps should track closely with changing sea levels, with foragers relocating autonomous seasonally occupied base camps to keep pace with both rising and falling shorelines. Baichtal and Carlson (2015) have verified this prediction for early Holocene (c. 10,500 – 7,500 cal BP) sites on Prince of Wales Island using a predictive model for site location based on elevation combined with ground-truthed subsurface testing.

Ames’ (1991, 2008) approach focuses on how the development of complementary social networks, rather than external environmental factors, facilitated the development of sedentism on the Northwest Coast. Within this framework, the emergence of hereditary chieftainships facilitated the viability of highly organized foraging systems (and vice-versa). Site-specific specialization and intensification in processed foods, as evidenced in features such as shell middens, fish traps, and clam gardens, serves to illustrate how
humans manipulated the environment to their favor (Yen, 1989). Integrating this increasingly diverse array of specialized foraging practices into a cohesive regional system necessitated certain economic, social, and ideological synergies (Ames, 1991). This model, in which chiefs directed the specific activity of their subordinates to ensure the long-term survival of the entire clan, has been used successfully to connect the social practices documented in the ethnohistoric present with analogous material expressions in the archaeological past (Ames & Maschner, 2000).

**Sea Level Curve**

The paleoshoreline model used in the paper is derived from interpolated sea level data from Alaska’s Alexander Archipelago to quantify the combined forces of global eustatic sea level rise and localized tectonic trends (Baichtal & Carlson, 2010; Dixon & Monteleone, 2014). Not only was the ocean rising due to melting polar ice, but the land was also sinking (and rising) as the underlying tectonic plates responded to receding continental ice sheets. The data informing the model consist of calibrated radiocarbon dates paired with *in situ* elevations relative to modern sea level. In this model, ancient marine material recovered from modern terrestrial context indicates periods of higher relative sea level, while ancient terrestrial material recovered from modern marine context indicates periods of lower relative sea level (R. J. Carlson & Baichtal, 2015). Although postdepositional taphonomic factors can affect individual data points,
aggregating date/elevation pairs from across the entire region and interpolating a best-fit moving average curve yields a robust model of changing sea levels (Figure 15).

Figure 15: Sea Level Model derived from radiocarbon-dated material

The middle and late Holocene portions of the model are derived directly from data from Prince of Wales Island and its immediate vicinity. The late Pleistocene and early Holocene portions of the model, for which direct evidence from Prince of Wales Island is sparse, also take into consideration data from nearby Haida Gwaii (Hetherington et al., 2003; Josenhans et al., 1997). Since Haida Gwaii is located directly on the Queen
Charlotte-Fairweather Fault, it experienced more pronounced isostatic tectonic effects than Prince of Wales Island, which is buffered by an additional 100 km of submerged continental shelf (Carrara et al., 2003; Koehler & Carver, 2018). This buffer dampened the effects of isostatic rebound and forebulge collapse on Prince of Wales Island relative to Haida Gwaii (Peltier & Fairbanks, 2006). Thus, a variable correction factor was applied to the data from Haida Gwaii to account for the differing timing and rate of tectonic change, shifting the modeled sea level curve upward and to the left to better model the specific conditions on Prince of Wales Island.

Normalizing the model against global trends in sea level rise (Peltier & Fairbanks, 2006) highlights the specific conditions affecting the shoreline of Prince of Wales Island (Figure 16). Although the global sea level rose relatively smoothly from the LGM to the present as the continent-spanning polar glaciers melted, the shoreline on Prince of Wales Island moved up and down due to localized tectonic forces affecting the continental shelf. During this period, the earth’s crust was subject to two major counteracting forces; the weight of icesheets pushing down was contested by the buoyancy of the magma of the earth’s mantle pushing up. At some times the interaction of these varying tectonic forces amplified sea level rise, while at other times it dampened or even reversed it (at least at the local scale).
The period from 18,000 through 11,000 years ago was characterized by decreasing geological uplift, as the isostatic forces pushing up the western edge of the North American plate began to wane. (Figure 17: Uplift). The geologically-brief reversal of this trend from 16,000 to 14,000 years ago coincides with the retreat of ice sheets.
directly overlying Prince of Wales Island, during which the earth’s crust rebounded (Carrara et al., 2003). By 11,000 years ago, the combined forces of interior crustal rebound and coastal forebulge collapse (R. J. Carlson & Baichtal, 2015; Carrara et al., 2003) served to amplify sea level rise, rapidly submerging areas that are had previously been dry land (Figure 17: Subsidence). Subsidence reached its peak 10,000 years ago, after which point the postglacial geological forces had largely stabilized and the landform and global sea level gradually settled into their present equilibrium.

**Paleointertidal Model**

Paleoshoreline models have been used successfully to reconstruct changes in the terrestrial landscape, (e.g Nunn 2005; Letham et al. 2018; Legg and Anderton 2010; Johnson and Melanie Stright 1991; Fedje and Christensen 1999; Carlson and Baichtal 2015), but in this paper I extend the typical method to examine intertidal and subtidal seascape. I combine the paleoshoreline model described above with tidal range data calculated from the nearest tidal monitoring station, Sitka #9451600 (NOAA, 2021), and on-site measurements taken during the 2012-2014 field seasons. Mean lower low water (MLLW) at Labouchere Bay (the average lowest point water reaches at low tide) is -0.65 m relative to modern global eustatic sea level. High-high water (HHW) at Labouchere Bay (the highest point reached by normal wave action at the highest high tide of the year) is 4.63 m relative to modern global eustatic sea level. Labouchere Bay is located only 3km from the deep water of Keku Strait and 70km from the open Pacific, so shoreline
fluctuations during the Holocene are unlikely to have significantly altered the overall tidal range. Applying this tidal range to the sea level curve yields a model that indicates the upper and lower boundaries of the intertidal zone at every point in the past (Figure 17).

![Holocene Tidal Ranges](image)

**Figure 17:** High tide (upper line) and low tide (lower line). Intertidal elevations shown in light blue. Subtidal elevations shown in dark blue.

This paleo-intertidal model can then be applied to a map of the modern landform to reconstruct the intertidal zone graphically. I obtained the basemap for this analysis from the USGS, which commissioned an aerial LiDAR survey of Prince of Wales Island.
in 2017 (Quantum Spatial, 2018). Using second-return data from the LiDAR point cloud, Quantum Spatial generated a digital surface model (DSM) of Prince of Wales Island with a horizontal resolution of 0.5m and vertical accuracy of 0.288m. I combined these terrestrial elevations with marine elevations obtained via sonar bathymetry of the surrounding waterways conducted by Scientific Fishery Systems, Inc. and compiled by Carrara et al. (2003) to create vertical contour intervals of 25m.

Using QGIS v.3.16.1, I overlaid the paleo-intertidal model onto the DSM and bathymetry contours to reconstruct the changing extent of the intertidal zone from 18,000 years ago through the present. Figure 18 shows the changing extent of the intertidal zone at Labouchere Bay from 10,000 years ago through 5,000 years ago, rendered in 1,000 year increments.
Figure 18: Paleoshoreline and tidal range from 10,000 – 5,000 cal BP in 1,000 year increments

Particular attention was given to the period from 10,250 years ago through 2,000 years ago, as this represents the periods of documented human activity at Labouchere
Bay. Sites with absolute radiometric dates were added and removed from the map as dictated by their upper and lower bounding dates (Table 5). Sites lacking absolute dates were assigned a most probable estimated time period based on their stratigraphy and diagnostic artifacts.

Table 5. Radiocarbon dates for Labouchere Bay sites.

<table>
<thead>
<tr>
<th>ATRS #</th>
<th>Depth Below Surface (cm)</th>
<th>Uncalibrated Age (BP)</th>
<th>2σ Calibrated Age (cal BP)</th>
<th>Material</th>
<th>Lab #</th>
</tr>
</thead>
<tbody>
<tr>
<td>49-PET-746</td>
<td>110</td>
<td>2492 ± 24</td>
<td>2590 ± 135</td>
<td>Wood Charcoal</td>
<td>D-AMS 010116</td>
</tr>
<tr>
<td>49-PET-746</td>
<td>175</td>
<td>5770 ± 25</td>
<td>6575 ± 25</td>
<td>Wood Charcoal</td>
<td>NOSAMS 118293</td>
</tr>
<tr>
<td>49-PET-792</td>
<td>60</td>
<td>3511 ± 25</td>
<td>3780 ± 90</td>
<td>Wood Charcoal</td>
<td>D-AMS 041221</td>
</tr>
<tr>
<td>49-PET-792</td>
<td>120</td>
<td>4014 ± 32</td>
<td>4480 ± 90</td>
<td>Wood Charcoal</td>
<td>D-AMS 025808</td>
</tr>
<tr>
<td>49-PET-791</td>
<td>10</td>
<td>4071 ± 32</td>
<td>4575 ± 225</td>
<td>Wood Charcoal</td>
<td>D-AMS 025807</td>
</tr>
<tr>
<td>49-PET-791</td>
<td>175</td>
<td>4916 ± 31</td>
<td>5640 ± 80</td>
<td>Wood Charcoal</td>
<td>D-AMS 025806</td>
</tr>
<tr>
<td>49-PET-789</td>
<td>50</td>
<td>7823 ± 30</td>
<td>8620 ± 100</td>
<td>Wood Charcoal</td>
<td>D-AMS 041220</td>
</tr>
<tr>
<td>49-PET-789</td>
<td>150</td>
<td>8436 ± 51</td>
<td>9455 ± 85</td>
<td>Wood Charcoal</td>
<td>D-AMS 025809</td>
</tr>
<tr>
<td>49-PET-786</td>
<td>60</td>
<td>&gt;Modern</td>
<td>&gt;Modern</td>
<td>Spruce Cone</td>
<td>Beta 325353</td>
</tr>
<tr>
<td>49-PET-786: SD1</td>
<td>480</td>
<td>9490 ± 40</td>
<td>10825 ± 245</td>
<td>Spruce Wood</td>
<td>Beta 325353</td>
</tr>
</tbody>
</table>
Results

24,000 – 16,000 cal BP: Glaciation

Northern Prince of Wales Island was overridden by glacial ice only during the peak of the last glacial maximum, 24,000 to 18,000 calendar years ago. The sheltered mountain valleys on the western side of the island served as refugia (locally ice-free biomes that could support large-bodied land mammals) during much of the last ice age (Dixon, 1999; Heaton et al., 1996; Heaton & Grady, 2003; Sawyer et al., 2019) By 16,000 cal BP, the Cordilleran Ice Sheet had retreated to 6km north of the valley that would one day become Labouchere Bay (Figure 19), leaving the western edge of Prince of Wales Island and the surrounding waterways free of permanent ice (Carrara et al., 2003; Lesnek et al., 2020). Vegetation at this time consisted of pine parkland interspersed with alder stands. (Ager, 2019)
Global sea levels at this time were over 100m lower than present (Lambeck et al., 2014), and the shoreline of Prince of Wales Island was located 1.5km to the west of what would become Labouchere Bay (Figure 19). The rapid marine transgression in the late Pleistocene and early Holocene disrupted marine mollusk habitat, but mollusk communities rapidly adapted to the resulting environment. Terrestrial flooding and glacial silting disrupted the preglacial status quo – offering more habitat for soft-substrate suspension feeders, and sparser habitat for grazing gastropods (Schnedl et al., 2018). No cultural material associated with this period was recovered from Labouchere Bay; it is likely that any archaeologically-visible human activity would have taken place near the now-submerged shoreline.

16,000 – 10,000 cal BP: Rapid Marine Transgression

At approximately 10,250 years ago, rapidly rising postglacial sea levels reached 0m elevation (Figure 20). At this time, Sitka spruce and mountain hemlock were the dominant vegetation, having become established approximately 1000 years prior. (Ager, 2019) Sea levels would continue to rise at a similar pace for another thousand years, but for a brief period the early Holocene coastline would have closely mirrored that of today. However, rather than fronting a gently sloping mudflat as exists today (and is therefore reflected in the eastern portion of the reconstructed map), the subtidal portion of Labouchere Bay may have dropped off into a deep rocky fjord more similar to the rocky
western shore. During this period of rapid sea level rise, high energy wave action quickly eroded any fine glacial sediments that had been deposited close to shore. (Barrie et al., 2021) Even the deeply sheltered innermost tip of the inlet shows evidence of this heavy wave action in the form of a 20-60cm stratum of coarse beach gravel.

Figure 20: 10,250 cal BP: Rising sea levels inundate Labouchere Bay for the first time since the last ice age. First evidence of human activity: lithic site PET-786

Situated within this beach gravel is PET-786, the oldest site in the study area (Appendix 1-A). PET-786 is a lithic scatter located within a single stratum of raised marine beach gravel at approximately 3-4m elevation, slightly above and below the
modern maximum high tide. The presence of a microblade core corroborates the site’s relative stratigraphic date corresponding to the period of marine transgression.

Rapid inundation continued, and by 10000 cal BP, PET-786 would have been entirely submerged in subtidal waters (Figure 21). Directly underlying the cultural stratum of PET-786 is SD1, a raised marine shell bed which extends 50m uphill to the southwest and downhill to the northeast an indeterminate distance where it merges with the live shell bed in the modern intertidal and subtidal areas of Labouchere Bay. A fragment of spruce wood from the upper portion of SD1 dates to 10825 ± 245 cal BP, and the shell bed extends down for several meters, terminating directly above sterile glacial clay. SD-2, an untested raised marine shell deposit in a parallel inlet 250m to the east, is likely an extension of this same ancient shell bed. This indicates that although the exposed western shore may have been scoured to bedrock by wave action during this period, substantial soft-substrate clam habitat remained well established throughout the
protected interior inlets.

Figure 21: 10,000 cal BP. Rising sea levels inundate lithic site PET-786

Data from SD-1 also provides evidence for ancient climactic trends. Since the rate at which bivalve shells precipitate CaCO$_3$ out of the surrounding water varies with temperature, the $\delta^{18}O$ values obtained from shells in SD1 can be used as a proxy for sea surface temperature (SST), with higher $\delta^{18}O$ values indicating lower temperatures (Burchell, Hallmann, et al., 2013; Hallmann et al., 2009, 2013; Killingley, 1981; Liu et
al., 2014; Urey, 1947). Stable $\delta^{18}O$ isotopes extracted from *Saxidomus gigantea* shells recovered from SD1 ranged from $-0.65\%_o$ to $+2.19\%_o$, indicating that the local sea temperature at this time was colder than at present (Figure 22).

**Figure 22.** Sea surface temperature proxy at SD-1 (early Holocene) compared to PET-746 (late Holocene) and modern range

6 I report isotopic results as δ values: $\delta^{18}O = 1000 \left( \frac{R_{samp}}{R_{std}} - 1 \right)$, where $R_{samp}$ and $R_{std}$ are the $^{18}O:^{16}O$ ratio of the sample and official reference standard, respectively. The internationally accepted standards for oxygen and carbon are Vienna-Standard Mean Ocean Water (V-SMOW) and Vienna-Pee Dee Belemnite limestone (V-PDB) respectively. The units are expressed as parts per thousand (%). I corrected raw $\delta^{18}O$ data for machine drift and fractionation associated with sample acidification using both a calcite and aragonite standard run in concert with the experimental sample.
9,500 – 8,500 cal BP: Maximum Inundation

By 9500 cal BP, the rising sea level reached the edge of the terrace on which the midden sites are located, turning the peninsula to the south into an island that was only accessible at low tide (Figure 23). This coincides with the basal date for the shell midden site PET-789 (Appendix 1-C), which was obtained from wood charcoal recovered from directly above bedrock at a depth of 150 cm below surface.

Figure 23: 9500 cal BP: First midden site (PET-789)
Although the use of shellfish as a food resource was already widespread throughout the Northwest Coast by this time, PET-789’s bounding dates of 9,455 ± 85 through 8,620 ± 100 cal BP (D-AMS 025809, D-AMS 041220) make it one of the oldest heavily-utilized midden sites in the region (Figure 24). The archaeological assemblage at PET-789 represents not just the occasional opportunistic consumption of shellfish, as was more common in contemporaneous sites (e.g. Ackerman 1996b; Davis 1996; Ramsey et al. 2004; Fedje and Sumpter 2007; Carlson and Dalla Bona 1996), but the systematic reuse of a dedicated shellfish harvesting location over many generations resulting in substantial accumulation of cultural material more typically characteristic of middle Holocene shell midden sites.
Figure 24. Midden accumulation at northern Northwest Coast sites. Labouchere Bay sites highlighted in bold

The occupation history of PET-789 is tied closely to changing sea levels. The site was established when rising sea levels first reached the edge of the terrace on which the site is located. With a sheltering bedrock bluff to the north and easy access to waterways directly south, this location would have been an ideal hub to process shellfish brought in by canoe from nearby intertidal areas. When the site was first established, it would have been possible to beach a canoe directly at the site at high tide. However, by 8,500 the
forces of local tectonic uplift began to wane, and local relative sea level began to fall (Figure 25). As the water level receded, PET-789 was no longer conveniently situated adjacent to the intertidal zone. As the steep northern slope of the previously inundated channel was exposed, access to PET-789 would have required a more treacherous mooring on the narrow shore followed by a steep climb up several meters of slick, newly exposed bedrock. It is likely that the increasingly difficult marine access precipitated the site’s abandonment.

Figure 25: 9,000 cal BP – 8500 cal BP

8,000 – 6,000 cal BP: Moderate Marine Recession

From 8,500 through 5,000 years ago, local sea levels continued to fall at an average rate of 3mm per year. Although not nearly as rapid as the inundation that occurred prior to 10,000 years ago, this change would have been perceptible on human timescales. Over the course of a single 70-year lifespan, living on the coast of Prince of Wales...
Island would have seen the ocean fall by nearly a quarter of a meter. By 8,000 years ago, relative sea level had declined to the point where the narrow channel that had formed between the northern and southern portions of Protection Head was replaced with an isthmus (Figure 26). Shell midden site PET-746 (Appendix 1D) was established 6,575 ± 25 years ago – over 2,000 years after the abandonment of PET-789. The absence of dated archaeological material in this gap may represent a period of abandonment, but more likely is a consequence of the overall low site visibility. The general similarity in the sites’ contents and their situation on the landscape suggests they share cultural continuity, and that sites dating to the intervening period might be obscured under the 2+ meters of fallen boulders, forest humus, and conifer root mats that obscure the ancient cultural strata of Labouchere Bay. Based on its proximity to the contemporaneous shoreline, undated site PET-788 (Appendix 1E) may have been occupied during this period.
Figure 26: 8,000 - 6,000 cal BP

5,500 cal BP – Present: Stability and Gradual Change

Over the last 5,500 years, sea level gradually receded to its present elevation at an average rate of .03mm per year. This change would have been imperceptible, with a total difference of only 2mm over the course of a human lifespan. Around 5,000 years ago, yellow cedar had colonized the area, producing a terrestrial environment very similar to the present with dense forests of hemlock, alder, spruce, pine and cedar (Ager, 2019). Multiple δ¹⁸O values obtained from a Saxidomus gigantea shell recovered from the uppermost cultural level of shell midden site PET-746 indicates that sea surface
temperature during the late Holocene (-.07‰ to -5.0‰ VPDB) was within the range of modern variation (Figure 27, see also Figure 22) (Williams et al., 2015).

Figure 27: Sea surface temperature at in the uppermost cultural stratum at PET-746

The overall size of the sampled specimen and variation in δ¹⁸O levels indicate that this individual was newly mature at 2 years old and was harvested during the late winter or early spring. Although it had reached physical maturity, it had not had an opportunity
to participate in the summer spawning cycle (Cowles, 2005). This harvesting pattern is consistent with managed clam populations, in which beaches are harvested every two to three years: immediately after the crop has reached physical maturity, but before sea surface temperatures rise to the point where toxic algae blooms are common. After the beach has been harvested, it is reseeded manually or allowed to repopulate passively via source-sink dispersal (Holt, 1985; Toba, 2005).

In addition to PET-746, which remained in use, three additional shell midden sites were occupied during this period: PET-791, PET-792, and PET-790 (Appendix 1:F-H). These new sites were situated on the gradual west-facing slope below the terrace, 75m or more from the nearest shore (Figure 28). The artifact assemblages from these sites are notable for the presence of ground stone, bone, and shell artifacts, which were absent in older sites (Appendix I).

Unlike in earlier time periods, proximity to the shoreline does not seem to be a factor in site location during this time period. When PET-746 was first established 6,500 years ago, it was conveniently situated only a few meters from the high tide line, yet by 5,500 years ago it was located 75m from the shore and 12m up a steep slope. Despite this inconvenience, the site continued to see active use for another three thousand years. Likewise, site PET-791, established 5640 ± 80 years ago (D-AMS 025806), was located 125m from the shore. Site PET-792, established 4480 ± 90 years ago was located 75m from the coast.
Figure 28: 5,500 cal BP through present
Discussion

Prior to 8,000 calendar years ago, site location tracked extremely closely with rapidly changing sea levels. Both lithic site PET-786 and shell midden site PET-789 were established directly adjacent to the contemporaneous high tide line. When changing sea levels made these sites inaccessible -- in the case of PET-786 by submerging it and PET-789 by replacing the convenient canoe moorage with a steep rocky climb – they were rapidly abandoned.

Subsequent to 8,000 years ago, site location did not correspond directly to changing sea levels. The shell midden sites PET-746, PET-791, and PET-792 are not situated in relation to the intertidal zone with any consistency. Rather, these seasonally reoccupied food processing centers are spaced roughly evenly along a terrace some 100-200m inland from the edge of the bay. Variation in the sites’ distance to the water does not correspond to changes in the contemporaneous paleoshoreline. Rather, the primary consideration appears to have been equitably sharing locations along the sheltered terrace, all of which likely shared a common mooring point near the tip of the inlet. It is possible that the specific locations of these sites were primarily influenced not by the geologic landscape, but by the human soundscape (Primeau & Witt, 2018). Anecdotally, my team’s experience excavating these sites revealed that they are distributed within “shouting distance” of each other: far enough apart that individuals were afforded a
measure of privacy while they worked, but close enough that a startled yell would attract help if an inquisitive bear or wolf got a bit too close for comfort.

**Conclusion**

The results of this analysis indicate that human activity at Labouchere Bay followed both Moss’ (2011) more environmentally deterministic framework and Ames’ (1991) more culturally-deterministic framework. Moss’ model best explains behavior patterns during the early Holocene, while Ames’ model best explains behavior patterns during the middle and late Holocene.

During the early Holocene, sea level changes would have been directly perceptible over the course of a single human lifespan. Thus, elders would have been able to pass on traditional ecological knowledge that a given location would soon no longer be suitable for its existing use, but that another area would be able to take its place. In a society of autonomous, highly mobile fisher-hunter-gatherers, this sort of intergenerational knowledge transmission would have facilitated logistical mobility and ensured the long-term viability of shellfish harvesting practices. Within this framework, environmental changes were the primary driver of when and how people decided to occupy particular sites.

During the middle and late Holocene, sea level changes were much more gradual and would not have been perceptible at the individual human timescale. Simultaneously, the predominant societal organization of the Northwest Coast was transitioning from
highly mobile autonomous bands toward more sedentary hierarchal chiefdoms. Likewise, the composition of the Labouchere Bay middens provides evidence for increasingly formal shellfish management practices consistent with the emergence of centralized hierarchal labor structures administered by hereditary chiefs (Williams, in review). Similarly, the ground stone, bone, and shell artifact assemblages from these sites reflect an increasing degree of craft specialization. In ethnohistoric accounts, these types of labor structures were closely associated with clan identity and territory control, so it is likely that the middle and late Holocene sites at Labouchere bay were operated by independent family units connected within the same overarching clan. If so, family relationships, differences in social status, and clan politics would have been more immediate concerns than the barely perceptible sea level fluctuations.
Chapter 5. Conclusion

The composition of midden 13.3 at Labouchere Bay site 49-PET-746, which was occupied between roughly 6,500 and 2,500 calendar years before present, reflects changes in how the human inhabitants of the site interacted with intertidal shellfish communities. The amount of shellfish from soft substrate habitats (mudflats) did not change significantly over time, while the amount of shellfish from hard substrate habitats (rocky tide pools) declined. This trend in the relative abundance of these shellfish in the midden may have been influenced by environmental factors but is more likely explained by changes in human behavior. These behavioral changes could represent foraging adaptations in response to resource depression at different tidal ranges or increasingly organized household economic systems.

Analyses of zooarchaeological remains recovered from all four shell midden sites at Labouchere Bay reveal specific changes in how human foragers interacted with intertidal shellfish communities. Over an occupation period spanning 5,000 years, human foragers at Labouchere Bay made optimal use of shellfish resources, but they had separate goals for how they approached different nearshore ecological communities. Foraging returns from hard-substrate tidepools (e.g. *Katharina tunicate*, *Littorina sitkana*) rose and fell in a pattern consistent with the predictions of optimal foraging theory in which humans seek to maximize caloric returns. Conversely, foraging returns
from soft-substrate mudflats (e.g. *Protothaca staminea*, *Saxidomus gigantea*) consistently remained within a bounded range despite human predation, suggesting that harvesting of these taxa was deliberately managed to minimize effort.

Although the specific rules for how such management may have been enforced cannot be directly observed in the archaeological record, a plausible explanation can be inferred using ethnographic analogy. Soft substrate shellfish were historically considered a low-status food in Northwest Coast societies, owing largely to the risk that they might carry deadly levels of invisible algal toxins. These shellfish served a critical role in ensuring that families would survive the lean winter when other sources of food were not reliably available, but their social stigma as a “poor person’s food” combined with the risk of paralytic shellfish poisoning (PSP) meant that soft substrate shellfish had little to no value in a reciprocity-driven prestige economy. Once one’s immediate family had avoided starvation, there was no incentive to continue harvesting this risky food. This social stigma placed an artificial limit on the amount of soft substrate shellfish that was harvested from any given location, despite the abundance and resilience of this resource. Conversely, since hard substrate shellfish carry a much lower risk of harboring PSP, they would have had value as gifts, and their harvesting would be unconstrained by social factors, eventually straining or outpacing the shellfish community’s capacity to repopulate. If an analogous socioeconomic system was practiced at Labouchere Bay during the middle Holocene, it would explain the pattern observed in the archaeological
assemblages, in which hard-substrate yields declined over time, while soft-substrate yields remained within a consistent range.

Examining all of the Labouchere Bay sites within the context of abiotic environmental changes provides further insight into how changes in the physical setting influenced human behavior at Labouchere Bay. The rapid postglacial marine transgression was associated with use of the shoreline for temporary encampments. The first evidence for long-term systematic shellfish exploitation coincided with the maximum sea level highstand during the early Holocene, c. 9,500 calendar years ago. As the sea level gradually receded primarily due to terrestrial subsidence throughout the middle and late Holocene (c. 7,000 - 2,500 years ago), shellfish harvesting activity at Labouchere Bay increased in intensity. Although the early occupation of Labouchere Bay was influenced heavily by changing sea level, later occupation seems to have been influenced more by cultural factors coinciding with the regional emergence of clan-oriented hierarchical labor allocation.
Appendix 1: Site Descriptions
A: PET-786: “Old Beach Site”

The stratigraphy of this site spans the geological history of Labouchere Bay from the LGM through the present, providing a useful reference for the sea level changes that shaped the surrounding coastline during the occupation of the nearby middens. Although the cultural component of this site has not been directly dated, the depositional context and artifact assemblage suggest that it is the oldest cultural material in the project area.

The deepest stratum of the site consists of fine blue glacial clay which rests directly on limestone bedrock, reflecting the period 20,000 to 17,000 years ago during which the Cordilleran ice sheets covering much of northern POWI began to recede (Heaton et al., 1996; Lesnek et al., 2018). Above this sits a 2-10m layer of blue-grey silty clay with a variety of clam shells (including *Tresus capax*, a deeper-water species) in growth position, designated SD1 (Shell Deposit 1). Auger tests indicate that shell bed extends 50m uphill to the southwest, underneath what is now a series of beaver ponds. Anaerobic waterlogged conditions within the shell bed have resulted in excellent preservation of organic material. A fragment of spruce wood from this stratum was dated to $10825 \pm 245$ cal BP (Beta 325353).

Directly overlying the shell bed is a 20-60cm thick layer of coarse beach gravel. This is the only stratum from which in-situ artifacts were recovered. Based on Carlson and Baichtal’s (2015) reconstructed sea level curve for northern POWI, these beach
gravels would have been laid down sometime between 11,000 and 10,500 years ago and
subsequently inundated from 10,500 through 5,500 years ago. This porous stratum is
located above the aquifer’s capillary fringe, and exposure to oxygen has resulted in the
degradation of organic material. Artifacts were recovered from the top portion of this
stratum site and are exclusively lithic in nature, including utilized flakes, debitage, cores,
and tested cobbles of locally available dacite and argillite. FS217 is the distal tip of an
exhausted wedge-shaped dacite microblade core which is characteristic of Northwest
Coast tool technology that emerged prior to 10,000 years ago (Magne & Fedje, 2007;
Morlan, 1970; Moss, 1998; Sanger, 1968). The assemblage also contains cores, flakes,
and utilized flakes primarily of dacite and argillite. Overall, the assemblage is
characteristic of Ackerman’s Period II lithic phase, which dates to c. 9,500-7,000 cal BP
(Ackerman, 1996a)

Overlying the cultural stratum is a 10-30cm layer of sandy silt, reflecting the
period from 10,500 through 5,500 years ago during which the site was rapidly inundated
by rising sea levels and then gradually exposed as sea levels retreated (R. J. Carlson &
Baichtal, 2015). Millenia of exposure to oxygen has resulted in the decomposition of any
marine organism remains or organic material that may have once existed in this stratum.
Overlying this final marine stratum is 20-100cm of forest humus. A spruce cone from the
bottom of the humus layer dates to the modern period, A.D. 1950 or younger (NOSAMS
118292). In the lower, easternmost portion of the site where the raised marine strata
extend into the modern intertidal zone, gentle tidal and estuarial erosion has deflated the fine sediments, leaving behind a thin palimpsest of shells and lithic artifacts on the ground surface.

**B: PET-787: “Serenity Site”**

PET-787 consists of a partially-collapsed rockshelter and the area in front of the rockshelter. Although this site was not selected for radiocarbon dating, the extremely thin layer of shell and charcoal suggests that this site may date to the early Holocene. Two one-meter test units were excavated at the site; one within the rockshelter and one on the adjacent terrace. Test Unit A contained a thin layer of shell, bone, and charcoal encountered underneath an overhang of the limestone bedrock, beneath roughly 1 meter of fallen rock. The test unit was placed at the most accessible point at the base of the limestone bluff; it is possible that the cultural deposit is more substantial slightly to the east, where the rock fall accumulation is more substantial.

Test Unit B, located in a circular depression outside the original extent of the bedrock overhang, contained a complex layering of ashy soils. Auguring revealed that the presence of charcoal extends 5m in every direction from the depression, covering the entire width of the terrace. This may reflect nonanthropogenic wildfire activity or highly-eroded remnants of human activity.
C: PET-789: “Salmonberry Midden”

PET-789 is comprised of a midden deposit on the steep slope near the base of a stone bluff. A 20cm wide profile unit was excavated into the steep hillside at a location where traces of shell were visible on the surface. The 40cm deep test unit was excavated into the side of the slope, which revealed a well-stratified midden deposit. Four pieces of lithic angular debris were recovered from this unit: two dacite, one clear quartz, and one red chert. Charcoal, shell, bird bone, fish bone, and bones of Canidae and an unidentified mammal were also recovered. Shovel testing indicates that the midden extends for at least 12 meters northwest from the existing logging road (USFS 20), up to and possibly underneath the base of the bedrock bluff.

D: PET-746: “Elderberry Midden”

Like PET-789, PET-746 is a midden site located on the same wave-cut terrace sheltered by a bedrock bluff. Wood charcoal from the uppermost and lowermost extent of the midden provide bounding dates of $6575 \pm 25$ and $2590 \pm 135$ cal BP ($NOSAMS 118293, D-AMS 010116$). PET-746 was subject to more extensive testing than PET-789, which included systematic excavation of several test units extending into a rockshelter beneath the bedrock escarpment. The site was tested with one 1 m x 1 m test unit on the east (downslope) side of the existing road and two 50 cm x 50 cm test units on the west side of the road at the base of the bedrock overhang. Excavation at this site ceased when
human remains were identified at a depth of 10cm in the second test unit inside the rockshelter.

Unlike PET-789, PET-746 continued to be occupied even when it was no longer situated conveniently close to the shoreline. When it was first established, PET-746’s location 50m to the southwest of the former location of PET-789 offered a moderately less steep path to the intertidal zone, which at that time was located 20m to the southeast. By then, the base of the channel had been exposed by falling sea levels, producing a gently sloping mudflat that extended 200m to the northwest. Although canoes could not pull up directly to the PET-746, it would have been easy to transport basketloads of shells from a beached canoe to the site for processing. At the same time, foragers at PET-746 likely did not have to travel as far afield as their predecessors. The newly-created mudflats in the bay directly to the east would have served as fertile habitat for clams, allowing people to remain closer to their base of operations. As sea levels continued to fall from 6,500 to 6,000 years ago, the amount of soft-substrate clam habitat in the immediate area increased.

A semicircular cobble alignment spans the inlet 130m northeast of PET-746 (Figure 29). This feature is 3m wide, 7m across, and contains cobbles ranging in size from 5 to 50cm in diameter. It extends across the intertidal mudflat until it reaches exposed bedrock on the north and south sides of the inlet. This feature may be the infilled remains of an intertidal fish trap or clam garden, or it may be the non-cultural product of
unknown alluvial or tidal forces. If this feature is of anthropogenic origin, it most likely
dates subsequent to the establishment of PET-746. Prior to 6,500 years ago, it would have
been located in the inaccessible subtidal zone, but afterwards it would have been within
the intertidal zone.

Figure 29. Intertidal stone feature

E: PET-788: “Raspberry Midden”

PET-788 is a midden site located on the north side of an existing logging road
(USFS 20). Traces of shell have eroded out of the midden and are visible on the surface
on both sides of the road, extending 30m to the west. Test Unit A was an 80cm wide
profile excavated into the side of a cut bank which was exposed where the road cut
through a small rise. The location of the unit was chosen because of dense deposits of crushed shell visible in and around the eroding cut bank. The unit was excavated to approximately 60 cm into the cut bank in order to expose undisturbed stratigraphy. Three lithic artifacts, two made from obsidian, were recovered in Test Unit A, along with charcoal, shell, and bone. Test Unit C was placed a few meters north of Unit A at a location where traces of shell were visible on the surface. This meter square test pit produced charcoal, shell, and bone. No lithic artifacts were recovered from Test Unit C. Test Unit A and Test Unit C together contained bird, fish, and mammal bone. The site has been damaged to an unknown extent during past logging road construction. Shell is visible in sinkholes that have opened beneath the road gravel, indicating that the site extends beneath the road area.

**F: PET-791: “Upper Midden”**

PET-791 is a midden on a terrace above the northern shore of Labouchere Bay. Two 1m x1m test units were excavated near where shell was visible in root throws: N121 E 108 and N128 E 112. Unit N128 E 112 was placed directly at the base of the northern (and uppermost) shell-bearing root throw. The unit was excavated to 60cmbd, and then a shovel test was conducted from the base of the unit to a sterile layer of red sandy gravel at 113cmbd. Excavation revealed a layer of shell, thermally-altered rock, bird/mammal bone, fish bone, and charcoal. An obsidian flake was recovered within this layer at 54cm
below the surface. The thin cultural layer was sandwiched between highly-disturbed strata of forest humus and unmodified stone cobbles, indicating possible disturbance from the tree root throw. Unit N121 E 108 was placed outside the estimated radius of the tree throw disturbance, at a location where traces of shell were visible on the surface. The SE quadrant of the unit was excavated to 140cm below the surface, and the remaining ¾ of the unit were excavated to 60cm. Excavation revealed an undisturbed 120 cm thick midden with stratified depositional units. Directly underlying the forest humus was a layer of thermally-altered rock, crushed shell, bird/mammal bone, fish bone, and charcoal. A possible hearth or steaming oven feature was identified in this stratum. Numerous artifacts were recovered from this layer, including the distal fragment of a ground slate point, a ground shell implement (possibly a fishing lure), an intact lanceolate bone point, and several fragments of worked bone. Numerous unworked fragments of mammal long bone of similar size were also recovered. Underlying this stratum were, in descending order, a layer of crushed shell, a layer of finely crushed mussel shell, and a layer of mostly unbroken clam shells. A sterile layer of red sandy gravel was encountered at the base of the unit.

**G: PET-792: “Abalone Midden”**

PET-792 is a midden on a terrace above the northern shore of Labouchere Bay. A single abalone shell and chiton plate were present on the surface at the base of the
bedrock bluff near the entrance to a rodent burrow, which initiated investigations at the site. Crushed shell and large intact butter clam shells were visible in a root throw a few meters away at the edge of a small gully. A 1m x 50cm test unit was placed at the base of the root throw. After 60cm of root removal from the disturbed three throw overburden, excavation was conducted in 10cm levels. Excavation results indicated that roughly the upper 60 cm of sub-surface sediments had been disturbed by the root throw, resulting in a highly-disturbed jumble of shell, decayed roots, and forest humus – but that the stratum from 60 to 120 cm comprised undisturbed shell midden. The bottom of the midden terminated directly overlying bedrock. A single obsidian flake was recovered at a depth of 60 cm. The midden contained many unbroken butter clams and littleneck clams, with a smaller number of other shellfish species. Charcoal was also present. Compared to other sites in the survey area, very little vertebrate fauna or thermally-altered rock was present.

**H: PET-790: “Lower Midden”**

PET-790 is situated between PET-791 and PET-792, adjacent to and within a small spring-fed stream. The site consists of a dense deposit of shell, bone, charcoal, and thermally-altered rock. Subsurface cultural deposits were first identified in the exposed streambed. Subsequent testing indicated that the midden deposit extends 5 m west of the stream (up to the base of a bedrock outcrop) and 15 m east of the stream. The maximum depth of the midden is unknown since the upper extent of the shell deposit is and around
the creek roughly coincided with the water table, making excavation difficult. Shovel tests and 1 m x 1 m test unit began to fill with water at approximately 50 cm below the present ground surface. The deepest point reached was in the shovel test at N99 E90, with midden deposit extending from 60 cm through at least 100 cm below the surface. The waterlogged conditions yielded excellent preservation conditions; a barbed bone point was recovered from this shovel test at a depth of 70 cm. Stratigraphic analysis indicated that PET-790 was subject to alluvial erosion that had redeposited cultural material downstream from its original point of deposition, so this site was not selected for radiocarbon dating. However, its location and bone artifact assemblage suggest that it is probably contemporaneous with PET-791 and/or PET-792.

I: Ground stone, bone, and shell artifacts

PET-791 and PET-792 provide evidence for toolmaking activity in addition to shellfish harvesting. These sites contain numerous large mammal long bone fragments representing all stages of production: from raw material to finished barbed points (Stewart, 1977). The bone point production sequence (Figure 35) involved engraving grooves along the length of a mammal long bone (FS205), then striking it with a hammerstone to create long flat strips (FS 291a). These strips were then cut and ground against a stone slab (FS297) to create smaller, thinner blanks (FS282, 291b). Finally, the
blanks were carved into their final shape using a knife or chisel (FS240, 301). Finished bone barbs could then be lashed into position as part of a composite hook or spear.

Figure 30. Bone point production sequence
Evidence for carving tools is also present in the form of two chisel blades and one handle fragment (Figure 37). FS 338 is a mussel shell hinge that was ground to form a narrow triangular profile. FS255 is a beaver tooth. These blades would have been mounted on a wood or antler handle. FS314 is the tip that was sawn off the end of an antler tine. This tip was discarded in the midden, but the remainder of the tine would have been the appropriate size to serve as the handle of a chisel or knife (Stewart, 1977)

Figure 31. Carving implement components
In addition to ground bone, ground shell was also present in the form of a trolling/jigging lure (Stewart, 1977). FS302 is a butter clam shell fragment that was ground into an oval shape and then perforated near one end (Figure 38). This type of lure would have been used in hook-and-line fishing that targeted nearshore subtidal species such as rockfish and cod. As the lure was pulled through the water on a fishing line, it would have spun around, attracting fish with its erratic motion and bright white color. This artifact was likely discarded during the manufacture process when pressure from drilling the hole caused the shell to fracture. During replication experiments, this was a common point of failure.
The shift from chipped stone to compound ground bone tools, especially trolling/jigging hook-and-line fishing tools, indicates increased craft specialization, possibly related to population-driven pressure to optimize subsistence practices. (Ames, 1991; D. R. Croes & Hackenberger, 1988)
Evidence for marine mammal hunting is present in the form of a ground slate harpoon point (Stewart, 1973). FS290 is a ground slate point, which would have been affixed either to a multicomponent toggle or straight harpoon shaft (Figure 33). Step fractures near the distal end of the point indicate that it was damaged by blunt impact near the tip, likely during a hunting episode in which it became lodged in the target and snapped. A pinniped metatarsus and femur fragment, also recovered from PET-790, provide further evidence for marine mammal hunting.

Figure 33. Ground slate harpoon point and pinniped metatarsus
J: Untested shell deposits

Five additional localities with exposed subsurface shell (SD-3 SD-4, SD-5, SD-6, and SD-7) were identified during pedestrian survey but were not systematically tested due to time limitations. These shell deposits are located on the same 10 - 20m high wave-cut terrace as the middens described above. The spatial distribution of these shell deposits and their distance of 70-200m from the present shoreline suggests that they are most likely contemporaneous with PET-791 and PET-792.
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